Adam J. Cohen
Michael Mercandetti
Brian Brazzo
Editors

The Lacrimal System

Diagnosis, Management, and Surgery

Second Edition

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Foreword

> The future belongs to the unreasonable ones, the ones who look forward not backward, who are certain only of uncertainty, and who have the ability and the confidence to think completely differently.
>
> —George Bernard Shaw

The historical course and evolution of lacrimal disorders and their management amply exemplify the above stated quote of Nobel laureate Bernard Shaw. From times immemorial, lacrimal disorders have continued to intrigue clinicians and pose significant challenges. Tough problems have fortunately met tougher, wise men at appropriate times and science continued to evolve at a rapid pace. The amazing progress, notably that of dacryocystorhinostomy, is paralleled by few surgical procedures in medicine. The present era of lacrimal practice is both exciting and at the same time challenging. The state-of-art equipments including high definition endoscopic systems, diagnostic and therapeutic dacryoendoscopy, and higher resolution yet safer imaging are increasingly contributing towards our understanding of the disorders as well as developing minimally invasive surgical options. The armamentarium of a lacrimal surgeon today is better equipped than at any other time and this very fact brings in more responsibility on us than at any other time, to take this forward in every possible way into the future!

It is in these contexts that the current textbook on lacrimal surgeries edited by Drs. Cohen, Mercandetti, and Brazzo plays a crucial role. It is a well-known fact that it takes an average of 5 years before an innovation or surgical advances are published in textbooks. This time span is precisely narrowed by the current lacrimal text and hence enhances the rapid transfer of knowledge and skills to clinical practice. This text spans over 200 pages with 21 chapters and more than 100 illustrations bringing together a combined experience and expertise of more than 30 renowned surgeons. Each chapter has well-established clinical relevance and hence carries a high value for clinical practice.

I am honored to write the foreword for the new edition of this well-established textbook. The editors, with whom I am well acquainted are established lacrimal surgeons gifted with unique innovative skills and lacrimal insights. This text would surely find itself on the shelves of Ophthalmologists and Oculoplastic surgeons, who strive to maintain the relevance of their clinical practice with the current times.

Hyderabad, India

Mohammad Javed Ali
Dacryology Service
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Preface

The first edition of *The Lacrimal System: Diagnosis, Management and Surgery* was published less than a decade ago; however, this textbook has evolved to reflect the continuing advances in the field of tearing and lacrimal disorders and to meet the growing information base required by residents, fellows, and practitioners alike. The second edition of this book has been both reworked to include new authors from around the world, as well as revised to make the most of the vital information available.

In shaping and revising this new version, we have committed ourselves to making the textbook as useful as possible to physicians coping with the demands of patients whose diagnosis is often not straightforward. Mastering surgery of the lacrimal system involves techniques that can be challenging and sometimes hard to predict results.

This edition has a format that facilitates quick reference and allows the inclusion of more high-quality illustrations and photographs than in the first book. While information on understanding of biology and physiology of the lacrimal system is necessary, this edition focuses more directly and extensively than ever on crucial aspects of appropriate diagnosis and treatment. Areas of emphasis include minimally invasive procedures, traditional techniques as well as etiologies of lacrimal disorders. Virtually every chapter in this edition has been substantially rewritten, and the chapters are either entirely new or have new authors. We are proud of the leaders in the field who have contributed to this edition.

These are only highlights of the changes that we hope will make the second edition a comprehensive yet concise, and balanced distillation of the best information on which to base clinical decisions.

Chicago, IL, USA — Adam J. Cohen, MD

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Anatomy of the Lacrimal System

1

Cat N. Burkat and Leslie A. Wei

Successful lacrimal surgery begins with a thorough history and clinical examination, both of which guide the surgeon to the correct diagnosis and appropriate management. A thorough understanding of all relevant anatomy will further optimize the surgical outcome. The following components of the lacrimal drainage system anatomy will be discussed in detail:

1. Embryology
2. Osteology
3. Nasal and paranasal sinuses
4. Secretory lacrimal system
5. Excretory lacrimal system

Embryology

Familiarity with lacrimal system embryology is necessary to understand congenital abnormalities of the nasolacrimal drainage system. The orbital walls are embryologically derived from neural crest cells. Ossification of the orbital walls is completed by birth except at the orbital apex. The lesser wing of the sphenoid is initially cartilaginous and undergoes endochondral ossification, unlike the greater wing of the sphenoid and other orbital bones that develop via intramembranous ossification. The membranous bones surrounding the lacrimal excretory system are well developed at 4 months of embryologic age and ossify by birth.

The lacrimal gland begins development at the 22- to 25-mm embryologic stage as solid epithelial buds arise from the ectoderm of the superolateral conjunctival fornix [1–5]. Mesenchymal condensation around these buds forms the secretory lacrimal gland. The early epithelial buds form the orbital lobe in the first 2 months, whereas the secondary buds, which appear later in the 40- to 60-mm stage, develop into the palpebral lobe [1–3]. Canalization of the epithelial buds to form ducts occurs, on average, at the 60-mm stage, but may be seen in as early as the 28.5-mm stage [1, 3, 5]. The developing tendon of the levator palpebrae superioris muscle divides the gland into two lobes around the tenth week of development [1, 5]. The lacrimal gland continues to develop until 3–4 years after birth [3].

The excretory system begins its development at an earlier stage. In the 7-mm embryo, a depression termed the naso-optic fissure develops, bordered superiorly by the lateral nasal process and inferiorly by the maxillary process. The naso-optic fissure or groove gradually shallows as the structures bordering it grow and coalesce. Before it is completely obliterated, however, a solid strand of surface epithelium thickens along the floor of the

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rudimentary fissure extending from the orbit to the nose. The thickened cord of epithelium becomes buried to form a rod connected to the surface epithelium at only the orbital and nasal ends. This separation from the surface typically occurs at 43 days of embryologic age [6]. The superior end of the rod enlarges to form the lacrimal sac, and gives off two columns of cells that grow into the eyelid margins to become the canaliculi [7, 8].

Canalization of this nasolacrimal ectodermal rod begins at the fourth month or the 32- to 36-mm stage of development, proceeding first in the lacrimal sac, the canaliculi, and lastly in the nasolacrimal duct [7–9]. The central cells of the rod degenerate by necrobiosis, forming a lumen closed at the superior end by conjunctival and canalicular epithelium and closed at the inferior end by nasal and nasolacrimal epithelium. The superior membrane at the puncta is usually completely canalized when the eyelids separate at 7 months of gestation, and therefore is normally patent by birth. In contrast, the inferior membrane (Valve of Hasner) frequently persists in newborns, resulting in congenital nasolacrimal obstruction [10–12]. Abnormalities of development in this region, occurring typically after the fourth month of gestation, can result in congenital absence of any segment of the nasolacrimal system, supernumerary puncta, and lacrimal fistulae [6–9, 12–15].

Embryologically the bony nose is formed by the frontonasal process. The nasal septum bisects the nasal cavity and comprises three portions:

- The bony perpendicular plate of the ethmoid (superoanterior).
- The vomer (posterior and anteroinferior), a cartilaginous anterior triangle.
- The inferior membranous columella that divides the nares anteriorly.

During the sixth week of embryologic development, before cartilage forms in the walls of the primitive nasal cavities, linear outgrowths of the lining epithelium occur on the sides and roof of each nasal side. Each outgrowing gutter becomes a meatus, whereas the ridges left behind form the turbinates [8, 16].

Osteology

Whitnall described the orbital rim as a spiral with its two ends overlapping medially on either side of the lacrimal sac fossa [16]. The medial orbital rim is formed anteriorly by the frontal process of the maxillary bone rising to meet the maxillary process of the frontal bone. The lacrimal sac fossa is a depression in the inferomedial orbital rim, formed by the maxillary and lacrimal bones. It is bordered by the anterior lacrimal crest of the maxillary bone and the posterior lacrimal crest of the lacrimal bone. The fossa is approximately 16-mm high, 4- to 9-mm wide, and 2-mm deep [16, 17], and is narrower in women [18]. The fossa is widest at its base, where it is confluent with the opening of the nasolacrimal canal. On the frontal process of the maxilla just anterior to the lacrimal sac fossa, a fine groove termed the *sutura notha* or *sutura longitudinalis imperfecta* of Weber runs parallel to the anterior lacrimal crest (Fig. 1.1) [16]. It is a vascular groove through which small twigs of the infraorbital artery pass through to supply the bone and nasal mucosa, and should be anticipated during lacrimal surgery to avoid bleeding.

The medial orbital wall is formed, from anterior to posterior, by the:

- Frontal process of the maxilla
- Lacrimal bone
- Ethmoid bone
- Lesser wing of the sphenoid bone

The thinnest portion of the medial wall is the lamina papyracea, which covers the ethmoid sinuses laterally. The many bullae of ethmoid pneumatization appear as a honeycomb pattern medial to the ethmoid bone (Fig. 1.2). The medial wall becomes thicker posteriorly at the body of the sphenoid, and again anteriorly at the posterior lacrimal crest of the lacrimal bone.

The frontoethmoidal suture is important in orbital bony decompression or lacrimal surgery as it marks the roof of the ethmoid sinus, or the fovea ethmoidalis. Bony dissection superior to this suture may expose cerebrospinal fluid and the dura of the cranial cavity. The anterior and posterior

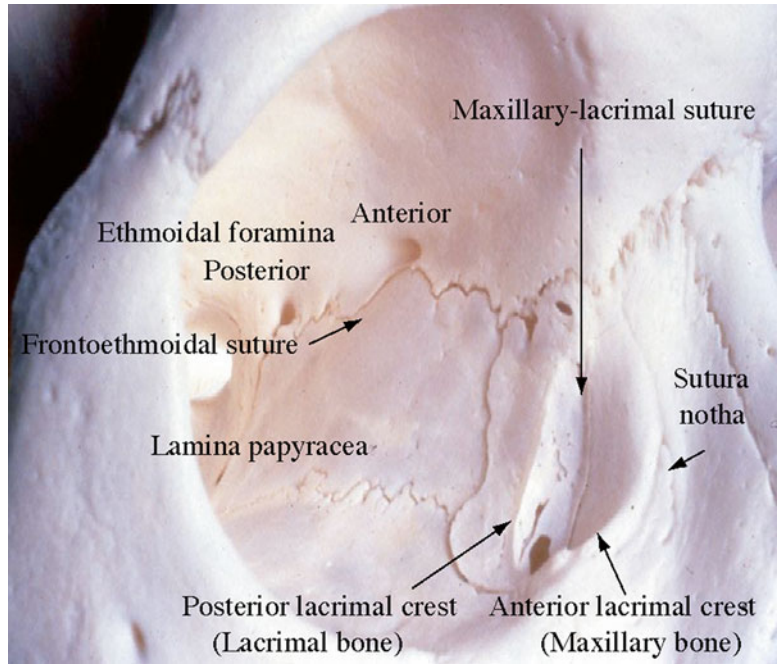

Fig. 1.1 Bony anatomy of the lacrimal sac fossa and medial orbital wall. The anterior and posterior lacrimal crests are formed by the maxillary and lacrimal bones, respectively

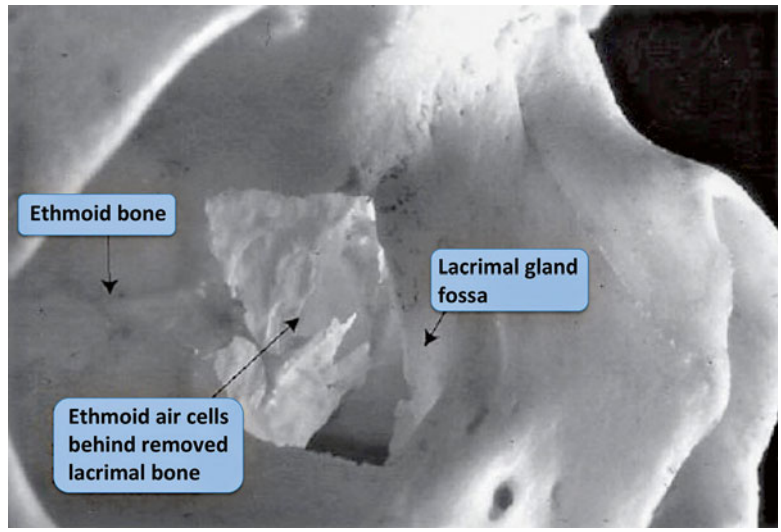

Fig. 1.2 The ethmoidal air cells are medial to the removed lacrimal bone, and may extend anteriorly to pneumatize the maxillary bone of the lacrimal sac fossa

ethmoidal foramina, conveying branches of the ophthalmic artery and the nasociliary nerve, are located at the frontoethmoidal suture, approximately 24- and 36-mm posterior to the anterior lacrimal crest, respectively (Fig. 1.3) [19]. Piagkou et al. found high anatomic variation, however, with anywhere from 1 to 6 ethmoidal foramina present in 249 human orbit specimens, with 61 % having 2 foramina [20].

The anterior lacrimal crest is an important landmark during external dacryocystorhinostomy surgery, as it represents the anterior border of the lacrimal sac fossa. In addition, the anterior limb of the medial canthal tendon attaches to the superior aspect of the anterior lacrimal crest. This attachment of the medial canthal tendon is often detached from the underlying bone along with the periosteum in order to gain better exposure during surgery.

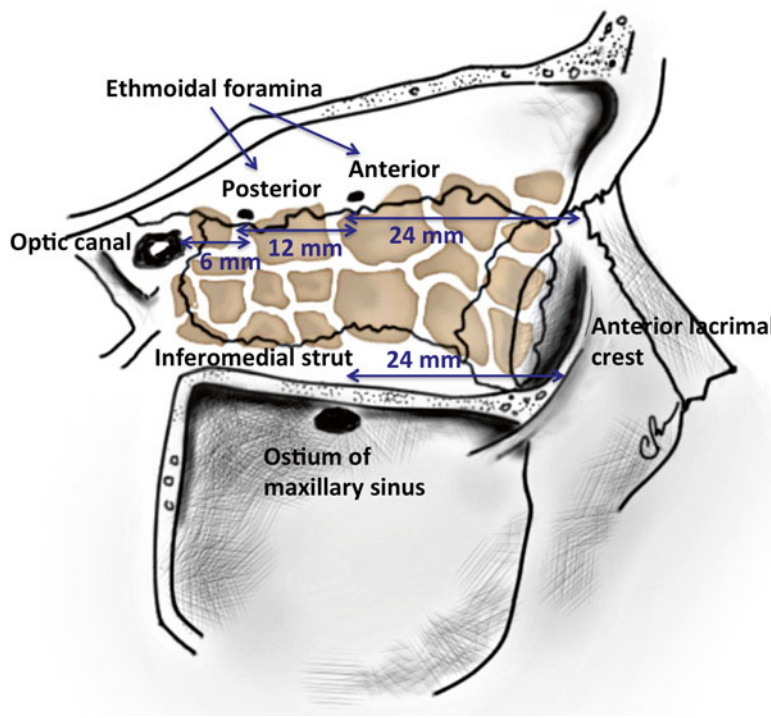

Fig. 1.3 Anteroposterior distances of the foramina from the anterior lacrimal crest. The ostium of the maxillary sinus lies approximately in a vertical line to the anterior ethmoidal foramen

A vertical suture runs centrally between the anterior and posterior lacrimal crests, representing the anastomosis of the maxillary bone to the lacrimal bone (see Fig. 1.1). A suture located more posteriorly within the fossa would indicate predominance of the maxillary bone, whereas a more anteriorly placed suture would indicate predominance of the lacrimal bone. The lacrimal bone at the lacrimal sac fossa has a mean thickness of 106 μm, which allows it to be easily penetrated to enter the nasal cavity at surgery [21]. In a patient with a maxillary bone dominant fossa, the thicker bone makes it more difficult to create the osteotomy. Twenty-five percent of Caucasian orbits are estimated to have a fossa that is equal parts maxillary and lacrimal bones, but up to a third may have a predominant maxillary bone [22].

At the confluence of the medial and inferior orbital rims, at the base of the anterior lacrimal crest, a small lacrimal tubercle may be palpated externally to guide the surgeon to the lacrimal sac located posterior and superior to it. In 28–34 % of orbits, the tubercle may project posteriorly as an anterior lacrimal spur [16, 23].

The nasolacrimal canal originates at the base of the lacrimal sac fossa, and is formed by the maxillary bone laterally and the lacrimal and inferior turbinate bones medially. The width of the superior opening of the canal measures, on average, 4–6 mm [16]. The duct courses posteriorly and laterally in the bone shared by the medial wall of the maxillary sinus and the lateral nasal wall for 12 mm, on average, to drain into the inferior meatus of the nasal cavity [24].

Nasal and Paranasal Sinuses

Knowledge of sinus anatomy enhances the understanding of surgical relationships to the orbit, and is particularly important in endonasal approaches. The bones forming the orbital floor, roof, and medial wall are pneumatized by air sinuses arising from the primitive nasal cavities. They retain communication with the nasal cavity and are thus lined by the nasal mucous membrane. The sinuses appear in early childhood, increase actively during puberty, and may continue to grow until 30 years of age [16].

The maxillary sinus is the largest of the paranasal sinuses, measuring 15 cm^3 [16]. The roof of the maxillary sinus forms the orbital floor that declines from the medial wall to the lateral wall at an angle of approximately 30°. The maxillary sinus drains into the hiatus semilunaris within the middle meatus through an ostium located near the level of the orbital floor, immediately inferior to the central portion of the maxilloethmoidal orbital strut. The ostium measures, on average, 24 mm from the orbital rim, which is approximately in a vertical line to the anterior ethmoidal foramen in the medial orbital wall (see Fig. 1.3) [25].

The ethmoid sinuses are the first to develop, reaching adult configuration at as early as 12 years of age [26]. Ethmoid bullae are particularly exuberant in their expansion, and frequently extend past the suture of the ethmoid bone and even into the lacrimal and maxillary bones of the lacrimal sac fossa (see Fig. 1.2) [27, 28]. The ethmoid sinuses are shaped like a rectangular box, slightly wider posteriorly where they articulate with the sphenoid sinus. The ethmoid sinuses comprise three main groups of air cells:

- Anterior—drain into the middle meatus
- Middle—drain into the middle meatus
- Posterior—drain into the superior meatus

The roof of the orbit slopes down as it travels medially, and this slope continues at the frontoethmoidal suture to become the roof of the ethmoid sinus, or *fovea ethmoidalis.* The ethmoid roof continues to slope inferiorly and medially to overlie the nasal cavity as the cribriform plate. The crista galli bisects the cribriform plate on its superior aspect, and continues inferiorly as the vertical nasal plate, or vomer. Because of this sloping, which is most prominent over the anterior ethmoid air cells, it is important to know the individual anatomy before surgery to avoid inadvertent cerebrospinal fluid leak or more severe intracranial injury [29].

The anatomic relationship of the anterior ethmoid air cells to the lacrimal sac fossa is important to understand before performing dacryocystorhinostomy in order to avoid confusion between the ethmoid and nasal cavities during creation of the ostium. A close anatomic relationship between the anterior ethmoid air cells, termed the agger nasi cells, to the lacrimal sac fossa has been demonstrated in several past studies [26–28, 30–33]. These agger nasi bullae may pneumatize the lacrimal bone, and rarely extend into the frontal process of the maxillary bone. A study by Whitnall in 1911 described the location of the anterior ethmoid air cells being:

- directly medial to the lacrimal sac fossa in 86 % of skulls [27]
- extending anteriorly to the vertical maxillary-lacrimal suture in 32 % of skulls
- and extending farther to the anterior lacrimal crest in an additional 54 %

The ethmoid cells were located consistently in the superior half of the fossa, with the inferior half of the fossa directly adjacent to the middle meatus of the nasal cavity.

Similarly, Blaylock et al. reviewed computed tomography (CT) scans of 190 orbits and found that in 93 % of the orbits, the anterior ethmoid cells extended anterior to the posterior lacrimal crest, with 40 % extending anterior to the maxillary-lacrimal bone suture and entering the frontal process of the maxilla [28]. In only 7 % of orbits was the nasal cavity directly adjacent to the entire lacrimal sac fossa. As described by Whitnall, the anterior extension of the air cells was most prominent adjacent to the superior half of the lacrimal sac fossa [26–28, 30, 32, 34]. The ethmoid air cells and sinus mucosa should thus be removed to create a proper osteotomy.

Understanding the anatomic relationship of the lacrimal sac fossa to the ethmoid sinus also helps avoid complications such as inadvertent dacryocystorhinostomy fistulization into the ethmoid sinus, cerebrospinal fluid leakage, orbital hemorrhage, and trauma to subsequent scarring of the nasal mucosa and nasal septum [35].

Laterally, the nasal wall has three or more horizontal ridges termed turbinates, with a corresponding meatus below each (Fig. 1.4). The inferior turbinate is the largest, arising from the medial wall of the maxillary sinus. The smaller and more posterior middle, superior, and supreme (if present) turbinates are outcroppings of the ethmoid bone. The supreme turbinate may be found in up to 65 % of patients. The inferior turbinate is visualized by directing a nasal speculum

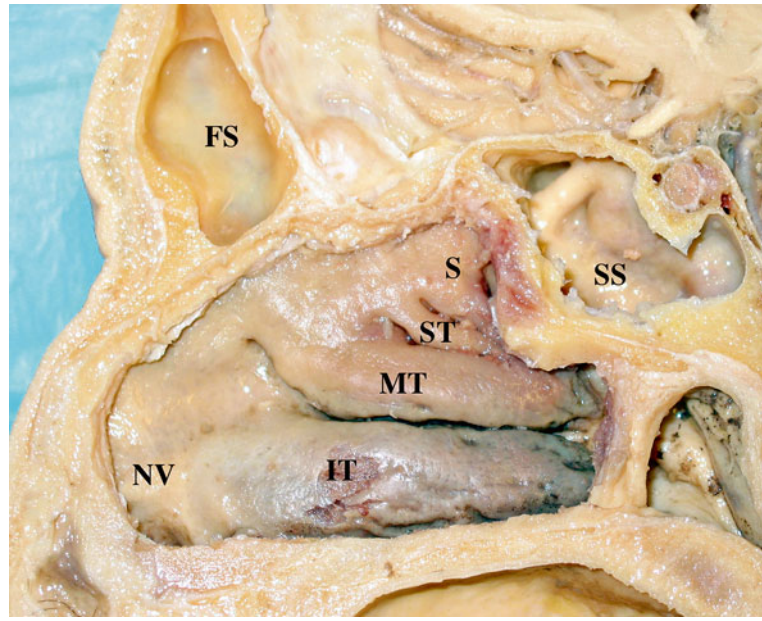

Fig. 1.4 Endonasal sagittal view. Each nasal turbinate has a corresponding meatal space located immediately below (*FS* frontal sinus, *IT* inferior turbinate, *MT* middle turbinate, *NV* nasal vestibule, *S* supreme turbinate, *SS* sphenoid sinus, *ST* superior turbinate)

parallel to the floor of the nasal cavity. The nasal vestibule is the large cartilaginous anterior dilatation of the nose above the nares, covered by squamous epithelium with hair follicles, to which the silicone tubes may be secured during surgery.

The middle turbinate originates posteriorly from the roof of the nose at the cribriform plate, and arises anteriorly from the medial wall of the maxillary sinus. The lacrimal sac fossa lies anterior and lateral to the anterior tip of the middle turbinate, thus the entry in an external dacryocystorhinostomy is at the anterior tip of the middle turbinate (Fig. 1.5). An ostium achieved by the endoscopic approach is usually more inferior to the routine external site.

Within the middle meatus lies a curvilinear gutter, the hiatus semilunaris, into which the ostium of the maxillary sinus drains. It is bordered inferiorly by a bony ridge termed the uncinate process, and superiorly by the bulla ethmoidalis prominence which represents the most anterior ethmoid air cells (Fig. 1.6) [36]. The ethmoid (anterior and middle), frontal, and maxillary sinuses empty into the middle meatus. The frontonasal duct drains the frontal sinus into the anterosuperior portion of the hiatus semilunaris.

Secretory System

Lacrimal Gland and Accessory Glands

The primary lacrimal gland is located in the superotemporal orbit in a shallow lacrimal fossa of the frontal bone. The gland is composed of numerous acini (lobular clusters of secretory cells) that drain into progressively larger tubules and ducts. The acini are made up of a basal myoepithelial cell layer with inner columnar secretory cells. Contraction of the myoepithelial cells helps force secretions into the tubules and drainage ducts [37].

The gland measures 20×12×5 mm and is divided by the lateral horn of the levator aponeurosis into a larger orbital lobe, and a lesser palpebral lobe below [38, 39]. The size of the lacrimal gland decreases with age but does not vary by gender [40]. The orbital lobe is the larger of the two lobes and lies posterior to the orbital septum and preaponeurotic fat and anterior to the levator aponeurosis [38]. Two to six secretory ducts from the orbital lobe of the lacrimal gland pass through the palpebral lobe or along its fibrous capsule, joining with ducts from the palpebral lobe to form 6–12 tubules that empty into the superolateral conjunctival fornix 4–5 mm above the tarsus [37, 41].

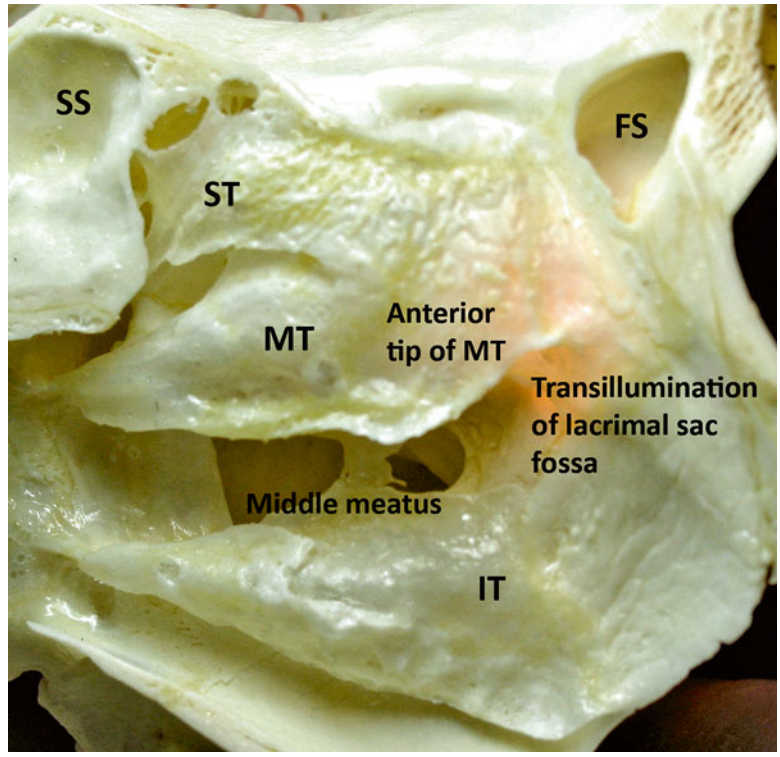

Fig. 1.5 Endonasal site of a dacryocystorhinostomy ostium. Transillumination through the lacrimal sac fossa demonstrates its location at the anterior tip of the middle turbinate (*FS* frontal sinus, *IT* inferior turbinate, *MT* middle turbinate, *SS* sphenoid sinus, *ST* superior turbinate)

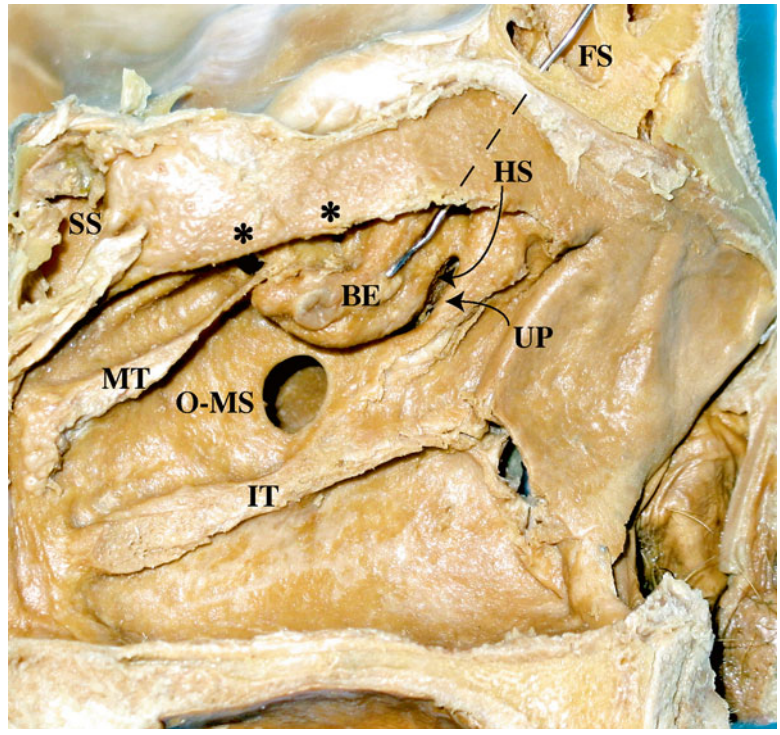

Fig. 1.6 Endonasal view of lateral nasal wall with turbinates removed (*BE* bulla ethmoidalis, *FS* frontal sinus, *HS* hiatus semilunaris, *IT* inferior turbinate, *MT* middle turbinate, *O-MS* ostium of maxillary sinus, *SS* sphenoid sinus, *UP* uncinate process, * ethmoid ostia)

Accessory lacrimal glands, located in the conjunctival fornices and along the superior tarsal border, are comprised of:

- Accessory glands of Krause—20–40 in the superior conjunctival fornix and 10–20 in the lower conjunctival fornix.
- Accessory glands of Wolfring—located in the upper lid superior tarsal border [38, 42].

The lacrimal gland receives innervation from cranial nerves V and VII, as well as from the sympathetics of the superior cervical ganglion [43]. The lacrimal branch of the ophthalmic division of the trigeminal nerve carries sensory stimuli from the lacrimal gland. The lacrimal gland receives arterial supply from the lacrimal artery, with contributions from the recurrent meningeal artery and a branch of the infraorbital artery. The intraorbital venous drainage travels adjacent to the artery and drains into the superior ophthalmic vein.

Parasympathetic secretomotor innervation to the lacrimal gland is more complex. Parasympathetic secretomotor fibers originate in the lacrimal nucleus of the pons, and travel a long course within the nervus intermedius, the greater superficial petrosal nerve, deep petrosal nerve, and the vidian nerve to finally synapse in the pterygopalatine ganglion [34]. Postganglionic parasympathetic fibers leave the pterygopalatine ganglion via the pterygopalatine nerves to innervate the lacrimal gland [44, 45]. In addition, some fibers may join the zygomatic nerve as it branches from the maxillary division of the trigeminal nerve and enters the orbit through the inferior orbital fissure. Branches of the zygomatic nerve may ascend and enter the posterior surface of the lacrimal gland either alone or in combination with the lacrimal nerve [38]. However, an anatomic study by Ruskell in 2004 found that parasympathetic fibers traveled along a branch of the middle meningeal artery through the superior orbital fissure before joining the ophthalmic or lacrimal artery to supply the lacrimal gland [46]. This was in contrast to the traditional assumption that secretomotor nerves pass to the gland via the zygomatic and lacrimal nerves.

Sympathetic nerves enter with the lacrimal artery and along with parasympathetics in the zygomatic nerve. The zygomatic branch of the maxillary trigeminal nerve gives off the lacrimal branch before dividing into zygomaticotemporal and zygomaticofacial branches. This lacrimal branch anastomoses with the lacrimal nerve of the ophthalmic trigeminal nerve or travels along the periorbita to independently enter the gland at its posterolateral aspect.

Excretory System

Lacrimal Drainage System

The lacrimal excretory pathway begins at a 0.3-mm opening on each medial eyelid termed the punctum [16, 41]. Because of more rapid growth of the maxilla compared with the frontal bone during embryologic development, the lateral migration pulls the inferior canaliculus laterally, resulting in the lower eyelid punctum being located slightly lateral to the upper eyelid punctum [8]. The punctal opening widens into the ampulla, which is 2 mm in height and oriented perpendicular to the eyelid margin, before making a sharp turn into the canaliculi which run parallel to the eyelid margins. The canaliculi, measuring 8–10 mm in length and 0.5–1.0 mm in diameter, are lined with stratified squamous epithelium and surrounded by orbicularis muscle (Fig. 1.7).

The superior and inferior canaliculi merge into a common canaliculus before entering the nasolacrimal sac in more than 90 % of individuals [41, 47]. In a large study using digital subtraction dacryocystograms, the common canaliculus was present in 94 % of lacrimal drainage systems. The upper and lower canaliculi joined at the wall of the lacrimal sac without a common canaliculus in an additional 4 %, with only 2 % of systems having completely separate drainage of the upper and lower canaliculi into the lacrimal sac [48]. More recent studies of human cadaver lacrimal systems have found distinct orifices in anywhere from <1 % to as high as 10 % of specimens [49, 50]. The common internal punctum visualized within the lacrimal sac during dacryocystorhinostomy surgery should be free of any mucosal membrane or fibrous stricture for long-term surgical success.

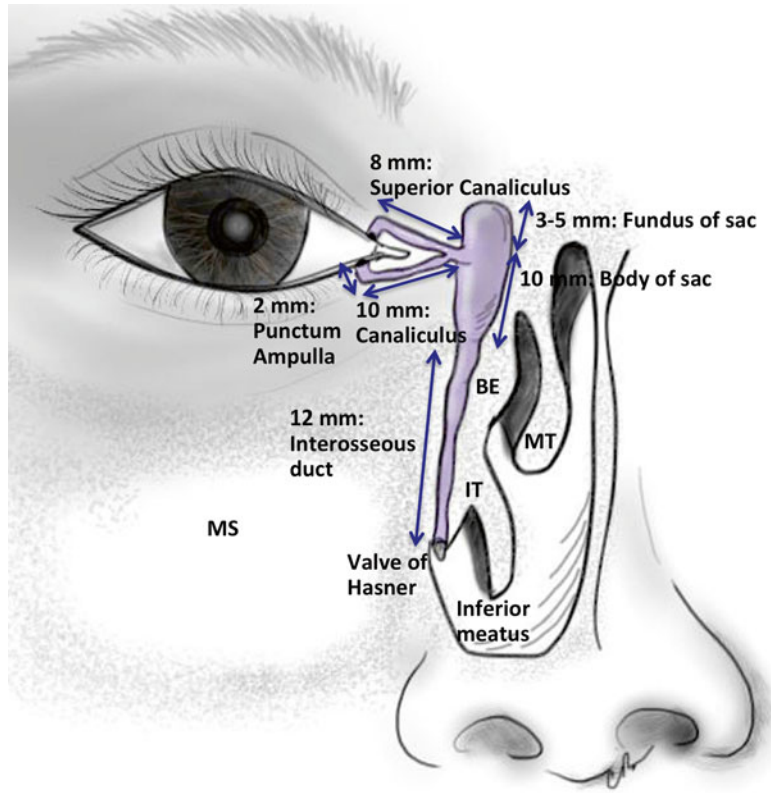

Fig. 1.7 Approximate dimensions of the lacrimal excretory system (*BE* bulla ethmoidalis, *IT* inferior turbinate, *MS* maxillary sinus, *MT* middle turbinate)

Tucker demonstrated a consistent pattern of angulation within the canalicular system [51]. The canaliculi first angle posteriorly behind the medial canthal tendon. They then bend at the canaliculus–common canaliculus junction at an angle of 118°, before passing anteriorly to enter the lacrimal sac at an acute angle of 58°. This consistent angulation may contribute to a valve-like effect that prevents retrograde flow from the lacrimal sac. The functional valve between the common canaliculus and the lacrimal sac has traditionally been attributed to the valve of Rosenmüller, although some studies have been unable to document this structure [6].

The nasolacrimal sac and duct are portions of the same continuous structure (Figs. 1.7 and 1.8).

- Both are lined by non-ciliated columnar epithelium.
- The total sac measures a length of 12–15 mm vertically and 4–8 mm anteroposteriorly.
- The fundus of the sac extends 3–5 mm above the medial canthal tendon.
- The body of the sac measures, on average, 10 mm in height [41].

