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EXPLORING CLINICAL, PATHOGENETIC, AND DIAGNOSTIC DIMENSIONS OF NASOLACRIMAL DRAINAGE SYSTEM PATHOLOGIES

Zhibek S. Dautbayeva[1], https://orcid.org/0000-0003-0619-3598
Zhanar S. Abdrakhmanova[1], https://orcid.org/0000-0002-1890-0862
Raushan I. Rakhimzhanova[1], https://orcid.org/0000-0002-3490-6324
Zeynet U. Akhmedyanova[1], https://orcid.org/0000-0003-3065-8973
Akerke Makenkyzy[1], https://orcid.org/0009-0009-7806-1181
Natalya F. Takeeva[1],
Kulbaram M. Saitova[1],
Assiya A. Kussainova[2], https://orcid.org/0000-0002-5738-0804
Laura T. Kassym[1*], https://orcid.org/0000-0003-4448-6455

[1] **NJSC "Astana Medical University", Astana, Republic of Kazakhstan;**
[2] **NJSC "Semey Medical University", Semey, Republic of Kazakhstan.**

Abstract

Introduction. Epiphora is the leading symptom of pathology of the nasolacrimal drainage system (NLDS). Chronic epiphora is associated with a significant reduction in patients' quality of life. There is no single ideal imaging modality for assessing nasolacrimal drainage system, and most existing imaging modalities are complementary.

The **aim** of this review is the investigation of the role of visual diagnostic methods in the management of patients with NLDS pathology.

Search strategy. The search for sources was conducted in the following databases: PubMed, Google Scholar, Embase, CyberLeninka, and eLibrary. The review encompassed primary studies (descriptive, analytical, clinical studies), secondary studies (systematic reviews and meta-analyses), clinical guidelines and recommendations, as well as expert opinions, in both Russian and English.

Results and conclusion. The epidemiological characteristics of nasolacrimal drainage system diseases are diverse and influenced by numerous factors such as age, gender, ethnicity, geographic location, and access to specialized medical care. Chronic epiphora, often a primary reason for ophthalmology consultations, significantly impairs quality of life. The spectrum of pathological conditions associated with epiphora is extensive and exhibits distinct features in both adult and pediatric ophthalmological practice. The variety of diagnostic methods in contemporary dacryology underscores the need for standardized approaches in selecting treatment modalities. Current literature lacks standardized diagnostic and treatment algorithms for evaluating the effectiveness of minimally invasive procedures for treating lacrimal duct obstruction, including the use of computed tomographic dacryocystography.

Keywords: *epiphora, nasolacrimal drainage system, computed tomographic dacryocystography.*

Резюме

КЛИНИКО-ПАТОГЕНЕТИЧЕСКИЕ И ДИАГНОСТИЧЕСКИЕ АСПЕКТЫ ПАТОЛОГИИ НОСОСЛЕЗНОЙ ДРЕНАЖНОЙ СИСТЕМЫ

Жибек С. Даутбаева[1], https://orcid.org/0000-0003-0619-3598
Жанар С. Абдрахманова[1], https://orcid.org/0000-0002-1890-0862
Раушан И. Рахимжанова[1], https://orcid.org/0000-0002-3490-6324
Зейнет У. Ахмедиянова[1], https://orcid.org/0000-0003-3065-8973
Ақерке Макенқызы[1], https://orcid.org/0009-0009-7806-1181
Наталья Ф.Такеева[1],
Кульбарам М. Саитова[1],
Асия А. Кусаинова[2], https://orcid.org/0000-0002-5738-0804
Лаура Т. Касым[1*], https://orcid.org/0000-0003-4448-6455

[1] **НАО «Медицинский университет Астана», г. Астана, Республика Казахстан;**
[2] **НАО «Медицинский университет Семей», г. Семей, Республика Казахстан.**

Введение. Слезотечение является ведущим симптомом патологии носослезной дренажной системы (НСДС). Хроническое слезотечение ассоциируется со значительным снижением качества жизни пациентов. Не существует единого идеального метода визуализации для оценки НСДС, и большинство существующих методов визуализации дополняют друг друга.

Цель обзора — изучение роли лучевых методов диагностики в менеджменте пациентов с патологией НСДС.

Стратегия поиска. Поиск источников проводился в следующих базах данных: Pubmed, Google Scholar, Embase, Cyberleninka, eLibrary. В обзор были включены первичные исследования (описательные, аналитические, клинические исследования), вторичные исследования (систематические обзоры и метаанализы), клинические руководства и рекомендации, а также экспертные мнения, на русском и английском языках.

Результаты и заключение. Эпидемиологические характеристики заболеваний носослезной дренажной системы (НСДС) разнообразны и зависят от множества факторов, включая возраст, пол, этническую принадлежность и географическое расположение, а также доступность специализированной медицинской помощи. Хроническое слезотечение, часто являющееся основной причиной обращения в офтальмологию, сопровождается значительным ухудшением качества жизни. Спектр патологических состояний, сопровождающихся слезотечением, широк и имеет свои особенности как во взрослой, так и в детской офтальмологической практике. Разнообразие методов диагностики в современной дакриологии свидетельствует о необходимости унифицированных подходов в выборе методов лечения. В современной литературе отсутствуют стандартизированные лечебно-диагностические алгоритмы для оценки эффективности минимально инвазивных процедур при лечении непроходимости слезоотводящих путей, включая применение компьютерно-томографической дакриоцистографии.

Ключевые слова: *слезотечение, носослезная дренажная система, дакриоцистография, компьютерная томография.*

Түйіндеме

НАЗОЛАКРИМАЛЬДЫ ДРЕНАЖДЫҚ ЖҮЙЕНІҢ ПАТОЛОГИЯСЫНЫҢ КЛИНИКАЛЫҚ-ПАТОГЕНЕТИКАЛЫҚ ЖӘНЕ ДИАГНОСТИКАЛЫҚ АСПЕКТІЛЕРІ

Жибек С. Даутбаева[1], https://orcid.org/0000-0003-0619-3598
Жанар С. Абдрахманова[1], https://orcid.org/0000-0002-1890-0862
Раушан И. Рахимжанова[1], https://orcid.org/0000-0002-3490-6324
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Ақерке Макенқызы[1], https://orcid.org/0009-0009-7806-1181
Наталья Ф.Такеева[1],
Кульбарам М. Саитова[1],
Асия А. Кусаинова[2], https://orcid.org/0000-0002-5738-0804
Лаура Т. Касым[1*], https://orcid.org/0000-0003-4448-6455

[1] **КеАҚ «Астана Медицина Университеті», Астана қ., Қазақстан Республикасы;**
[2] **КеАҚ «Семей Медицина Университеті», Семей қ., Қазақстан Республикасы.**

Кіріспе. Жас ағу - назолакримальды дренаждық жүйесінің патологиясының жетекші симптомы. Созылмалы жас ағу пациенттердің өмір сүру сапасының айтарлықтай төмендеуімен байланысты. Назолакримальды дренаждық жүйесінің күйін бағалау үшін бірыңғай идеалды бейнелеу әдісі жоқ және бар бейнелеу әдістерінің көпшілігі бір-біріне қосымша болып табылады.

Осы шолудың **мақсаты** - назолакримальды дренаждық жүйесінің патологиясы бар науқастарды басқарудағы визуальды диагностика әдістерінің рөлін зерттеу

Іздеу стратегиясы. Дереккөздерді іздеу келесі мәліметтер қорларында жүргізілді: Pubmed, Google Scholar, Embase, Cyberleninka, eLibrary. Шолу орыс және ағылшын тілдерінде бастапқы зерттеулерді (сипаттамалық, аналитикалық, клиникалық зерттеулер), екіншілік зерттеулерді (жүйелі шолулар мен мета-талдаулар), клиникалық нұсқаулар мен ұсыныстарды, сондай-ақ сарапшылардың пікірлерін қамтыды.

Нәтижелер және қорытынды. Назолакримальды дренаждық жүйесі ауруларының эпидемиологиялық сипаттамалары әртүрлі және көптеген факторларға, соның ішінде жасына, жынысына, этникалық және географиялық орналасуына, сондай-ақ мамандандырылған медициналық көмекке қолжетімділікке байланысты. Созылмалы жас ағу, көбінесе офтальмологиялық мамандарға барудың негізгі себебі, өмір сапасының айтарлықтай нашарлауымен бірге жүреді. Жас ағумен бірге жүретін патологиялық жағдайлардың ауқымы кең және ересектер мен балалар офтальмологиялық тәжірибесінде өз ерекшеліктеріне ие. Қазіргі дакриологиядағы диагностикалық әдістердің әртүрлілігі емдеу әдістерін таңдауда біртұтас тәсілдер қажет екенін көрсетеді. Заманауи әдебиеттерде лакрималды түтіктердің бітелуін емдеуде аз инвазивті процедуралардың тиімділігін бағалаудың стандартталған емдеу және диагностикалық алгоритмдері жоқ, оның ішінде компьютерлік томографиялық дакриоцистограмманы қолдану.

Түйінді сөздер: *жас ағу, назолакримальды дренаждық жүйесі, компьютерлік томографиялық дакриоцистография.*

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Background

Chronic lacrimation is a common complaint in ophthalmology, affecting 5-12% of patients [8]. Most cases result from anatomical issues, primarily blockages in the lacrimal ducts [53]. A retrospective study of 280 Israeli patients at an oculoplastic center found that 29% of lacrimation cases were due to nasolacrimal or canalicular obstructions [51]. Another study of 237 patients with lacrimation as the primary complaint revealed that 46% had lacrimal duct blockages [64]. A recent investigation at an eye clinic in Ankara identified that out of 595 patients, 62.5% had nasolacrimal drainage system obstructions, 10.5% had lacrimal puncta stenosis, and 7.3% had eyelid ectropion [12].

Global data on the prevalence and incidence of nasolacrimal drainage system pathology (NLDS) is limited, with most studies coming from individual specialized centers. For instance, a study from Singapore reported that among 623 patients, 60.3% had eyelid diseases, 20.6% had eyeball diseases, and 16.3% had lacrimal apparatus issues [70]. Similarly, South Korean researchers noted that over half of the 355 patients who underwent surgery at a specialized center had eyelid diseases, while a quarter had orbital or lacrimal pathology [34]. Ethnographic differences can influence these epidemiological findings. For example, a retrospective study at a Nigerian tertiary hospital found no cases of NLDS pathology among 563 operated patients [1]. The contrasting prevalence rates of nasolacrimal drainage system pathology across countries can be attributed to differences in the organization of specialized medical care and the ethnic variations in the anatomical structure of the eye.