The sac rests in the lacrimal sac fossa, with its medial aspect tightly adherent to the periosteal lining of the fossa. The lower nasolacrimal fossa and the nasolacrimal duct are narrower in females, which may account for the female predominance of nasolacrimal obstruction [18]. Traditionally it is taught that the nasolacrimal duct travels inferolaterally and slightly posteriorly in its bony course to the inferior turbinate for an interosseous distance of approximately 12 mm. Recent studies have challenged this notion and shown the bony nasolacrimal canal to often be parallel to the sagittal plane or even inclined medially [52]. The long axis of the duct and canal forms an angle of 15–25° posterior to the frontal plane, or in a line connecting the medial commissure to the first molar tooth (Fig. 1.9) [16]. The nasolacrimal duct ostium within the inferior meatus is located 25–30 mm posterior to the lateral margin of the anterior nares [16].

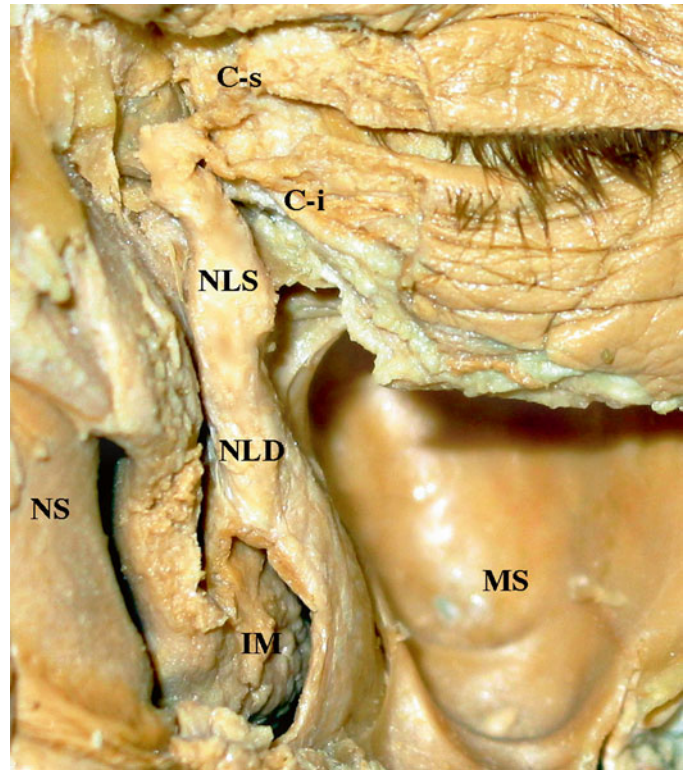

Fig. 1.8 Anatomic dissection of the lacrimal drainage system within the bony wall between the nasal cavity and maxillary sinus. The nasolacrimal duct drains into the inferior meatus (*C-i* inferior canaliculus, *C-s* superior canaliculus, *IM* inferior meatus, *MS* maxillary sinus, *NLD* nasolacrimal duct, *NLS* nasolacrimal sac, *NS* nasal septum)

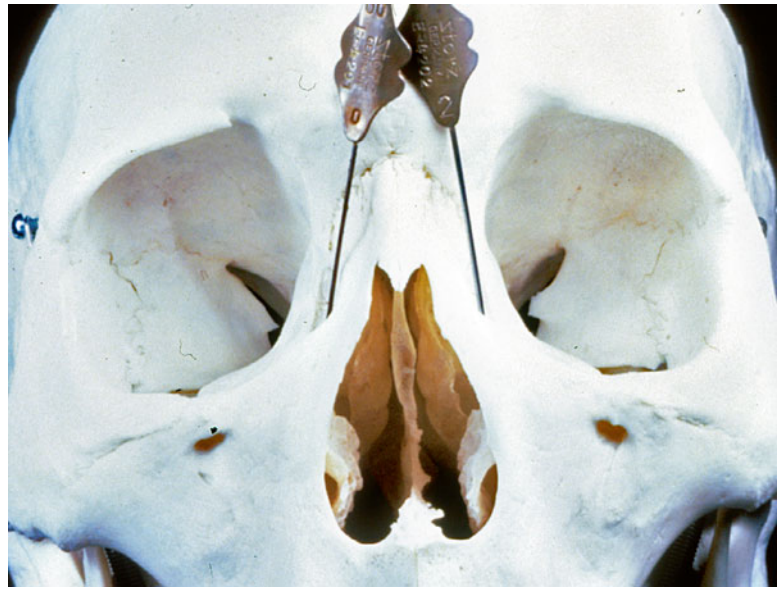

Fig. 1.9 The nasolacrimal duct travels inferolaterally and slightly posteriorly in its bony course to the inferior turbinate, forming an angle of approximately 15–25° posterior to the frontal plane

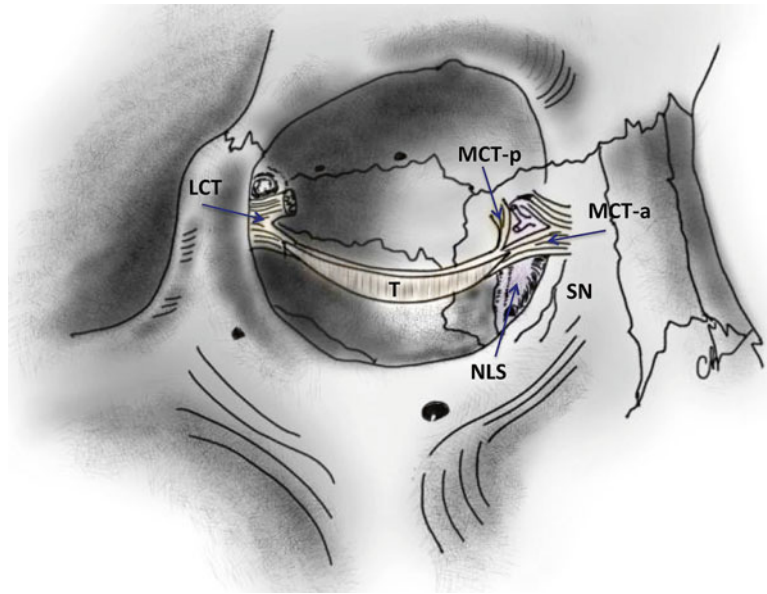

Fig. 1.10 Relationship of the medial canthal tendon to the lacrimal sac. The thick anterior limb of the medial canthal tendon wraps along the anterior upper half of the lacrimal sac to insert onto the anterior lacrimal crest, while the thin posterior limb passes behind the sac to insert onto the posterior lacrimal crest (*LCT* lateral canthal tendon, *MCT-a* medial canthal tendon-anterior limb, *MCT-p* medial canthal tendon-posterior limb, *NLS* nasolacrimal sac, *SN* sutura notha, *T* tarsus)

Wormald et al. used CT dacryocystograms to evaluate the relationship of the lacrimal sac to the insertion of the middle turbinate on the lateral nasal wall in 76 patients [53]. The mean height of the lacrimal sac above the middle turbinate insertion was measured to be 8.8 mm and below it was 4.1 mm.

Multiple mucosal folds and sinuses have been reported within the lacrimal drainage system, although their role and presence are unclear:

- Valve of Rosenmüller—located at the junction of the common canaliculus and sac
- Valve of Krause—located between the sac and duct
- Valve of Hasner (*plica lacrimalis*)—located at the opening of the duct into the inferior meatus of the nose [54]

The inferior oblique muscle arises from a shallow depression in the orbital plate of the maxilla at the anteromedial corner of the orbital floor just lateral to the lacrimal excretory fossa. Care must be taken during external dacryocystorhinostomy surgery to delimit the bony ostium to just medial to this depression.

The superficial pretarsal orbicularis oculi muscles envelope the canaliculi as they traverse the medial eyelids and medial canthal region. The lacrimal sac is ensheathed in the lacrimal fascia, which consists of the periorbital lining that splits at the posterior lacrimal crest into one layer that lines the fossa, and another layer that encases the lateral sac to reach the anterior lacrimal crest. Additionally, the lacrimal sac is wrapped by the thick anterior and thin posterior limbs of the medial canthal tendon (Fig. 1.10). Almost immediately after the medial canthal tendon arises from the tarsal plates, it divides into a thicker anterior limb that wraps along the anterior upper half of the lacrimal sac before inserting onto the anterior lacrimal crest, and a very thin posterior limb that passes behind the sac to insert onto the posterior lacrimal crest (Fig. 1.10). However, in a recent study, Poh et al. studied the histology of the structure typically identified as the posterior limb of the medial canthal tendon and found it to be composed of Horner's muscle and the lacrimal diaphragm [55]. Horner-Duverney muscle (*tensor tarsi* or *pars lacrimalis)* is classically taught as being the deep portion of the pretarsal orbicularis muscle that passes posterior to the lacrimal sac and the posterior limb of the medial canthal tendon, and inserts onto the upper posterior lacrimal crest [7, 16, 41, 56]. The orbital septum inserts along or just posterior to the inferior posterior lacrimal crest.

Creation of a large osteotomy helps to increase the chance of success of dacryocystorhinostomy

surgery. As much as one-third of the lacrimal sac may lie above the medial canthal tendon; therefore, to create an adequate osteotomy for apposition of the entire lacrimal sac and nasal mucosa, the osteotomy should extend superior to the level of the medial canthal tendon. Bone may be carefully removed with the rongeur or drill until thickening of the frontal bone is noted, as the anterior cranial fossa will lie slightly above the medial canthal tendon level. This point should generally lie 5 mm or more above the common internal punctum. One study found that the oblique distance between the common internal punctum and the most anterior aspect of the cribriform plate was 25 ± 3 mm [57]. Using a retrospective study of coronal maxillofacial CT scans from 40 adults, McCann found that the mean vertical dimension between the medial canthal tendon and the level of the cribriform plate was 17 ± 4 mm [58].

The angular artery branch of the facial artery runs along the line of the nasojugal skinfold and passes superficial to the medial canthal tendon. The angular vein courses immediately lateral to the artery, with both vessels located approximately 5 mm anteromedial to the anterior lacrimal crest, or 8 mm medial to the medial commissure of the eyelids [16].

Lacrimal Pump

The lacrimal pump theory was popularized by Jones, in which he proposed that contraction of the pretarsal orbicularis muscle fibers during eyelid closure compresses and shortens the canaliculi, pumping tears toward the lacrimal sac [7, 41]. Furthermore, simultaneous lateral movement of the lateral lacrimal sac from contraction of the deep head of the preseptal orbicularis muscle was thought to generate a negative pressure within the lacrimal sac that draws tears into the sac from the canaliculi. In contrast, other anatomic and physiologic studies have found that a positive-pressure mechanism, rather than a negative-pressure mechanism, is responsible for the lacrimal pump during eyelid closure [56, 59–63]. Thale used histological, immunohistochemical, and scanning electron microscopic techniques to demonstrate that the wall of the lacrimal sac is composed of collagen, elastic, and reticular fiber bundles arranged in a helical pattern. He proposed that the lacrimal sac distends and is pulled superolaterally because of its medial attachments when the lacrimal orbicularis muscle contracts with blinking. In addition, the helical collagen and elastic fibers encircling the sac may result in the sac being "wrung out" as another proposed mechanism for lacrimal drainage [64, 65]. However, using magnetic resonance dacryocystography, Amrith et al. demonstrated that there is no change in lacrimal sac volume during eyelid closure [66]. Clearly, the lacrimal pump mechanism remains to be fully elucidated.

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Nasal Anatomy and Evaluation

2

Humbert Massegur-Solench, Jacinto García-Lorenzo, and Juan Ramon Gras-Cabrerizo

Introduction

The lacrimal drainage system sits in the lateral wall of the nasal cavity. Most of it is lodged in a canal excavated in the maxilla that runs craneocaudally for 30 mm leading to the inferior meatus. Many structures in the lateral wall have a close relationship with this canal, serving as surgical landmarks. In addition to that, anatomical variations of nasal structures may distort this canal disrupting lacrimal drainage.

This complex relationship between nasal anatomy and the lacrimal system requires a good understanding by the surgeon (ophthalmologist or otolaryngologist) to avoid complications during the different approaches.

Osteology of the Medial Wall of the Orbit

The Orbit (*Cavitas Orbitalis*)

The orbit is a bony structure in the shape of a quadrangular pyramid limited by seven different bones: frontal, ethmoid, lacrimal, sphenoid, zygomatic, palatine, and maxilla (Fig. 2.1). It has an anterior base, a posterior apex, and four walls (superior, inferior, lateral, and medial) [1].

Both lateral walls form a 90° angle, while each of them is situated at 45° from the medial wall. Orbital walls are curved in order to maintain the projection of the ocular globe while cushioning trauma to the eye.

In an adult, the height of the orbit is approximately 35 mm and the width 40 mm. The volume of the orbit is 30 mL, including 7 mL corresponding to the ocular globe [2, 3].

Medial Wall (*Paries Medialis*)

It separates the orbit from the ethmoid sinus and the nasal cavity. From anterior to posterior, the medial wall is constituted by the frontal process of the maxilla (*processus frontalis*), the lacrimal bone (*os lacrimale*), the lamina papyracea of the ethmoid bone (*lamina orbitalis*), and the sphenoid bone (*os sphenoidale*) (Fig. 2.1).

The lamina papyracea comprises the largest portion of the medial wall. It is an extremely thin layer of bone (0.2–0.4 mm) [4] that becomes thicker in its posterior part, where it inserts in the sphenoid body. In this area it conforms the medial wall of the optic canal (*canalis opticus*) [1]. Superiorly, the lamina papyracea articulates with the roof of the orbit at the frontoethmoid suture. The foramina of the anterior and posterior ethmoidal canals can be found at this level (Fig. 2.1).

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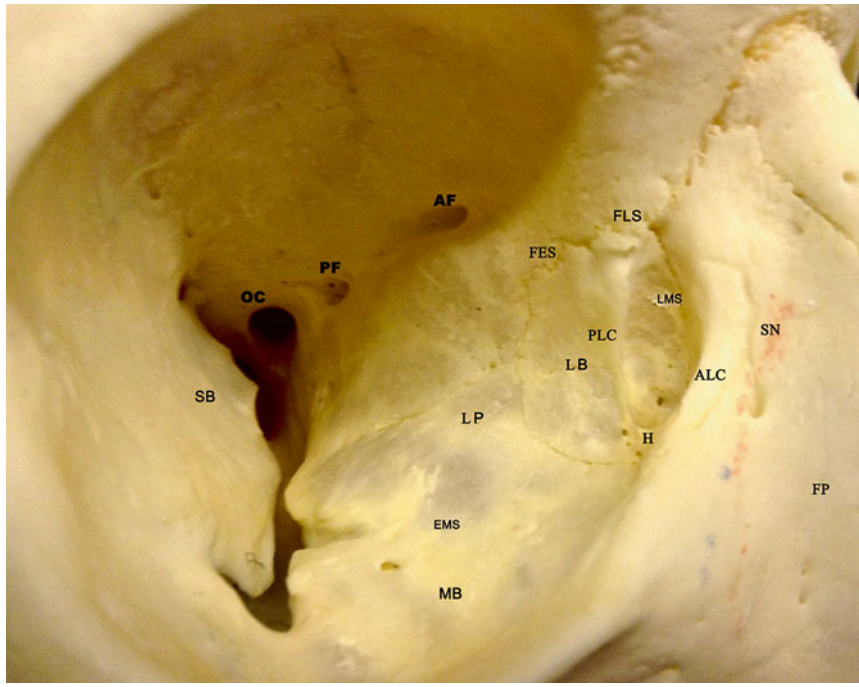

Fig. 2.1 Middle wall of right orbit. *PLC* posterior lacrimal crest, *ALC* anterior lacrimal crest, *H* hammulus, *LMS* lacrimo maxillar suture, *FES* fronto ethmoid suture, *FP* frontal process, *LP* lamina papyracea, *LB* lacrimal bone, *SN* sutura nota, *AF* anterior foramen (anterior ethmoid artery), *PF* posterior foramen (posterior ethmoid artery), *OC* optic canal (optic nerve), *SB* sphenoid bone, *MB* maxilla *EMS* ethmoidomaxillary suture

Through these canals, branches of the ophtalmic artery and the nasociliary nerve exit the orbit towards the nasal cavity.

The rule 24–12–6 has been suggested to remember the distance in millimeters from the anterior lacrimal crest to the anterior ethmoidal foramen (24 mm), from anterior to posterior foramina (12 mm), and from the posterior foramen to the optic canal (6 mm) [5]. The medial wall articulates with the orbital floor at the ethmoidomaxillary suture.

Lacrimal Fossa (*Fossa Sacci Lacrimalis*)

The lacrimal sac is contained in a groove excavated in the inferomedial region of the medial orbital wall called the lacrimal fossa. It is limited by the anterior lacrimal crest (*crista lacrimalis anterior*) of the frontal process of the maxilla and the posterior lacrimal crest (*crista lacrimalis posterior*) of the lacrimal bone. The distance between both lacrimal crests is approximately 8–9 mm [6, 7] (Fig. 2.1).

The articulation between the frontal process of the maxillary bone (*margo lacrimalis*) and the lacrimal bone is a vertical crest called lacrimomaxillary suture. Endonasally, this suture corresponds to the maxillary line [8] which is a very important landmark, easy to identify by endoscopic approach. For external DCR, however, the most important landmark is the anterior lacrimal crest. Anterior to this crest lies a fine vascular groove termed *sutura nota* that conveys a small branch of the infraorbital artery that may cause significant bleeding during dissection of this area [9].

The distance between the anterior lacrimal crest and the lacrimomaxillary suture is 4 mm, representing roughly the midpoint of the lacrimal fossa. Vertically, the lacrimal fossa measures 10–17 mm [7, 10, 11].

The palpebral portion of the orbicularis muscle (*pars palpebralis*) inserts in the anterior lacrimal crest by the medial palpebral ligament.

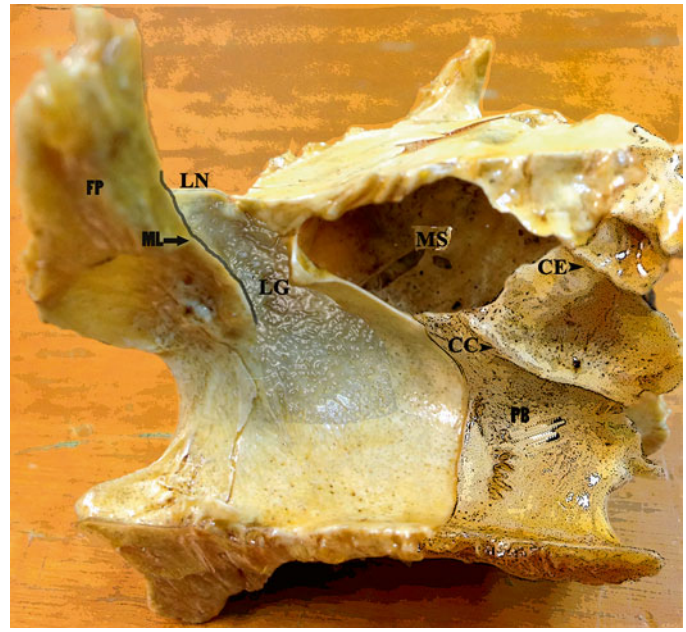

Fig. 2.2 Maxilla and palatine bone. *FP* frontal process, *ML* margo lacrimalis, *LG* lacrimal groove, *MS* maxillary sinus, *PB* palatine bone, *CE* crista ethmoidalis, *CC* crista conchalis, *LN* lacrimal notch

This portion has a deeper part that originates in the posterior lacrimal crest (*pars lacrimalis*) that runs behind the lacrimal sac and helps to its dilatation [1]. This portion was first described by Professor W.E. Horner in 1824 and has been named Horner's muscle [12].

The Lacrimal Bone

The lacrimal bone is a quadrilateral sheet of bone divided in two regions by the posterior lacrimal crest. The posterior part articulates with the lamina papyracea of the ethmoid bone, which lies at the same level. The anterior part forms the posterior boundary of the lacrimal fossa. The lacrimal bone has a thickness of 106 μm [13]. This minimal thickness allows the osteotomies to be done with laser during endocanalicular DCR.

Superiorly, the lacrimal bone articulates with the internal orbitary process of the frontal bone, forming the frontolacrimal suture (Fig. 2.1).

Nasolacrimal Canal (*Canalis Nasolacrimalis*)

The nasolacrimal canal opens at the base of the lacrimal fossa. It is limited laterally by the maxillary bone and medially by the lacrimal bone and the inferior turbinate.

The superior orifice is formed by the articulation of a small hook-like projection of the lacrimal bone (*hamulus lacrimalis*) with the upper portion of the lacrimal notch (*incisura lacrimalis*) of the maxilla (Fig. 2.2). The lacrimal process of the inferior turbinate (*processus lacrimalis*) and the inferior margin of the lacrimal bone close the canal inferiorly. The mean length of the bony canal is about 11 mm. The mean transverse diameter is approximately 3.5–4.6 mm, and the anteroposterior diameter is 5.6–6.8 mm. A narrowing is usually found at entrance of the canal that has an oblique inferior and posterior course, forming a 15–25° angle posterior to the frontal plane [14–17] (Figs. 2.3 and 2.4).

Inferior Orifice of the Nasolacrimal Canal (*Ostium Canalis Nasolacrimalis*)

The orifice of the nasolacrimal canal is located at the roof of the inferior nasal meatus. It can be located approximately 1.5 cm superior to the nasal floor, 1.5 cm posterior to the anterior attachment of the inferior nasal turbinate to the lateral nasal wall, and 2.4 cm from the anterior nasal spine [10, 18]. This orifice is usually covered by a mucosal fold called Hasner's valve [19] (Figs. 2.5 and 2.6).

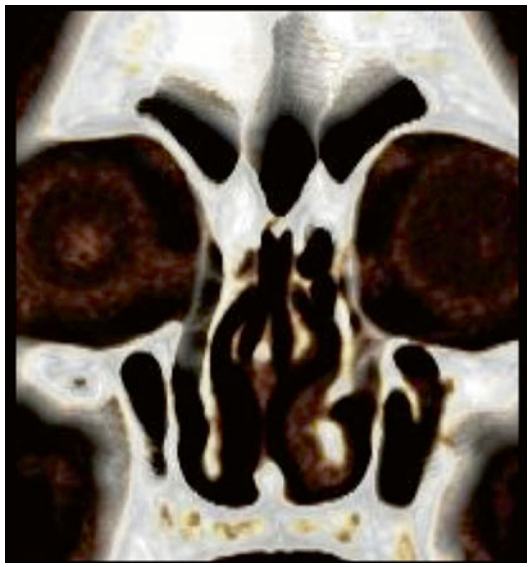

Fig. 2.3 Cranial CT scan of cadaver specimen showing the bony portion of the lacrimal system (nasolacrimal canal)

Lateral Wall of the Nasal Cavity

The Maxilla (*Maxila*)

The maxilla is a paired bone that takes part in both the facial massif and the lateral wall of the nasal cavity. It is composed of a central body and four processes: zygomatic, frontal, alveolar, and palatine. The body of the maxilla contains the maxillary sinus that opens into the nasal cavity through the *hiatus maxillaris.* The palatine process articulates with its contralateral counterpart to form the anterior segment of the hard palate (Fig. 2.2). The frontal process grows superiorly from the anterior part of the body, to articulate cranially with the frontal bone, in the posterior margin with the lacrimal bone, in the medial aspect with the middle turbinate, and in the inferior margin with the inferior turbinate (Fig. 2.7).

The lacrimal groove (*sulcus lacrimalis*) is excavated in the body of the maxilla posterior to the frontal process. In most cases it is an open or partially covered groove, but eventually a complete conduct can be found. The lacrimal groove lodges part of the lacrimal sac and the membranous duct to its outlet in the inferior meatus.

The nasolacrimal canal is completed medially by the lacrimal bone in the uppermost part and

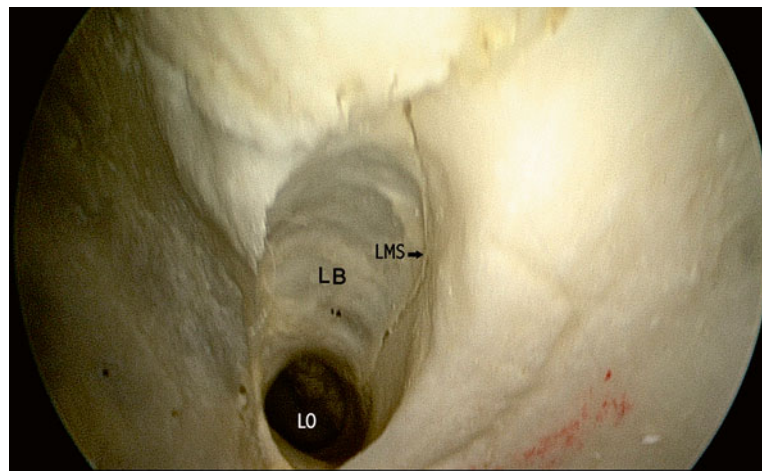

Fig. 2.4 Right nasolacrimal canal. View from the lacrimal fossa. *LMS* lacrimo maxillar suture, *LB* lacrimal bone, *LO* lacrimal orifice

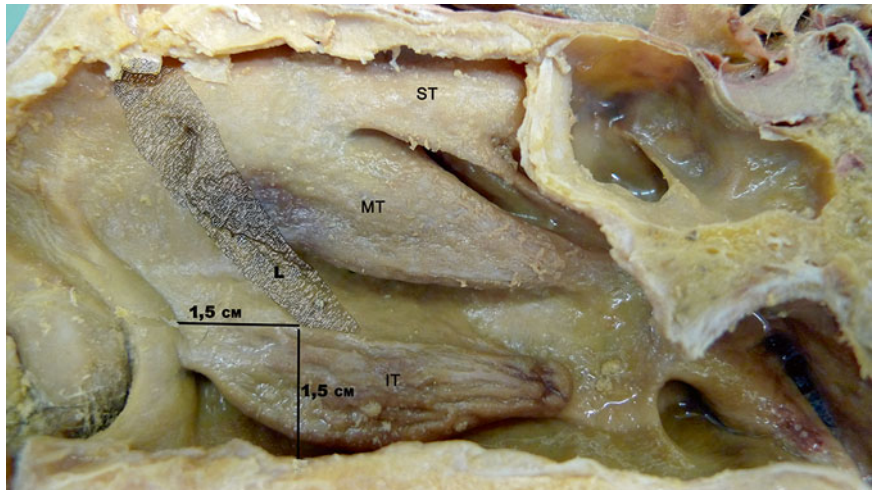

Fig. 2.5 Projection of the lacrimal system canal in the lateral wall of the right nasal cavity. *L* projection of the lacrimal system, *MT* middle turbinate, *IT* inferior turbinate, *ST* superior turbinate

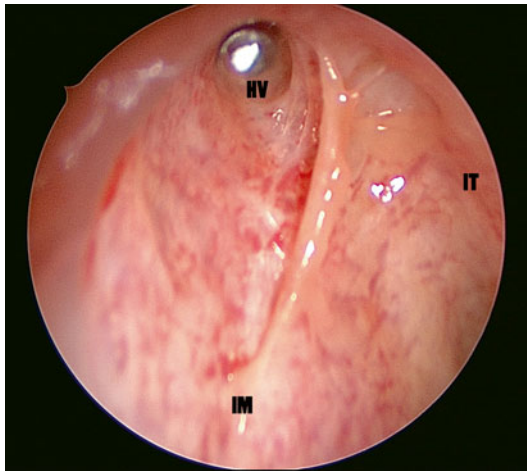

Fig. 2.6 Endoscopic view of the inferior meatus. 45° angled endoscope. *IM* inferior meatus, *HV* Hasner's valve, *IT* inferior turbinate

the lacrimal process of the inferior turbinate inferiorly (Fig. 2.8).

The maxilla articulates dorsally with the palatine bone, which in turn articulates with the pterygoid process of the sphenoid bone, serving as boundary for the pterygopalatine fossa. At the same time, they compose the lateral wall of the nasal cavity and give support to the ethmoidal air cells, and the middle, superior, and supreme turbinates.

The Palatine Bone (*Os Palatinum*)

The palatine bone is located between the maxilla and the pterygoid process of the sphenoid. It has horizontal and perpendicular plates. The horizontal plate articulates with the horizontal plate of the maxilla forming the hard palate. The perpendicular plate has two processes, orbital and sphenoidal, and a notch that is converted into a foramen by the apposition of the pterygoid plate of the sphenoid. This foramen serves as passage for the sphenopalatine vessels and nerves to the nasal cavity. The nasal surface of the perpendicular plate has two crests. The superior crest (*crista ethmoidalis*) gives insertion to the middle turbinate and the inferior (*crista conchalis*) to the inferior turbinate (Figs. 2.2, 2.7, and 2.9).

The Ethmoid Bone (*Os Ethmoidale*)

The ethmoid bone sits in the middle of the sinonasal structures and is part of both the lateral and the middle walls of the nasal cavity. On its superior face, the lamina cribosa separates the anterior cranial fossa from the nasal cavity. The perpendicular plate (*lamina perpendicularis*) hangs on a sagittal plane that forms the upper part

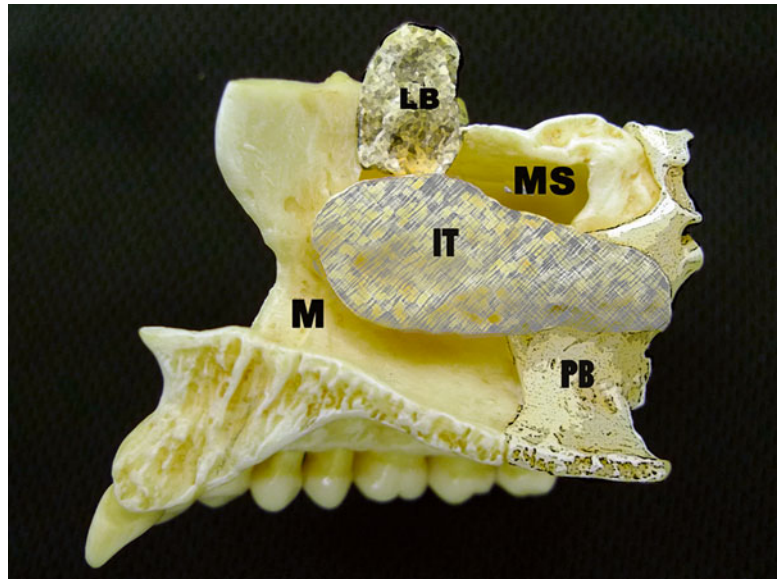

Fig. 2.7 Lateral wall of right nasal cavity: maxilla. *IT* inferior turbinate, *LB* lacrimal bone, *MS* maxillary sinus, *PB* palatine bone, *M* maxilla

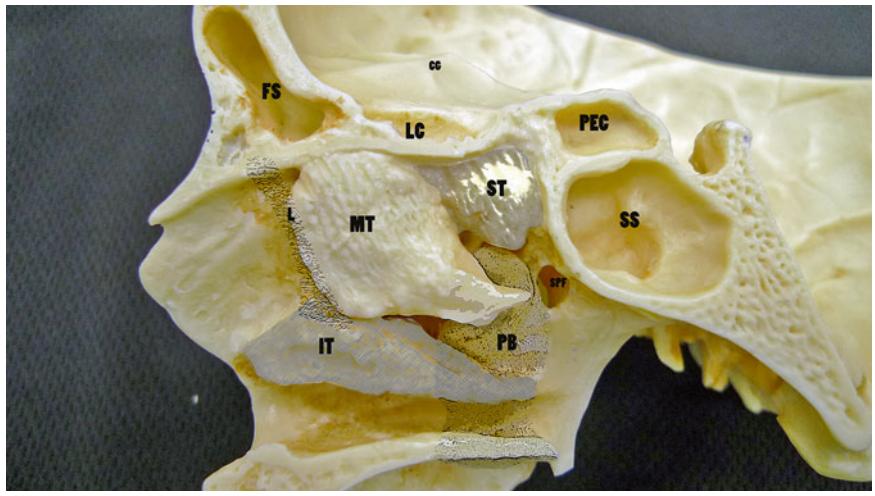

Fig. 2.8 Lateral wall of right nasal cavity. *FS* frontal sinus, *LC* lamina cribosa, *PEC* posterior ethmoidal cell, *MT* middle turbinate, *ST* superior turbinate, *IT* inferior turbinate, *PB* palatine bone, *SS* sphenoid sinus, l projection of the lacrimal system

of the nasal septum. The ethmoid bone has two lateral masses that contain the ethmoidal cells (*labyrinthus ethmoidalis*). The external wall of the lateral mass is called lamina papyracea and contributes to the medial wall of the orbit, together with the lacrimal bone and the lateral wall of the sphenoid bone. In its superior border there are two small grooves that house the anterior and posterior ethmoidal arteries. The medial surface of the lateral mass is part of the lateral wall of the nasal cavity. The middle, superior, and sometimes, the supreme turbinates are the main structures in this medial surface (Fig. 2.9). Each turbinate limits it corresponding meatus (middle, superior, or supreme). The lacrimal canal is partially located in the anterior part of the middle meatus in close relationship with the middle turbinate (Figs. 2.9 and 2.10a, b).

The middle meatus is the space between the middle turbinate and the lateral wall of the nasal cavity. It receives the drainage of the frontal and maxillary sinuses as well as the anterior ethmoidal air cells. The most evident landmarks are the uncinate process (*processus unciforme*) and the ethmoidal bulla (Figs. 2.11, 2.12 and 2.13).

The uncinate process is a half-moon-shaped ridge that descends from its insertion above the axilla of the middle turbinate, at the level of the projection of the cranial end of the sac. It is approximately 3.4 mm wide and 1.5–2 cm in length reaching the ethmoidal process of the middle turbinate where it inserts. It is directly related with the frontal recess and with the hiatus maxillaris. The latter is divided by the uncinate process in two spaces, the anterior and posterior fontanellae that constitute the surgical access to the maxillary sinus called middle antrostomy.

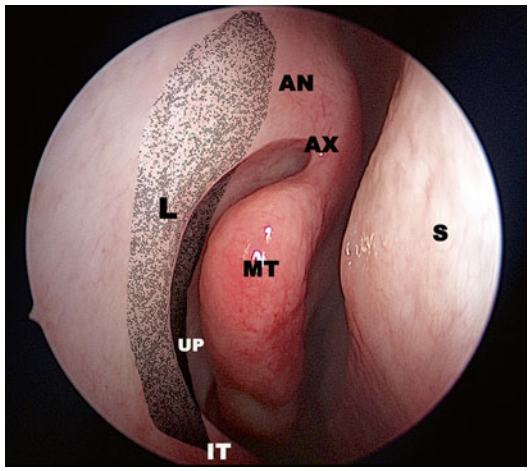

Fig. 2.9 Endoscopic view of the right nasal cavity. *L* projection of the lacrimal system, *UP* uncinate process, *MT* middle turbinate, *IT* inferior turbinate, *S* septum, *AN* agger nasi, *Ax* axila

The ethmoidal bulla is immediately behind the unciform process. It is a rounded structure with thin walls containing the main anterior ethmoidal cell. The three dimensional space delimited by the uncinate process, the ethmoidal bulla, and the lamina papyracea is called ethmoidal infundibulum (*infundibulum ethmoidalis inferior*). Drainage of the frontal and maxillary sinus, as well as the anterior ethmoidal cells ends in this infundibulum. The *hiatus semilunaris* is the two-dimensional area between the posterior margin of the uncinate process and the corresponding line in the ethmoidal bulla that serves as entrance to the ethmoidal infundibulum.

The middle meatus is closed posteriorly by the basal lamella of the middle turbinate that inserts in the lamina papyracea, separating anterior and posterior ethmoidal cells.