Gender differences also play a significant role in the prevalence of lacrimal apparatus diseases. An epidemiological study of 2,215 elderly Thai prisoners found that diseases coded as lacrimal apparatus disorders were significantly more common in women (5.63% vs. 2.41%; p=0.0191) [72]. This higher prevalence among women is supported by other studies, which attribute it to the smaller diameter of the nasolacrimal duct and hormonal differences [37, 81, 21]. *Shigeta K. et al. (*2007) further explain this by noting the anatomical characteristics of women's facial skeletons, including a narrower nasolacrimal canal and a more acute angle between the bone canal and the nasal cavity [65].

Large-scale retrospective epidemiological studies are feasible with the use of electronic medical records, which can capture detailed socio-demographic and clinical data. An exemplary study by *Das A. et al.* (2018) analyzed 20,102 visits to an eye institute in India from 2013 to 2017. They found that over half the patients (51.56%) had primary acquired nasolacrimal duct obstruction (PANDO), while a quarter (26.83%) had congenital nasolacrimal duct diseases. Notably, two-thirds of the PANDO cases were in women, whereas congenital cases were equally distributed between genders. The study also highlighted that three-quarters of the patients were city residents, and two-thirds described their material wealth as "average, above average, or high [15].

Anatomical and Functional Characteristics of the Human Nasolacrimal Drainage System

The nasolacrimal drainage system (NLDS) is an anatomical complex that removes small foreign bodies from the eye and drains excess tear fluid. Its development begins in the fourth week of fetal life with the formation of maxillary and frontal protrusions, creating a groove. By the fifth week, the epidermis forms a cord in this groove, extending from the nasal cavity to the inner corner of the eye. The lacrimal sac develops from the top of this primary cord.

By the tenth week, epidermal cords invaginate from the upper and lower eyelids to form tubules. Canalization of these cords starts in the fourth month, progressing until the seventh month when the puncta open. The lower part of the nasolacrimal duct opens into the lower nasal passage by the eighth month. Approximately 70% of newborns have an obstruction of Gasner's membranes, which typically opens within the first month but can take longer. Deformities of the lacrimal system can occur at any stage of fetal development and are more severe if they occur early [16].

The lacrimal apparatus consists of two main structures: tear-producing and tear-draining. The primary tear-producing gland is the lacrimal gland, which produces 90% of the tear fluid. Additional glands, Krause and Wolfring, are located in the conjunctival angles. The lacrimal gland, a large bilobed exocrine gland, is located in the fossa of the lacrimal gland of the frontal bone. It has two lobes: the upper (orbital) and lower (palpebral or secular), separated by the lateral horn of the levator aponeurosis of the eyelid. The lower lobe can be seen as a lobular pink formation when the upper eyelid is everted. Tear secretion is mainly controlled by parasympathetic innervation [53].

The tear-draining system starts at the lacrimal puncta (upper and lower), located at the medial commissure of the eyelids, with openings 0.2–0.3 mm in diameter. Each punctum leads to the lacrimal canaliculus, which has a 2-

mm vertical and a 10-mm horizontal part, lined with non-keratinizing squamous epithelium. In 95% of cases, the lacrimal tubules merge and open into Mayer's cavity within the lacrimal sac [80].

The lacrimal sac is a vertical ampulla, 10-15 mm long, with its bottom typically extending above Mayer's cavity or the outlet openings of the lacrimal canaliculi. Between the drainage section of the lacrimal canaliculi and the lacrimal sac cavity is the Rosenmüller valve, a mucous protrusion that prevents the backflow of tears. The lacrimal sac is located in a bony fossa at the inner edge of the orbit, and its mucosa consists of multi-row columnar epithelium with a few glandular cells.

The lacrimal sac continues into the nasolacrimal duct, which is lined with double-layered columnar epithelium and microvilli. The duct runs through a bony canal in the maxillary bone and opens into the inferior nasal meatus near the head of the inferior concha. The nasolacrimal duct is 12-18 mm long and directed slightly sideways and backward relative to the lacrimal sac. It empties into the inferior nasal passage through a slit-like opening, and the flow is regulated by the valve of Hasner, a mucous structure separating the nasolacrimal duct and the nasal cavity. Tears flow into the nose, which is why tear fluid is released from both the eyes and the nose when crying [29, 30, 82].

The tear drainage system functions like a pump, actively moving tear fluid from the eyes. This process involves more than just gravity; it relies on the dynamic pumping action of the nasolacrimal drainage system. When the eyelids close, the muscles around the eyeball contract, increasing pressure in the lacrimal sac. This pressure closes the Rosenmüller valve, pushing tears down the nasolacrimal duct. Upon opening the eyelids, negative pressure is generated in the lacrimal sac. The Rosenmüller valve then opens, allowing tears to be drawn through the puncta and down the lacrimal canaliculi into the lacrimal sac, where the cycle repeats. This lacrimal pump mechanism is crucial for tear outflow. The orbicularis oculi muscle, particularly its lacrimal portion, attaches to the posterior lacrimal crest of the lacrimal bone and surrounds the posterior wall of the lacrimal sac. Dysfunction of this muscle can lead to lacrimal pump insufficiency or functional blockage of the lacrimal ducts. Proper functioning of the lacrimal sac and nasolacrimal duct depends on the coordinated motor and secretory activities of the surrounding mucous membrane and choroid plexuses [29, 30].