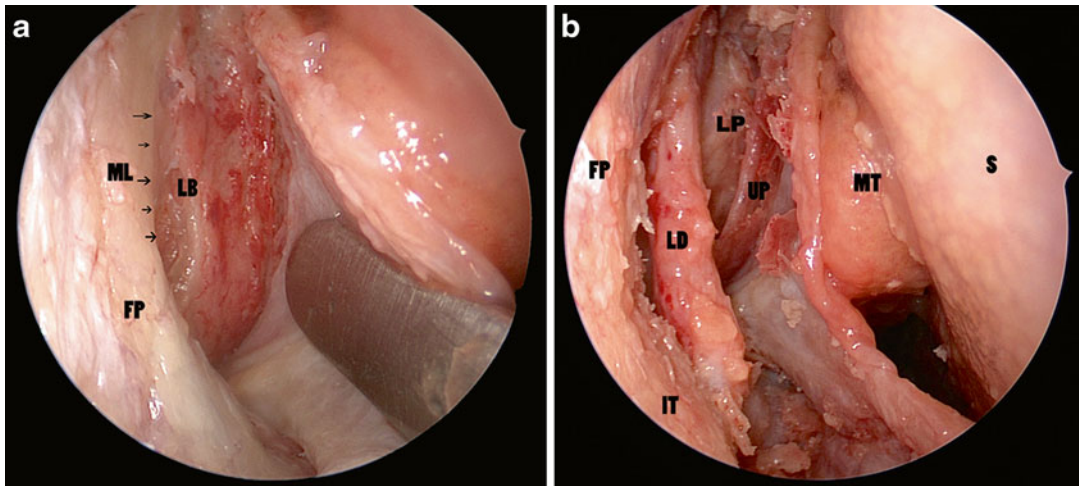

Fig. 2.10 (**a**) Lacrimal system. Endoscopic view. *FP* frontal process of maxilla, *ML* maxillary line, *LB* lacrimal bone. (**b**) Dissection of the lacrimal system. Endoscopic view. *FP* frontal process of maxilla, *IT* inferior turbinate, *LD* lacrimal duct, *LP* lamina papyracea, *UP* uncinate process, *MT* middle turbinate, *S* septum

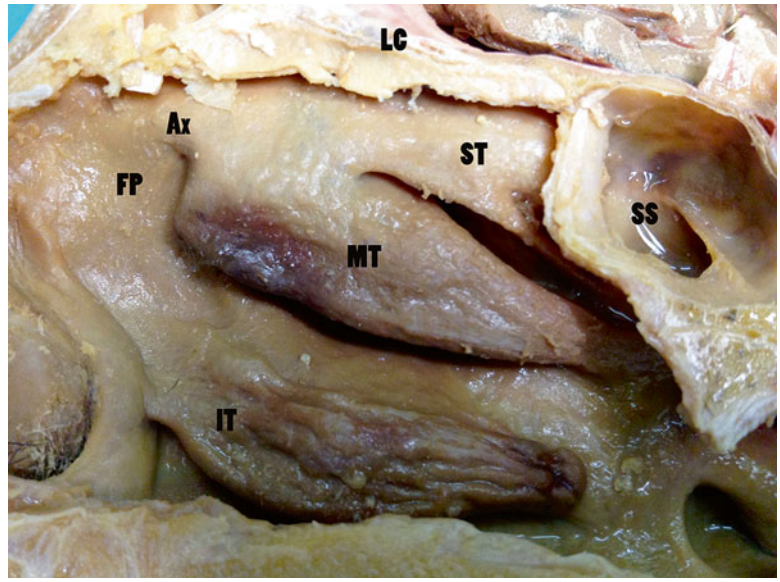

Fig. 2.11 Lateral wall of the nasal cavity. *LC* lamina cribosa, *Ax* axilla, *FP* frontal process, *ST* superior turbinate, *MT* middle turbinate, *IT* inferior turbinate, *SS* sphenoid sinus

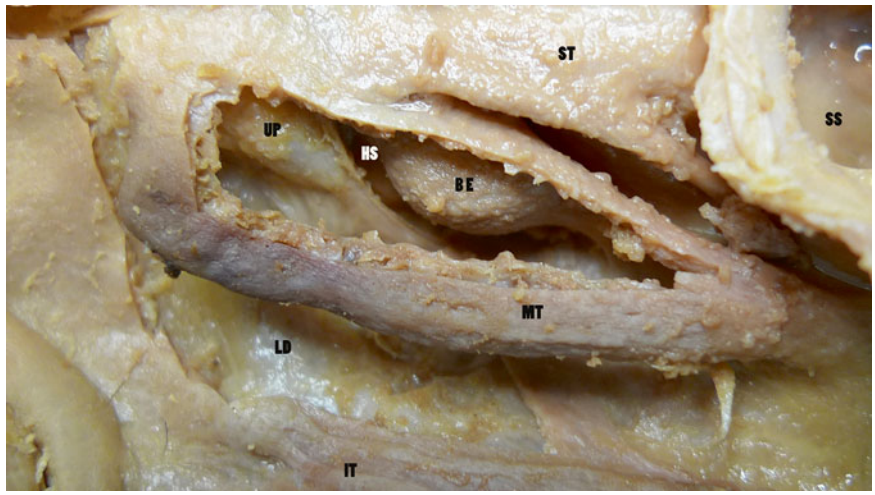

Fig. 2.12 Middle turbinate dissected to expose the middle meatus and the relationship with the lacrimal duct. *ST* superior turbinate, *SS* sphenoid sinus, *UP* uncinate process, *HS* hiatus semilunaris, *BE* bulla ethmoidalis, *MT* middle turbinate, *LD* lacrimal duct, *IT* inferior turbinate

Nasal Septum (*Septo Nasalis*)

The nasal septum separates both nasal cavities. It is composed by the quadrangular septal cartilage, the vomer, and the perpendicular plate of the ethmoid bone. It is usually irregular and may have deviations that hamper the location of the lacrimal system, particularly when they affect the upper segment of the cartilaginous septum.

The Inferior Turbinate (*Concha Nasalis Inferior*)

The inferior turbinate is an independent bone, articulated to the ethmoidal complex. It forms the inferior margin of the *hiatus maxillaris* and closes the inferior lacrimal canal with its anterior-superior lacrimal process. The lateral surface of the inferior turbinate forms the inferior meatus,

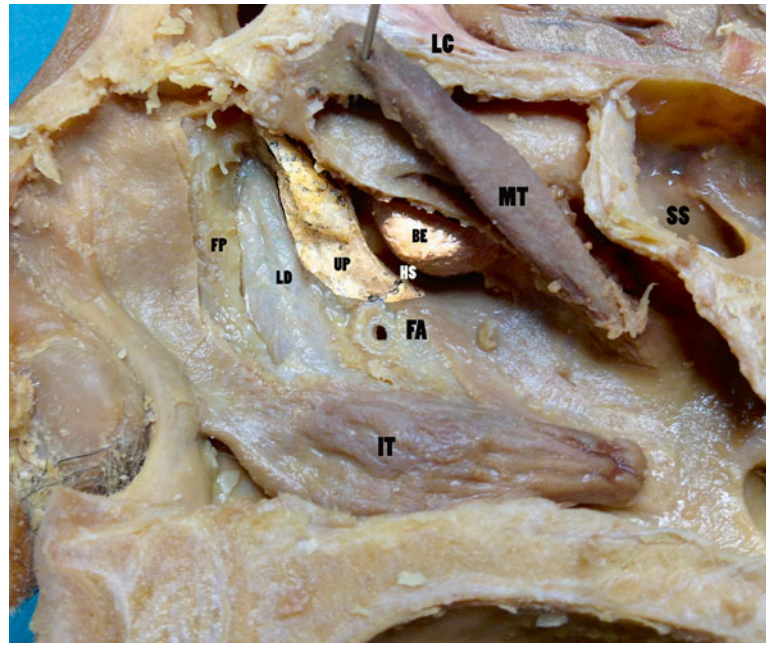

Fig. 2.13 Middle meatus and lacrimal duct. *FP* frontal process, *LD* lacrimal duct, *UP* uncinate process, *HS* hiatus semilunaris, *BE* bulla ethmoidalis, *MT* middle turbinate, *LC* lamina cribosa, *SS* sphenoid sinus, *FA* fontanelle area, *IT* inferior turbinate

where the Hasner's valve opens to the nasal cavity. The ethmoidal process articulates with the uncinate process posteriorly (Figs. 2.7 and 2.8).

Relationships and Landmarks

The lacrimal system has close relations to several structures that can serve as landmarks for exploration and surgery. The synostosis between the lacrimal bone and the frontal process of the maxilla (lacrimomaxillary suture) produces a half-moon-shaped ridge in the nasal mucosa called the maxillary line. This is the main landmark for the endonasal DCR because most of the lacrimal system rests posterior and lateral to this line (Figs. 2.9 and 2.10a, b).

The head of the middle turbinate inserts in the medial aspect of the frontal process of the maxilla, medially to the maxillary line. The anterior point of insertion of the middle turbinate into the lateral nasal wall is called the axilla of the middle turbinate. The *agger nasi* is a protuberance that can usually be observed anterior to the axilla. It can be more or less evident depending on the degree of pneumatization. The mean distance between the cranial end of the lacrimal sac and the *axilla* is 8.8 mm [20] (Figs. 2.9 and 2.14a, b). The rhinostomy must be performed at this level to ensure a wide opening of the lacrimal sac that warrants long-term patency. It must be kept in mind that the distance to the *lamina cribosa* at this level is only around 10 mm [10], so the risk of an injury leading to a CSF leak is not negligible. This is especially true for external approaches performed without endoscopic control.

The middle turbinate can show anatomical variations that can add significant difficulty to the surgical approach to the lacrimal system because 50 % of these variants produce narrowing of the *hiatus maxillaris* [21].

The concha bullosa is the most prevalent anatomical variation, found in 28–47 % of the cases [21–23]. It is produced by an intra-turbinal pneumatization that dilates the turbinate both anteroposteriorly and mediolaterally. The consequence is the narrowing of the opening between the middle turbinate and the lateral wall that leads to the middle meatus (meatal hiatus). Additionally it may alter the relationship between the maxillary line and the head of the middle turbinate. The maxillary line is usually found slightly anterior to the head of the middle turbinate. In the case of a concha bullosa, the maxillary line appears into

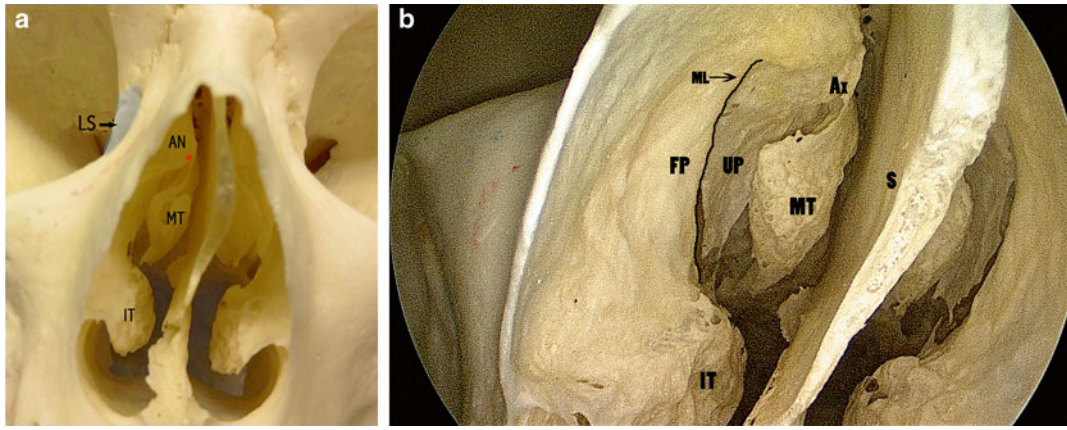

Fig. 2.14 (**a**) Osteology of the nasal cavity. (**b**) Endoscopic view of the right nasal cavity. *LS* lacrimal sac, *AN* agger nasi, *FP* frontal process, *ML* maxillary line, *UP* uncinate process, *Ax* axilla, *MT* middle turbinate, *S* septum, *IT* inferior turbinate

the middle meatus, hidden by the enlarged turbinate. Removal of the lateral wall of the concha bullosa must be the first surgical step to grant access to the lacrimal system.

Paradoxical curvature of the middle turbinate is less frequent, appearing in 12–23 % of the cases [21–23]. It consists in an aberrant outwards folding of the middle turbinate. The image of the coronal CT scan shows a characteristic hook-shaped image with lateral convexity. This anomaly leads to a narrowing of the middle meatus that hampers endoscopic control especially in intracanalicular laser surgery.

The relationship of the uncinate process with the lacrimal system is variable, but it is usually considered the posterior limit of the rhynostomy in the endoscopic DCR approach.

The upper end superposes on the maxillary line and contacts the lacrimal bone.

As it curves down and posteriorly it separates completely from the lacrimal system. In most cases it represents no obstacle for surgery but some authors advocate its systematic removal [24] (Fig. 2.15). Pneumatized uncinate processes were found in 2–3 %. These cases usually require removal to access the lacrimal system [22, 25].

Occasionally, the laser diode fiber can twist backwards, appearing lateral to the uncinate process in the space between the ethmoidal bulla and the lamina papyracea (*infundibulum ethmoidalis inferior*). This situation requires complete removal of the uncinate process to achieve a wide rhynostomy.

Blood and Nerve Supply

The nasal cavity receives arterial supply from both the internal and the external carotid arteries via the ethmoidal arteries and the sphenopalatine artery respectively.

The sphenopalatine artery is the terminal branch of the maxillary artery. It emerges from the superomedial part of the pterigopalatine fossa and enters the nasal cavity through the sphenopalatine foramen. It gives off two main branches: the posterior lateral nasal branch (PLNB), which supplies the region of the lateral nasal wall and then anastomoses with branches of the anterior and posterior ethmoidal arteries, and the posterior septal branch (PSB), which courses the anterior inferior wall of the sphenoid sinus and distributes on the nasal septum. The distal extreme of this septal branch, the nasopalatine artery, ends in the incisive canal where it anastomoses with the greater palatine artery (Fig. 2.16).

The anterior and posterior ethmoidal arteries irrigate the roof of the nasal cavity.

Innervation of the nasal cavity depends on the first and second divisions of the trigeminal nerve.

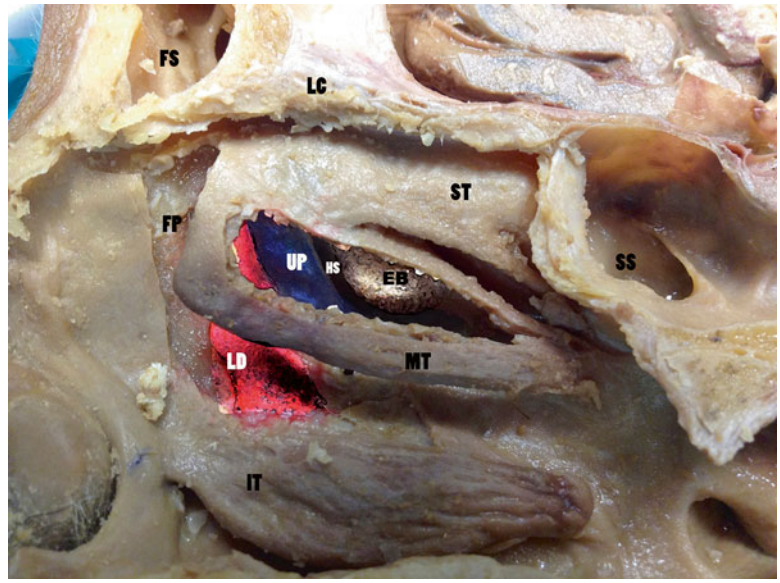

Fig. 2.15 Middle meatus. View through opening in the middle turbinate. *FS* frontal sinus, *LC* lamina cribosa, *FP* frontal process, *UP* uncinate process, *HS* hiatus semilunaris, *BE* bulla ethmoidalis, *MT* middle turbinate, *LD* lacrimal duct, *IT* inferior turbinate, *SS* sphenoid sinus

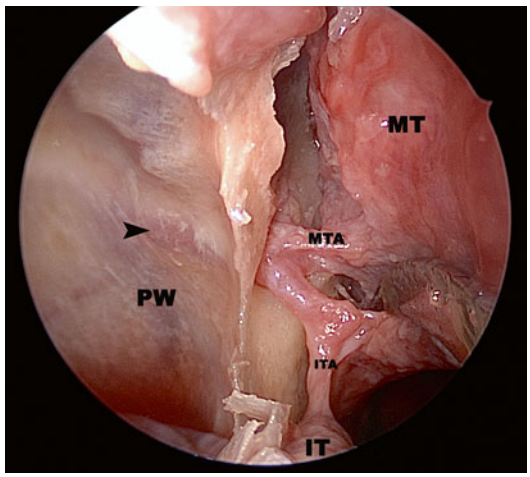

Fig. 2.16 Branches of the right sphenopalatine artery. *IT* inferior turbinate, *MT* middle turbinate, *ITA* inferior turbinate artery, *MTA* middle turbinate artery, *PW* posterior wall of maxillary sinus; arrow: bulging of the sphenopalatine artery in PW

The ophthalmic nerve gives off anterior and posterior ethmoidal branches and the nasociliary nerve. The maxillary nerve has posterior superior lateral and medial nasal branches.

Autonomous sympathetic and parasympathetic innervation of the nasal cavity relies on branches from the greater and lesser petrosal nerves distributed from the pterygopalatine ganglion.

The lacrimal system receives superior and inferior palpebral arteries from the ophthalmic artery. There are significant contributions from the angular artery, branch of the facial artery in the superior portion, and the sphenopalatine artery inferiorly.

The infratrochlear nerve, branch of the ophthalmic nerve (V1), crosses under the trochlea of the superior oblique muscle to the medial commissure of the eye. It provides sensory innervation to the lacrimal sac, the caruncle, and the surrounding skin.

Evaluation

Surgical planning requires careful evaluation of the nasal cavity to rule out anatomical variations that may hamper surgical access (Figs. 2.17, 2.18, and 2.19).

Flexible or 0° rigid nasal endoscopy is considered the gold standard nowadays. A first exam avoiding topical anesthesia and decongestants is recommended. Secondly, pledgets soaked in 2 % lidocaine and 0.05 % oxymetazoline are placed to allow introduction of the endoscope in the middle meatus.

The recommended procedure consists in the insertion of the endoscope along the floor of the

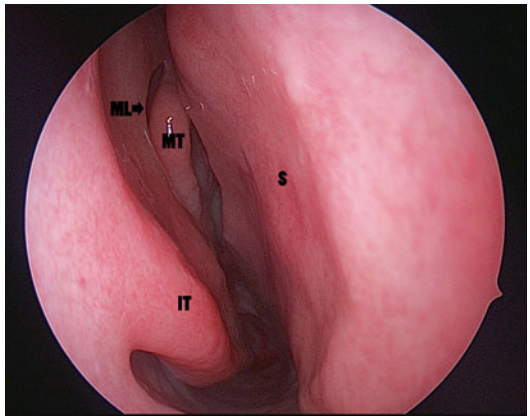

Fig. 2.17 Endoscopic view of right nasal cavity. *IT* inferior turbinate, *S* septum, *MT* middle turbinate, *ML* maxillary line

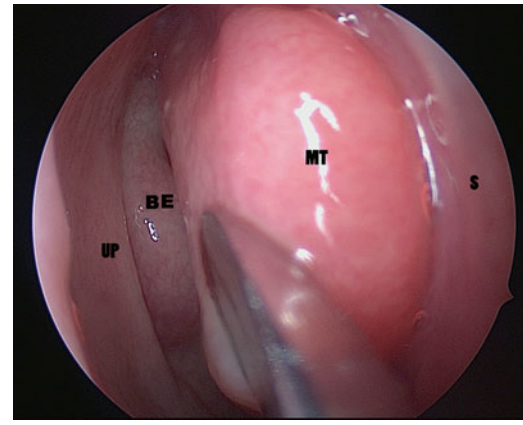

Fig. 2.19 Endoscopic view of the right middle meatus. A Freer elevator separates the middle turbinate. *MT* middle turbinate, *S* septum, *UP* uncinate process, *BE* bulla ethmoidal

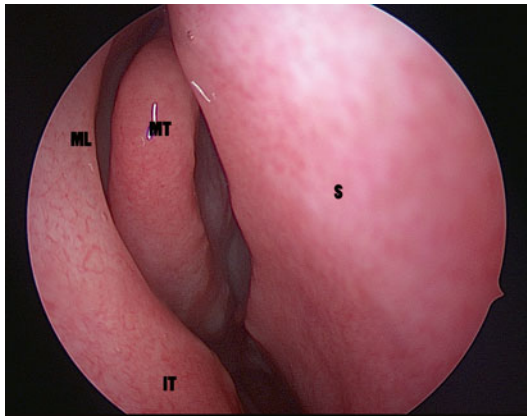

Fig. 2.18 Endoscopic view of the right middle meatus. *IT* inferior turbinate, *MT* middle turbinate, *ML* maxillary line, *S* septum

nasal cavity, identifying the head and the body of the inferior turbinate. Full evaluation of the nasal septum is mandatory, reporting any deviation or spur. When the choana is reached, slow withdrawal of the endoscope allows visualization of the opening of the middle meatus up to the axilla of the middle turbinate where the maxillary line can be identified.

The following list of items must be evaluated at this level:

- The space between the head of the middle turbinate and the lateral wall (meatal hiatus).
- The axilla of the middle turbinate.
- The projection of the maxillary line.
- The distance between the maxillary line, the head of the middle turbinate, and the uncinate process.
- The morphology of the uncinate process and its relationships with the lacrimal system.
- The existence of a paradoxical turbinate or concha bullosa.
- The presence of deviations in the superior nasal septum that obstruct total or partially the exposure of the middle turbinate and the maxillary line (Fig. 2.20a, b).
- The distance between the root of the middle turbinate and the lamina cribosa (Figs. 2.8 and 2.11).
- The existence of inflammatory mucosa, polyps, or infection with purulent discharge (Figs. 2.21 and 2.22).
- Synechiae or scarring secondary to previous surgery (i.e., absence of the middle turbinate).

Gently, the endoscope can be insinuated in the middle meatus to observe the uncinate process as it courses downwards, the ethmoidal bulla and the fontanellae area. The presence of pathologic conditions that could affect surgery or its outcome must be considered.

Endoscopic evaluation of the inferior meatus and Hasner's valve can be more challenging. It

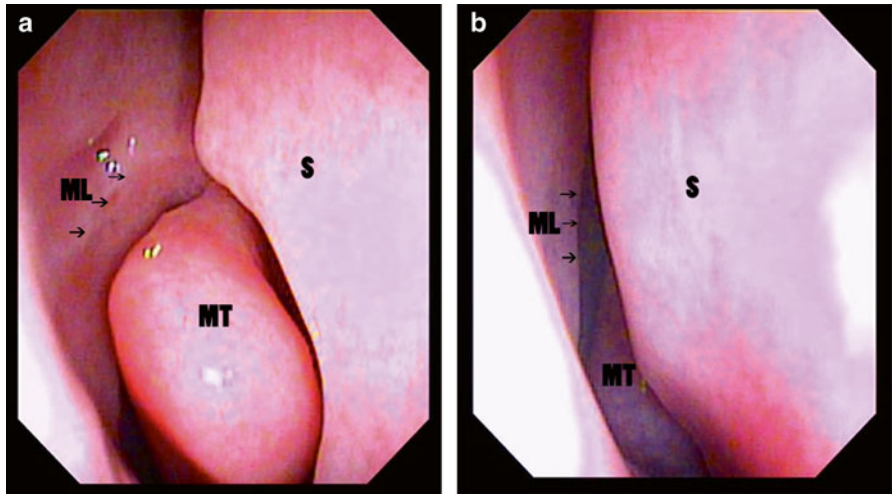

Fig. 2.20 (**a**, **b**) Anatomical variations of the nasal septum that affect surgical approach to the lacrimal system. (**a**) Normal. (**b**) High septal deviation precluding endoscopic DCR, that requires previous septoplasty. *ML* maxillary line, *MT* middle turbinate, *S* septum, *FP* frontal process, *IT* inferior turbinate, *SD* septal deviation

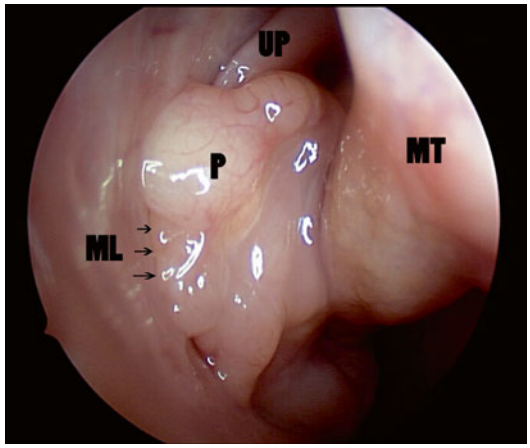

Fig. 2.21 Polypoid mass (papilloma) that overlaps the lacrimal duct. *ML* maxillary line, *P* papilloma, *UP* uncinate process, *MT* middle turbinate

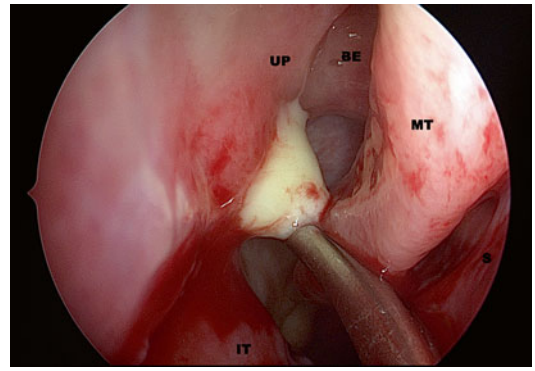

Fig. 2.22 Purulent sinusitis. *UP* uncinate process, *BE* bulla ethmoidalis, *MT* middle turbinate, *IT* inferior turbinate, *S* septum

usually requires an instrument such as a Freer elevator to luxate the turbinate medially while introducing a 30° angled endoscope.

Once the nasal evaluation is complete, the surgeon must choose the best surgical approach for every particular patient, considering the obstacles that are likely to affect the surgical procedure and its results [26, 27].

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Gender and Racial Variations of the Nasolacrimal System

3

Roberta E. Gausas, Usiwoma Abugo, and Susan R. Carter

Optimizing a surgical procedure and its outcome requires comprehensive understanding of underlying anatomy, its relationship to other structures, and any variations thereof. Anatomic variations of the nasolacrimal system exist across individuals, as well as, between gender and race. The nasolacrimal bony canal may vary in width, length, bony thickness, and in proximity to ethmoidal air cells. External soft tissue may vary in skin thickness, presence or absence of epicanthal folds, and nasal projection. Morphologic differences in the nasolacrimal systems between gender and race will be discussed as they pertain to external and endoscopic lacrimal surgery. Appreciation of such variations in anatomy contributes to better understanding of the etiology of lacrimal disease, and leads to improved surgical outcomes and improved patient satisfaction.

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Nasolacrimal Region Variations: Bony Anatomy

Nasolacrimal Canal Width and Length

A body of literature has supported the finding of a gender difference in the width of the nasolacrimal canal, where women were generally found to have a narrower canal than men. Groessl et al. [1] measured the nasolacrimal canal at three different levels in axial computed tomographic (CT) scans of 36 men and 35 women. The dimensions of the lower and middle canal were found to be smaller in women than in men. Janssen et al. [2] measured the minimum diameter of the nasolacrimal canal on axial CT scans in 50 male and 50 female controls and 19 individuals with primary acquired nasolacrimal duct obstruction (PANDO). The mean minimum diameter in women, 3.35 mm, was statistically smaller than that of men, 3.70 mm, and the smallest mean minimum diameter, 3.0 mm, was found in the patients with PANDO. Shigeta found the sectional area of the bony nasolacrimal canal to be 13 % smaller in females versus males in a study of CT scans of 314 Japanese patients [3].

It has been hypothesized that these studies demonstrating an overall narrower nasolacrimal canal in women may explain the higher incidence of PANDO seen in women as compared with men. The theory that this anatomical variation (narrow canal) would predispose (via increased

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resistance to tear flow) to a disease state (obstructed canal) has logical appeal, but has not been found across all populations. For instance, Fasina unexpectedly found a smaller nasolacrimal canal diameter in a CT study of 401 normal adult Nigerian patients, as compared to African Americans, Asians, and Whites, despite a reported lower prevalence of PANDO among black Africans. Interestingly, within the author's study population, a gender variation was still found. The mean difference in canal diameter of 3.52 mm in the 286 male patients and 3.36 mm in the 115 female patients was statistically significant [4].

Along the same line of thought, in an audit of lacrimal surgery in Auckland, it was theorized that a narrower nasolacrimal canal accounted for the higher prevalence of PANDO, and consequently, the higher incidence of dacryocystorhinostomy (DCR) surgery reported among Pacific People (Cook Island Maori, Fijian, Niuean, Samoan, and Tongan) as compared to New Zealand Maori and Whites. However, in an analysis of 178 CT scans, McCormick unexpectedly found a larger nasolacrimal canal diameter in the population of Pacific People, despite their higher rate of DCR. In that study, both Whites and New Zealand Maori had similar mean nasolacrimal canal diameter of 3.7 mm, whereas the mean canal diameter in Pacific People was larger at 4.1 mm. As in other studies, women were found to have narrower canals (3.6 mm) than men (3.9 mm) [5].

Both of these studies found opposing relationships between nasolacrimal canal width and prevalence of nasolacrimal duct obstruction, therefore suggesting that nasolacrimal canal width is not the only factor in the etiology of nasolacrimal duct obstruction. Other pathologic factors affecting the mucosal lining of the nasolacrimal duct itself have also been suggested to play a larger role, such as inflammation, infection, hormonal differences between men and women, and more recently the description of submucosal capacitance vessels in the nasolacrimal duct and their effect on tear drainage regulation [6, 7]. That nasolacrimal canal diameter does not necessarily play a primary role in duct obstruction is supported by recent work by Ramey. In that CT study of 72 patients, no significant difference was found in nasolacrimal canal diameter between gender, Black, White, younger or older patients. The authors attribute the difference in their findings, namely lack of a gender or racial difference in canal diameter, to a more robust and accurate technique of measurement than that used in previous literature. They made use of high-resolution CT and three-dimensional post-processing imaging techniques to characterize nasolacrimal canal differences, which was felt to eliminate the error induced in taking measurements on axial images [8].

Gender and racial differences in nasolacrimal canal length may exist among Whites, Asians, and Blacks, but findings have not been consistent. Although Ramey et al. found no gender or racial difference in nasolacrimal canal diameter, they did however find a difference in canal length and volume. The nasolacrimal canal length and volume were found to be significantly greater in men (12.3 mm) than in women (10.8 mm), and the cross-sectional area of the canal base was 24 % greater in Blacks than in Whites. Ni et al., in an article in the Chinese literature, examined the nasolacrimal canal in 80 half-skulls of Chinese adults and found the mean length to be 14.14 mm [9]. However, Groell et al., examining CT scans from 147 patients at the Medical School in Austria with a presumably primarily white population, found the mean nasolacrimal duct length to be 11.2 mm with a range of 6–21 mm [10]. Although the methods of measurement of the nasolacrimal canal differed, the Chinese nasolacrimal duct was not substantially shorter than that of the Austrian group. A well-controlled comparison study is needed to further address this issue.

Lacrimal and Maxillary Bone Thickness

Clinically, the lacrimal bone frontal process of the maxilla appears thicker in Asians and Blacks than in Whites during DCR, although few studies

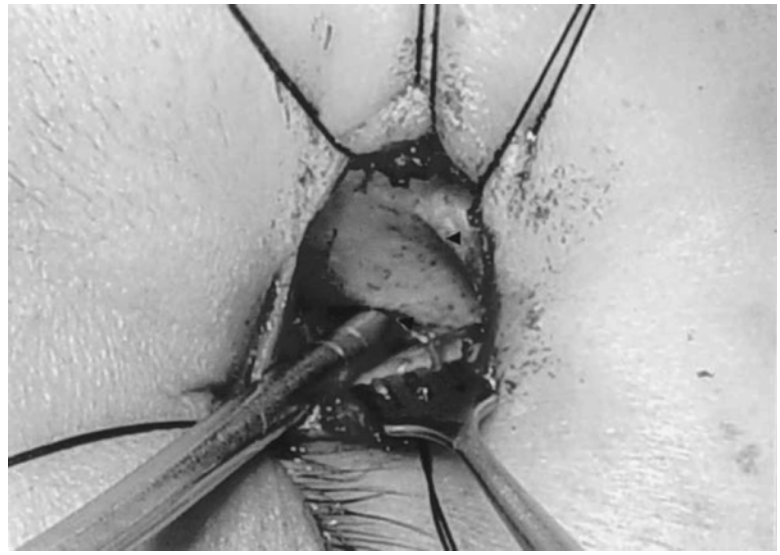

Fig. 3.1 External DCR intraoperative view of lacrimal sac fossa in an Asian patient. Suction tip points to the area of lacrimal bone suture line. The thick maxillary bony portion and anterior crest of the fossa lie above it. In this case, the maxillary bone is 2.5–3 times the width of the suction tip

exist to confirm this experience (Fig. 3.1). Woo and Kim report that, in their experience, endonasal DCR procedures for Asians are more difficult than for whites and suggest that they therefore may require different guidelines. In a study of 152 eyes in 76 patients with normal orbital CT scans, they found a significant negative correlation between the height and length of the nasal bone with the thickness of the frontal process of the maxillary bone. Patients with a low nasal bridge, had a thicker frontal process of the maxilla, which they felt accounted for the greater challenge in creating an adequate osteotomy during endonasal DCR in Asians [11].

In 69 lacrimal bones from 48 Finnish patients, Hartikainen et al. found the mean lacrimal bone thickness to be 106 μm, leading him to conclude that the lacrimal bone at the lacrimal sac fossa is so thin that it is easily penetrated in most cases [12]. However, Lui et al. measured lacrimal bone thickness in 386 Taiwanese patients during DCR and found the average thickness to be 5.8 ± 0.9 mm in males, and 4.2 ± 0.8 mm in females [13].

Anticipation of lacrimal and maxillary bone thickness by the lacrimal surgeon is important in selection of surgical approach. Adequate bony opening is critical in achieving surgical success. Paper-thin lacrimal bones easily lend themselves to large osteotomies with routine instruments, whereas achieving an adequate osteotomy in thick bone is more challenging and may require additional instrumentation, such as a drill. Selection of either an external or endoscopic approach to DCR should take into account anticipated lacrimal bone thickness.

Disease state itself may alter bone thickness. Hinton et al. found evidence of active bone remodeling in 19 % of bone pieces harvested from DCRs and conjunctivodacryocystorhinostomies [14]. Additionally, lacrimal bone thickness and density have been found to correlate with systemic bone density, suggesting that low-density, thin lacrimal bone may be found during DCR in patients with osteoporosis [15]. Osteoporosis is more common in women than men, and this may contribute to the clinical experience of easier osteotomies in women than men [16, 17].

Lacrimal Sac Fossa Relationship to Ethmoidal Sinus

In 1964, Zhang and Lui undertook detailed measurements of 100 Chinese orbits and lacrimal fossas. In 56 % of the specimens, they found

ethmoidal air cell extension into the lacrimal sac fossa [18]. In 76 % of the specimens, the anterior portion of the middle turbinate was also encountered in this area. An intervening ethmoid sinus between the lacrimal sac and the nose may cause confusion when performing a DCR leading to an inadequate or false passage. Ethmoid sinus mucosa can be differentiated from nasal mucosa by being much thinner. Entering the anterior portion of the middle turbinate surgically may cause excessive bleeding, and partial blockage of the ostium by the middle turbinate may lead to obstruction. Lui suggests that such variations in nasal and lacrimal anatomy may account for the perceived difficulty of performing lacrimal surgery on Asian patients [13]. However, initial entry into the ethmoid air cells rather than the nasal cavity was described in 23 of 50 DCRs (46 %) by Talks of the United Kingdom in a presumably predominately white population [19]. Therefore, it behooves the lacrimal surgeon to understand the possible variations of nasal anatomy during all cases.

Lacrimal Sac Fossa Relationship to Cribriform Plate

Another surgically pertinent, possible difference between Whites and Asians is the location of the cribriform plate with respect to the lacrimal apparatus. Botek and Goldberg, in a dissection of five human cadaver heads, found the distance between the internal common punctum and the cribriform plate to be 25.1 ± 2.95 mm [20]. Neuhaus and Baylis performed DCRs and anatomic dissections on 3 fresh cadavers and found that the distance from a 15-mm vertical and 18-mm horizontal osteotomy to the floor of the anterior cranial fossa was 5.0 mm (range 1–7 mm) [21]. In a cadaver study of 28 Japanese skulls, Kurihashi and Yamashita measured the distance from a point 10 mm posterior to the medial canthus superiorly to the anterior cranial fossa floor. Although the distance ranged from 1 to 30 mm, with an average of 8.3 mm, 21 % had a distance of 3 mm or less. They recommended that surgeons not make a bony ostomy beneath the medial canthal tendon because of the possibility of violation of the cribriform plate [22].

Lacrimal Region Variations: Soft Tissue

External differences exist in the lacrimal region of Whites, Asians, and Blacks, particularly the absence or presence of epicanthal folds, the broad nasal bridge, and the thickness of the skin. Placement of skin incisions for an external DCR must take these factors into consideration. In a patient with a broad nasal bridge, the incision is more visible from a frontal view than in a patient with a prominent nasal bridge. Precise placement of the angle and length of the incision, particularly if a bilateral procedure is being performed, is essential for proper postoperative patient cosmesis. In patients with thicker skin of the nasal bridge, the incision should be placed closer to the medial canthus where thinner skin will more likely hide the scar. However, the epicanthal fold of some Asians must be avoided at all costs to prevent medial canthal webbing with scar contracture. An endoscopic DCR would avoid any potential problems arising from these external differences; however, one would need to take the thicker bone of the lacrimal region, often encountered in Asians and Blacks, into consideration.

Conclusion

In summary, some morphologic differences between the nasolacrimal systems of males and females and of different races have been well documented. Variations in anatomy also exist within each gender and race. These variations may or may not play a role in predisposition to disease, but they can play a role in surgical outcomes. The key to being a successful lacrimal surgeon lies in the awareness of such nuances and the ability to adjust surgical technique when an anatomic variation is encountered in any patient. Future comparative studies are needed to fully address such anatomic differences and provide better surgical guidelines.

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Congenital Etiologies of Lacrimal System Obstructions

4

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Congenital nasolacrimal duct obstruction occurs in approximately 5 % of newborn infants. The incidence of this disorder is higher in children who have craniofacial disorders and Down's syndrome. The most common location of nasolacrimal duct obstruction occurs at the Valve of Hasner at the distal end of the nasolacrimal duct. However, other sites in the upper nasolacrimal system (puncta, canaliculi, common canaliculus) or lower system (lacrimal sac, nasolacrimal duct) can also be affected. Within these structures, the etiology of the obstruction may range from abnormal embryogenesis with failure of the dehiscence of embryonic membranes to other strictures that curtail the normal outflow of tears.

Development of the nasolacrimal system begins at approximately the sixth week of embryonic life. An epithelial layer of ectodermal tissue is entrapped as a core between the lateral (frontonasal) and maxillary process (Fig. 4.1). The developmental anomalies of the nasolacrimal system can be classified as either a failure in complete separation of this epithelial core from the surface ectoderm or incomplete patency of the apparatus attributed to the failure of canalization [1]. This ectodermal core projects into the upper and lower lids as a bifurcation at the medial canthus to form the canaliculi and puncta. Incomplete formation, misdirection, accessory budding, and deformation from amniotic bands can also contribute to a developmental obstruction of the nasolacrimal system. A third process described by Duke-Elder [1] is a complete absence of the nasolacrimal passage caused by a nonunion or clefting of the nasal and maxillary processes during embryogenesis. This rare developmental anomaly has been seen in cyclopia, cryptophthalmos, or from amniotic band pressure necrosis. No specific gene locus has consistently been identified in the development of nasolacrimal duct obstruction. However, in a study by Foster et al. [2], a mutation in the IGSF3 gene was implicated in one family with congenital nasolacrimal duct obstruction.

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Evaluation of Congenital Nasolacrimal Duct Obstruction

The correct diagnosis of a tearing child requires a thorough examination. This begins with evaluation of the child's eyelid position and structure in order to determine if other possible etiologies

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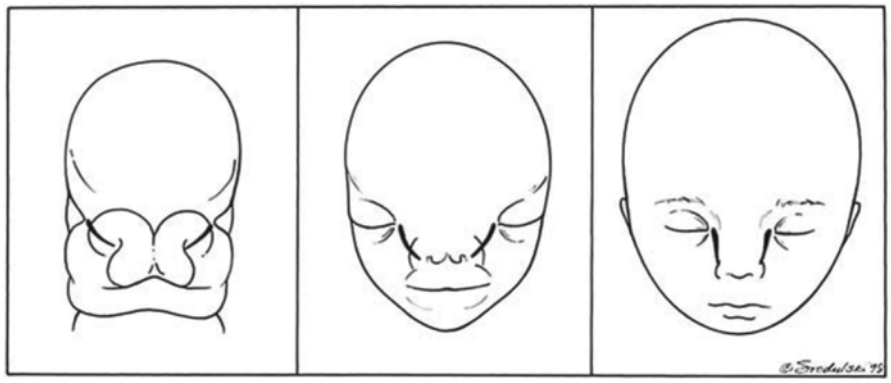

Fig. 4.1 Development of the nasolacrimal system begins at approximately the sixth week of gestation. An epithelial layer of ectodermal tissue is entrapped as a core between the lateral (frontonasal) and maxillary processes

exist. Congenital lid malpositions such as congenital entropion or ectropion, telecanthus, hypertelorism, and lid colobomas can cause poor apposition of the punctum to the globe resulting in poor tear outflow. Tearing may also be a result of misdirected lashes causing conjunctival or corneal touch. Congenital seventh nerve palsies can cause tearing due to an inadequate pumping mechanism.

Congenital Obstructions of the Upper Nasolacrimal System

Abnormalities of the Puncta

The examination of the nasolacrimal system begins with evaluation of the puncta. Not uncommonly, a child may have punctal atresia or agenesis. This may present with a veil or membrane consistent of conjunctiva and canalicular epithelium that occludes the punctal orifice. This membrane may be present within the punctal orifice or may lie over the punctum as a veil and appear only as a small dimple in the lid margin.

Less commonly, a child may have an actual congenital absence of the punctum. This can be attributed to failure or incomplete outbudding of the nasolacrimal core (Fig. 4.2). This specific abnormality has demonstrated an autosomal dominant inheritance pattern [2]. Syndromes associated with absent puncta include ectodactyly-ectodermal dysplasia-clefting syndrome (EEC syndrome) and lacrimo-dento-digital syndrome (Lewis-Hollister syndrome) [3].

Abnormalities of the Canalicular System

Abnormalities of the canalicular system include developmental aberrations such as canalicular atresia or absence of the canalicular system. Canalicular atresia can be classified as proximal, mid-canalicular, or distal. Absence of the canalicular system may be attributed to the anomalous development of the epithelial core [1].

Supernumerary (Anlage) Ducts

Lacrimal anlage ducts or lacrimal fistulae may result from additional extensions of the embryonic epithelial cord or as outpouchings from the developing canaliculi. Accessory channels may exist and communicate with the skin ending in the canalicular system, the lacrimal sac, or even the lacrimal duct. The openings of these channels may be on the skin below the punctum, at the lid margin, or at the medial aspect of the lower eyelid crease (Fig. 4.3).

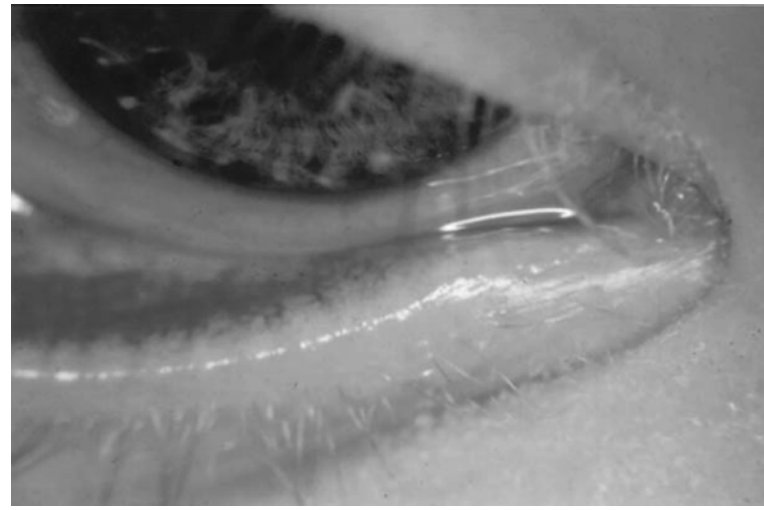

Fig. 4.2 Congenital absence of the punctum can be attributed to failure or incomplete outbudding of the nasolacrimal core

Fig. 4.3 Accessory channels may exist and communicate with the skin ending in the canalicular system, the lacrimal sac, or the lacrimal duct. The openings of these ducts may be on the skin below the punctum, at the lid margin, or at the medial aspect of the lower lid crease

Dacryoliths

Dacryoliths or stones are more commonly associated with acquired nasolacrimal duct obstruction and are not seen in congenital cases. There have been no reports of dacryoliths causing congenital nasolacrimal duct obstruction.

Congenital Obstructions of the Lower Nasolacrimal System

Congenital obstructions involving the lower nasolacrimal system can be attributed either to an abnormal separation of the epithelial core or abnormal canalization.[1]

Congenital Fistula of the Lacrimal Sac

Abnormal canalization can lead to direct communication between the skin and the lacrimal sac. Canalization begins at the fourth month of gestation and can be caused by a defect in the optic end of the naso-optic fissure [4]. An internal fistula between the lacrimal sac and nasal cavity may also occur, although this is not a cause of obstruction.

Congenital Dacryocystocele

Entrapment of fluid in an obstructed nasolacrimal system may present as a dacryocystocele. Clinically, this is seen as a mass below the medial canthus representing distention of the lacrimal sac (Fig. 4.4). Other clinical signs include presence of a bluish discoloration. The entrapped fluid may represent mucus (mucocele) or amniotic fluid (amniotocele). Dacryocystoceles occur more commonly in neonate females due to narrower nasolacrimal ducts in females compared to males. Rarely, an encephalocele may cause distention in the region of the lacrimal system. This occurs when the neural tube fails to close completely during fetal development. More commonly, this will present above the medial canthal tendon and may have associated pulsations. Hemangiomas and dermoids may also present with distention in the medial canthal region. Malignant tumors of the lacrimal sac are uncommon in the pediatric population. Imaging studies such as ultrasonography or nasal endoscopy may aid in the diagnosis.

Congenital Intranasal Cyst

A serious complication of a dacryocystocele occurs when there is a large intranasal cyst component causing blockage of the nasal cavity (Fig. 4.5). Diagnosis of a dacryocystocele with intranasal cyst is made through physical examination, clinical history, nasal endoscopy, and imaging. It is important to note that these patients occasionally do show the typical external enlargement of the lacrimal sac, as most of the distention is in the nasal cavity. These patients may repeatedly fail probing as the probe may not pass beyond the cyst wall. In these cases, imaging and/or nasal endoscopy is necessary and successful treatment has been reported with marsupialization of the cyst [5]. Neonates are obligate nasal breathers. Nasal obstruction caused by the presence of an intranasal cyst is a potential for acute respiratory distress and is especially evident during feeding and sleeping. When the child cries, the airway becomes more patent and the caregivers can note

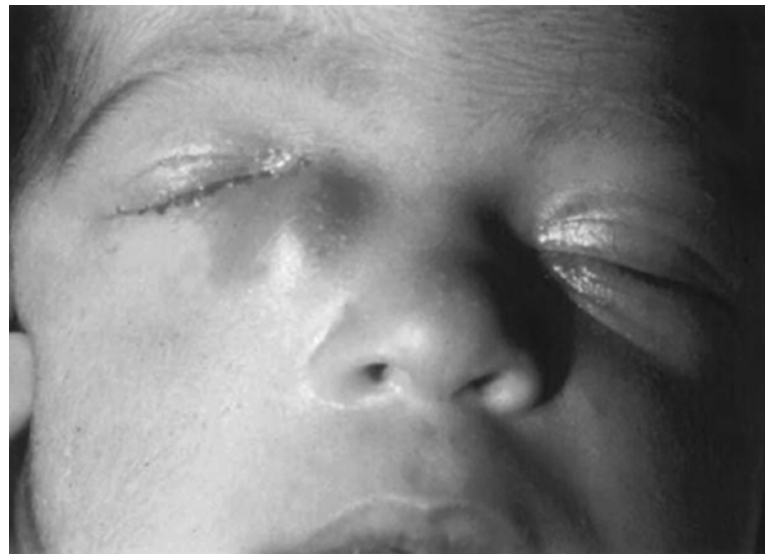

Fig. 4.4 When fluid is entrapped in a nonpatent nasolacrimal system, a neonate may present with a mass below the medial canthus, representing cystic distention of the lacrimal sac. This entity may be caused by entrapped mucus (mucocele) or amniotic fluid (amniotocele)

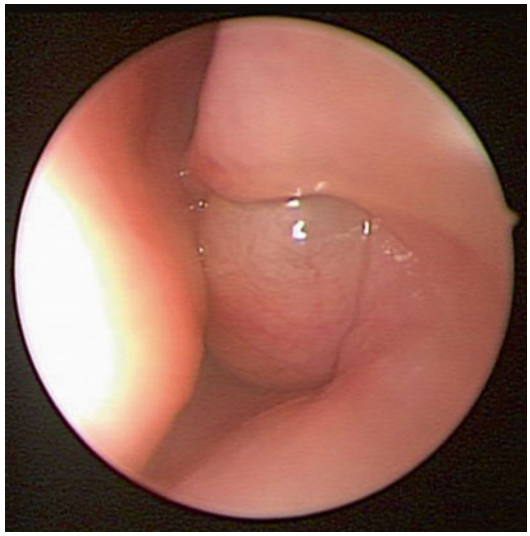

Fig. 4.5 Endoscopic view of a neonate with an intranasal cyst

a "cyclic cyanosis." If intranasal cysts obstruct both nasal airways, the neonate has a potentially life-threatening disorder. Also a child born with airway compromise can also have choanal atresia, however the diagnosis of intranasal cyst should always be considered [6–8].

Congenital Dacryocystitis

The term "congenital dacryocystitis" is a misnomer. The condition develops after birth and is not a true inflammation of the sac wall, but rather an infection of the retained excretions from the lacrimal sac. However, the condition is congenital in the sense that children at risk are those that have a congenital obstruction [9]. Dacryocystitis can occur in the setting of a dacryocystocele or more simply, an obstructed nasolacrimal duct. The onset of symptoms can be shortly after birth or within a few days or weeks of birth. The majority of pediatrics patients develop symptoms within the first month of life. These children present with mucopurulent discharge without the presence of an inflamed mass below the medial canthus. Edema at the common canaliculus prevents decompression of the sac, causing an acute dacryocystitis (Fig. 4.6). The most common organisms isolated from the lacrimal sacs of children with dacryocystitis include *Staphylcoccus aureus*, Haemophilus influenza, B-hemolytic *Streptococcus*, and pneumococcus.

Dacryostenosis

As previously discussed, the most common cause of congenital nasolacrimal duct obstruction is a persistent membrane covering the nasolacrimal ostium at the Valve of Hasner. Failure of dehiscence of this epithelial-membrane creates a blockage or valve-like fold over what is normally the Valve of Hasner. This membrane was found in 87 % of nasolacrimal ducts of 15 full-term stillborn infants that were studied by serial histologic sections [10]. This membrane has been described histologically as attenuated nasal mucosa and stretched epithelium from the nasolacrimal duct lining [1]. Clinically this membrane can be opened by probing of nasolacrimal system. There is lack of resistance during probing until entering the lower portion of the system, followed by reaching a point of obstruction that can be easily perforated when advancing the probe [11].

The location of the distal end of the nasolacrimal duct can vary [12]. This can be appreciated clinically if one encounters an unusual pathway that does not respond to simple perforation when probing the distal end of the duct. In this instance, nasal endoscopic examination may be of value. If one cannot safely pass a probe at the time of examination, however, then consideration should be given to further diagnostic imaging such as dacryocystography or magnetic resonance imaging. More definitive surgical intervention such as a dacryocystorhinostomy may be required based on the information obtained from these studies.

Facial Clefts

Congenital facial clefts can disrupt the nasolacrimal system in the newborn. These can involve the soft tissue of the face and extend into the bony structures. Tessier devised a clock-face system to describe the craniofacial clefting syndromes. According to the Tessier classification system,

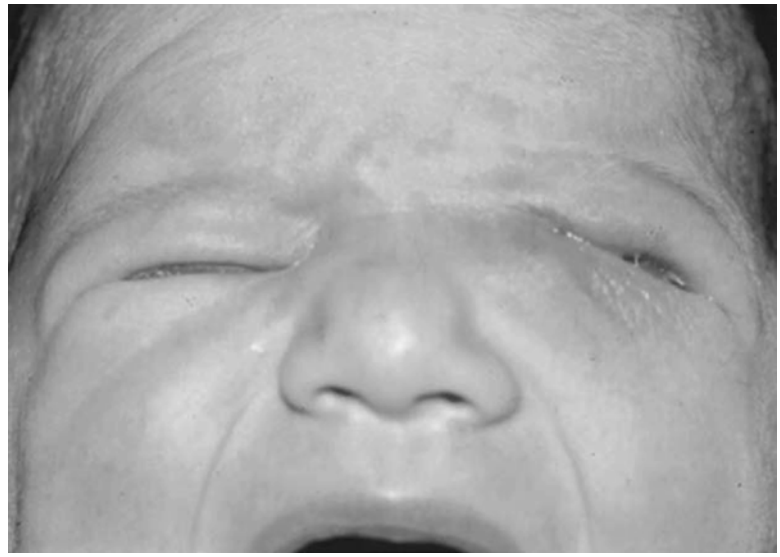

Fig. 4.6 When bacteria infect the lacrimal sac, edema at the common opening prevents decompression of the sac contents leading to an acute dacryocystitis

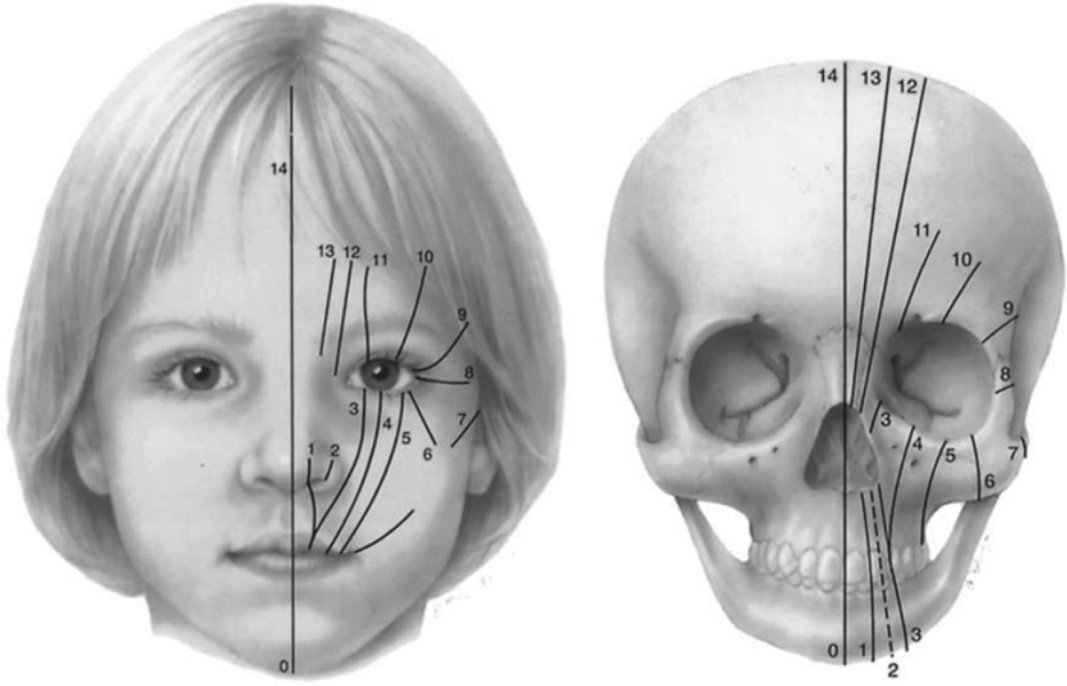

Fig. 4.7 Congenital facial clefts can disrupt the nasolacrimal system in the newborn. These can involve the soft tissue of the face and extending into the bony structures. Tessier devised a clock-face system to describe the craniofacial clefting syndromes

clefts 2–4, located in the lower medial canthal and nasolacrimal region, are associated with congenital nasolacrimal abnormalities. The cause of these clefts can be attributed to external or internal forces. Amniotic bands formed in utero from amniotic sac rupture can wrap across the developing fetus, thus causing strictures and pressure necrosis. If these bands are swallowed in utero by the developing fetus they may specifically constrict across the face. There are many reports in the literature of various internal influences on clefting syndromes, from genetic causes to exposures to intrauterine infectious or pharmacologic agents (Fig. 4.7) [13–15].

Conclusion

There are various etiologies that can lead to congenital nasolacrimal duct obstruction. An understanding of the different embryologic abnormalities and anatomic sites of the obstruction can assist in the diagnosis and management of congenital nasolacrimal duct obstruction. It is imperative to rule out other possible causes of tearing such as lid malposition, misdirected lashes, or an abnormal pump mechanism. Although no specific gene has been implicated in the development of this disorder, genetic factors do play a role in the syndromic entities associated with congenital nasolacrimal duct obstruction.

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Acquired Etiologies of Lacrimal System Obstructions

5

Daniel P. Schaefer

Acquired obstructions of the lacrimal excretory outflow system will produce the symptoms of epiphora, mucopurulent discharge, chronic conjunctivitis, pain, acute or chronic dacryocystitis, and even cellulitis, prompting the patient to seek the ophthalmologist for evaluation and treatment. Our understanding and knowledge of the anatomy and pathophysiology of the lacrimal drainage system has been increased through the advancements in radiology, microbiology, and clinical studies. The lacrimal drainage system is composed of the puncta, canaliculi, the lacrimal sac, and nasolacrimal duct which facilitates the drainage of the tears produced by the lacrimal glands, accessory lacrimal glands, and the glands of Krause and Wolfring, along with the suspended debris in the tears. Epiphora is the spillover of tears from the eye onto the eyelids and adnexa. It is determined by a balance between tear production and tear drainage and not by the absolute function or dysfunction of either. Symptomatic tearing can result when a normal lacrimal drainage system is overwhelmed by hypersecretion or when a drainage system is anatomically or physiologically compromised and unable to handle normal tear production. It is not a diagnosis, but a clinical sign indicating obstruction of tear drainage or less commonly, overproduction. The tearing may be unilateral or bilateral, constant or intermittent. Discharge or crusting of the eyelashes generally indicates a chronic or acute infection. The acute onset of epiphora most often results from irritative ocular conditions such as foreign bodies, allergic, bacterial or viral conjunctivitis.

The nasolacrimal system is essential to the ocular surface health, and is a vital component of ocular homeostasis. This system provides for the proper distribution and elimination of the tear constituents across the ocular surfaces, supporting the tear layer of the eye and ocular health. Lid-globe apposition directs tears across the ocular surface and into the lacrimal drainage system. Impaired tear outflow may be functional, structural, or both, causing visual blur from the increased tear meniscus and/or epiphora. The cause may be primary, those resulting from inflammation of unknown causes that lead to occlusive fibrosis, or secondary, resulting from infections, inflammation, traumatic, malignancies, toxicity, or mechanical causes. Secondary acquired dacryostenosis and obstruction may

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result from many causes, multifactorial, both common and obscure. Occasionally, the precise pathogenesis of nasolacrimal duct obstruction will, in spite years of investigations, be elusive. Most of these causes are not vision-threatening, but patients find the epiphora to be a serious problem causing blurred vision, ocular discomfort, skin irritation and social embarrassment. Symptoms may be exacerbated by environmental factors such as cold, wind, pollen, sleep deprivation, near-point strain, or emotional stress.

This unique physiologic system is simple and elegant in design, yet is elaborate in the function of tear drainage, with the lacrimal pump and its anatomical construction. In order to properly evaluate and appropriately treat the patient, the ophthalmologist must have knowledge and comprehension of the lacrimal anatomy, the lacrimal apparatus, pathophysiology, ocular and nasal relationships, ophthalmic and systemic disease process, as well as the topical and systemic medications that can affect the nasolacrimal duct system. Tearing is a common complaint, and the evaluation of the tearing patient and lacrimal disorders requires a complete workup that is multifaceted and organized, including a detailed history as well as a comprehensive ophthalmic exam. The evaluation of the tearing patient can usually be adequately performed with an external examination of the eyelids, periorbital area, and ocular surface; slit-lamp biomicroscopy; fluorescein and rose Bengal staining; and simple office tests—the fluorescein dye disappearance test, Jones I and Jones II dye test, and diagnostic lacrimal irrigation and probing.

Tears drain through the superior and inferior puncta, canaliculi, the lacrimal sac, and the nasolacrimal duct to finally empty into the inferior meatus of the nasal cavity and absorbed by the mucosa of the nasolacrimal duct system and nasal mucosa. The canaliculi are lined by a nonkeratinized stratified squamous epithelium surrounded by the orbicularis muscle, while the lacrimal sac and nasolacrimal duct are lined with pseudostratified columnar epithelial cells with a ciliated surface. The sac also contains scattered goblet cells, mucus secretors, and serous glands. The common internal punctum is the transition from the canaliculi to the lacrimal sac and shares histologic features of both [1].

One must be able to assess if the cause is secondary to outflow anomalies, hypersecretion or reflex secretion, pseudoepiphora, eyelid malposition abnormalities, trichiasis, floppy eyelid syndrome, overriding of the upper and lower lids, Molluscum contagiosum, foreign bodies and conjunctival concretions, keratitis, tear film deficiencies or instability, meibomian gland dysfunction, squamous metaplasia of the conjunctiva, tarsal papillary or follicular reaction, dry eye syndromes, ocular surface abnormalities, irritation or tumors affecting the trigeminal nerve, allergy, medications, or environmental factors. It can be an isolated disorder or may involve multiple levels, at any level of the lacrimal drainage system.

The orbicularis muscle provides the pump mechanism for excretion of tears. With eyelid closure, the orbicularis muscle contracts and creates a negative pressure within the lacrimal drainage system that propels tears into the nasolacrimal sac. When the eyelids open, the orbicularis muscle relaxes, creating a positive pressure, forcing the tears from the sac into the duct. Any abnormality that affects the lacrimal pump or any condition in which the puncta are not in apposition to the globe can produce epiphora. Abnormalities of the lacrimal pump function can result from involutional changes, eyelid laxity, facial nerve paralysis, floppy eyelid syndrome, all of which displaces the punctum from the lacrimal lake.

The location and extent of the obstruction can frequently be determined by lacrimal drainage system irrigation and probing. One should remember that the irrigation may pass freely into the nasal cavity, indicating a patent nasolacrimal drainage system, but this is a nonphysiological test, since there is an increased hydrostatic pressure on the irrigating solution, and a functional obstruction may still be present. If the cause is secondary to obstruction of the nasolacrimal duct system, the ophthalmologist must be able to determine where the anomaly is and what the cause is, in order to provide the best treatment possible for the patients. The surgeon does not want to be confronted by clinical surprises, especially during surgery, and therefore should not

assume that what appears to be a straightforward case is always that, and should always perform a complete evaluation.

It is important to look for clues in the history and physical examination. The history is very important since it can often lead to the appropriate diagnosis. Evaluate the where, what, and why of the problem. Question how much tearing there is, how often the patient needs to dab the eyes or wipe the tears, to determine the severity. Question when the tearing is worst. Question if the tearing occurs from the medial or lateral aspect of the eyelid. If associated with sharp pain and followed by tearing is classic of dry-eye induced tearing. Swelling and pain of the eyelid or medial canthus may indicate a dacryocystitis. The skin around the affected eye in patients with chronic tearing is often erythematous and scaly, especially at the medial and/or lateral canthus; worsen by rubbing or dabbing the eye. The history of chronic rhinosinus infections, previous traumas, or cosmetic rhinoplasty can cause a nasolacrimal duct obstruction.

Tearing is a common complaint, and a complete workup is multifaceted and requires a detailed history as well as a comprehensive ophthalmic exam with special emphasis on the eyelids, conjunctiva, periocular adnexal structures, the blink mechanism, anterior segment, lacrimal system, and nasal cavity. The evaluation of tear chemistry testing, tear secretion tests, and tear recovery tests should be considered. Various imaging techniques have been developed, including dacryocystography, nuclear scintigraphy, digital subtraction dacryocystography, echography, CT with 3-D reconstruction and rotation, and MRI, small-gauge fiber-optic endoscopy of the nasolacrimal drainage system, nasal endoscopy, each of which has advantages and disadvantages, but provides anatomic information regarding the lacrimal outflow system, allows dynamic visualization of contrast passing through the lacrimal system, and transit times, but also the surrounding soft tissues, bony structures, and sinuses. Radiologic studies help to delineate if there is a mass within the lacrimal sac or duct and determine if the density is consistent with air, soft tissue, calcified tissue, or mass.

The cause of tearing can be secondary to hypersecretion, lacrimation, or impairment of drainage. The patient should be questioned regarding the following: unilateral versus bilateral; subjective symptoms of foreign body sensation, burning; constant versus intermittent; allergies; prior use of medications; prior probing; sinus disease; prior trauma; midfacial trauma; nasal fractures; radiation treatment to the periocular or paranasal sinus area; ocular diseases; ocular or periocular surgeries; prior episodes of lacrimal sac inflammation or infection; clear or a mucus discharge or bloody tears.

Inspection of the eyelids and lashes may find signs of blepharitis, acne rosacea, psoriasis, eczema, concretion, cyst, Molluscum contagiosum, chalazion, ectropion, entropion, trichiasis, lid laxity, lagophthalmos, poor blinking mechanism which may be secondary to seventh cranial nerve paralysis, poor lacrimal pump function, and overriding of the upper and lower lids. The lower eyelid should be checked for the presence or absence of laxity with the snap test. The eyelid is distracted away from the globe to see if it returns to its normal position against the globe, or requires a blind to restore its position. If the eyelid can be stretched more than 8 mm, or if it takes more than 8 s to return to its normal position, then the eyelid is considered to be lax. Check if the eyelid is in its normal position and if the lateral canthus is above or below medial canthus. An inferior displacement of the lateral canthus may suggest eyelid laxity as the cause of epiphora. A notch on the lid-margin secondary to trauma or surgery may allow tears to flow out of the tear pool onto the face. The punctum should be evaluated for size, stenosis or occlusion, its position, movement and for possible obstruction by the conjunctiva, the plica semilunaris, an enlarged caruncle, conjunctivochalasis or hyperplasia. Punctal eversion, ectropion, or facial palsy may also impair the lacrimal pump action. Trichiasis and distichiasis will cause a reflex tearing and will require epilation, cryosurgery, electrolysis, or the various eyelid margin procedures. Entropion will also cause a reflex tearing secondary to irritation from the lashes or skin.

If massage of the lacrimal sac produces fluid or mucopurulent discharge, then a nasolacrimal duct obstruction is probably present. Overabundance of tears (as assessed with fluorescein dye and a cobalt blue illumination), lack of tears, rapid evaporation of tears, poor tear coverage over the ocular surfaces, corneal damage, and conjunctiva must all be evaluated in the differential diagnosis of symptomatic tearing. Giant fornix syndrome can lead to chronic purulent discharge. The deep fornices can harbor pathogenic bacteria leading to chronic infections. A nidus of infection of protein coagulum develops in the superior fornices, which may be secondary to a disinsertion of the levator aponeurosis, which pulls on the superior conjunctiva, increasing the depth of the fornix. A badly slit puncta or canaliculus may also be a source of chronic epiphora. Palpation with pressure over the lacrimal sac may produce a reflux of mucoid or mucopurulent material through the canalicular system and punctum if the common canaliculus and valve of Rosenmuller are patent.

Lacrimal fistulae often appear as small orifices that may go undetected, and are often asymptomatic. Lacrimal fistulae are a rare anomaly in development, and generally originate from the common canaliculus, and occasionally from the lacrimal sac. Congenital lacrimal fistulas are estimated to occur one in 2,000, and are generally inherited in an autosomal dominant fashion. Most are unilateral, but familial cases have a higher incidence of bilateral involvement [2]. Since these fistulas generally occur inferior to the medial canthal area, they will present with epiphora. If the patient develops a mucoid discharge or epiphora, surgical intervention may be required.

Examination of the nose should be performed to rule out the possibility of intranasal tumors, allergic rhinitis, polyposis, turbinate impaction or other possible obstructions of the distal end of the nasolacrimal duct. A nasal speculum and a muscle light or indirect headlamp light source (such as that used for indirect ophthalmoscopy) or endoscopy can be used. Nasal endoscopy in the evaluation and during probing can determine structural nasal abnormalities, such as hypertrophy of the inferior turbinate, which may compromise the inferior meatus and nasolacrimal duct ostium, or strictures of the inferior meatus.

Symptoms of epiphora can reflect excess tearing, or hypersecretion of tears, due to the reflex arcs initiated by such processes as keratoconjunctivitis sicca, keratitis, allergies, or uveitis. As the epiphora progress and the chemistry of the tears changes, erosion of the epidermis from tear wiping can occur and cause ulcerative fissures at the canthal areas and along the lid margins. In some patients the clinical examination is unremarkable and the cause of epiphora remain unclear, a functional block. Occasionally the patient with epiphora and incomplete obstruction will respond to a topical antibiotic-steroid ophthalmic solution and nasal spray with steroid and/or decongestant, a functional block, since these patients will have a greater inflammatory component than fibrosis, while the patient with complete obstruction and therefore a greater degree of fibrosis and less inflammation will not be expected to resolve to topical therapy. Medical treatment of systemic diseases, such as Wegener's granulomatosis and Sarcoidosis may not alleviate the obstruction of the nasolacrimal system occlusion, but will improve the success rate if surgical treatment is required.

Unilateral tearing is suggestive of a lacrimal outflow problem because of either obstruction or poor function of the tear pump due to weakness of the orbicularis muscle, seventh cranial nerve palsy or lower lid laxity. Check the patient's blinking for both strength and rate and for lagophthalmos. Increased blinking may be secondary to ocular irritation or blepharospams causing tearing. Blinking contributes to the tear film stability by spreading and clearing tears which helps to eliminate the potentially harmful cytokines, toxins, allergens, and microbes [3]. Also to be considered in unilateral tearing is the possibility of intracranial processes, such as an acoustic neuroma, which can compress the lacrimal innervation pathway in the central nervous system and result in decrease tear production and unilateral dry eye symptoms and signs, including epiphora. Lymphoma, adenoid cystic carcinoma, or other tumors of the lacrimal gland can infiltrate the gland and/or its innervation causing decrease tear production on one side, with reflex epiphora. However bilateral outflow abnormalities can occur and result in bilateral tearing.

Symptomatic tearing can result when a normal lacrimal drainage system is overwhelmed by hypersecretion, or when a drainage system is anatomically comprised and unable to handle normal tear production. Epiphora is determined by a balance between tear production (0.02 μL/s, but reflexive tear secretion can increase this up to 100-fold), evaporation, and tear drainage and not by the absolute function or dysfunction of either. Tears enter the puncta at a rate of 0.6 μL/min, 90 % are reabsorbed through the nasolacrimal duct mucosa and 10 % drain into the nasal cavity. The conjunctival fornix can hold 7 μL in the upright position (the average eye drop is 20–30 μL) [4]. In the evaluation of these patients, many may be found to have patient lacrimal drainage systems and have other causes for their epiphora, such as dry eye syndrome with reflex tearing, evaporative loss, tear hyperosmolarity and tear instability secondary to xerophthalmia, ocular allergy, toxicity from preservatives in topical medications and artificial tears, contact lens, and meibomian gland dysfunction. The elevation of the tear hyperosmolarity causes the stimulation of cytokines that result in ocular surface inflammation, leading to a decrease of the goblet cell function and epithelial damage. The neurosensory stimulation from the corneal and conjunctival surface may lead to increase lacrimal gland tear secretion in an attempt to reduce tear film osmolarity and the reflex tearing [5]. These neuronal arc feedback systems are initiated by tear film instability and hyperosmolarity, then induces ocular surface inflammation and the release of pro-inflammatory cytokines, interleukins 1 and 6, and tumor necrosis factor. Dry eye syndrome, keratoconjunctivitis sicca may affect up to 14.6 % of patients 65 years or older [6], and has an increase prevalence in postmenopausal females and patients with autoimmune conditions. These patients should be evaluated for tear hyposecretion or evaporative loss, tear hyperosmolarity, and ocular surface inflammation. This altered tear film and ocular surface inflammation may cause ocular irritation that stimulates reflex tear secretion as a compensatory mechanism, causing many of these patients to present with watery eyes or frank epiphora.