The spiral structure of the mucous membrane in the lacrimal ducts aids in regulating tear flow by enhancing the motor properties of the mucous membrane. Muscle fiber contraction and relaxation, along with varying blood flow in the dense vascular network surrounding the duct, cause the mucous membrane's spiral to contract and relax, thereby accelerating tear passage [39].

Functional disorders of the nasolacrimal drainage system include issues with the lacrimal pump mechanism. These can result from facial paralysis, scarring of the eyelid skin due to burns, and conditions like scleroderma. Additionally, there are numerous anatomical conditions that can block tear drainage, such as stenoses, strictures, and obstructions of congenital, traumatic, inflammatory, or neoplastic origins. These will be discussed in detail in subsequent sections of the review [7].

Etiopathogenesis, Pathomorphology, and Clinical Aspects of Nasolacrimal Drainage System Diseases

The primary cause of lacrimation in nasolacrimal drainage system diseases is mechanical obstruction. This blockage prevents the natural outflow of tears, leading to their retention in the lacrimal sac. Patients typically experience excessive tearing, tear accumulation in the lacrimal lake, and mucopurulent discharge. In some cases, tear fluid stagnation leads to infectious and inflammatory conditions such as dacryocystitis. Acute dacryocystitis is characterized by swelling, pain, and redness around the medial commissure of the eyelids. Palpation and massage of the lacrimal sac can produce pus discharge. Patients may also notice spontaneous pus discharge, particularly after prolonged sleep, leading to sticky eyelids. Dacryocystitis can present in acute, subacute, and chronic forms [46].

Trimarchi M. et al. (2021) categorize NLDS obstructions into proximal and distal types, based on their etiopathogenesis. This classification helps determine when to involve other specialists, such as otolaryngologists or oncologists, in patient management [71]. Other researchers suggest that a topographic approach to identifying the anatomical level of NLDS damage can improve patient care [16, 24].

Das A. et al. (2018) analyzed a registry of 20,102 cases to identify the common causes of nasolacrimal duct obstruction: primary acquired nasolacrimal duct obstruction (PANDO) in 10,364 cases (51.56%), congenital obstruction in 5,394 cases (26.83%), acute dacryocystitis in 1,074 cases (5.34%), stenosis of the lacrimal opening in 603 cases (3%), and complications from unsuccessful dacryocystorhinostomy in 460 cases (2.29%). The most frequent complaints were lacrimation (69.18%), eye discharge (20.01%), regurgitation (19.21%), acute dacryocystitis symptoms (5.34%), and lacrimal sac abscess (0.96%) [15].

PANDO is a common lacrimal duct disease caused by nonspecific inflammation leading to partial stenosis or complete occlusion due to fibrosis. It primarily manifests as lacrimation, with symptoms worsening under certain weather conditions such as strong sunlight, wind, or cold temperatures [9, 38, 78,]. Potential causes include anatomical narrowing of the nasolacrimal duct, hormonal imbalances, dysbiosis, parasympathetic dysregulation, lysosomal dysfunction, gastroesophageal reflux, genetic factors, use of specific topical medications, allergic reactions, swimming pool exposure, and use of cosmetic products [2]. The pathomorphological changes in PANDO follow a similar staged progression, as described by *Lindberg J.V. and McCormick S.A.* (1986):

1) active phase: characterized by periductal edema and intense lymphoplasmacytic infiltration of subepithelial tissues, with early signs of squamous metaplasia and reduced goblet cells; macroscopic stenosis of the nasolacrimal duct (NLD) can be observed;

2) intermediate phase: lymphoplasmacytic infiltration decreases, but subepithelial fibrosis appears, significantly narrowing the NLD lumen;

3) fibrous phase: complete obliteration of the NLD by fibrous tissue, with the absence of epithelial and glandular cells [36].

PANDO is more prevalent in women, leading some researchers to explore anatomical and hormonal factors as primary causes [4]. A population-based study by *Woog J.J.* (2007) found that out of 397 PANDO patients, 73% (290) were women, mostly aged 65 and older [79]. *Janssen A. et al.* (2001) supported this gender prevalence by using computed axial tomography, which showed that the nasolacrimal duct width was significantly smaller in women compared to men (3.35 mm vs. 3.70 mm; p<0.001). Furthermore, in patients with PANDO, the NLD width was reduced to three millimeters [27]. Contrary to these findings, other studies dispute the role of facial skeletal structure in PANDO etiology. *Fasina O. et al.* (2013) examined nasolacrimal parameters in 401 healthy Nigerians using computer tomography. The NLD width in men was 3.52 mm and 3.36 mm in women. The study concluded that the lower incidence of PANDO among Black populations could not be attributed to broader NLD, suggesting that NLD size alone does not explain the disease's development [18].

The condition of the lacrimal ducts' soft tissues, including local immunity, hormonal status, and neurohumoral regulation, is also crucial [73]. *Paulsen F. et al.* (2000) studied lacrimal duct tissue samples from 20 cadavers using light microscopy, immunohistochemistry, and transmission electron microscopy. They discovered a vascular network surrounding the lacrimal sac and NSD, intertwined with the corpus cavernosum of the inferior turbinate. This vascular complex has neurohumoral regulation involving myelinated and unmyelinated nerve fibers responding to stimuli such as protein S-100, neuron-specific enolase, and anti-200 kDa neurofilaments. The density of nerve fibers and various neuropeptides regulate blood flow, which affects the lumen of the lacrimal duct and the outflow of tears, through the swelling and subsidence of the corpus cavernosum [56].

Researchers from India and Germany investigated the role of eight hormones in the etiopathogenesis of PANDO through an immunohistochemical study of hormone receptor expression in the lacrimal duct mucosa from cadaveric and clinical samples. They found strong expression of estrogen and oxytocin receptors in individuals without PANDO. In healthy postmenopausal women, testosterone and progesterone receptors were predominantly expressed in the basement membrane of the epithelial lining. In contrast, tissue samples from PANDO patients showed significantly reduced or absent receptor expression for these hormones, except for prolactin [5]. Other potential factors in PANDO development include various microorganisms from the nasolacrimal drainage system and the nasal cavity. However, studies have not identified a specific infectious pathogen or local dysbiosis as a clear cause. More importantly, several antimicrobial peptides (e.g., defensins, psoriasin, lysozyme, lactoferrin) were found to have impaired regulation in PANDO patients [19, 57].

Makselis A. et al. (2022) provided a detailed clinical description of PANDO in 275 patients at an eye center. Most cases (218; 79.2%) involved nonspecific inflammation, with fibrotic changes observed in 54 patients (19.6%). On average, the disease duration exceeded 24 months. The most common complaint was chronic lacrimation (213; 77.5%), with half of the patients experiencing purulent discharge. Additionally, three patients with lacrimation were diagnosed with nasolacrimal drainage system tumors, highlighting the importance of comprehensive examinations for accurate diagnosis [38].

Congenital pathologies of the nasolacrimal drainage system are the primary cause of lacrimation in newborns due to partial or complete blockage at various levels. The most common form is congenital nasolacrimal duct stenosis (CNDS). *McEven C.J. & Young J.D.H.* (1991) report an incidence of up to 20% in the first year of life, with spontaneous regression occurring in up to 90% of cases within the same age range. This high rate of natural resolution can lead to differing management approaches among pediatric specialists [44]. The typical pathological variant involves incomplete canalization of the caudal nasolacrimal duct, where an imperforate membrane at the Garner valve blocks tear fluid. Clinically, CNDS presents as chronic lacrimation (starting around two weeks of age), sticky eyelashes, an enlarged lacrimal lake, mucopurulent discharge, and tear regurgitation. It is often misdiagnosed as conjunctivitis, but CNDS lacks light sensitivity and conjunctival redness. Persistent eyelash stickiness and friction can lead to eyelid inflammation, and severe cases may develop into abscesses or phlegmon [33].

Diagnosis relies on clinical signs and a positive compression test, where pressing the lacrimal sac releases pus. A simple diagnostic method involves assessing duct patency with a color test: instill a 1% fluorescein sodium solution into the conjunctival cavity after squeezing out lacrimal sac contents and check for the dye in the nasal cavity [77]. Another congenital NLDS pathology is nasolacrimal duct obstruction, which causes lacrimation and conjunctivitis without dacryocystitis, a condition often seen with CNDS. Anatomical variations include stenosis or atresia of the proximal NLD, dislocation, or absence of one or both lacrimal puncta and canaliculi, and variations in how the canaliculi open into the lacrimal sac. These factors are crucial in developing reconstruction procedures [75].

Acute dacryocystitis (ADC) is an infectious inflammation of the lacrimal sac, resulting from chronic disruption and stagnation of tear fluid in the nasolacrimal drainage system. It can present in either acute or chronic forms. Clinically, ADC manifests as lacrimation, erythema, and swelling in the medial canthus of the eyelids. Most commonly, strains of Streptococcus or Staphylococcus are isolated from the mucopurulent discharge. Although rare in pediatric practice, ADC can be severe. Children with ADC often exhibit restlessness, difficulty feeding, and pronounced systemic signs of inflammation, such as fever and leukocytosis [3]. In adults, ADC is a common issue among ophthalmic patients over 40. Treatment typically involves oral antibiotics and local heat for uncomplicated cases. More severe cases may require surgical opening and drainage. Chronic dacryocystitis often necessitates dacryocystorhinostomy surgery [58].

A significant concern in treating ADC is the development of antimicrobial resistance, necessitating ongoing research into the structure of resistance to current drugs [13, 55, 76].

Diagnosis of Nasolacrimal Drainage System Diseases

In ophthalmological practice, both traditional tests and modern instrumental methods are employed to diagnose NLDS diseases. The choice of method depends on the complexity of the diagnosis and the presumed cause of the pathology. During a routine examination of a patient with suspected NLDS pathology, the following tests can be performed:

(a) canalicular test: colored solutions (1% fluorescein sodium or 3% collargol) are instilled into the conjunctival sac. In a healthy system, the solution is absorbed within five minutes, and the patient is asked to blow their nose to check for the presence of the dyed solution in the nasal cavity;

(b) nasolacrimal test: colorless, flavored solutions (0.9% sodium chloride or 0.25% chloramphenicol) are used to assess the patency of the duct;

(c) reflux test: mucus, pus, or dye appears on the conjunctiva when pressure is applied to the area of the lacrimal sac and canals [66].