Hypersecretion of tears is rare but can occur with compressive lesions of the nervus intermedius that transmit the parasympathetic lacrimal fibers; aberrant regeneration of the seventh cranial nerve causes gustolacrimal reflex or "crocodile tearing"; dacryoadenitis and medications such as cholinergic agonists.

Nasolacrimal duct occlusion is more common in the middle-age female, in the fifth to sixth decade of life, with a mean age of 55.5 years, with the incidence highest in the postmenopausal women [7]. Dacryocystitis is normally not seen in patients under age 30 unless there is some form of congenital nasolacrimal duct obstruction, an underlying systemic condition such as infectious mononucleosis and Epstein-Barr virus, or facial trauma. It is often of unknown etiology, and may present with or without dacryocystitis. This higher prevalence of primary acquired nasolacrimal duct obstruction in females may be secondary to their narrower nasolacrimal ducts, or/and the possible hormonal effects on its mucosal lining leading to obstruction. There is an increase incidence of dacryocystitis in females (71.3 %) [8].

Cicatricial nasolacrimal duct drainage obstruction has been reported to result from various medical therapies, both topical and systemic medications, radiation, systemic chemotherapy, and bone marrow transplantation.

Down's syndrome patients have been noted to develop dacryostenosis, more frequently caused by anatomic abnormalities, canalicular stenosis, and atresia. Punctual atresia and canalicular obstruction are also more common in patients with midface abnormalities.

Bartley modified the Linberg and McCormick etiologic classification system for "primary acquired nasolacrimal duct obstruction" (PANDO), those that are an idiopathic fibroinflammatory obstruction of unknown cause, and published an expanded classification for "secondary acquired lacrimal drainage obstruction" (SALDO). The etiological causes of SALDO were divided into five categories: infectious, inflammatory, neoplastic, traumatic, and mechanical [9] (Table 5.1).

We will first discuss the areas of the nasolacrimal system and the various processes that affect each area. Then we will review the etiological causes.

Table 5.1 Causes of secondary acquired nasolacrimal duct obstruction

Neoplastic

Primary

Secondary

Metastatic

1. Primary neoplasms
   - (a) Adenoid cystic carcinoma
   - (b) Adenocarcinoma
   - (c) Angiofibroma
   - (d) Angiosarcoma
   - (e) Cavernous hemangioma
   - (f) Cyst
   - (g) Dermoid cyst
   - (h) Fibroma
   - (i) Fibrous histiocytoma
   - (j) Granular cell tumors
   - (k) Glomus tumor
   - (l) Hemangioendothelioma
   - (m) Hemangiopericytoma
   - (n) Leukemia
   - (o) Lymphoma
   - (p) Lymphoplasmacytic infiltrate
   - (q) Lymphoproliferative diseases
   - (r) Melanoma
   - (s) Mucoepidermoid carcinoma
   - (t) Neurofibroma
   - (u) Neurilemmoma
   - (v) Oncocytic adenoma
   - (w) Oncocytic adenocarcinoma
   - (x) Oncocytoma
   - (y) Papilloma and inverted papillomas
   - (z) Plasmacytoma
   - (aa) Pleomorphic adenoma
   - (bb) Pyogenic granuloma
   - (cc) Squamous cell carcinoma
   - (dd) Transitional cell carcinoma
2. Secondary involvement by neoplasm
   - (a) Adenoid cystic carcinoma
   - (b) Amyloid
   - (c) Basal cell carcinoma
   - (d) Capillary hemangioma
   - (e) Dermatofibrosarcoma protuberans
   - (f) Esthesioneuroblastoma
   - (g) Fibrous dysplasia
   - (h) Fibrosarcoma
   - (i) Intraosseous cavernous hemangioma
   - (j) Kaposi's sarcoma
   - (k) Leukemia
   - (l) Lymphoma
   - (m) Maxillary and ethmoid sinus tumors
   - (n) Midline granuloma
   - (o) Mucoepidermoid carcinoma
   - (p) Mycosis fungoides
   - (q) Neurofibroma
   - (r) Osteoma
   - (s) Papilloma
     - Conjunctival
     - Inverted (schneiderian)
   - (t) Rhabdomyosarcoma
   - (u) Schwannoma
   - (v) Sebaceous gland carcinoma
   - (w) Squamous cell carcinoma
3. Metastatic
   - (a) Breast carcinoma
   - (b) Melanoma
   - (c) Prostate carcinoma
   - (d) Others—rare, but metastatic lesions have been reported to arise from the bladder, colorectal, esophageal gastric pharyngeal pulmonary, ovarian thyroid, and uterine

Inflammations

1. Endogenous
   - (a) Wegener's granulomatosis and other forms of vasculitis
   - (b) Sarcoidosis and sarcoid granuloma
   - (c) Blepharitis
   - (d) Cicatricial pemphigoid
   - (e) Steven-Johnson syndrome (erythema multiforme)
   - (f) Sinus histiocytosis
   - (g) Orbital Inflammatory Syndrome (Pseudotumor)
   - (h) Kawasaki's disease (mucocutaneous lymph node syndrome)
   - (i) Lethal midline granuloma
   - (j) Linear immunoglobulin A disease
   - (k) Porphyria cutanea tarda
   - (l) Epidermodysplasia verruciformis, ichthyosis, scleroderma
   - (m) Idiopathic punctal stenosis
   - (n) Benign Squamous Metaplasia
   - (o) Sjogern's syndrome
   - (p) Thyroid disease
   - (q) Lichen planus
   - (r) Nicolas-Favre lymphogranulomatosis
2. Exogenous
   - (a) Eyedrops
     - Antiviral agents
       - Idoxuridine
       - Vidarabine
       - Trifluridine

(continued)

Table 5.1 (continued)

- Acyclovir
- Antiglaucoma medications
  - Demecarium
  - Echothiophate
  - Isoflurophate
  - Furmethide
  - Neostigmine
  - Physostigmine
  - Epinephrine
  - Timolol
  - Betaxolol
  - Dipivefrin
  - Prostaglandin analogs
- Silver nitrate, silver protein, colloidal silver
- Thiotepa
- Cyclopentolate hydrochloride
- Topical Chemotherapeutic medications
  - Fluorouracil
  - Mitomycin

(b) Radiation therapy
- External radiation therapy
- Cobalt and iridium brachytherapy
- Radioiodine ablation, I^{131} therapy for thyroid carcinoma

(c) Systemic chemotherapeutic medications
- Fluorouracil
- Docetaxel
- Paclitaxel

(d) Graft-versus-host disease

(e) Bone marrow transplantation

(f) Pyogenic granuloma

(g) Foreign body granuloma

(h) Allergy
- Ocular
- Nasal

(i) Burns
- Thermal
- Chemical

(j) Chronic sinus disease

Infections

1. Bacterial
   (a) *Actinomyces* sp.
   - *A. israelii*
   - *A. meyeri*

   (b) *Propionibacterium propionicus* (*Arachnia propionica*)

   (c) *Fusobacterium* sp.

   (d) *Bacteroides* sp.

   (e) *Mycobacterium* sp.
   - *M. fortuitum*
   - *M. leprae*
   - *M. tuberculosis*

   (f) *Chlamydia trachomatis*

   (g) *Nocardia asteroids*

   (h) *Enterobacter cloacae*

   (i) *Aeromonas hydrophile*

   (j) *Treponema pallidum*

   (k) *Staphylococcus aureus*
   - Methicillin-resistant *Staphylococcus aureus* (MRSA)
   - Community-acquired MRSA (CA-MRSA)

   (l) *Staphylococcus epidermidis*

   (m) *Pseudomonas aeruginosa*

   (n) *Proteus mirabilis*

   (o) *Haemophilus influenzae*

   (p) *Peptostreptococcus*

   (q) *Streptococcus viridans*

   (r) Gamma *streptococcus*

   (s) Diphtheroids

   (t) *Klebsiella*

   (u) *Moraxella*

   (v) Mononucleosis

   (w) *S. pneumoniae*

   (x) *Moraxella*

   (y) *Escherichia coli*

   (z) *N. gonorrhea*

   (aa) *N. catarrhalis*

   (bb) Trachoma

   (cc) Leprosy

   (dd) Tuberculosis

2. Viral
   (a) Herpes simplex virus

   (b) Herpes zoster virus
   - Varicella

   (c) Small pox

   (d) Adenovirus

   (e) Vaccinia virus

   (f) Epstein-Barr virus

   (g) Human papillomavirus

   (h) Mumps virus

3. Fungal
   (a) *Aspergillus* sp.
   - *A. fumigatus*
   - *A. niger*

   (b) *Candida* sp.
   - *C. albicans*
   - *C. parapsilosis*

   (c) *Pityrosporon* sp.
   - *P. orbiculare*
   - *P. pachydermatis*

(continued)

Table 5.1 (continued)

- (d) *Rhinosporidium seeberi*
- (e) *Sporothrix schenckii*
- (f) *Streptomyces somaliensis*
- (g) *Trichophyton rubrum*
- (h) *Cephalosporiosis*
- (i) *Blastomycosis*
- (j) *Cryptococcosis*
- (k) *Conidiobolus coronatus* (class zygomycetes)

4. Parasitic
   - (a) *Ascaris lumbricoides*
   - (b) *Distoma felineum*
   - (c) Myiasis
   - (d) Leishmaniasis
5. Systemic infections
   - (a) Influenza
   - (b) Scarlet fever
   - (c) Diphtheria
   - (d) Chickenpox
   - (e) Smallpox
   - (f) Tuberculosis

Traumatic

1. Iatrogenic
   - (a) Punctal occlusion for dry eyes
   - (b) After nasolacrimal duct probing with or without silicone intubation
   - (c) After canalicular repair with pigtail probe
   - (d) Punctoplasty—one snip, two snip, three snip, or punch
   - (e) After dacryocystorhinostomy
   - (f) After conjunctivodacryocystorhinostomy
   - (g) After transantral orbital decompression
   - (h) After sinus surgery (conventional or endoscopic)
   - (i) After rhinoplasty, rhinotomy, or other nasal surgery
   - (j) After craniofacial surgery
3. Noniatrogenic
   - (a) Laceration of canaliculus
   - (b) Laceration of lacrimal sac
   - (c) Avulsion of eyelid and canaliculus secondary to blunt trauma
   - (d) Fractures involving nasolacrimal duct, nasoethmoid fractures, midfacial trauma.
   - (e) Chemical burns
   - (f) Thermal burns

Mechanical

1. Internal
   - (a) Dacryolith
     - Idiopathic
     - Eyelash nidus
     - Epinephrine cast
     - Quinacrine deposits
     - Argyrosis
   - (b) Migrated or retained medical device
     - Punctal plug
     - Veirs rod
     - Fragment of nasolacrimal probe
     - Modified myringotomy tube
     - Remnants of silicone tubing
   - (c) Pellet (BB)
   - (d) Canalicular cysts
   - (e) Blood
   - (f) Dacryops
2. External
   - (a) Kissing puncta
   - (b) Conjunctivochalasis, enlargement of the plica, semilunaris, and/or caruncle
   - (c) Dermoid cyst
   - (d) Mucocele and mucopyoceles
   - (e) Migrated or malpostioned orbital floor or medial wall implants after repair of orbital floor and/or medial wall fractures
   - (f) Paget's disease
   - (g) Osteopetrosis
   - (h) Rhinolith or other nasal foreign bodies
   - (i) Suture stent after esophagocolostomy
   - (j) Exudative Rhinitis
   - (k) Acute intranasal inflammation
   - (l) Nasal mucosal edema
   - (m) Lymphoid hyperplasia of the nasal cavity
   - (n) Nasal malformations.
   - (o) Nasal Polyps or Polyposis
   - (p) Neurilemmoma of the ethmoidal nerve
   - (q) Systemic syndromes or dysmorphism that involve abnormalities of facial development (clefting or malposition of the orbits or midface)
   - (r) Intranasal tumors; benign and malignant
   - (s) Impacted or hypertrophy of the turbinate
   - (t) Nasal packing
   - (u) Intranasal scaring secondary to trauma, radiation therapy, surgery, or allergic

Modified table from:

1. Linberg JV, McCormick SA. Primary acquired nasolacrimal duct obstruction: a clinicopathologic report and biopsy technique. Ophthalmology. 1986;93:1055–62
2. Bartley, GB. Acquired lacrimal obstruction: an etiologic classification system, case report, and a review of the literature. Part 1. Ophthal Plast Reconstr Surg. 1992;8(4):237–42
3. Bartley, GB. Acquired lacrimal drainage obstruction: an etiologic classification system, case report, and a review of the literature. Part 3. Ophthal Plast Reconstr Surg. 1993;9(1):11–26

Location of Stenosis or Occlusion

Punctum and/or Canaliculi. Acquired stenosis or occlusion of the punctum, ampullae, and canaliculi may be caused by a variety of conditions, including inflammatory conditions, infections, trachoma, cicatrizing diseases of the conjunctiva, secondary to the toxic effect of topical or systemic medications, especially systemic chemotherapeutic medications, masses in the area of the punctum, retained punctal plugs, surgery, burns, trauma, longstanding ectropion or lid malposition, aging changes, chronic infections, viruses (herpes simples or human papilloma viruses), blepharitis, lichen planus, trauma, tumors, graft-vs.-host disease or iatrogenic. Most traumatic injuries are due to lacerations, such a stab wound or animal bites, or secondary traction that results from a sudden lateral displacement of the eyelid, avulsing the medial canthal tendon and canaliculus. The canaliculus is without tarsal support, and therefore the weakest part of the eyelid. Abnormally large puncta can also cause epiphora due to the disruption of the lacrimal pump. This prevents the development of an adequate seal when the eyelids are closed, and prevents the creation of negative pressure, and suctioning of tears. Enlargement of the puncta is frequently secondary to iatrogenic injury, "cheese-wiring" due to canalicular stents, punctoplasty, excision of adjacent lesions. Extreme care should always be taken when dealing with the puncta because there is no effective treatment available, leaving a Conjunctivodacryocystorhinostomy (CDCR) as the only treatment option.

Punctal agenesis is frequently associated with the absence of the associated canaliculi, especially when both the superior and inferior puncta are absent. In patients that are symptomatic, surgical exploration is required to determine if there is also agenesis of the canaliculi that can be salvaged (if more than 8 mm of canaliculi exist, surgical intervention may be curative), or the patient will require a CDCR [10].

Punctal stenosis is more common in post-menopausal female, probably secondary to hormonal changes. Chronic blepharitis causes inflammatory and cicatricial changes resulting in inflammatory membrane formation, conjunctival epithelial overgrowth, and keratinization of the walls of the punctum. Membranous stenosis at the internal punctum is the most common location for canalicular stenosis. Involutional changes of these tissues, atrophy, dense fibrous stricture of the punctum cause it to be less resilient and the orbicularis muscle fibers to become atonic and stenotic.

Conjunctivochalasis, excess conjunctiva that occludes the inferior punctum is often overlooked. The etiology is not completely known, and may be secondary to natural aging, eye rubbing, abnormalities of the eyelid position and ocular movement, changes in Tenon's capsule leading to a loss of the adhesion between the conjunctiva and underlying sclera, an over-expression of matrix metalloproteinases which modifies or degrades the extracellular matrix, a nongranulomatous inflammation along with elastosis, increased collagenolytic activity, all of which may contribute to conjunctival laxity and conjunctivochalasis. Conjunctivochalasis is generally bilateral, seen in older patients, and characterized by loose redundant conjunctival folds interspersed between the eyelid and the globe, more frequently along the lower eyelid temporally. This can misdirect the tear flow toward the outer corner of the eye. In mild cases it may cause tearing due to tear film instability, in moderate cases it may cause obstruction of the punctum, interrupting the tear meniscus, and in severe cases due to foreign body sensation and irritation that results from ocular surface exposure. If the patient is experiencing pain, then apply slight pressure in the area of the pain before a topical anesthetic is applied, and have the patient look up and down; this will reproduce the pain assisting in making the diagnosis of conjunctivochalasis. If the symptoms are not resolved with topical treatment, then surgical treatment may be indicted.

Chronic recurrent mucopurulent conjunctivitis may be secondary to Giant Fornix Syndrome. The superior fornix is usually large and can harbor a coagulum of proteinaceous debris colonized with bacteria that can cause relapses of purulent conjunctivitis and toxic keratitis [11].

Obstruction may occur within either the upper or lower canaliculus or in the common canaliculus. Canalicular obstructions may involve the proximal segment, the first 2–3 mm, the midcanalicular segment, 3–8 mm from the puncta, and or the distal segment, at the opening of the common canaliculus into the lacrimal sac. Membranous stenosis at the internal common punctum is one of the most common locations for canalicular stenosis. Causes of acquired canalicular obstruction include trauma and toxicity due to medications (5-fluorouracil, idoxuridine, phospholine iodide, eserine, preservatives in ophthalmic medications, etc.). Canalicular obstructions may be caused by chlamydial infections (trachoma), viruses (herpes zoster, herpes simplex, chicken pox and small pox), bacteria, cicatrizing diseases (Stevens–Johnson syndrome or Pemphigoid), or atopic conjunctivitis can cause a cicatrizing conjunctivitis and punctal stenosis.

Punctal plugs may be associated with punctal and canalicular complications: punctal sphincter rupture during insertion, pyogenic granuloma, migration, local inflammatory reaction, canaliculitis, which can lead to stenosis or occlusion [12, 13]. Repeated probing, especially when not performed correctly, may lead to canalicular stenosis.

Canalicular cyst presents as a bluish mass or a cyst-like swelling. These cysts may arise after an episode of canaliculitis with an ecstatic canalicular diverticulum, an encysted abscess or chronic canaliculitis, in which both the medial and lateral ends of the canaliculus are obstructer, creating a one-way valve effect, allowing ingress of fluid but preventing egress. The canalicular enlargement has been termed a canaliculocele or canaliculops. Intrinsic canaliculi tumors such as papillomas and pyogenic granulomas may occlude the canaliculi and produce a secondary inflammation and stenosis. Skin cancer may invade the puncta and canaliculi. Irradiation of tumors in the area may cause an occlusion of the canaliculi, but the placement of canaliculi tubes may prevent this complication. Other lesions arising from the adjacent areas include those arising from the lacrimal sac (dacryocystocele, lacrimal sac diverticulum, lacrimal sac tumor); eyelid (ocular adnexal cyst or tumors); paranasal sinuses (sinus mucoceles); orbit (dermoid cyst, epidermoid cyst); or intracranial space (meningoencephalocele associated with hypertelorism) [14].

Lacrimal Pump. The lacrimal pump is the mechanism that assists the tears in their travels from the tear pool through the nasolacrimal duct system into the interior meatus of the nose. The action of the pretarsal and preseptal orbicularis oculi, Horner muscle, produces the forces that drive the lacrimal pump. Additional functions such as gravity, pressure gradients in the lacrimal tract, and tear reabsorption by the cavernous structure support the lacrimal drainage.

Patients with tearing whose nasolacrimal duct systems are patent to syringing may have an incomplete anatomic obstruction or nonfunctional segments of the lacrimal passage from prior episodes of dacryocystitis, or an anatomically normal nasolacrimal duct system, but a physiologic dysfunction of the eyelids, punctum, lacrimal pump, or a lacrimal sac that drains poorly.

Lacrimal Sac and Duct. The mucosal lining of the nasolacrimal sac and duct are inherently resistant to microbial invasion. The mucous membrane of the lacrimal sac and duct is a pseudostratified columnar epithelium, with the underlying lamina propria that consists of two strata: a loose connective tissue with scattered lymphocytes or groups of lymphocytes and a rich venous plexus situated under the loose connective tissue, a cavernous body that may facilitate opening and closure of the lumen of the lacrimal passage by shrinkage and swelling that regulates tear outflow. It produces a broad spectrum of antimicrobial peptides that have a therapeutic potential in infections and also accelerate epithelial healing. The antimicrobial peptides IgA and immunocompetent cells, lymphocytes and macrophages, provide a defense mechanism. These peptides also promote fibrin formation and cell proliferation which may also cause scarring and the resultant dacryostenosis. This may be an integral part of the specific mucosal immune system and belongs to the mucosa-associated lymphoid tissue (MALT) [15]. They excrete a range of

mucin materials, carbohydrates, TFF-peptides, and antimicrobial peptides, which may aid in the flow of tears and provide a defense against microbes. Researchers have identified mRNA for a variety of mucins in human lacrimal sacs and ducts. Reduced level of mucin mRNA in patients with epiphora secondary to a nonfunctioning segment of the nasolacrimal drainage system, but still patent to irrigation, suggests that mucins may reduce drag and enhance tear flow through the nasolacrimal drainage system [16]. When an obstruction occurs, the tears that are laden with inflammatory material that accumulates and the increase in inflammatory cytokines induce changes in the mucosal cellular structures. These changes in the lacrimal sac and duct epithelium and lamina propria allow the microbial buildup, creating an environment unopposed to the spread of infection. In patients with functional dacryostenosis, it has been noted that the epithelia of the nasolacrimal drainage system is characterized by squamous metaplasia with loss of goblet-cell-associated mucins MUC2, -5AC, and -5B. There were no changes in MUC7 which is antibimicrobial and may explain the low incidence of dacryocystitis in patients with functional dacryostenosis. The malfunction of the pathophysiology of the cavernous body of the lacrimal sac and nasolacrimal duct may reduce absorption of tears as they pass through the nasolacrimal system or cause swelling and obstruction and lacrimal pump dysfunction.

Inflammation, trauma, canal tortuosity, soft tissue physiology, irritations, hormone-induced epithelial changes, osteoporosis, or congenital defect in the drainage system may cause epiphora, dacryostenosis, and dacryocystitis. An anatomical etiology can explain some of the causes of obstruction, but does not fully explain all the epidemiologic variabilities. Inflammation originating at the eye, conjunctival sac, diverticula of the lacrimal system, or from the nose, infections or diseases of the nasal mucous membrane or sinuses can induce swelling of the lacrimal system's mucous membranes, resulting in narrowing or occlusion of the nasolacrimal system from the epithelial changes and fibrosis of the lamina propria [7]. The various mechanisms that cause inflammation result in a secondary fibrosis that causes a narrowing of the nasolacrimal duct system, and eventually occlusion by scar tissue. The lacrimal sac and duct undergo similar changes, as the pseudostratified, ciliated, columnar epithelium undergoes squamous metaplasia and hyperplasia with loss of goblet cells, and ulceration. The underlying submucosa develops a secondary fibrosis. Basement membrane thickening may develop in the nasal mucosa but not in the lacrimal sac. The inflammation may cause a fibrosis of the lacrimal sac and the internal common punctum, which may result in obstruction, and in post-op cases, to failure of dacryocystorhinostomies [17].

Several valves are present in the nasolacrimal duct system to prevent the retrograde flow of tears. The most important valve clinically is the valve of Hasner, located at the entrance of the nasolacrimal duct into the inferior meatus, and frequently responsible for congenital nasolacrimal duct obstruction. The valve of Rosenmuller is found at the junction of the common canaliculus into the lacrimal sac. The superior and inferior canaliculi join together to form a common canaliculus that drains into the lacrimal sac in 90 % of patients, while in 10 % of patients, each canaliculus enters separately into the lacrimal sac [18]. This valve prevents retrograde flow of fluid from the sac into the canaliculi and fornix. In episodes of dacryocystitis, this valve may swell closed even more tightly. Tears and the infection cannot drain out of the sac into the nose, or to the fornix. The valve of Rosenmuller is not a true valve, but an angulated entrance of the common canaliculus into the sac, functioning as a valve.

Descending inflammation from the eye or ascending inflammation from the nasal cavity may initiate swelling of the mucous membranes of the nasolacrimal duct system, remodeling of the helical arrangement of connective tissue fibers, malfunctions in the subepithelial cavernous body with reactive hyperemia, and temporary occlusion of the nasolacrimal duct system. The submucosa is a very vascular, cavernous structure and rich in lymphatics so that a slight infection once established will settle. The constriction of the tissue within the fixed space of the bony canal makes it understandable that any significant

swelling will lead to blockage. The submucosa of the nasolacrimal duct system surrounded by bone contains arterioles with sphincters and cavernous vessel complexes, which can cause swelling and approximation of the lumen according to the blood flow. A cascade of multifactorial events leads to the development of inflammation, obstruction, and stasis. This result in vascular congestion and edema from the inflammation causing obstruction while the cellular debris and mucus trapped in the nasolacrimal sac and duct causes an infection-induced fibrosis and atrophy of the walls. Repeated episodes of dacryocystitis will result in permanent changes of the epithelial and subepithelial tissues, loss of goblet and epithelial cells which are important in the tear outflow mechanism, fibrosis of the helical system of connective tissue fibers, and reduction and destruction of the vascular plexus, leading to a malfunction of the tear flow mechanism, all of which results in a vicious cycle [7]. These structural epithelial and subepithelial changes, may lead to either a total fibrous closure of the lumen of the nasolacrimal duct system or to a nonfunctional segment that may cause chronic epiphora and discharge, but may patent to syringing.

Dacryocystitis has various causes, but the common end result is complete obstruction of the nasolacrimal duct, resulting in stasis of tear flow, leading to secondary infections, which may ultimately progress to mucocele, pyocele-mucocele, chronic conjunctivitis, preseptal and orbital cellulitis and abscess formation if left untreated, or inadequately treated. Gram-positive bacteria are the most common cause, but gram-negative organisms should be suspected in patients with diabetes or are immunocompromised.

Inflammation may involve the lacrimal sac can be involved by inflammation, the most common being nongranulomatous inflammation, the granulomatous inflammation, granulation tissue, lymphocytic infiltrate, inflammation and ulcerations, and sarcoidosis. The epithelial lesions that involve the lacrimal sac are inverted papilloma, papilloma, transitional cell carcinoma, oncocytoma, granular cell tumor, carcinoma, and adenocarcinoma. The nonepithelial lesions are lymphoma, lymphoplasmacytic infiltrate, plasmacytoma, and chronic lymphocytic leukemia. Infections that involve the lacrimal sac can be secondary to fungus, *Actinomyces*, and bacteria. The lacrimal sac can also be affected by dacryolith, scarring, foreign body, pyogenic granuloma, amyloidosis, orbital and midfacial fractures, blood, trauma, migration of an alloplastic orbital floor or medial wall implant, and papillary hyperplasia.

Lacrimal diverticula, outpouchings of the canaliculi or the lacrimal sac are rare but may cause intermittent or permanent swelling, near the lacrimal sac. Most arise from the lateral sac wall, since this area is only covered by the periorbita, offering little resistance to distention of the sac. They may be congenital, inflammatory, secondary to prior episodes of dacryocystitis, or traumatic in origin. This communication may be open or act as a one-way valve, becoming symptomatic and may cause epiphora, swelling, and/or a dacryocystitis like symptoms. Dacryoliths may form inside the diverticulum.

The nasolacrimal canal is a bony conduit from the nasolacrimal fossa that enters the inferior meatus adjacent to the attachment of the inferior turbinate and is formed by the three facial bones; the maxilla, the lacrimal bone, and the inferior turbinate. The nasolacrimal canal is variable and differs in size with age, gender, and race. Obstruction of the intraosseous segment of the nasolacrimal duct may be secondary to trauma, chronic sinus disease, granulomatous disease (Wegener granulomatosis, Sarcoidosis, and lethal midline granuloma), possible Crohn's disease, osteopetrosis, dacryocystitis, or involutional stenosis. Involutional stenosis is probably the most common cause, seen more frequently in older females, and may be secondary to hormone-related changes in the mucosa of the nasolacrimal system, and narrowing of the bony nasolacrimal canal. The smaller diameter of the bony canal may play a role in the development of obstruction due to swelling of the mucosa.

Dacryocystocele is a diffuse enlargement of the lacrimal sac that results from proximal and distal obstructions of the nasolacrimal system, often presents as a bluish enlargements of the lacrimal sac filled with secretions derived from the epithelial linings, goblet cells, and submucosal

accessory seromucinous glands. This can involve the lacrimal sac and also the lacrimal duct. If there is mucus in the cyst's contents, this is a dacryocystomucocele.

A retrospective study of 377 dacryocystorhinostomy (DCR) specimens demonstrated non-granulomatous inflammation (321 cases, 85.1 %), granulomatous inflammation consistent with Sarcoidosis (8 cases, 2.1 %), lymphoma (7 cases, 1.9 %), papilloma (4 cases, 1.11 %), lymphoplasmacytic infiltrate (4 cases, 1.1 %), transitional cell carcinoma (2 cases, 0.5 %), and single cases of adenocarcinoma, undifferentiated carcinoma, granular cell tumor, plasmacytoma, and leukemic infiltrate. Neoplasms resulting in chronic nasolacrimal duct obstruction occurred in 4.6 % of cases and were unsuspected before surgery in 2.1 % of patients [19].

Obstruction of the Nasal Portion of the Nasolacrimal Duct. Mechanical obstruction is frequently found with enlargement or flattening of the inferior turbinate which may almost obliterate the anterior part of the inferior meatus and may cause a local rhinitis. A deviated septum may compress the inferior turbinate against the lateral nasal wall.

Inflammatory conditions, chronic nasal catarrh, acute and suppurative infections, may spread into the inferior portion of the nasolacrimal duct, resulting in obstruction. Sinus disease frequently occurs in conjunction with or may contribute to the nasolacrimal duct obstruction. Atrophic and destructive conditions of the nasal mucosa may create a patulous ostium permitting extension of the disease process upwards and allowing the direct entrance of infective secretion into the duct on blowing the nose.

Congestive and hypertrophic conditions of the mucosa, such its vasomotor rhinitis or inflammation, may cause obstruction at or in the inferior portion of the nasolacrimal duct, as well as a nasal polyp or neoplasm. Dacryocystitis has also been reported following packing of the nose.

External compression of the nasolacrimal duct can be secondary to nasal polyps that can erode the lacrimal bone and frontal process of the maxilla. These patients will require a polypectomy and not a dacryocystorhinostomy.

Intranasal pathology may affect the nasolacrimal duct. Intranasal scarring with inferior turbinate adhesions that occurs from trauma, radiation therapy, surgical procedures, or nasal mucosal hypertrophy from allergic rhinitis may cause obstruction of the duct. It is therefore important that the appropriate imaging and nasal endoscopy should be part of the routine assessment of the tearing patient, which will improve the diagnostic accuracy in dacryostenosis. CT scans will detect the bony defects in the lacrimal fossa or the nasolacrimal duct. MRI scans will depict the margins of a mucoceles, its contents, mucosal thickening, retained secretions, retention cysts, differentiate tumors from inflammation, and helps differentiates between the various pathologic soft-tissue lesions. Lacrimal surgeons must know what they are dealing with before they embark on a treatment plan or surgical procedure. In patients with nasal polys, one should consider Samter's triad, which consists of recurrent nasal polyposis, allergy to aspirin, and bronchial asthma [20].

Congenital nasolacrimal duct obstruction occurs in approximately 6 % of infants, and generally result from a blockage or incomplete canalization somewhere along the length of the nasolacrimal system, most commonly at the valve of Hasner. The majority of these cases will resolve spontaneously with conservative medical treatment, but occasionally will require treatment with probing and irrigation, balloon dacryoplasty, or the placement of canalicular stenting. Dacryocystocele is an enlargement of the lacrimal sac due to a congenital nasolacrimal duct obstruction distal to the sac, and the proximal blockage of the valve of Rosenmuller, causing the sac to fill with tears and secretions of the cells lining the sac. They typically present as a bluish, cystic diffuse enlargement of the lacrimal sac that is painless unless a concomitant dacryocystitis develops.

Etiological Causes

Infectious. The infectious causes of nasolacrimal duct obstruction may be secondary to bacteria, viruses, fungi, and parasites. Generalized infections

are occasionally responsible for the onset of dacryocystitis, as seen with the occurrence of inflammation during the course of influenza, scarlet fever, diphtheria, chickenpox, smallpox, and tuberculosis.

The occurrence of acute dacryocystitis is dependent on the entry of a virulent strain of an organism into the stagnant contents of a lacrimal sac where the nasolacrimal duct is obstructed. Pathogens can enter the nasolacrimal system from the conjunctival sac, from diverticula of the lacrimal system, from the nasal cavity, or infections of the nasal mucous membranes or sinuses.

Chronic dacryocystitis may be primary or secondary to an anatomical abnormality that has led to tear flow stasis. Obstructed lacrimal duct systems are colonized by increased numbers of pathogenic microorganism. Some cases of nasolacrimal system obstruction may be secondary to unrecognized low-grade dacryocystitis. The organisms in the lacrimal sac may contribute to inflammation and scarring and therefore to the obstruction and then dacryocystitis. The microbiology of acute dacryocystitis has been reported to be frequently secondary to species of *Staphylococcus*, *Streptococcus*, *Pneumococcus*, and *S. pyogenes*, with mixed infections being common. The most commonly cultured organisms were *Staphylococcus epidermidis* and *S. aureus*. The common gram-negative rods include *Pseudomonas aeruginosa*, *Proteus mirabilis*, *Enterobacter cloacae*, and *Haemophilus influenzae*. Frequently these studies interpreted cultures taken from the conjunctival cul-de-sac in cases of chronic dacryocystitis and therefore may not accurately identify the causative organism. Studies have shown that there is not a significant correlation between organisms cultured from the lacrimal sac to those obtained from the conjunctiva and/or nose; therefore the preoperative conjunctival and/or nasal cultures do not accurately predict the causative organism of the dacryocystitis [21].

Methicillin-Resistant *Staphylococcus aureus* (MRSA) and community-acquired MRSA (CA-MRSA) are becoming increasingly prevalent as causes of ophthalmic infections, including dacryocystitis. Empiric antibiotic therapy should include coverage for MRSA especially in endemic areas until the cultures and sensitivity results are available.

The viruses of primary herpes simplex, herpes zoster, chicken pox, smallpox, vaccinia, epidemic keratoconjunctivitis, and Epstein-Barr viruses may cause inflammatory and cicatrical changes of the canaliculi resulting in varying degrees of obstruction or occlusion. These infections can extend beyond the stratified squamous epithelium to involve the elastic tissue of the substantia propria rather than the canalicular epithelium alone, or due to the adherence of the raw surfaces caused by the inflammation of the mucous membranes, resulting in stenosis, and then occlusion. Bacterial infections do not frequently affect the elastic layer. During the first few weeks of these viral infections, the mucosal epithelium is edematous, causing a stenosis that will still able to be probed. The cicatrization that occurs over the next several weeks to months, generally causing an obstruction that involves the mid-zone or distal portions of the superior and inferior canaliculi, may occasionally may cause punctal occlusion. Early recognition, probing and intubation when indicated can prevent permanent canalicular obstruction and the need for a conjunctivodacryocystorhinostomy.

Infectious mononucleosis, mumps, Nicolas-Fayre lymphogranulomatosis, trachoma, Stevens–Johnson syndrome and pemphigus may cause dacryostenosis.

Dacryocystitis has been reported to result from infections with several species of mycobacteria: *Mycobacterium fortuitum*, *M. leprae*, and *M. tuberculosis*.

Chlamydia trachomatis has been reported to cause punctual occlusion, canalicular scarring, and nasolacrimal duct obstruction.

Other bacteria associated with lacrimal drainage obstruction include *N. asteroids*, *Enterobacter cloacae*, *Aeromonas hydrophila*, *Treponema pallidum*, and *S. aureus*.

Fungi generally occlude the lacrimal drainage system by the formation of a stone or cast. *Aspergillus fumigatus*, *A. niger*, *Candida albicans*, *C. parapsilosis*, *Pityrosporum orbiculare*, *P. pachydermatis*,

S. somaliensis, *Actinomyces*, and *Trichophyton rubrum* may cause lacrimal stones or casts.

Parasitic obstruction is unusual, but has been reported with *Distoma felineum*, Myiasis, and the nematode *Ascaris lumbricoides*. The *Ascaris lumbricoides* worm gains entrance to the nasolacrimal system through the valve of Hasner and then emerges from the punctum. The protozoan parasite, Leishmaniasis has been reported to cause chronic dacryocystitis [22].

Verruca Vulgaris and multiple viruses may cause a bloody epiphora when they involve the punctum or canaliculus.

Nocardia, *Sporotrichosis*, *Rhinosporidiosis*, *Cephalosporiosis*, *Pseudomonas*, *Candida*, *Aspergillus*, which is commonly associated with other bacteria, such as *H. influenzae*, *T. vincentii*, *Rhinosporidium seeberi*, *Sporothrix* fungus, as well as *Treponema*, and Tuberculosis, have been reported to cause dacryocystitis.

Dacryoliths are typically yellow or white, "sulfur granules" and are frequently secondary to *Actinomyces* organisms, but may occasionally be seen in infections secondary to *Nocardia*, *Streptomyces*, and *Staphylococcus*. The exact mechanism that causes the formation of dacryoliths is not precisely known. Structural epithelial and subepithelial changes may lead to obstruction. Pathological analysis demonstrate the dacryoliths to be friable, molding to the sac and duct, consisting of lamellae of cellular breakdown products and mucoproteins with or without calcium or ammonium salts. Stagnant tear flow secondary to inflammatory obstruction may precipitate dacryolith formation, and squamous metaplasia of the lacrimal sac may play a role. Eyelashes and occasionally particles of makeup have been noted in dacryolith and may act as a nidus for dacryolith formation. Hyphae or yeast have been noted, especially in *Candida* infections. An obstruction or partial obstruction allows partial tear drainage which may facilitate the accumulation of debris. In addition to the above, casts have also been reported to form from the oxidative products of long-term topical epinephrine use, and also sinonasal trauma. Dacryoliths formation is poorly understood, but usually become symptomatic if they cause a partial or complete nasolacrimal duct obstruction, and pain. Dacryoliths can occur in any part of the lacrimal system. Cigarette smoking has been observed as a statistically significant risk factor, and males seem to be more often affected than females [23].

Canaliculitis. Canaliculitis generally occurs when there is a partial or complete obstruction of the canaliculi. This leads to tear stagnation and an environment capable of supporting anaerobic bacterial growth. Canaliculitis is a frequently missed diagnosis due to the combination of its rarity and the various other ocular conditions that can present similarity. It frequently occurs in postmenopausal women and patients who have had intracanalicular plugs placed. These cases generally present as an ipsilateral epiphora, a swollen pouting punctum, mucopurulent discharge, and recurrent conjunctivitis. Canaliculitis may be caused by a variety of bacterial, viral, chlamydial, or mycotic organism. *Actinomyces israelii* is a filamentous gram-positive rod that is reported as one of the most common causes. *Actinomyces*, previously named *Streptothrix israelii*, an obligate parasite whose only host is humans, causes a canalicular obstruction and inflammation. *A. Israeli* is a gram-positive aerotolerant rod with true branching, which causes inflammation rather than a blockage of the lacrimal duct. Most cases of canaliculitis are unilateral. *Actinomyces* organisms are sensitive to penicillin, but topical antibiotic therapy is usually ineffective without mechanical expression or surgical removal of the canalicular stones. *Propionibacterium propionicus*—formerly *Arachnia propionica*—is gram-positive and has a branching, rod-shape morphology. It is facultatively anaerobic, carbon dioxide is not necessary for growth, unlike *Actinomyces. Fusobacterium*, *A. israeli*, and *Bacteroides* have also been cultured from cases of canaliculitis.

A. meyeri, principally found in the periodontal sulcus, is an uncommon pathogen, nonfilamentous, branching, may be difficult to demonstrate, and can cause canaliculitis.

Fungi generally occlude the lacrimal drainage system by the formation of a stone or cast, which can be seen with *Aspergillus fumigatus*, *A. niger*, *Candida albicans*, *C. parapsilosis*, *Pityrosporum*

orbiculare, *P. pachydermatis*, *S. somaliensis*, *Actinomyces*, and *Trichophyton rubrum*.

Inflammatory. Inflammation caused by numerous diseases and other factors may cause narrowing or obstruction of the nasolacrimal system. Kawasaki's disease, for which infectious as well as allergic causes have been proposed, is a systemic panvasculitis and perivasculitis disease. The inflammatory scarring of the mucosa of the nasolacrimal duct may result in the obstruction of the nasolacrimal duct [24]. Local nasal or sinus problems such as anterior ethmoidal inflammatory disease may cause lacrimal drainage problems, or may be part of the same disease process in that region.

Endogenous Origin. Granulomatous diseases can occasionally produce a mass within the lacrimal sac, as seen with extraorbital manifestations of Idiopathic Orbital Inflammatory Syndrome (Idiopathic Inflammatory Pseudotumor) lethal midline granuloma, and sarcoidosis. In patients with sarcoidosis, and the other inflammatory diseases, initially a successful dacryocystorhinostomy will have an increased incidence of late failure due to the progression of the inflammation in the nasal and lacrimal sac mucosa.

Wegner's granulomatosis, a vasculitis that classically involves the triad of the upper respiratory tract, the lung, and the kidneys, may cause obstruction of the nasolacrimal system. Nasolacrimal obstruction is typically associated with advance nasal disease, late in the disease process. This obstruction is frequently secondary to contiguous nasal disease, but may also be secondary to a vasculitis of the lacrimal sac mucosa. Treatment of the nasolacrimal obstruction should be deferred until the inflammation is quiescent, if possible. Other forms of vasculitis may cause similar obstruction of the nasolacrimal duct system.

Cicatricial pemphigoid, Stevens–Johnson syndrome and Nicolas-Favre lymphogranulomatosis may cause nasolacrimal obstruction with advanced disease.

Sinus histiocytosis, a benign disease of unknown etiology, which may be related to an allergy or an immunologic abnormality of histiocytes, Kawasaki's disease (mucocutaneous lymph node syndrome), thyroid disease, and Sjogern's syndrome may cause nasolacrimal obstruction.

Punctual stenosis may occasionally occur spontaneously or secondary to inflammatory diseases. The punctum may become stenotic with cicatricial diseases affecting the eyelid margin. Chronic punctal eversion may also result in stenosis of the puncta. Obstruction of the proximal sac or common canaliculus has been reported with epidermodysplasia verruciformis, ichthyosis, scleroderma, and the sclerodermoid variant of porphyria cutanea tarda. Lower lid ectropion, which often has an inflammatory or cicatricial component, which may be associated systemic diseases, has been reported occasionally to be associated with dacryostenosis [25].

Lichen planus, an immune-mediated skin and mucosal disease similar to pemphigoid, may cause lacrimal stenosis and obstruction. There is a cell-mediated reaction at the level of the epithelial basement membrane. This may also cause a cicatrizing conjunctivitis with shortening of the fornices, symblepharon formation, and a keratitis.

Exogenous Factors. Ocular and periocular disorders, such as atopic disease, sinus and nasal inflammations, exudative rhinitis, and allergies, may develop nasolacrimal stenosis and obstruction.

Ocular rosacea is an inflammatory condition of the facial skin. Ocular changes are present in more than 50 % of patients and include Meibomian gland dysfunction, telangiectasia and erythema of the eyelid margins, conjunctivitis, blepharitis, the formation of hordeolum and chalazia, keratitis, iritis, and episcleritis. Swollen and slit-like punctal openings are noted in patients with allergy, rosacea, and inflammatory Meibomian gland dysfunction. Conjunctivochalasis secondary to inflammatory diseases can lead to a pseudoblockage of the puncta from the overhanging conjunctiva.

Allergic conjunctivitis in patients who chronically rub their eyes can cause an intermittent allergic obstruction at the level of the puncta, canaliculus or lacrimal sac, which may progress to a permanent occlusion.

When removing the silicone tube, it is important to remove all remnants of silicone tubing from the lacrimal system to prevent secondary obstruction due to inflammatory masses, since the mucosal surfaces are prone for the development of granulation tissue, pyogenic granuloma and true granulomas and nongranulomatous reactions to the silicone tube may occasionally occur.

Tumors (*Neoplastic*). Lacrimal sac and nasolacrimal duct malignancies are rare. Early symptoms are often nonspecific and can easily be mistaken for the benign and more common conditions. The insidious nature of lacrimal sac tumors, may present as dacryostenosis or dacryocystitis. The mass is usually above the medial canthal tendon. The position of the medial canthal tendon does not frequently allow distention of the sac by fluid, or distention from dacryocystitis superior to the tendon. A tumor within the sac can create a mass effect above the tendon that cannot be reduced on palpation or compression. Therefore any distention of the lacrimal sac superior to the medial canthal tendon should be considered to be a tumor until proven otherwise. The dacryocystitis symptoms produced may differ from other causes of dacryocystitis, in that the irrigation fluid may pass into the nose, blood may reflux from the punctum, telangiectasia, and regional lymphadenopathy. With many malignant and nonmalignant lacrimal tract tumors, the lacrimal system will frequently remain open and patent to irrigation in the early course of the tumors, but especially with carcinomas, complete obstructions will gradually occur. This insidious slow growth and obstructive symptoms often leads to the wrong diagnosis of chronic dacryocystitis, and the correct diagnosis is delayed until late in the course of the disease. Malignant tumors of the lacrimal sac have a mortality of 37 %, with lymphatic metastasis noted in 27 % and hematogenous metastasis in 9.1 % [26].

Intermittent epiphora, sanguineous discharge, or an irreducible mass should always lead one to suspect a lacrimal sac tumor. A high index of suspicion and a detail history and examination are important for the early diagnosis and treatment of these potentially lethal tumors. Hemolacria, bloody tears, is not only associated with lacrimal sac tumors, but can also be secondary to conjunctival telangiectasias and hemangiomas, infections, nasal and paranasal sinus tumors, Henoch-Schönlein purpura, during menstrual periods, and retrograde epistaxis [27].

Approximately 45 % of lacrimal sac tumors are benign and 55 % are malignant. Malignant epithelial tumors tend to spread along the epithelium proximally toward the eyelids and distally to the nasal cavity. There have been cases reported in which the initial symptoms of epiphora, or dacryocystitis were found at surgery to be secondary to tumors. Squamous cell papillomas and carcinomas are the most common. Pyogenic granulomas are composed of well-vascularized friable tissue, containing an infiltration of lymphocytes, plasma cells, and a few eosinophils, may often involve the lacrimal sac. Many papillomas initially grow in an inverted pattern into the lacrimal sac wall, and therefore are often incompletely excised, with recurrence, and malignant degeneration that can occur. Lipoid proteinosis, Urbach-Wiethe or hyalinosis cutis et mucosae syndrome may be associated with nasolacrimal duct obstruction.

Primary tumors of the nasolacrimal duct system are uncommon, but can arise from within the puncta, canaliculi, lacrimal sac, nasolacrimal duct, or about its entrance into the nasal cavity, at the valve of Hasner. The epithelial tumors account for 75 % of the lacrimal sac tumors, and the nonepithelial tumors for 25 %, which include mesenchymal tumors, melanoma, malignant lymphomas, and leukemia, particularly in older patients with chronic lymphocytic leukemia. The mucosa of the nasolacrimal duct system serves as an adenoid layer, mucosal-associated lymphoid tissue, in which malignant lymphoid infiltrates of hematologic neoplasms can develop. This may be a primary or metastatic lesion of a systemic lymphoma or leukemia. Tearing is a common manifestation of these lymphoproliferative diseases and may often precede the development of a firm medial canthal mass, acute or chronic dacryostitis. Because of the amount of lymphoid tissue that normally surrounds the highly vascular nasolacrimal system, leukemic or lymphomatous tumors are not unexpected. Secondary tumors and metastatic lesions can infiltrate or compress

the nasolacrimal system resulting in symptoms of dacryostenosis and dacryocystitis that are much more common than primary tumors. Cutaneous T-cell lymphoma, mycosis fungoides, is an uncommon cause of dacryocystitis, since it has a propensity for epidermal involvement. Since these tumors are an unusual cause of epiphora, but should be suspected in any patient with a history of lymphoproliferative disease, biopsy of the lacrimal sac or duct should be performed to obtain a definitive diagnosis. Leukemic or lymphomatous tumors typically respond to radiotherapy and/or chemotherapy with alleviation of symptoms and control of the disease process. The secondary tumors include adenoid cystic carcinoma, basal cell carcinoma, capillary hemangioma, esthesioneuroblastoma, fibrous dysplasia, fibrosarcoma, intraosseous cavernous hemangioma, leukemia, lymphoma, lymphomatous diseases, mucoepidermoid carcinoma, osteomas, conjunctival papillomas, inverted papillomas, sebaceous gland carcinoma, squamous cell carcinoma, and rhabdomyosarcoma.

The most common primary tumors of the nasolacrimal system of epithelial origin are papillomas and squamous cell carcinomas. Less frequently are adenoid cystic carcinoma, angiofibroma, angiosarcoma, cavernous hemangioma, transitional cell carcinoma, dermoid cyst, fibroma, fibrous histiocytoma, hemangioendothelioma, hemangiopericytoma, lacrimal sac cyst, lymphoma, melanoma, mucoepidermoid carcinoma, neurofibroma, neurilemmoma, oncocytic adenoma, oncocytic adenocarcinoma, pleomorphic adenoma, dermatofibrosarcoma protuberans, neurilemmoma, and adenocanthoma more commonly involves the lacrimal sac. Schwannoma, fibrous histiocytoma, leukemia, and granulocytic sarcoma may infiltrate the lacrimal sac. Human papilloma virus infection is known to be causal in the development of epithelial benign and malignant neoplasms of the nasolacrimal duct system [28].

The most common neoplasms of the lacrimal sac are epithelial tumors. The most common benign epithelial tumor is a papilloma. Papillomas exhibit epithelial papillomatosis and acanthosis, and an inflammatory papilloma exhibits granulomatous tissue. Inverted papillomas can arise de novo in the lacrimal sac or more commonly arise from an extension from the lateral aspect of the nasal cavity or maxillary sinus. The lesion is not malignant but has a high recurrence rate. Metaplastic transformation to squamous cell carcinoma occurs in 10–15 % of cases, and therefore should be treated as a malignant lesion. The other forms of lacrimal sac epithelial carcinomas are less common. These include adenocarcinoma and epidermoid carcinoma. Mucoepidermoid carcinoma is a very aggressive cancer but rare.

The surrounding vascular plexus which is in a system of collagen bundles, elastic, and reticular fibers arranged in a helical pattern and the mucosa of the nasolacrimal duct system may be an area where leukemic or lymphomatous tumors may form primary or metastatically from hematologic spread due to its' mucosal-associated lymphoid tissue and higher blood flow, and more frequently occurs in the middle-aged or elderly. Epiphora will often be the first complaint, before a mass develops or dacryocystitis occurs, and the system may remain patent to probing and irrigation. These lesions usually respond to local irradiation, stenting of the nasolacrimal duct system and/or chemotherapy.

Lymphoproliferative diseases may involve the nasolacrimal system leading to epiphora, acute or chronic dacryocystitis. They are the second most common type of tumor causing nasolacrimal obstruction. Lymphomas are more frequent than benign lymphoproliferative lesions. Lymphosarcomas, reticulum cell carcinomas, and Hodgkin's have been reported to occur in the lacrimal sac.

The most frequent secondary tumors are those that arise from eyelid lesions, particularly basal cell carcinoma, then squamous cell carcinoma, and less frequently sebaceous cell carcinoma, which can involve the medical canthal region, and the nasolacrimal duct system or cause pressure and compression, and the resultant dacryostenosis and dacryocystitis. The most frequent maxillary sinus lesion is squamous cell carcinoma. The most common lesions arising from the nasopharynx are lymphomatous and squamous cell carcinomas. Metastatic disease as a cause of

dacryostenosis and/or dacryocystitis is very rare; lymphoma is the most common, but cases secondary to prostate carcinoma, breast carcinoma, and malignant melanoma have been reported [29].

Both benign and malignant tumors of mesenchymal elements, capillary and cavernous hemangiomas, hemangiopericytomas, dermoid cysts, have been reported to involve or compress the lacrimal sac. Melanomas, neurilemmoma, plexiform neuroma, and osteoma can involve the lacrimal sac both intrinsically and extrinsically. Fibromas, Kaposi's sarcoma and other sarcomas can rarely involve the lacrimal sac.

A hybrid of vascular leiomyoma and cavernous hemangioma with low neoplastic potential have been reported to involve the lacrimal drainage apparatus, the wall of the lacrimal sac and the nasolacrimal duct, which on radiologic imagining demonstrated enlargement of the bony canal [30].

Sinus tumors invade the orbit and nasolacrimal duct system and can be benign or malignant. The benign lesions include inverted papillomas, osteomas, juvenile angiofibroma, and neuroectodermal tumors. Inverted papilloma is the second most common lesion that invades the orbit after squamous cell carcinoma. Inverted papillomas can arise from the lateral nasal wall or the mucosa of the ethmoidal sinus. Mucocele of the paranasal sinuses can invade the orbit and cause nasolacrimal obstruction. Squamous cell carcinoma, adenocarcinoma, adenoid cystic carcinoma, esthesioneuroblastoma, lymphoma, and melanoma can occur in the paranasal sinus and rare tumors of the odontogenic tumors, which includes ameblastoma, and ameloblastic fibrosarcoma, as well as fibrosarcoma, chondrosarcoma, sinus glioblastomas multiforme, and mucoepidermoid carcinoma and may cause dacryostenosis. The most frequent sinus tumor is squamous cell carcinoma of the maxillary sinus, then lymphomas, adenocarcinoma, adenoid cystic carcinoma, transitional cell carcinoma, olfactory neuroblastoma, osteoblastoma, and malignant histiocytosis. A case of an anterior ethmoidal nerve neurilemmoma encroached on the nasolacrimal duct causing dacryocystitis has been reported [31].

When neoplasms are excised in the medial canthal area, complete resection must be performed with frozen borders analysis or Moh's technique, including any portion of the nasolacrimal system that is involved. The canaliculi may be marsupialized if not involved by the tumor, but a DCR or CDCR should be delayed for 5 or more years to ensure that there are no recurrences, to decrease the morbidity and mortality.

The treatment of these nasolacrimal duct tumors requires the knowledge and careful initial management to ensure adequate local and systemic control of the disease process. If atypical mucosa is encountered during a dacryocystorhinostomy, it should be biopsied and small papillomas or pedunculated tumors excised and sent for frozen sections before proceeding with the procedure and performing the osteotomy into the nasal cavity, to help prevent the tumor spread into the adjacent sinuses and nasal cavity, causing significant morbidity. If the froze section determines the lesion to be an infiltrative tumor, the surgery should be aborted, further imaging studies obtained, and then the management should be based on the histopathology and extent of the disease process. Lymphomas will require systemic staging and treatment. Noninvasive carcinoma and extensive papillomas require complete excision of the system, and invasive diseases require a wide en bloc excision, radiation therapy and/or chemotherapy, since these are potentially life-threatening. Due to the anatomy of the nasolacrimal duct and lacrimal sac, the proximity to the orbit, maxillary sinus, ethmoid sinus, nasal cavity, and CNS, a multidisciplinary surgical approach is recommended. These cases will require long-term and frequent follow-up in order to detect any recurrences early. This demonstrates that it is always important to consider the possibility of a neoplasm when evaluating and treating patients with dacryostenosis and dacryocystitis, especially in a middle-age man with unilateral epiphora of uncertain etiology. The gradual onset of symptoms and the rarity of these neoplasms may cause a delay or misdiagnosis and a poorer prognosis for these patients. It is therefore important that there is a high index of suspicion to yield an early diagnosis and prompt appropriate therapy.

Traumatic. Thermal or chemical burns may cause inflammation, dacryostenosis, and obstruction secondary to exposure to fire, chemicals, electrical, scalding agents, and radiation.

Blunt trauma or lacerations usually damage the canaliculus, the lacrimal sac, or the nasolacrimal duct. The dense fibrous tissue of the tarsus is much stronger than the medial canalicular portion of the eyelid; therefore any tractional force along the eyelid margin can result in avulsion of the medial eyelid with canalicular involvement. If there is any laceration of the eyelid medial to the punctum, there is a laceration of the canaliculi, unless proven otherwise. All canalicular lacerations should be repaired within 1 day of the injury, to prevent scarring and epithelialization of the wound.

Midfacial trauma and the resultant facial fractures frequently involve the bone about the lacrimal sac fossa, and/or nasolacrimal ducts, leading to obstruction of the nasolacrimal system. Fractures involving the distal portions of the nasolacrimal duct include the midface fractures of nasoorbital, LeFort II, and LeFort III factures. It is always important to consider and evaluate for involvement of the nasolacrimal duct with these types of fractures rather than waiting for the patient to present with epiphora and/or dacryocystitis. Even if lacrimal irrigation is easy and disappearance of fluorescein dye normal, only lacrimal duct probing can identify and define the extent of injury in these cases, since the fluid may pass into the nose through boney and membranous defects caused by the trauma and fractures. Detachment of the medial canthal tendon may cause compression of the lacrimal sac and may compromise the lacrimal pump function. Direct repair of these injuries is frequently not possible due to involvement of the bony nasolacrimal duct, but stent placement will help to promote patency. Prophylactic intubation with silicone tubing should be considered to prevent this occlusion when indicated. Bony fractures may also initiate an inflammatory and cicatrizing reaction that may result in nasolacrimal duct obstructions shortly after or years after the injury.

The surgical repair of these midfacial fractures may also damage and cause obstruction of the nasolacrimal system such as when transnasal wiring is performed incorrectly or with the improper placement of plates and/or screws that are employed in the repair of the fractures.

Iatrogenic Obstruction

Dacryostenosis and obstruction may result from many procedures, such as repeated and traumatic aggressive probing of the canalicular system. Poor technique in the probing of the nasolacrimal ducts may cause the creation of a false passage and subsequent scarring of the lacrimal drainage system.

The exact risk and incidences of complications of probing have not been fully evaluated and reported. Probing, if not performed correctly, may result in damage to the lacrimal epithelium, leading to stenosis and obstruction, and may prevent the success of later treatment. There has been reported a 44 % incidence of canalicular stenosis after failed probing. Bleeding from the punctum, which may be a sign of damage of the lacrimal epithelium, has been reported in 20 % of 60 probings causing an iatrogenic stenosis [32, 33].

The pigtail probe has frequently been reported to cause iatrogenic damage to the nasolacrimal duct system, and many consider it to be a potentially harmful device. The original pigtail probe had a sharp crochet hook on the tip, which was a destructive feature, especially when reversing the course of the instrument. The present probes have a round tipped, eyed probe, but still can cause iatrogenic damage to the functioning canaliculus. There have been reported cases of treatment of a single canalicular laceration, or congenital agenesis of only one puncta/canaliculus with the pigtail probe that resulted in obstruction of both canaliculi, which will then commit the patient to a conjunctivodacryocystorhinostomy.

Cheese-wiring of silicone intubation tubes through the puncta, as well as migrating nasally with complete healing of the eroded puncta and canaliculus can occur. The erosion of the punctocanaliculi may also be due to chronic irritation by the tubes, or tubes that were placed under tension. The tubes may become colonized with bacteria, including atypical *Mycobacterium*.

Punctal occlusion, which is frequently performed for the treatment of dry eye syndrome, keratoconjunctivitis sicca, may in a few patients cause subsequently epiphora, and less frequently, dacryocystitis. Punctal plugs include the absorbable plugs, collagen, gelatin, catgut, and hydroxypropyl cellulose, and the nonabsorbable plugs, silicone, polymethylmethacrylate, polyethylene, and *N*-butyl cyanoacrylate plugs. Partial or complete dacryostenosis, pyogenic granulomas, intracanalicular migration, canaliculitis, and dacryocystitis have been reported after the placement of permanent punctal plugs.

Collared punctal plugs are designed to be removable, but rarely there have been cases of these plugs fracturing during removal, with migration of the remainder of the plug into the lacrimal system. The intracanalicular plugs have been noted to cause pyogenic granulomas, indicating that they are associated with an inflammatory process that disrupts the normal cellular functions, and can cause fibrosis and a reactive mass. They have also been hypothesized to facilitate the overgrowth of bacteria and a chronic canaliculitis that can result in canalicular obstruction, may erode through the canalicular mucosa, resulting in synechia, symptomatic lacrimal stenosis, or even the formation of fistula [34].

Intracanalicular plugs used for the treatment of dry eye syndrome, which are implanted in the horizontal canaliculus, may be difficult to remove and may be associated with significant lacrimal complications. It may be difficult to irrigate these intracanalicular plugs through the nasolacrimal system. Irrigation does not reliably flush these intracanalicular plugs from the nasolacrimal system. The collarless intracanalicular plugs, theoretically can be flushed through the nasolacrimal system, but is not recovered from the nose. Therefore successful removal cannot be objectively documented. Their retention may act as a nidus for infection, inflammation, epiphora, canaliculitis, and eventually obstruction of the nasolacrimal duct system, with dacryocystitis. Distal migration of the plugs may require complicated canalicular surgery, dacryocystorhinostomy, or conjunctivodacryocystorhinostomy.

Herrick plugs may cause irreversible chronic adverse reactions with persistent inflammation and epiphora. They may cause destruction of the normal canalicular architecture, proliferative tissue reaction, pericanalicular fibrosis, granulomatous tissue, pyogenic granuloma, giant cells reaction, canaliculitis, dacryocystitis, and lymphocytic infiltration. This reaction will cause chronic epiphora and canaliculitis.

Cautery has also been used to occlude the puncta, but is not as easily reversible as removing punctal plugs are. The smaller-sized punctal plugs were designed to facilitate their insertion, but this design increases the incidence of migration, irritation, corneal erosions, canalicular stenosis after removal of the plug, foreign body sensation, epiphora, pruritus, pyogenic granuloma, fragmentation of the plug, and the possible sequelae of canaliculitis and dacryocystitis. Forceful insertion of any of these plugs may result in the erroneous placement of the plug into the canaliculus.

Dacryostenosis may occur after a dacryocystorhinostomy due to new or persistent stenosis at the internal common punctum or to an improperly fashioned osteotomy. DCR failure may be due to retained stenting material. Migrated medial or orbital floor implants, or poorly placed or secured medial or orbital floor implants may cause an external compression or occlusion of the nasolacrimal sac and/or duct.

Transantral orbital decompression has been reported to cause obstruction of the nasolacrimal duct system, possible secondary to delayed scarring around the nasoantral window. Dacryostenosis and obstruction has been reported as a complication of nasal operations, rhinoplasty, paranasal sinus surgery, both endoscopic and conventional external procedures, and craniofacial procedures.

Nasoantral window procedures are generally placed at the most anterior–inferior portion of the maxillary sinus. If they are placed too high or too posterior, or when the maxillary sinus ostium is enlarged anteriorly, or if the nasolacrimal duct is in an anomalous position, damage to the duct may occur. The Ogura procedure of orbital decompression that removes the medial wall and floor of the orbital, through an antrostomy, may also cause damage to the lacrimal duct.

Mechanical

Mechanical compression or blockage of the nasolacrimal duct system can result from external compression or occlusion of the system from an intraluminal foreign body, hematoma, or stone. Direct occlusion or external compression may impede or block the canaliculi or nasolacrimal duct.

The most common cause of internal mechanical obstructions are dacryoliths. Some are secondary to fungal infections, but frequently the cause is indeterminate. There are cases reported where an eyelash served as a nidus for formation of the dacryoliths. Others have postulated that metabolic factors such as high calcium and phosphate levels within an obstructed lacrimal system may contribute to the formation of dacryoliths. Various medications, epinephrine, and quinacrine have been reported to contribute to the formation of casts within the nasolacrimal ducts. Dacryoliths occur more frequently in younger patients, under age 50, and in heavy smokers. These patients generally present with intermittent dacryocystitis and localized pain and tenderness.

The foreign bodies that may cause internal mechanical obstruction are generally migrated or retained medical devices, such as punctal plugs, or incompletely removed silicone tubing. Rarely, intranasal bleeding can cause a hematoma of the lacrimal sac and duct.

External factors may cause a mechanical obstruction of the puncta of the lacrimal system. Opposing superior and inferior puncta may cause a proximal obstruction, as in ptosis. Redundancy of the bulbar conjunctiva, conjunctivochalasis, may cause a mechanical obstruction, epiphora, and foreign body sensation. Excision of an ellipse of the redundant conjunctiva is often curative. Enlargement of the caruncle, megalocaruncle, may extend laterally to block the punctum or displace the puncta away from the globe and tear pool. Epidermoid and dermoid cysts usually arise superior to the medial tendon, have a fleshy-yellow color, are firm to the touch, normally arise from the bone sutures, and are adhered to the periosteum. Orbital lymphangioma and osteoma, may compress the nasolacrimal system externally.

Masses arising from the paranasal sinuses, nasal polyps, mucoceles, mucopyoceles, nasal mucosal edema, lymphoid hyperplasia of the nasal cavity, exudative rhinitis, or tumors may cause an external compression of the lacrimal sac or duct. Nasal mucosal edema and mucopurulent exudates may lead to obstruction of the nasolacrimal duct at the intranasal osteum, valve of Hasner. Allergic, viral or bacterial pharyngitis and rhinitis can produce sufficient nasal mucosal edema, lymphoid hyperplasia, and exudates to result in obstruction of the nasolacrimal duct and progression to a dacryocystitis.

Lacrimal sac cysts, dacryops, are congenital or traumatic in origin. They grow slowly, and may present as a painless epiphora or dacryocystitis.

Maxillary sinus cysts, antral mucoceles, retention cysts, pseudocysts, dentigerous cysts and keratocysts, ameloblastoma, ossifying fibroma, giant cell granuloma and cholesteatoma, ethmoid or maxillary sinusitis, may rarely lead to nasolacrimal obstruction. Due to the close anatomical location of the ethmoid and maxillary sinuses, the thin bone, lamina papyracea, and lacrimal bone, infection may cause orbital and/or lacrimal sac infections, or symptoms that mimicking dacryocystitis. The ethmoid air cells extend to the level of the lacrimal sac and infections may occur due to direct extension through the thin ethmoid or lacrimal bones, congenital bony defects, or infected thromboemboli along the valveless venous connections between the orbit and paranasal sinuses. Patients who present with clinical symptoms of acute dacryocystitis and a patent nasal lacrimal system to irrigation, the differential diagnosis of pseudodacryocystitis due to sinuses disease should be considered.

Nasal malformations, systemic syndromes or dysmorphisms that involve abnormalities of facial development, such as clefting or malposition of the orbits or midface, can be associated with maldevelopment of the nasolacrimal duct system. Patients with the Centurion Syndrome have an anterior displacement of the medial canthal tendon, a prominent nasal bridge, and displacement of the punctum away from the tear pool, resulting in epiphora.

Paget's disease and osteopetrosis have been reported as causes of acquired nasolacrimal

obstruction [29]. Sarcoid granuloma, oncocytoma, rhinoliths, inverted nasal papillomas, and nasal foreign bodies in the inferior meatus can cause a mechanical obstruction of the nasolacrimal duct system at the valve of Hasner.

Medications

Acquired dacryostenosis may result from the use of antiviral, antiglaucoma, or systemic chemotherapeutic medications. The most common cause of iatrogenic punctual or canalicular stenosis and occlusion is ophthalmic medications. Idoxuridine, vidarabine, trifluridine, acyclovir, demecarium, echothiophate, isoflurophate, adenine arabinoside, furmethide, floxuridine, fluorouracil, neostigmine, physostigmine, epinephrine, pilocarpine, cyclopentolate hydrochloride, quinacrine, dipivefrin, latanoprost and the prostaglandin analogs, dorzolamide, silver preparations, timolol, practolol, and thiotepa have been most frequently associated with dacryostenosis and occlusion.

More common topical anti-glaucoma medications associated with nasolacrimal duct obstruction are, echothiophate iodide, timolol, pilocarpine, furmethide iodide, dipivefrin, betaxolol, prostaglandin analogs and epinephrine [35].

Idoxuridine, trifluridine, and adenine arabinoside generally cause occlusion of the punctum, rather than the mid-zone of the canaliculi as seen from viral infections. The punctal stenosis that occurs from antiviral toxicity will frequently reverse on discontinuation of the medication early on. The antiglaucoma medication may cause a cicatricial conjunctivitis that may be similar to, and indistinguishable from cicatricial pemphigoid.

Chronic topical epinephrine may affect the vascular plexus of the nasolacrimal duct system. This specialized vascular system permits opening and closing of the lumen of the lacrimal passage, and is regulated by the bulging and subsiding of the vascular system, which can regulate tear outflow [7]. Frequent topical cyclopentolate hydrochloride has been reported to cause dacryostenosis.

Medicamentosa can develop not only from the medication but also may be secondary to the preservatives in topical ophthalmic medications. Patients taking topical antiglaucoma medications demonstrated an increase incidence of developing lacrimal drainage system obstruction. This may be associated with the medications themselves, the preservative, and/or the duration of topical treatment. Conjunctival metaplasia, decrease in goblet cells, increase in macrophages, and lymphocytes in the epithelium, and an increase in fibroblasts, macrophages, mast cells, and lymphocytes in the substantia propria have been noted on histologic examination. Dacryostenosis may also occur as part of a cicatrizing process, a drug-induced pemphigoid condition, which may occur after the long-term use of antiglaucoma medications. The inflammation causes a decrease in the clearance of the medication and preservative, and their continued use will result in more inflammation and stenosis, and therefore a longer clearance time resulting in a higher concentration and longer transit time, leading to a vicious cycle.

Topical Mitomycin C is used for the treatment of corneal-conjunctival intraepithelial neoplasia, primary acquired melanosis with atypia, conjunctival malignant melanoma, and pagetoid sebaceous carcinoma, and cause epiphora secondary to punctal–canalicular stenosis in up to 14–43 % of patients [36, 37].

The systemic use of some antineoplastic agents, such as 5-flurourycil and docetaxel has been reported to cause punctal and canalicular stenosis and occlusion with epiphora [38].

Systemic 5-fluorouracil, a pyrimidine analog that blocks the enzyme thymidylate synthetase and docetaxel, can cause obstruction of the nasolacrimal system, punctal and canalicular stenosis and obstruction. Tissues that have rapidly proliferating cellular elements are most affected. The rapidly proliferating cellular elements such as the mucous membranes, gastrointestinal tract, bone marrow, and skin are also affected and this leads to the possibility of these side effects. 5-Fluorouracil may also cause lacrimation, conjunctivitis, blepharitis, keratitis, blurred vision, pain, ankyloblepharon, and cicatrical ectropion. It may cause an inflammatory response in mucosal membranes, as evident

by conjunctivitis, as well as oral and gastrointestinal inflammation. The inflammation and fibrosis of the lacrimal drainage system causes extensive fibrous adhesions that obstruct the canaliculi and lacrimal sac [39]. These drugs and similar ones cause damage to the mucosal lining, which occasionally may cause permanent damage to the lacrimal system. The ocular abnormalities are most likely secondary to the inhibition of cellular proliferation in the conjunctiva, cornea, and the eyelid, that generally occurs within days to weeks of the initiation of treatment. These complications will usually resolve after the treatment is completed. 5-FU is secreted in the tears after intravenous administration and therefore affects the ocular surface, and the constant bathing of the puncta and canalicular system causes a chronic inflammation that eventually causes stricture and stenosis. The rapidly proliferating cells of the puncta and canalicular epithelial cells are damaged, causing a chronic inflammation of the substantia propia leading to a stenosis.

Docetaxel is an effective chemotherapeutic agent for advanced breast cancer and other common malignancies in the antineoplastic class of taxanes. Epiphora and permanent canalicular stenosis can occur in up to 50 % of patients receiving weekly docetaxel and to a lesser percent in patients receiving docetaxel every 3 weeks. Chronic inflammation and extensive fibrotic changes have been demonstrated in the stroma of the lacrimal sac and the nasal mucosa. In advanced cases this occlusion is not reversible. The mechanism of canalicular stenosis may be secondary to secretion of docetaxel in the tear film and fibrosis of the canaliculi from direct contact, or the mucous membrane lining of the puncta and canaliculi develop a fibrosis secondary to the systemic effects of the drug similar to the widespread edema and fibrosis seen elsewhere in the body. Patients receiving docetaxel should be screened for epiphora and canalicular stenosis, and in mild cases, topical steroids, artificial tears, and probing in the office may decrease mucosal inflammation and dilute the concentration of the drug in the tears decreasing the histologic changes in the mucosal lining of the lacrimal system. The treatment of moderate or severe canalicular stenosis may require silicone intubation to prevent the need for a conjunctivodacryocystorhinostomy [38]. With the newer regimens that use lower doses of the drug for shorter periods than in the past, lacrimal stenosis and occlusion should be less frequent. These patients should receive frequent monitoring and examinations, including probing and irrigation in the office to detect early involvement, and if present, treat these patients with topical steroids to decrease mucosal inflammation, as well as the use of frequent artificial tears after each infusion of Docetaxel to dilute the concentration of the drug in the tear film. Moderate or progressive dacryostenosis requires silicon intubation of the lacrimal drainage system to hopefully prevent the development of irreversible damage and the need for a DCR or CDCD.