The most common endoscopic method used in dacryology is dacryoendoscopy. This technique allows detailed examination of the lacrimal canaliculi, common lacrimal duct, lacrimal sac, and nasolacrimal canal. Dacryoendoscopes vary in length, diameter, flexibility, tip curvature, and image clarity. Larger diameters improve camera resolution and image quality. Dacryoendoscopy is integrated into advanced functional endoscopic systems, aiding in surgical interventions such as plastic and recanalization procedures without extensive surgical access [32]. Dacryoendoscopy requires special training and experience. The procedure is typically performed under general anesthesia, with vasoconstrictor-soaked tampons placed in the nasal cavity and local anesthetic instilled into the conjunctival sac. It is usually well tolerated and performed on an outpatient basis with minimal complications. Contraindications include acute dacryocystitis, conditions with increased bleeding, and proximal obstruction of the lacrimal canaliculi [43]. The dacryoendoscope (tip diameter usually ≤1 mm) is inserted vertically through the upper or lower lacrimal opening, then turned horizontally to examine the lacrimal sac and NLD. Narrowings are commonly found where the lacrimal canaliculus enters the sac and at the lower opening of the NLD. Visualization is enhanced by low-pressure air or saline irrigation. The mucous membrane of the tubules is smooth and pale pink; the sac's membrane is red-pink with folds and visible vessels. Narrowing occurs at the transitions between these structures [67]. Dacryoendoscopy (DE) is used to diagnose various pathological conditions in both adults and children. It is particularly useful in identifying congenital NLDS anomalies and acquired conditions in children [28]. For example, *Sasaki H. et al.* (2013) used DE to identify nonspecific inflammation with severe edema and granulation in the NSDS of children aged 14 to 74 months [61]. Canalicular stenosis, a common pathology of the NLDS, can be effectively diagnosed and treated using dacryoendoscopy (DE). Besides detecting stenosis, DE can clear ducts of granulosa or fibrous tissue, perform curettage, and facilitate stent placement [69]. DE is valuable for the differential diagnosis of NLDS obstructions, including mucous plugs, mucopurulent plugs, intraductal stones, granulations, stenosis, fibrosis, and tumors [35]. It supports various invasive procedures such as recanalization, dacryoplasty, foreign body removal, biopsies, drug administration, and fibrous tissue removal. However, post-procedural complications like granulation tissue development should be considered. *Mimura M. et al.* (2016) found that 10.6% of patients developed granulation tissue within 2-8 weeks after silicone drain implantation, treatable with prednisolone acetate without drain removal [48]. Endoscopy provides detailed visualization of the NLDS, allowing for accurate diagnosis and treatment of obstructions. Endoscopic dacryocystorhinostomy is the preferred treatment for many cases of NLDS obstruction, despite a 10% recurrence rate [31]. This method, along with balloon dacryocystoplasty and stent placement, benefits significantly from preoperative visualization to determine the appropriate treatment strategy.

Radiation Diagnostic Methods in Dacryology

Modern dacryology employs various radiation diagnostic methods to assess NSDS conditions, including: conventional dacryocystography (DCG); computed tomographic DCG (CT-DCG); digital DCG; magnetic resonance imaging DCG (MR-DCG).

Conventional dacryocystography (DCG) involves introducing a contrast material into the NLDS followed by a series of X-rays. It was the first radiological method to assess the lacrimal ducts' condition [47]. DCG can identify various causes of NSDS obstruction, such as stenosis, fistulas, diverticula, neoplasms, and stones. In pediatric patients, it is useful for diagnosing congenital anomalies and recurrent obstructions post-therapeutic probing. Indications for DCG include chronic lacrimation and discharge of pus or blood from the lacrimal punctum.

The procedure involves injecting a contrast agent through the inferior lacrimal punctum using a cannula, followed by a series of photographs taken in occipitofrontal and bitemporal projections while the patient is sitting. Images are captured immediately after contrast injection and within 15 minutes [45]. The contrast agent must be homogeneous, non-toxic, non-irritating, and optimally viscous. Modern dacryoradiology uses both fat-soluble (e.g., lipoidol) and water-soluble substances (e.g., iohexol, iopamidol, sinographfin). Although fat-soluble agents provide better image quality, they are more viscous, do not mix well with tear fluid, and can cause granulation if NLDS tissues are overstretched [17, 41, 50].

Few studies have used conventional DCG in healthy individuals. *Malik S.R. et al. (*1969) described the NLDS components' dimensions in 37 healthy adults, finding the lacrimal sac to be 2.4x4.0 mm and the nasolacrimal duct lumen to be 2.3x2.8 mm [40]. Other studies have shown wide variability in NLDS parameters. A study of 99 healthy volunteers found a wide and tortuous NLD in 63% of cases, angle deviations in 17%, and small diverticula in 14% [60]. In a study of 169 patients with chronic lacrimation, 11% showed no pathology, 11% had NLD course folding, and 8% had diverticula [40].

While conventional DCG effectively documents structural changes in the NLDS, it is unsuitable for assessing the ducts' functional state. Digital DCG shares this limitation. Digital DCG, or "boneless" radiography, uses water-soluble contrast to obtain a cast-like image of the NLDS [20]. *Saleh G.M. et al.* (2007) compared simple NLDS probing with digital DCG in 17 patients with lacrimation. Probing detected anatomical causes of obstruction in 88% of cases, while digital DCG detected them in 84%. Digital DCG also identified additional features such as narrowings, dacryoliths, fistulas, and individual anatomical variations in 28% of cases [62].

Magnetic resonance dacryocystography (MR-DCG), first performed in 1993, is a valuable tool in modern dacryology for diagnosing subtle anatomical deviations in the nasolacrimal drainage system (NLDS) [14]. It provides detailed visualization of soft tissue formations, including neoplasms, papillomas, mucous pockets, and valves. MR-DCG typically uses gadolinium-based contrast injected through the lacrimal canaliculus, though saline solution can also be used. The procedure involves periodic instillation of the contrast every three minutes for the first 15-20 minutes to prevent soft tissue hyperextension. MR-DCG can be performed using various pulse sequence modes, such as turbo spin-echo, fast spin-echo, gradient echo, and inversion recovery. These options can reduce the procedure time from the usual 20-30 minutes to 7-12 minutes [14]. This method is especially useful for diagnosing functional lacrimation or suspected tumors. For instance, a study by *Amrith E.N. et al.* (2005) assessed tear flow in seven healthy volunteers, revealing that the lacrimal sac is never completely emptied, and saline flows into the nasolacrimal duct in separate, equal volumes [6].

A study by *Higashi H. et al.* (2016) further validated the diagnostic accuracy of MR-DCG. The authors compared MR-DCG results with dacryoendoscopy and intraoperative findings in 31 patients with suspected NLDS obstruction. Using fast T2-weighted spin-echo imaging in coronal and axial planes, MR-DCG accurately diagnosed stenosis at the lacrimal canaliculi level in nine patients (100%). However, there was a 12.5% incidence of misdiagnosis for "obstruction at the lacrimal sac level." Overall, MR-DCG correctly identified the obstruction site in 84% of cases [25]. A recent study by *Ce M. et al.* (2023) demonstrated that MR-DCG without contrast is a valid method for diagnosing obstructions in the nasolacrimal system. The study compared MR-DCG results with endoscopic and surgical findings to assess its accuracy in localizing nasolacrimal duct obstructions. The study involved 21 patients with suspected nasolacrimal duct obstruction who underwent dacryoendoscopy and subsequent surgery. MR-DCG was performed using a T2-weighted fast spin echo sequence in coronal planes, with sterile 0.9% NaCl solution injected into both conjunctival sacs prior to imaging. Stenosis or obstruction was diagnosed in all patients. The site of obstruction was identified as the lacrimal sac in 12 patients (57%), the nasolacrimal duct in 6 patients (29%), and the canaliculi in 3 patients (14%). In 85.7% of cases, the obstruction site identified by MR-DCG matched the findings from endoscopy and surgery [11].

Despite its advantages, MR-DCG is not considered a first-line technique due to its high cost and time requirements. There is no single ideal imaging modality for assessing NSDS; most are complementary. While advances in dacryoendoscopy are significant, radiation diagnostic methods remain important for certain indications, such as partial obstruction and functional lacrimation. Conventional and digital DCG have limitations in assessing the functional state of the NSDS because the instilled contrast does not accurately reproduce the natural flow of tears. Additionally, MR-DCG is often not cost-effective for patients in developing countries [23].

The Role of Computed Tomographic Dacryocystography in Managing Nasolacrimal Drainage System Pathologies

Despite the availability of various imaging methods, including traditional dacryocystography, nuclear scintigraphy, and magnetic resonance imaging, computed tomography (CT) remains the most common and accessible option in ophthalmological practice [7]. Combining dacryocystography with computed tomography (CT-DCG) allows for a detailed assessment of the nasolacrimal drainage system (NLDS) and its relationship with surrounding soft tissues and bone structures. This enhances the ability to evaluate the level and complexity of stenosis, improving preoperative preparation quality [52,54].

CT-DCG involves the administration of iodinated contrast, either through cannulation or by instilling low-osmolar water-soluble drops into the conjunctival sac five minutes before the CT scan. Cannulation with local anesthesia is typically used if contrast from drops alone is insufficient. Additionally, rinsing the conjunctiva and lightly massaging the lacrimal sac before contrast administration are recommended to avoid interpretation errors. Images are taken in axial and coronal projections with the patient in a supine position [74]. The resulting series of images, coupled with three-dimensional reconstruction, provides a comprehensive visual assessment of the NSDS, both under normal conditions and in cases of complete or partial obstruction [67].

In CT-DCG, the immediate entry of contrast agent into the nasal cavity from the lacrimal sac indicates an unobstructed NLDS. Partial obstruction is suggested by delayed contrast entry, while complete obstruction is indicated by the absence of contrast in the nasal cavity [63]. However, radiographic findings may not always align with clinical symptoms; for instance, elderly patients may exhibit CT signs of NLD obstruction despite lacking lacrimation due to age-related lacrimal gland atrophy [27].

CT-DCG offers several advantages in dacryological practice, including accessibility, affordability, short procedure duration, and the ability to assess bone structures. This makes it the preferred diagnostic tool for facial skeleton injuries, suspected NLDS congenital defects, and benign/malignant neoplasms. Nevertheless, radiation exposure should be considered, especially for certain patient groups. Safer alternatives like MR-DCG may be preferable for pediatric patients or those with iodinated contrast allergies [54]. While CT-DCG has proven valuable in diagnosing NLDS injuries and tumors, debates persist regarding its comparative diagnostic value. Caldemayer et al.'s seminal study found that CT-DCG and MR-DCG both successfully visualized the NLDS, with CT-DCG offering superior bone structure visualization [10]. Similarly, Manfre et al. concluded that MR-DCG is comparable to CT-DCG in detecting NLD obstructions, emphasizing its validity as the primary method for NSDS assessment in lacrimation patients [42].