Radiation

External radiation in the treatment of neoplasia can cause inflammation of the lacrimal drainage system, stenosis, and occlusion. The reported dose in the literature varied greatly, and it has occurred in a cases receiving as little as 1,800 rad (cGy). Other reports state that the lacrimal passages are relatively immune to radiation therapy until significantly higher doses are delivered. It is hypothesized that the epiphora probably results from a combination of anatomic lacrimal obstruction, conjunctival epithelial alterations, damage to conjunctival epithelial cells, and damage to conjunctival goblet cells and glands. It is recommended that intubation should be considered in patients undergoing radiation for medical canthal tumors. Topical corticosteroid may also be useful in preventing punctal stenosis [40].

Cobalt and iridium brachytherapy have been reported to cause severe dermatitis and lacrimal drainage stenosis. Lovato et al. in a prospective study reported that 11 out of 12 patients that had prophylactic nasolacrimal intubation with silicone tubing maintained lacrimal duct patency, whereas 10 out of 12 patients who did not receive prophylactic silicone intubation developed punctal occlusion after helium ion therapy for uveal melanoma.

Radioiodine ablation, I^{131} therapy for thyroid carcinoma at cumulative activities of 150 mCi of I^{131} or higher, may produce clinically significant nasolacrimal drainage system obstructions in 4.6 % of patients. Radioiodine has been found in extrathyroidal tissue, including the salivary and lacrimal glands, and in tear secretions, and known to cause conjunctivitis and dry eye syndrome. The areas of obstruction involved the nasolacrimal duct, common canaliculus, and rarely, the superior and inferior canaliculi, causing a foreign-body reaction and fibrosis. The mechanism of the dacryostenosis may be a contribution of local toxicity from direct radiation injury from the passive flow of radioactive tears and/or active uptake and concentration of I^{131} in the nasolacrimal drainage tissues from the blood by the sodium/iodide symporter, the same iodine uptake mechanism used by the thyroid gland. Radioiodine has been recovered from the lacrimal gland and in the tears of patients receiving radioactive iodine therapy. The most common side effects are xerophthalmia and chronic and recurrent conjunctivitis. Sodium iodide symporter, the ion transporter that has the ability to take up iodine, is present in the pseudostratified columnar epithelial cells of the lacrimal sac and nasolacrimal ducts. The sodium/iodide symporter is a membrane glycoprotein that mediates active iodide uptake in the thyroid gland, and in the periocular area, is located in the ciliary body, the nasolacrimal duct, and lacrimal gland. The areas of obstruction involve the nasolacrimal duct, common canaliculus, and rarely, the superior and inferior canaliculi. The mechanism of the dacryostenosis may be a contribution of local toxicity from direct radiation injury from the passive flow of radioactive tears and/or active uptake and concentration of I^{131} in the nasolacrimal drainage tissues from the blood by the sodium/iodide symporter. The inflammatory reaction is probably induced by radioiodine, causing a swelling and fibrosis and finally an obstruction or occlusion of the lumen. This increased incidence of dacryostenosis and obstruction is likely to be dose-related. Symptomatic patients should receive early evaluation and treatment with possible silicone tube placement, since once complete obstruction has developed it has proven to be difficult to manage [41].

Hopefully these classification systems will be useful in the evaluation and treatment of nasolacrimal disorders. The location of the stenosis or occlusion and the etiologic classification system presented above provide a useful mechanism in the formulation of a differential diagnosis and help to develop the appropriate evaluation and treatment plan for each individual patient. These divisions may not be completely isolated, there will be cases that overlap, and there are some diseases, medications, and/or clinical situations that have not been included in this review.

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Tear Pump Function and Dysfunction

6

Michael Mercandetti, Adam J. Cohen, and Brian Brazzo

On the human eye, the multicomponent tear film is assisted in its dispersion across the surface of the eye including the cornea and conjunctiva by the blinking of the lids. This same blinking action is the essential physiological activity that powers what is referred to as the lacrimal or tear pump. This mechanical process facilitates the egress of the tears from the surface of the eye via the lacrimal excretory system. While evaporation accounts for a significant amount of tear film evaporation, dysfunction of the tear pump results in epiphora or tearing.

Historically, Jones described his theory of the lacrimal pump function [1]. In his anatomic studies, the medial canthal tendon consistent both anterior and posterior limbs. The anterior limb which is broad and consists of fibrous tissue attaches to the frontal process of the maxilla and the lacrimal bone. It is also the origin of the pretarsal orbicularis muscle. Within this area are connected fibers from the preseptal orbicularis as well as preseptal fibers that connect to the lacrimal sac.

Jones focused on the action of the muscle and tendons and their effects on the lacrimal sac. The tears journey began with the closing of the lids via blinking, pushing the tears towards the puncta in the upper and lower lids. This action also pressed on the canaliculi. When the lid opened, the canaliculi were decompressed, creating a negative pressure allowing the tears to be swept into the puncta and canaliculi via this negative pressure. Repeating the closure part of the blink forced the tears into the lacrimal sac. Simultaneously, the deep head of the preseptal orbicularis muscle pulled on the lacrimal sac creating further negative pressure, assisting in the egress of the tears [1–4]. Scintillography studies supported this pump function [5].

Additional theories have been developed through anatomic and physiologic studies to further explain the physiologic aspects of tear pump function.

The orientation of the medial aspects of the lower and upper eyelids allows for contact to occur between the puncta in the processes of the lids closing during a blink. With this occlusion in addition to constriction of the muscle around the ampulla, the remainder of the blink contracts the canaliculi and pulls on the lacrimal sac. The tears that are already within the canaliculus of each lid

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at the beginning of the blink are forced into the sac and then the duct, assisted by gravity as well as by the elasticity of the tissues. Once the blink relaxes and the eyelids open, the pretarsal and preseptal muscular contraction having relaxed, allows the canaliculi to regain their decompressed forms elongating them. However the puncta are still occluded and this creates a partial vacuum. With the continuation of the opening of the eye lids the puncta open allowing the tears within the tear lake to be drawn into the canaliculi and the process repeats itself [6].

Pressure differential a also are important in the outflow of tears and seem to be most important in the canaliculus [7]. Over 50 % of the resistance to outflow occurs in the canaliculus in normal tear systems [8].

The lacrimal pump mechanism is not felt to be a major mechanism for the removal of tears as evaporation is regarded as more important. To some degree the integrity of the lacrimal pump mechanism was considered not essential; for outflow of tears can still occur in the presence of dacryocystorhinostomies [9]. However, manometric studies indicate that with both external and endonasal dacryocystorhinostomies, negative pressure is detected during the blinking process and is greater in the patients treated with endonasal surgery. This was in contrast to patients who had epiphora or failed dacryocystorhinostomies where positive pressures were recorded [10]. Additionally in MRI studies in patients after endonasal and external dacryocystorhinostomies the lacrimal pump function was still present and performed better in the endonasal patients [11]. Other authors have postulated a vital role of the lacrimal sac in the lacrimal pump by virtue of the fibrils helical orientation and the medial attachment that is "wrung out" by the orbicularis contraction [12]. Movement of the lacrimal sac has been documented endoscopically during blinking [13].

Gravity's effect on the tear pump mechanism may be variable. Patients can drain tears even with the head upside down [9]. However, lacrimal drainage increased when gravity was factored in independent of blink rate [14]. The pumping function was considered important to progress the tears into the canaliculi, but gravity was the factor for drainage through the duct [15].

Frieberg, who had measured pressure gradients from the canaliculus to the sac, found that if a canaliculotomy is done, the pressure gradient is lost [16]. Both canaliculi partake in the lacrimal pump function [17, 18], but the loss of one canaliculus does not significantly affect tear outflow [19]. It had been proposed that both puncta should be occluded to assist dry eye patient by preventing tear outflow [20]. Even in patients with Jones tubes the blink contributes to the egress of tears, as those with lid laxity do not drain as well [21]. Microvilli within the lacrimal excretory system as well as the valves within the system also contribute to the pump function [22, 23].

Tear pump dysfunction can have a singular cause or be multifactorial.

Malposition of the lids comprises a significant portion of tear pump dysfunction within this consortium are:

Entropion (Figs. 6.1 and 6.2)
Ectropion (Fig. 6.3)
Lagophthalmos (Fig. 6.4)
Lid retraction (Figs. 6.5–6.9)
Floppy eyelid syndrome
Traumatic injury
Palsy such as Bell's palsy (Figs. 6.9 and 6.10)
Imbrication (Figs. 6.11 and 6.12)
Botox injections with resultant orbicularis weakness.

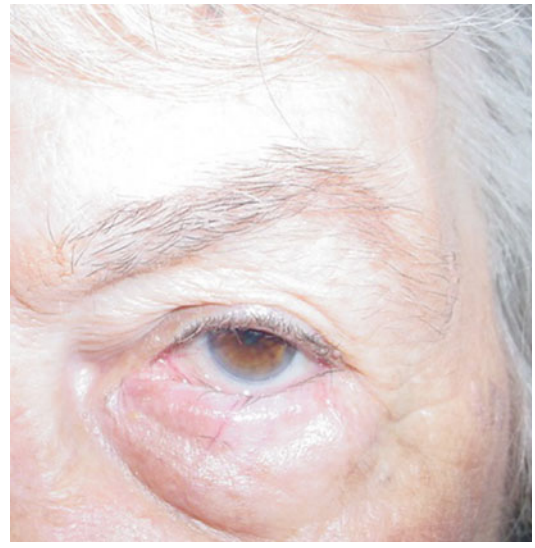

Fig. 6.1 Entropion with trichiasis

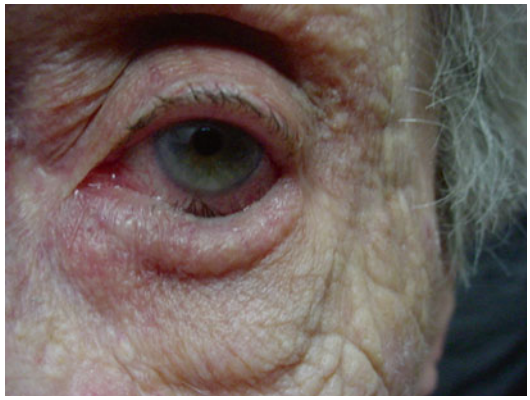

Fig. 6.2 Entropion with trichiasis

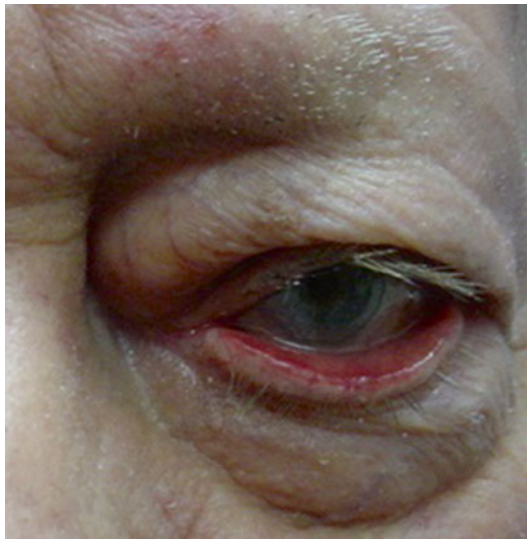

Fig. 6.3 Ectropion with punctal eversion

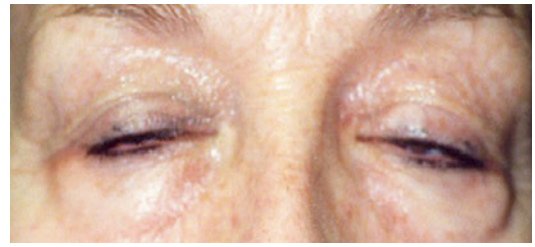

Fig. 6.4 Lagophthalmos

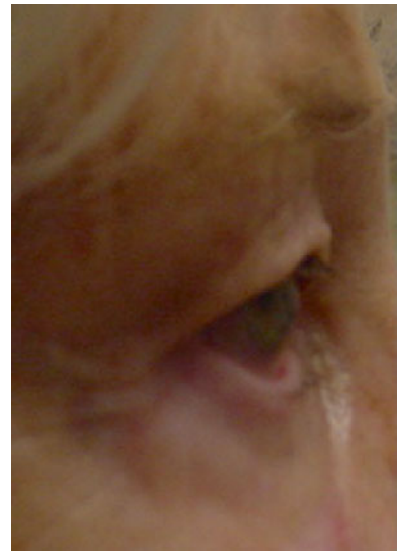

Fig. 6.5 Retraction side view

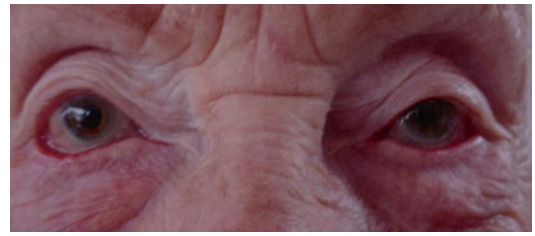

Fig. 6.6 Retraction and ectropion

Entropion which denotes in turning of the lid margin toward the eye can occur with or without trichiasis. Trichiasis would be where the lashes are rubbing on the eye. Different forms of entropion include senile, mechanical, spastic, and cicatricial.

Ectropion which is the converse of entropion where the lid margin is turned away from the eye also adversely affects to pump function. Different subtypes include senile, mechanical, spastic, and cicatricial.

Lagophthalmos which is due to an incomplete closure of the eyelids has paralytic, mechanical, and cicatricial forms. Examples of paralytic lagophthalmos would be from a Bell's palsy or facial palsy and even iatrogenically from Botox injections.

Lid retraction is often referred to as a pulling down of the lower lid or up of the upper lid. Often times with facial aging changes the lid can sag down and increase the scleral show of the eye.

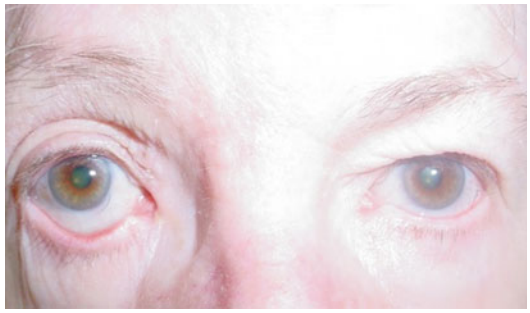

Fig. 6.7 Retraction margin ectropion and punctal eversion

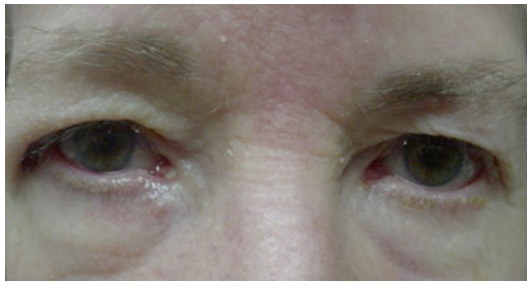

Fig. 6.8 Post repair with no grafts of same patient in Fig. 6.7

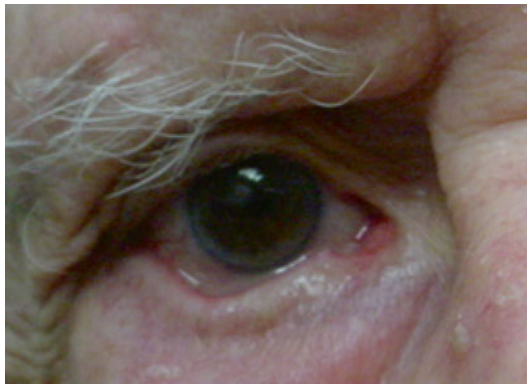

Fig. 6.9 Bells palsy

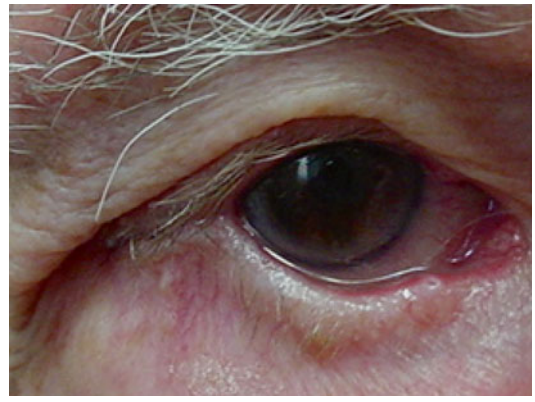

Fig. 6.10 Bells palsy post lateral tarsorrhaphy

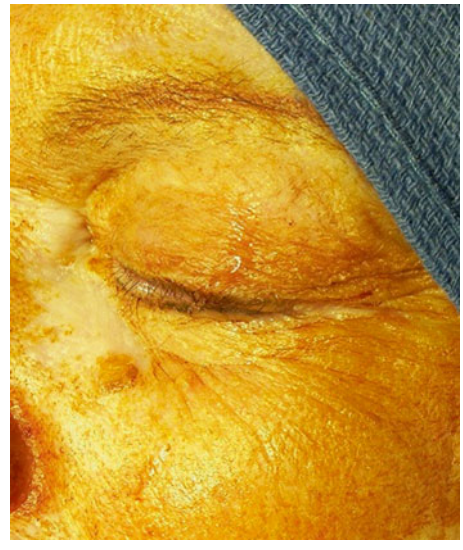

Fig. 6.11 Mild imbrication

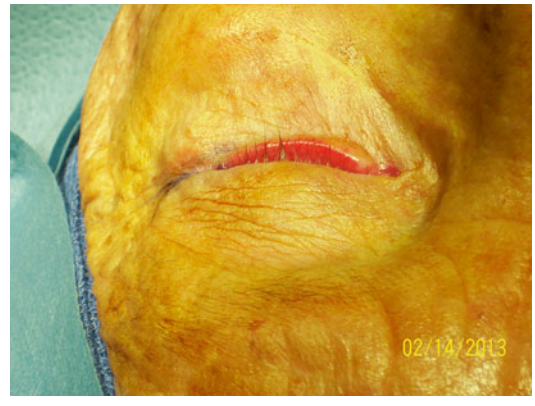

Fig. 6.12 A severe case of imbrication

This might preclude adequate tear pumping function. Additionally with canthal tendon laxity, whether lateral canthal, medial canthal, or both, canthal laxity compromises pump function.

Floppy eyelid syndrome could be considered a form of laxity associated with sleep apnea affecting the lacrimal pump function.

Trauma, including that induced by surgery, cannot only affect the tear pump function by affecting a component or multiple components of the tear drainage system but any irregularities created from the trauma in the lids itself can adversely affect this function.

All of these pathological conditions of the lids affect the blink of the lid not allowing for the proper pumping of the tears into the drainage system.

Additional Dysfunctions

The tear pump function can also be affected by position of the punctum. Most commonly punctal eversion can occur where the punctum is not facing the tear lake. This may be an isolated problem or part of an malposition of the lid. This more commonly affects the lower lid punctum. The upper lid can also slip behind the lower lid and push it out. This condition has been referred to as imbrication.

The punctum can also be affected stenosis by thereby decreasing the openness of the punctum, diminishing the ability of the tears to enter into the drainage system. Similarly canalicular stenosis can also preclude the flow of tears within the tear drainage system affecting the pumping function. Obstructions of the nasolacrimal sac and duct similarly have an adverse effect. These issues are covered in other chapters of this book.

Summary

Despite decades of anatomic and physiological studies our understanding of the lacrimal or tear pump while comprehensive is incomplete. One would think that at the very least the anatomic structures would be clearly known. However, more studies call into question the exact composition of structures involved in the pump function. A 2012 cadaver study in Caucasians, could find no posterior limb of the medial canthal tendon. In fact, the aforementioned limb consisted of Horner's muscle and lacrimal diaphragm [24]. There may even be a physiologic valve created by the anatomy of the medial canthus in relation to the lacrimal excretory system that actively drains tears through the excretory system [25], structurally created by Horner's muscles [26].

As our understanding of the anatomy, including ethnic variations, and the precise physiologic functions of these anatomic structures on a macroscopic and microscopic level evolve, so too will our comprehension of the tear pump mechanism.

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Clinical Evaluation and Imaging of Lacrimal Drainage Obstruction

7

Jonathan J. Dutton

The lacrimal drainage apparatus is an intricate mucous membrane-lined conduit, whose function depends on a complex interplay of anatomy and physiology [1]. Appropriate drainage of tears depends on several factors, including the volume of tear production, eyelid position, normal pump mechanisms, anatomic status of the puncta and drainage passages, gravity, and nasal air convection currents [2]. The patient with symptomatic epiphora may have a normal anatomic system overwhelmed by an oversecretion syndrome, or a drainage system that is anatomically compromised and is therefore unable to handle normal or even reduced tear production. Conversely, patients may have partial or complete blockage of the nasolacrimal system but experience no symptoms or even have symptoms of dry eye if tear production is significantly reduced. The clinical picture along the spectrum from bothersome epiphora to dry eyes thus depends on the balance between tear production on the one hand and tear drainage on the other, not on the absolute anatomy or function of either one alone.

The etiologies of lacrimal drainage dysfunction can be divided into two categories, anatomic and physiologic. Anatomic obstruction refers to a gross structural abnormality of the nasolacrimal drainage system. This can be a complete obstruction, such as punctal occlusion, canalicular blockage, or nasolacrimal duct fibrosis. The causes of partial obstruction include punctal or canalicular stenosis, inflammatory narrowing of the duct, or mechanical obstruction within the lacrimal sac from tumors or concretions. Physiologic etiologies result from failure of functional pump mechanisms despite normal anatomy. These types of dysfunction may result from anatomic deformity, such as punctal eversion or other eyelid malpositions, or from lacrimal pump inadequacy from poor orbicularis muscle tone or eyelid laxity. Determining the type of dysfunction and the exact location of any anatomic blockage with physical exam and ancillary testing is essential if appropriate therapy is to be offered.

The clinical evaluation of gross lacrimal function is usually not difficult and the diagnosis of epiphora can often times be made largely on history alone. However, determination of the etiology of epiphora may be more difficult and often requires a variety of diagnostic procedures. There is no single test that will pinpoint the anatomic site or physiologic basis for an imbalance between tear production and tear drainage. Frequently, a combination of factors may be contributory. A host of clinical tests have been described, many of which must be used together to diagnose specific disease processes correctly. In this chapter, we briefly describe the most important tests and imaging techniques and discuss the clinical significance of each.

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Clinical Diagnosis

The following diagnostic tests have been devised to evaluate the tear production and lacrimal drainage systems. These tests include some simple clinical procedures that should be a routine part of every evaluation, as well as more complex radiographic and echographic examinations that can be used in selected patients. In most cases of epiphora, several tests will be employed to determine the specific etiology and to plan appropriate therapy.

Clinical History

Clinical history is one of the most important aspects in the evaluation of the patient with symptomatic epiphora, yet it is frequently glossed over or completely overlooked. Taking an adequate history will usually narrow the possible causes and in most cases will allow the surgeon to decide which tests are appropriate. Epiphora in a child with a history of tearing since birth is almost always the result of a developmental blockage at Hasner's membrane, whereas acquired epiphora in an adult will have a very different etiology such as canalicular or lacrimal duct obstruction. It is important to elicit a history of prior facial trauma, as this should prompt evaluation of the bony nasolacrimal canal. Prior use of ophthalmic medications, certain systemic chemotherapeutic agents, or orbital irradiation should lead the clinician to suspect canalicular obstruction. Previous sinus surgery, particularly intranasal antrostomy, polypectomy, or ethmoidectomy should alert the surgeon to potential direct duct injury. History of a rapidly growing palpable medial canthal mass or bleeding from the puncta should raise the suspicion for the presence of malignancy. Intermittent epiphora can be related to early inflammation of the membranous duct or to allergic rhinitis. Recurrent episodes of dacryocystitis usually suggest lower nasolacrimal duct (NLD) obstruction, but may lead to stenosis of the proximal system as well. Taking a thorough history as part of the routine evaluation will make further investigation considerably more efficient.

External Examination

Evaluation of epiphora begins with a careful examination of the external ocular surface and eyelid structures for causes of hypersecretion or for mechanical obstruction of drainage. Conjunctival or corneal irritation, either inflammatory or mechanical, may cause hypersecretion with resultant epiphora, even in the presence of a normally functioning drainage system. Blepharitis and allergic conjunctivitis will often trigger increased lacrimation. Occlusion of the puncta or a narrow medial palpebral fissure with resulting punctal opposition and mechanical occlusion will block tear drainage. Conjunctivochalasis is seen with increasing frequency especially with advancing age, and it has been shown that contact lens wear is an additional risk factor [3, 4]. When severe, the redundant conjunctiva can cover and mechanically occlude punctal drainage [5]. Mass lesions in the medial canthal region or symblepharara may also mechanically obstruct tear drainage. Careful palpation of the lacrimal sac will reveal the presence of a sac mucocele, and pressure behind the anterior lacrimal crest may produce reflux of mucopurulent material suggestive of a dilated lacrimal sac from lower system obstruction. Examination of the nasal vestibule must be made, as hypertrophic mucosa or nasal polyps can obstruct the nasolacrimal ostium, and in children a narrow inferior meatus will often impede drainage even after successful probing. Rarely, a nasal tumor can obstruct the lacrimal duct and may extend into the nose.

Eyelid laxity with poor orbicularis muscle tone from aging or other causes may result in a functional acquired epiphora from a weakened orbicularis muscle pump mechanism [6–8]. In such cases the patient may complain of epiphora, from delayed tear drainage. However, there may be no evidence of punctal or canalicular stenosis or malposition, and the NLD can be patent to irrigation without reflux. Quantitative scintigraphy studies have shown a positive correlation between delayed drainage and eyelid or medial canthal laxity [9]. Eyelid laxity associated with malpositions such as entropion, with or without trichiasis, can produce corneal irritation and

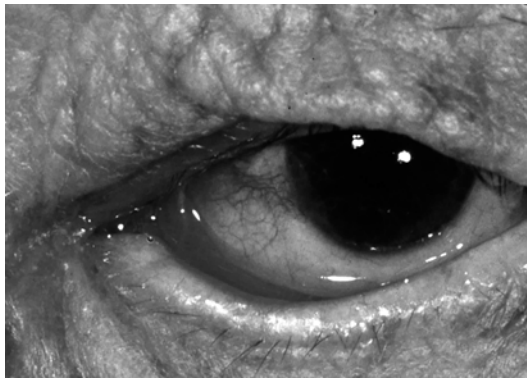

Fig. 7.1 Eyelid laxity with medial punctal ectropion and chronic epiphora

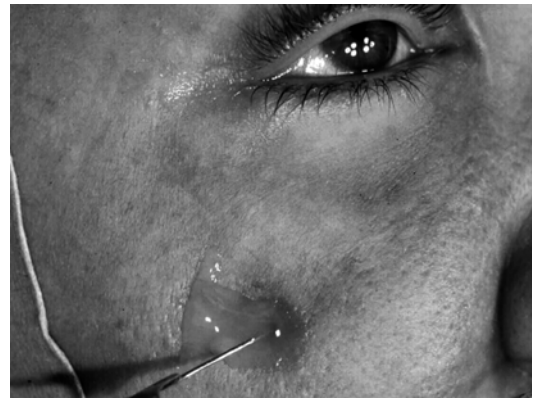

Fig. 7.2 Dacryocystitis in a child with a mucoid draining cutaneous fistula on the lower cheek

secondary reflex tearing. Ectropion from lid laxity or facial nerve palsy may lead to exposure keratopathy and reflex epiphora. Medial ectropion causes the punctum to rotate away from the tear lake, impairing tear drainage (Fig. 7.1).

Punctal stenosis is a common finding, reported in more than 50 % of normal individuals. The prevalence increases with advancing age and it is often related to chronic blepharitis [10]. Punctal and canalicular stenosis are also common complications of chemotherapy such as systemic 5-fluorouracil and docetaxel, or topical mitomycin-C [11–13]. Since punctal stenosis can be seen without accompanying eyelid laxity, any epiphora evaluation should specifically look for this condition.

Some cases of dacryocystitis may be associated with a cutaneous fistula from the lacrimal sac. There may be a history of tearing or mucoid discharge from the skin at the medial canthus, and this should elicit a careful examination for a small opening in the skin over the lacrimal sac area. Irrigation through the punctum with fluorescein will usually demonstrate the fistula as dye-stained fluid egresses. Occasionally, a fistulous tract may extend away from the medial canthus, even down onto the cheek (Fig. 7.2).

Schirmer Tests

In 1903, Schirmer described this technique for evaluation of tear production. Since that time the Schirmer tests have become an important clinical tool for the diagnosis of dry eye and hypersecretion syndromes. The Schirmer I test is used to evaluate gross tear production. It is usually performed without topical anesthetic. A strip of #41 Whatman filter paper, 50 mm long and 5 mm wide, is folded 5 mm from one end, and the small folded end is placed into the inferior conjunctival fornix at the junction of the lateral and middle thirds of the lower eyelid. The amount of wetting on the filter paper is measured at 5 min [14]. The test should be performed in subdued lighting, and both eyes must be tested simultaneously. This test measures the aqueous component of the tear film and does not distinguish between basic and reflex tear production. It gives only a very crude estimate of tear flow, since the paper itself may stimulate reflex lacrimation. It is important to blot any tears that are in the fornix prior to performing this test. If the investigator is not careful to wipe the tear lake from the conjunctiva prior to inserting the paper strips, an excessive degree of wetting will be recorded. If the tear drainage system is functioning, a significant volume of tear flow passes into the puncta without being recorded on the paper strip. The fractional volume lost is in proportion to the adequacy of the drainage system and may be significantly more than the volume recorded on the strip. Normal values for the Schirmer I test range from 10 to 30 mm of wetting at 5 min, with values over 25 mm typical of patients under age 30 and values of 10 mm or less in those over age 60. It is important to remember that any specific measurement,

say 15 mm of wetting, will have very different meanings in patients with a normal drainage system compared to those with some degree of obstruction.

If the Schirmer I test is abnormal, the test may be modified to separate the reflex component from basic secretion. A drop of topical anesthetic is instilled into the eye and the test is repeated. This test should be performed in subdued lighting, as light can stimulate reflex tearing from the lacrimal gland. Any combination of basic and reflex tearing may be found in patients with symptomatic dry eye or epiphora, and the volume of aqueous flow alone is not a complete indication of lacrimal system function.

When the Schirmer I test is below normal, the Schirmer II test will give some indication of stressed reflex capability. Topical anesthetic is used in the eye, and the nasal mucosa is stimulated mechanically with a cotton swab or chemically with ammonium chloride. The amount by which the Schirmer II test exceeds basic production represents stressed reflex secretion.

The 5-min testing interval used in the standard Schirmer test can cause discomfort to some patients and may cause hypersecretion that can produce a falsely high test result. Karampatakis et al. [15] showed that a 2-min test gave acceptable results that correlated well with the 5-min results in 94.5 % of cases, where most normal individuals show wetting equal to or greater than 10 mm.

Rose Bengal Staining

Rose Bengal is a chloride-substituted iodinated fluorescein dye that stains devitalized epithelial cells. Increased conjunctival staining is a sensitive indicator of inadequate tear function, regardless of gross aqueous tear flow determined by the Schirmer test. In such cases, essential layers such as surfactant and lipids can make the tear film inadequate to protect the cornea. In the patient with epiphora and significant staining, reflex hypersecretion and inadequacy of tear physiology should be suspected.

Tear Breakup Time

Stability of the normal tear film depends upon its basal mucin layer, which increases the hydrophilic quality of epithelial cells, allowing uniform wetting of the corneal surface. When this mucin component is reduced, the tear film will break up on the relatively more hydrophobic corneal surface. The tear breakup time is a simple clinical test for evaluation of this component of tear function. One drop of fluorescein is placed in the eye and the patient is instructed to blink once. Observing the corneal surface under slit-lamp magnification with cobalt blue illumination, the observer notes the time it takes in seconds for dry spots appear in the tear film. Normal tear breakup time is between 15 and 30 s. A tear breakup time of less than 10 s indicates a probable mucin deficiency, which may result not only in the symptoms of dry eye syndrome, but also in reflex hypersecretion of the aqueous tear component and in epiphora.

Dye Disappearance Test

The dye disappearance test is usually performed as part of the primary Jones dye test (Jones I test). It is a rudimentary measurement of the rate of tear flow out of the conjunctival sac. One drop of 2 % fluorescein is placed in the lower conjunctival fornix and the amount remaining at 5 min is graded on a 0 to 4+ scale, with 0 representing no dye remaining and 4+ representing all the dye remaining. The test is most meaningful when both sides are compared simultaneously. Little or no fluorescein remaining in the conjunctival sac (a positive test) indicates probable normal drainage outflow, whereas most or all of the dye remaining (negative test) indicates partial or complete obstruction, or pump failure. Care must be taken to note any overflow of tears onto the cheek, and the patient is instructed not to blot the eyes with tissue during the test. In addition, a significant amount of dye may disappear in the presence of a large dilated sac mucocele even with a more distal obstruction. The test cannot

distinguish between physiologic and anatomic causes of drainage dysfunction, nor can it localize the site of any mechanical blockage. It only indicates whether tear flow out of the fornix is normal or delayed. The dye disappearance test has been shown to be positive (normal outflow) in 95 % of asymptomatic normal individuals and may be more sensitive than the primary Jones test [16]. Unlike the latter, it does not appear to be dependent upon gross tear flow as measured by the Schirmer test.

Primary Jones Dye Test

In 1961, Jones described a simple test of lacrimal drainage function that has become one of the most used procedures in the evaluation of epiphora. The primary Jones dye test (Jones I) is a true functional test and should be carried out in as nearly physiologic conditions as possible. The patient should be in an upright position, and should blink normally. Topical anesthesia is not used, although the clinician may anesthetize the nasal mucosa for comfort. Two percent fluorescein solution is instilled into the conjunctival sac and a fine cotton-tipped applicator is passed beneath the inferior turbinate to the level of the nasolacrimal ostium after 2 min and again after 5 min. Alternatively, the patient is asked to blow their nose onto a clean tissue. The test is positive if dye is recovered in the nose, and indicates patent anatomy and adequate physiological function. However, the dye may be very difficult to retrieve and therefore there is a high false negative rate with this test. Transit time for the dye to reach the nose is quite variable and shows a significant correlation with the Schirmer test. Even in eyes without epiphora, passage of dye into the nose may take considerably longer than the 5 min allowed for the test. A 10 min interval will result in a greater number of positive tests. Also, testing conditions may alter results since transit time is influenced by factors such as blink rate, head position and gravity, and fluorescein volume. Experience in placing the dye (drops vs. strips) and techniques for obtaining dye from the nose may also influence the recovery rate. Although a positive test strongly suggests a normal system, it does not completely rule out physiological dysfunction or mild anatomic obstruction. More significantly, a negative test alone does not necessarily indicate abnormal drainage, and even in asymptomatic normal patients the overall positive recover rate is typically only in the range of 85 % [17].

The fluorescein appearance test, described by Flach, is a modification of the primary Jones dye test [18]. It is designed to avoid the difficulty and variability involved in recovering dye from the inferior nasal meatus. Two percent fluorescein is placed in the conjunctival sac and the oropharynx is examined with ultraviolet light, beginning at 5 min and continuing up to 1 h if necessary. With this technique 90 % of normal individuals are said to show oropharyngeal fluorescence within 30 min, and 100 % within 60 min. This procedure is best used as a supplement to a negative primary Jones test and can be performed 20–30 min later. Because of the persistence of fluorescence, only one eye can be tested by this technique during a single office visit.