Ongoing debates persist regarding the comparative advantages of CT-DCG versus MR-DRG. *Singla A. et al.* conducted a recent study comparing both modalities in diagnosing NLDS obstruction. Their findings indicated that both CT-DCG and MR-DRG were equally effective. While CT-DCG provides detailed topical characterization, MR-DRG can pinpoint the location of luminal narrowing without the need for contrast agents, thus reducing patient discomfort [68]. *Qian Z.B. et al.* demonstrated the utility of CT-DCG in diagnosing neoplasms in patients with NLDS pathology. Comparing it with color Doppler ultrasound combined with CT, they found similar detection rates for tumors. This underscores the effectiveness of CT-DCG in tumor diagnosis [59]. CT-DCG's importance extends to assessing NLDS post-dacryocystorhinostomy and managing facial trauma patients. *Glatt H.J. et al.* utilized CT-DCG to describe NLDS status in postoperative patients, identifying various bone abnormalities. This method is also pivotal in managing facial trauma, providing crucial information for preoperative planning and intraoperative decision-making. *Mukherjee B. & Dhobekar's M.* retrospective analysis highlighted CT-DCG's role in determining surgical interventions and ensuring successful outcomes in facial trauma cases [22, 49].

Conclusion

Research findings, both domestic and foreign, underscore the importance of our study topic. Firstly, epidemiological aspects of nasolacrimal drainage system (NLDS) diseases vary widely and are influenced by factors such as age, gender, ethnicity, geographical location, and socio-economic conditions affecting access to specialized medical care. Chronic lacrimation, a common reason for seeking ophthalmic help, significantly impacts quality of life. Secondly, the spectrum of pathologies causing lacrimation is extensive and differs between adult and pediatric ophthalmology. Thirdly, the array of diagnostic methods in modern dacryology highlights the absence of standardized approaches in treatment selection. Additionally, literature lacks unified treatment and diagnostic algorithms for assessing the effectiveness of minimally invasive interventions in treating lacrimal duct obstructions, including computed tomographic dacryocystography techniques.

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Information about authors:

[1]**Dautbayeva Zhibek Seitkhanovna** - PhD, Associate professor of the Department of Eye Diseases, NJSC "Astana Medical University", phone: +7 777 770 0733, e-mail: dautbayeva.zh@amu.kz, https://orcid.org/0000-0003-0619-3598, Astana, Republic of Kazakhstan;

[1]**Abdrakhmanova Zhanar Sagatbekovna** - Doctor of Medical Sciences, Associate professor of the Department of Radiology, Scientific Research Institute of Radiology named after ZH.H. Khamzabayev, NJSC “Astana Medical University”, phone: 8 701 536 00 31, e-mail: zhanna-ayan74@mail.ru, https://orcid.org/0000-0002-1890-0862, Astana, Republic of Kazakhstan;

[1]**Rakhimzhanova Raushan Ibzhanovna** - Doctor of Medical Sciences, Department of Radiology, Scientific Research Institute of Radiology named after ZH.H. Khamzabayev, NJSC “Astana Medical University”, phone: 8 701 228 80 58, e-mail: rakhimzhanova01@rambler.ru, https://orcid.org/0000-0002-3490-6324, Astana, Republic of Kazakhstan;

[1]**Akhmedyanova Zeynet Ugubaevna** - Candidate of Medical Sciences, Professor, Head of the Department of Eye Diseases of NJCS "Astana Medical University", phone: +7 702 493 3177, e-mail: ahmedyanova.z@amu.kz , https://orcid.org/0000-0003-3065-8973, Astana, Republic of Kazakhstan;

[1]**Makenkyzy Akerke** – PhD student, NJSC "Astana Medical University", phone +7 778 523 50 54, e-mail: akerkemakenkyzy@gmail.com, https://orcid.org/0009-0009-7806-1181, Astana, Republic of Kazakhstan;

[1]**Takeeva Natalya Frantsevna** - Doctor of Radilogy, Scientific Research Institute named after Academician Zh.Kh. Khamzabaeva, NJSC "Astana Medical University", phone: +7 701 313 30 03, mail: natasfra1982@gmail.com, Astana, Republic of Kazakhstan;

[1]**Saitova Kulbaram Mendybaevna** - Doctor of Radilogy, Scientific Research Institute of Radiology named after Zh.Kh. Khamzabayev, NJSC "Astana Medical University", phone: +77770717567, e-mail: nurpeisova_kulbaram@mail.ru, Astana, Republic of Kazakhstan;

[2]**Kussainova Assiya Abikhasovna** - PhD, assistant of the Department of Infectious Diseases, Dermatovenerology and Immunology, NJSC "Semey Medical University", phone: 8 707 498 73 48, e-mail: kuzilas@mail.ru, https://orcid.org/0000-0002-5738-0804, Semey, Republic of Kazakhstan;

[1]**Kassym Laura Talgatkyzy** – PhD, Associate Professor Department of General practice with a course of evidence-based medicine, NJSC "Astana Medical University", phone: 8 777 735 10 62, e-mail: laura.kassym@gmail.com, https://orcid.org/0000-0003-4448-6455, Astana, Republic of Kazakhstan.

*** Corresponding author:**

Kassym Laura Talgatkyzy – (Associate Professor Department of General practice with a course of evidence-based medicine) NJSC "Astana Medical University", Astana, Republic of Kazakhstan.

Postal address: Republic of Kazakhstan, 010000, Astana, Beibitshilik street 49A.

E-mail: laura.kassym@gmail.com

Phone: 8 777 735 10 62