In 1973, Hornblass [19] elaborated on a variation of the primary Jones dye test originally mentioned by Lipsius [20]. In this version, 0.4 mL of 1 % sterile solution of sodium saccharin is instilled into the conjunctival sac and the patient is asked to report when he or she tastes the solution. Hornblass found a mean transit time to the nose of 3.5 min, with 65 % of normal individuals reporting a positive test within 6 min, and 90 % reporting positive results within 15 min. Transit times in excess of 15 min suggest partial nasolacrimal duct obstruction. The test depends on a subjective response from the patient, and before the solution can be tasted it must pass into the pharynx, where threshold taste sensitivity is quite variable. Lipsius noted that 3 % of normal individuals were incapable of tasting saccharin.

Secondary Jones Dye Test

A negative primary Jones dye test suggests delayed transit time through the lacrimal drainage system but it does not differentiate physiologic

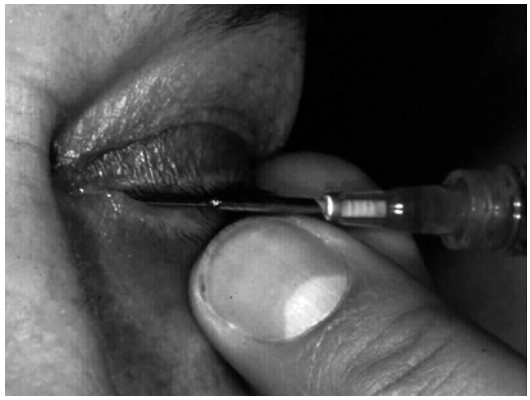

Fig. 7.3 Secondary Jones dye test with irrigation of saline through the inferior canaliculus

dysfunction from anatomic obstruction. The secondary Jones dye test (Jones II) evaluates anatomic patency of the system in such cases. Residual fluorescein left from the primary test is flushed from the conjunctival sac and a topical anesthetic is instilled. The patient sits with head tilted slightly forward while clear saline is irrigated into one canaliculus through a cannula (Fig. 7.3). The patient is instructed to blow or spit any fluid that passes into the nose or pharynx onto a clean tissue. The passage of any fluid into the nose indicates gross anatomic patency of the nasolacrimal system. In this situation, complete obstruction is not present since saline did traverse the system under pressure. Dye in the fluid demonstrates normal punctal and canalicular anatomy, since the dye must have passed freely into the sac during the previous Jones I test. However, such a result does not rule out a partial anatomic block at the level of the lower sac or duct. Recovery of clear saline in the nose without fluorescein suggests punctal or canalicular stenosis or pump failure, where dye from the primary Jones test did not enter the lacrimal sac. If fluid does not reach the nose at all, but regurgitates from the puncta, a high-grade NLD obstruction is likely that cannot be overcome with increased hydrostatic pressure. Punctal regurgitation of dye-stained fluid suggests blockage at the level of the lower sac or duct, with residual dye in the sac being flushed out by the irrigation. Very rarely, a dilated canalicular mucocele may retain sufficient dye to produce similar results. Regurgitation of clear saline from the opposite punctum suggests obstruction at the level of the distal common canaliculus or upper sac with no residual dye from the primary Jones test. When clear saline regurgitates from the same punctum that is being irrigated without flow from the opposite punctum, a proximal obstruction in that canaliculus is likely.

During the irrigation of saline, distension of the lacrimal sac to palpation may sometimes be seen and is suggestive of lower nasolacrimal duct obstruction. Under such conditions a palpable sac without fluid passing into the nose suggests complete nasolacrimal duct blockage, whereas a palpable sac with fluid passing into the nose implies a partial obstruction. A sac that is contracted and fibrotic because of chronic inflammation will not dilate under these conditions.

The secondary Jones dye test evaluates anatomic patency under increased hydrostatic pressure. When positive, it does not differentiate between epiphora caused by physiological dysfunction and epiphora resulting from partial anatomic obstruction. When a primary Jones test is positive (dye recovered in the nose), the secondary Jones test should always be positive and is therefore unnecessary. With a negative primary test, a positive secondary test would be consistent with physiologic or partial anatomic dysfunction. Negative results (no dye recovered) on both the primary and secondary tests confirm a high-grade obstruction.

False-positive results are not uncommon when a diagnosis of NLD obstruction is based on the irrigation test alone. Beigi et al. [21] noted a high rate of false tests where re-examination showed canalicular stenosis, punctal abnormalities, or hypersecretion.

Dacryomeniscometry

Dacryomeniscometry has been used in the past to evaluate dry eyes. More recently, it has been applied to evaluation of tear meniscus height in patients with epiphora from primary acquired

nasolacrimal duct obstruction and from functional nasolacrimal drainage system failure [22]. The tear meniscus in patients with functional or anatomic NLD obstructions is significantly higher than in normal controls [23], and reduces to near normal after corrective DCR surgery. The technique may be useful to identify individuals with drainage dysfunction from a variety of etiologies, but must be combined with other tests in order to diagnose the specific etiology.

Probing

When the secondary Jones test indicates canalicular obstruction, the canaliculus in question should be probed gently to the lacrimal sac with a small Bowman probe (Fig. 7.4). The punctum may first be dilated by pulling the lid laterally to prevent canalicular kinking and inserting a pointed dilator. The distance of the stenosis or blockage from the punctum is noted in millimeters by measuring directly on the probe. In most individuals, a short common canaliculus is present 6–9 mm from the puncta. The canalicular system should not be probed without prior indication of possible obstruction because of the risk of inadvertent injury and subsequent fibrosis.

Diagnostic Imaging Techniques

Diagnostic Ultrasonography

The techniques of A- and B-mode ultrasonography provide a simple, noninvasive method of evaluating the normal lacrimal sac and duct (Fig. 7.5a, b) [24]. It has also proved useful in the evaluation of gross anatomic lacrimal system abnormalities [25, 26]. Physiological dysfunction cannot be evaluated, nor can the precise site of anatomic obstruction be localized in most cases. However, a dilated lacrimal sac can easily be distinguished

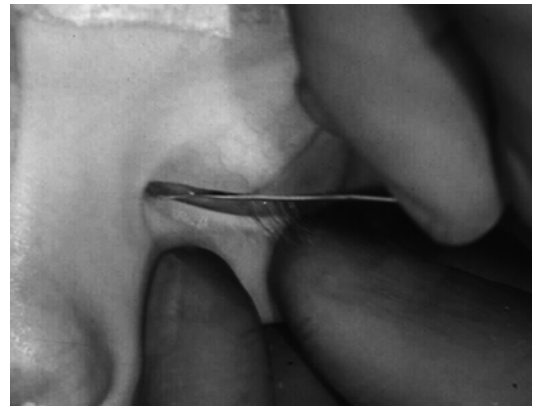

Fig. 7.4 Probing of the inferior canaliculus with a number 0 Bowman probe

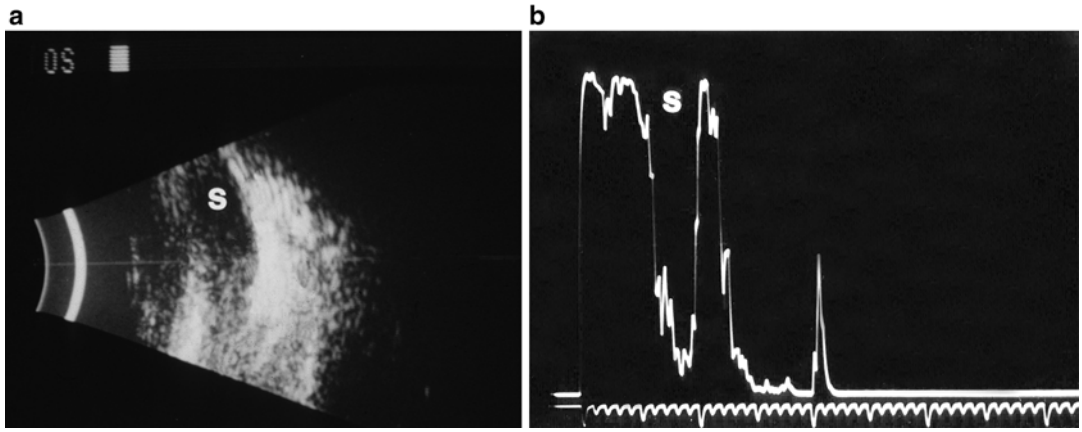

Fig. 7.5 (**a**) B-scan ultrasound of a nasolacrimal system with a normal nasolacrimal sac (S). The anterior lacrimal crest can be visualized anteriorly and inferiorly and the lacrimal bone is seen posteriorly. (**b**) A-scan ultrasound of a normal nasolacrimal system. Nasolacrimal sac with low reflectivity (S) and sharply defined anterior and posterior walls. The smaller peak represents lacrimal bone

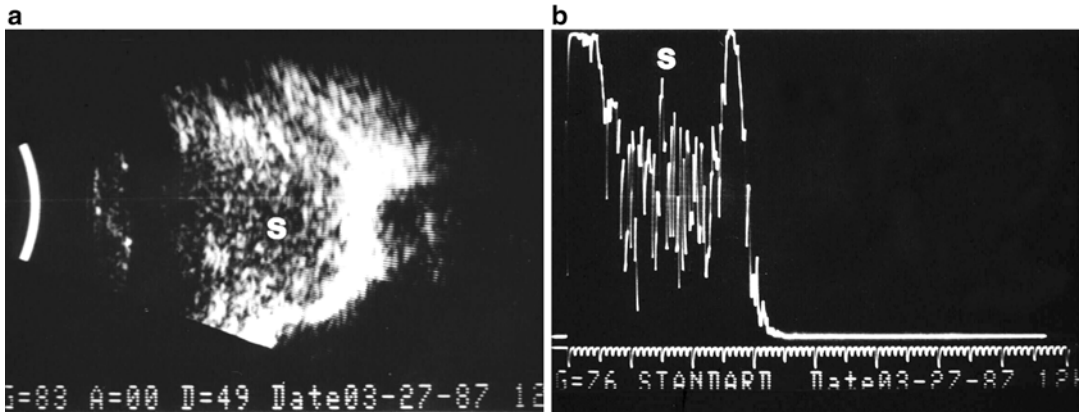

Fig. 7.6 (**a**) B-scan ultrasound of a patient with acute dacryocystitis demonstrating a massively enlarged nasolacrimal sac (S) and thickened anterior and posterior walls. (**b**) A-scan ultrasound of the same patient as Fig. 7.2a showing dilated nasolacrimal sac (S) with irregular, medium reflectivity indicating the presence of mucopurulent exudates

from one of normal dimensions (Fig. 7.6a, b). It is also possible to differentiate air from mucus or solid masses, making the identification of lacrimal sac neoplasms possible [27]. Lacrimal sac concretions can be visualized, and these may occur in 6–7 % of patients with NLD obstruction [28]. Tost et al. [29] reported visualization of the canaliculi, but this requires intracanalicular injection of sodium hyaluronate.

With the B-mode probe placed in the medial canthus, oriented vertically and aimed toward the lacrimal sac fossa, an oblique longitudinal cross section of the lacrimal sac and upper duct is obtained. The canaliculi cannot usually be visualized unless they are significantly dilated. The diameter of the sac and upper duct may be evaluated and the thickness of the walls can often be appreciated [30]. Diverticuli may also be identified and a variety of echogenic densities within the system such as inflammatory membranes, tumors, and concretions can be detected. The position and size of a surgically created ostium may also be imaged with this technique (Fig. 7.7), although its patency cannot easily be evaluated [31].

For precise measurements of the sac and evaluation of the internal reflectivity of sac contents, A-mode scanning is used. The A-probe is first oriented as for a periocular orbital study, but with the beam aimed just behind the anterior

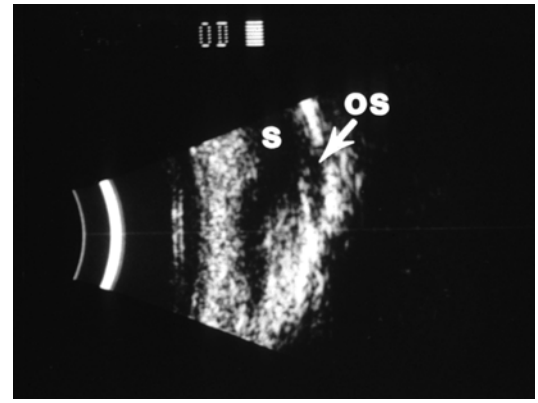

Fig. 7.7 Post-dacryocystorhinostomy B-scan ultrasonography showing the surgically created lacrimal-nasal ostium (OS). The lacrimal sac (S) is somewhat dilated because of soft tissue closure of the ostium

lacrimal crest toward the sac fossa. An oblique anterolateral–posteromedial transit of the sac is thus obtained. If the sac is filled with air it appears as an echolucent defect bounded by sharply defined vertical anterior and posterior sac walls. Often the presence of dilated diverticula can be detected. Mucus in the sac produces uniform, homogeneous, low-density internal echoes, and inflammatory exudates and membranes show stronger, more irregular echoes. Multiple strongly echogenic, irregular echoes with infiltration of the sac walls suggest a sac tumor. A transocular A-mode image of the sac is obtained with the

probe held above the lateral canthus and directed toward the lacrimal sac fossa through the eye. This technique gives an approximate horizontal cross section of the sac. The average dimensions of the sac in normal individuals is 2.5 mm (SD = 0.95 mm) in horizontal diameter and 4.0 mm (SD = 1.49 mm) in anteroposterior extent. A sac more than 4.5 mm wide or 7.0 mm deep should be considered abnormally dilated.

Contrast Dacryocystography

The first attempt to visualize the lacrimal drainage system radiographically was made by Ewing in 1909. He used bismuth paste for retrograde filling of the nasolacrimal duct. Such early attempts proved unsatisfactory, and the technique was used infrequently until the introduction of better aqueous contrast media such as Sinografin and Angiografin, and especially the low-viscosity iodized oils such as Pantopaque, Ethiodol, and ultrafluid Lipiodol. In a standard dacryocystography (DCG) study, the canaliculi are intubated with intravenous catheters. Contrast material is injected into the lower canaliculus on each side and films are taken immediately in Caldwell's posteroanterior frontal projection and in both lateral projections. Repeat films are obtained at 5 and 15 min and upright films may be taken to evaluate the effects of gravity on lacrimal drainage. DCG can also be combined with CT or MR imaging to give further information on the nasolacrimal system.

In 1968, Iba and Hanafee described the technique of distension dacryocystography, first used by Barrie Jones in 1959 [32]. Here, films are taken during injection of 0.5–1.0 mL of contrast material so that the lacrimal system is imaged in the distended state. Both sides are studied simultaneously and injection is accomplished through the placement of canalicular indwelling tapered Teflon catheters or IV catheter tubing. This method provides maximum visualization of the anatomic structure of the system and, because of the back pressure, gives good filling of the canaliculi. It is the best technique for demonstration of fistulae, diverticulae, supernumerary canaliculi,

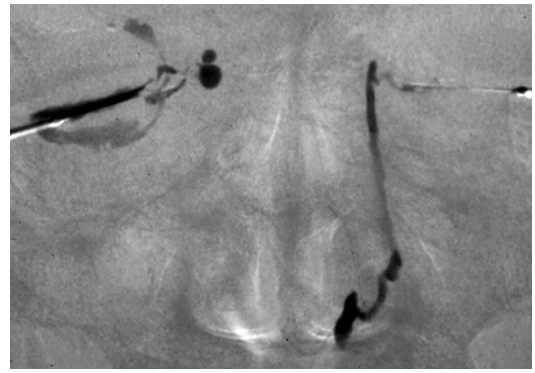

Fig. 7.8 Digital subtraction contrast dacryocystogram. Pt with normal passage of contrast through the left nasolacrimal system and complete blockage of the right proximal nasolacrimal duct and mild dilation of the right nasolacrimal sac

and the presence of concretions and sac tumors. However, it does not reveal sac and duct dimensions under normal physiologic conditions. This test also requires either the ophthalmologist or a skilled technician to be in the radiology suite to inject the material and can lead to some patient discomfort.

Improved imaging is achieved with a technique adopted from subtraction angiography that eliminates confusing bony shadows (Fig. 7.8). A scout film is taken before injecting contrast material and is used to produce bone-free images of the dacryocystogram. More sophisticated computer-assisted digital subtraction images can be produced using fluoroscopically controlled angiographic equipment and an image intensifier [32, 33].

The dacryocystogram of a normal lacrimal drainage system will usually show the canaliculi when less viscous aqueous contrast media are used [34]. The sac appears as a smooth narrow duct to the sac–duct junction. The duct widens at the level of the bony rim and its inner surface becomes more irregular because of the presence of mucosal folds. Such folds may be exceptionally well developed in younger children. Further constrictions are seen in the duct's mid-portion in the region of Hytle's and Taillefers' valves. Finally, in its lower third, the duct widens again. Visualization by DCG reveals considerable variations in the structure of the sac and duct among

normal individuals. Atypical narrowing and widening of the sac and duct, as well as unusual angulations and diverticula, may all be seen in the absence of clinical symptoms.

A combination of subtraction, distension, and macrodacryocystography provides the best visualization of the anatomic structure of the lacrimal drainage system. This approach will provide accurate localization of any anatomic obstruction in the majority of cases. Imaging of the canaliculi with dye failing to pass into the sac or duct implies obstruction at the common canaliculus. Obstruction at the sac–duct junction usually results in a dilated sac with no dye reaching the duct or nose, even on late films. Obstruction at the level of the nasolacrimal duct will show dilatation of the sac, with dye in the duct, but not reaching the nose. A patent dacryocystorhinostomy ostium is easily demonstrated by passage of contrast into the nose at the level of the middle meatus. Demonstration of patent lacrimal passages by DCG in the face of epiphora suggests physiological dysfunction or a mild incomplete anatomic block.

DCG is considered the gold standard for imaging of the nasolacrimal system, but it does not allow for imaging of the soft tissue or bony structures surrounding the nasolacrimal sac or duct. DCG can be combined with CT and MR studies to get a complete picture of the nasolacrimal system and the surrounding anatomy.

In a recent study, Lee et al. used fluoroscopic dacryocystography to evaluate dynamic changes in lacrimal drainage system anatomy during the blink cycle [35]. This study showed that with eyelid closure the canaliculi contract while the lacrimal sac dilates, both contributing to the pump mechanism. This has expanded to our knowledge of lacrimal physiology under normal conditions, and may add to an understanding of proximal system pathology.

Computed Tomography

In selected cases computed tomography (CT) of the lacrimal system can be extremely useful in the evaluation of epiphora [36]. This is especially useful when patency of the lacrimal system is uncertain, and when dacryolith or tumor is suspected [37]. This technique also allows evaluation of surrounding tissues in cases of trauma or anatomic variants that may complicate planned surgery [38].

Axial scans through the lower orbit will show the lacrimal sac fossa as a depression in the anteromedial orbital wall (Fig. 7.9a). In successively lower sections, the duct appears as a round to oval defect in the frontal process of the maxillary bone at the anteromedial corner of the antrum. The duct may be filled with air or fluid. As the duct is traced inferiorly, it can be seen to open beneath the inferior turbinate. Cross sections of the system are seen in coronal reformatted images since the line of section is oriented downward and obliquely backward. Parasagittal reformatted images will reveal the entire length of the system in longitudinal section.

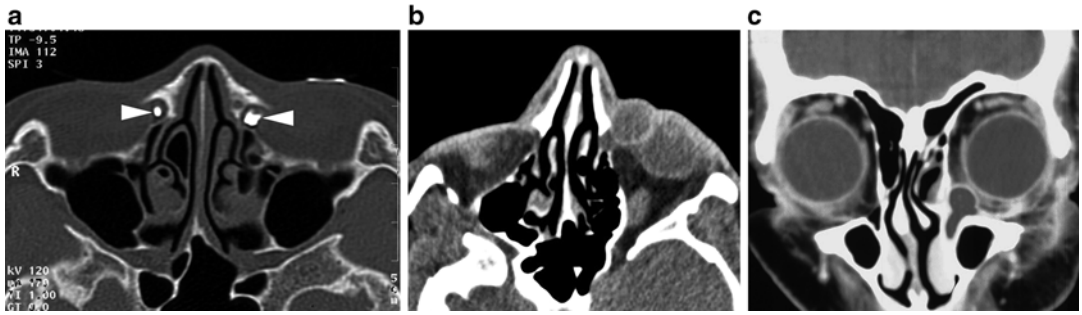

Fig. 7.9 (**a**) Axial bone window CT-DCG demonstrating contrast filled lacrimal sacs (*arrowheads*). The left system is dilated compared with the right. (Courtesy of Susan K. Freitag, M.D., reprinted with permission from Lippincott, Williams & Wilkins ©2002). (**b**) Axial soft tissue window CT with a dilated left lacrimal sac from dacryosystitis. (**c**) Coronal soft tissue CT showing a dilated lacrimal sac and duct from dacryocystitis

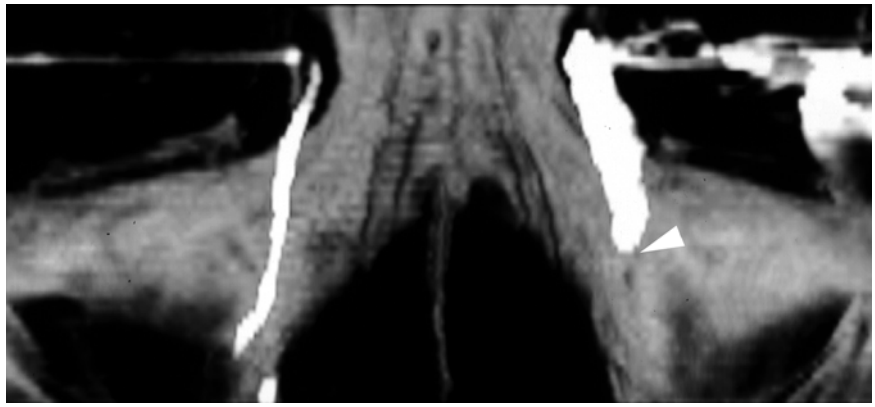

Fig. 7.10 CT-DCG three-dimensional reconstruction in the left oblique projection confirms the left complete obstruction and proximal dilation. Right system is normal (Courtesy of Susan K. Freitag, M.D., reprinted with permission from Lippincott, Williams & Wilkins ©2002)

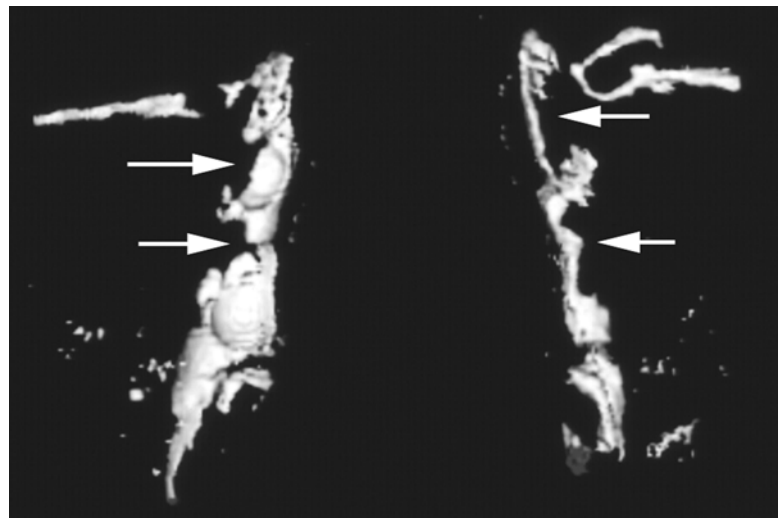

Fig. 7.11 CT-DCG three-dimensional reconstruction demonstrates bilateral filling defects (*arrows*) in distorted and dilated lacrimal systems (Courtesy of Susan K. Freitag, M.D., reprinted with permission from Lippincott, Williams & Wilkins ©2002)

Dilatation of the lacrimal sac from dacryocystitis can easily be seen on CT (Fig. 7.9b, c). The modality is also useful in detecting lacrimal sac mucoceles, and can sometimes show concretions within the sac and duct. Extrinsic lesions, such as nasosinus tumors, sinusitis, and nasal polyps that can cause tear drainage dysfunction, may also be visualized [39]. When epiphora follows trauma, and subsequent clinical studies indicate nasolacrimal duct obstruction, CT dacryocystography may reveal facial fractures compressing the sac or duct [40]. CT imaging can distinguish a dacryocystocele from recurrent tumor following resection of sinonasal cancer [41]. In most cases of suspected malignancy, especially if there is a history of bloody epiphora or pain, a CT scan may demonstrate soft tissue masses in the sac or in the adjacent paranasal sinuses. In cases of congenital lacrimal amniocele, CT will reveal the dilated duct, often associated with bony changes. It is essential to differentiate this soft, near-midline dilated lacrimal conduit from a meningocele. MRI is more sensitive for soft tissue abnormalities but does not image the bony structures well.

When combined with dacryocystography, 3-dimensional CT (3-D CT-DCG) is excellent at identifying bony structures around the nasolacrimal system (Figs. 7.10 and 7.11). Using modern spiral CT techniques, with topical or injected contrast material, the surgeon can identify accurately

obstructions in the nasolacrimal system [37, 42]. This can be especially useful in patients that have had facial trauma, prior sinus or lacrimal surgery, or tumors of the medial canthus [43]. Newer techniques utilizing spiral CT and 3D reconstruction technology have improved the diagnostic accuracy of patients with partial obstructions of the nasolacrimal system by allowing the surgeon to view a 3D rotational image of the entire system from multiple projections [36].

Cone-beam computed tomography is a new technology that utilizes a C-arm angiography system that rotates around the patient to produce high-resolution 3-D images with computer reconstructions in axial, coronal, and sagittal planes. The technique allows the simultaneous assessment of the nasolacrimal duct together with its surrounding soft tissue and bony structures [38].

There are some disadvantages to CT scan. As mentioned previously, it is not the best study for evaluating soft tissue masses of the nasolacrimal system. Also, in standard CT, the images are presented as a series of axial images that make identification of small obstructions difficult. Longitudinal and oblique images can be created, but this reconstruction results in decreased spatial resolution in the reformatted images. The exposure to ionizing radiation is also more than for standard DCG, and is less appropriate for young children.

Magnetic Resonance Imaging

Since 1990, dynamic magnetic resonance imaging dacryocystography (dMRI-DCG) has been used as an adjunctive diagnostic test in the evaluation of lacrimal system pathology that allows for excellent resolution of the nasolacrimal system [44–47]. When combined with a contrast agent, 3D MRI offers several advantages over other imaging techniques [46]. Gadolinium can be given as a topical solution diluted from 1:10 to 1:100 with normal saline, one drop to each eye per minute for 5 min. The patient should stay in an upright position until just prior to image acquisition. Because the lacrimal system is not cannulated, and therefore not under increased hydrostatic pressure, this study gives a picture of the functional status of the nasolacrimal system. There have been no reports of ocular complications from the administration of topical gadolinium and this obviates the need to risk damage to puncta from the direct instillation of contrast agents.

dMRI-DCG has a very high correlation with the gold-standard contrast DCG in detecting NLD obstruction, and has a sensitivity of 94 % and a specificity of 100 % in detecting a dilated sac [48]. MRI also allows high-resolution evaluation of soft tissue structures within and surrounding the nasolacrimal drainage system that is comparable to dacryocystography combined with computed tomography [48–52]. The superficial location of the nasolacrimal system facilitates imaging with small surface coils, which can give a spatial resolution of $0.3 \times 0.3 \times 3$ mm or better [47]. Manipulation of signal intensities, repetition times and tip angles, as well as the use of fat suppression algorithms can often allow for differentiation of mucous or blood from solid neoplasms. Because of volumetric acquisition, MRI images can be viewed in any plane without degradation of the image quality. This is a key advantage over CT-DCG which requires reformatting of images that are out of plane and results in degradation of image resolution. Coronal images are superior for determining the distal extent of contrast transit and axial images are excellent for examining the lumen of the nasolacrimal duct and intraductal pathology.

Although MRI can be a useful diagnostic study, it is an expensive study and therefore is not used routinely. Other drawbacks include poor ability to image bony structures and there can be artifact from the nearby ethmoid air cells. MRI is also susceptible to movement artifact because of the relatively long acquisition times required.

Radionuclide Dacryoscintigraphy

The first use of radionuclide tracer to image the lacrimal drainage system was by Bozoky and Korchmaros, who used radioactive ^{198}Au and measured the buildup of activity over the sac and duct.

Rossomondo et al. [53] introduced the first modern nuclear imaging technique for the lacrimal drainage system. They instilled a drop of saline with [99mTc] sodium pertechnetate, and imaged the system with a gamma camera. In the first clinical evaluation of the technique, Carlton et al. [54] demonstrated its value in visualizing the lacrimal system, and in measuring some physiological parameters of tear flow. In their study of 28 asymptomatic volunteers they recorded a transit time for the nuclide of 4–43 s to the sac, and 4–323 s to the nose. While there is a high degree of correlation between dacryoscintigraphy and contrast dacryocystography, the former is more sensitive to incomplete blocks, especially in the upper system. Since dacryoscintigraphy is a physiologic test it is very sensitive in localizing the site of anatomic blockage as well as finding abnormalities in patients with physiologic pump dysfunction [55, 56]. A high correlation has been shown between symptomatic epiphora and quantitative lacrimal scintigraphy measures as tracer flow times [57].

The technique commonly employed today uses [99mTc] sodium pertechnetate in saline or technetium sulfur colloid delivered as a 10 μL drop to the lateral conjunctival sac by micropipette. The patient is advised to blink normally, and the nasolacrimal system is imaged every 10 s for the first 2–3 min. Late images are obtained every 5 min thereafter for a total of 20 min (Fig. 7.12). The specific activity of this dose is in the range of 50–150 μCi, and results in radiation exposure to the lens of less than 2 % of that for a complete contrast dacryocystogram.

Dacryoscintigraphy does not provide the detailed anatomic visualization available with contrast DCG. In standard nuclear studies the proximal canalicular system is usually poorly imaged unless dilated, but the lacrimal sac and duct are usually well outlined [58]. Complete or partial obstructions of the drainage system are easily seen, with a sensitivity of better than 90 % [59]. Although the precise site of obstruction is difficult to determine with scintigraphy alone, the approximate level, such as presac, preduct, or intraduct, can often be determined [57]. Generation of dynamic activity curves for specific regions of interest will demonstrate incomplete anatomic obstructions as well as rather subtle degrees of functional impairment [58, 60]. This technique is most accurate and reproducible for the upper lacrimal system. Transit times become quite variable for the lower system, with 25–32 % of asymptomatic individuals showing no tracer in the nose after 12 min. This is consistent with findings on the primary Jones dye test. By using more sophisticated rapid sequence display and computer interfacing for image optimization by contrast enhancement, background subtraction, and frame arithmetic, quantitative evaluation of tracer movement provides the most revealing interpretation of lacrimal function and tear flow dynamics currently available.

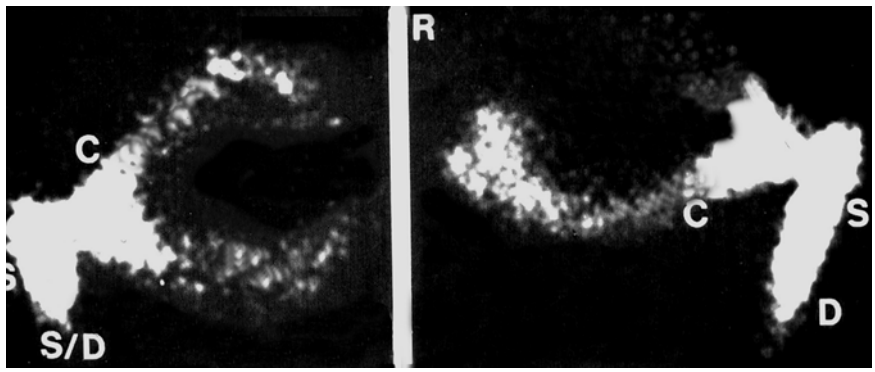

Fig. 7.12 Dacryoscintigraphy in a patient with unilateral epiphora on the left side. The right lacrimal drainage system fills normally, with tracer concentrated in the canaliculi (C), sac (S), and duct (D). The left system shows no tracer below the sac–duct junction (S/D)

Dacryoscintigraphy has been shown to be useful in evaluating persistent epiphora following dacryocystorhinostomy surgery [61]. It can show partial or complete obstructions or decreased tear transit at the presac or sac level.

Other Diagnostic Techniques

Percutaneous Contrast Dacryocystography

The common canaliculus is a common site of obstruction seen on radiographic imaging in patients with epiphora. When such blockages are complete, routine DCG of the lower system is not possible, and the concomitant presence of lower sac or duct pathology cannot easily be demonstrated unless echography is used to detect a dilated sac. In 1972, Putterman [62] described a technique of percutaneous injection of aqueous contrast material directly into the lacrimal sac to bypass the occluded common canaliculus. In his small series of four patients there were no complications and results were good.

Chemiluminescence

Chemiluminescent materials can provide a nonradiologic technique for demonstrating the outline of the lacrimal drainage system and verifying its patency. The luminescent agents are dimethylphthalate and tertiary butyl alcohol activated by dibutlphthalate, which produce an intense cold light. When these agents were injected into the lacrimal drainage system of monkeys, the glow was visible through the skin and clearly outlined the lacrimal sac [63]. The lacrimal duct was not readily demonstrated. The compounds are safe and nontoxic if confined within the lacrimal system, but extravasation into tissues or onto the globe can produce severe complications of corneal scarring and vascularization, purulent infection, granuloma formation, and fibrosis [64]. Chemiluminescence has not yet been used in humans so that its clinical effectiveness as an alternative or adjunct to other procedures cannot be evaluated.

Lacrimal Thermography

The canaliculi and lacrimal sac have been visualized by thermography, using an infrared scanner and color monitor with a resolution of 0.5° [65]. The lacrimal system is easily differentiated from surrounding tissues by irrigation with cold water, and decreased temperature in the nose demonstrates patency. A large dilated sac can be visualized, and persistent inflammation will produce increased temperature within the sac. The duct is not demonstrated with this method.

In a related technique, a mini-thermocouple probe has been used to detect temperature differences with the lacrimal sac. Increased temperatures are seen with vascularity and inflammation, and decreased temperatures with hemorrhage and mucocele formation. Nasolacrimal duct obstruction without associated inflammation shows no difference in temperature compared with the contralateral uninvolved side.

Interpretation of Diagnostic Tests

Like many diagnostic tests in medicine, most of those described above require some subjective interpretation in order to determine the probable etiology of epiphora (Tables 7.1 and 7.2). Some knowledge of the variability in patient response, as well as of the reliability of the specific tests in suggesting pathology is needed before meaningful conclusions can be drawn. The mere demonstration of lacrimal system pathology, either anatomic or physiological, does not indicate lacrimal dysfunction. Patients with significant degrees of partial or even complete obstruction may be entirely asymptomatic as long as tear production and drainage balance is maintained.

Not every test mentioned here must be performed on each patient with epiphora. In most cases, a relatively simple clinical evaluation in the office will adequately demonstrate the cause of tearing and allow appropriate therapeutic decisions. Some cases, however, will present more difficult diagnostic challenges, particularly those with proximal system anatomic stenosis and physiologic dysfunctions. Here, more elaborate

Table 7.1 Interpretation of clinical tests in the evaluation of Epiphora

Dye disappearance test (0 to 4+)	Jones I	Jones II	Canalicular probing	Sac palpation (mass or reflux)	Probable diagnosis
0	+	+	Normal	Normal	Probable oversecretion
0–1	+	+	Normal	Normal	Normal vs. functional
0–1	–	+	Normal	Normal	Normal vs. functional vs. mild NLD obstruction
1–2	–	+	Normal	Abnormal	Partial NLD obstruction with dilated sac
1–2	–	+	Normal	Normal	Mild NLD obstruction vs. functional
3–4	–	+	Normal	Normal or abnormal	Partial NLD obstruction
3–4	–	–	Normal	Normal or abnormal	Complete NLD obstruction
3–4	–	+	Stenotic	Normal	Partial canalicular obstruction
3–4	–	–/+	Stenotic	Normal	Combined NLD obstruction with canalicular obstruction
3–4	–	–	Blocked	Normal or abnormal	Complete canalicular obstruction

NLD nasolacrimal duct, + positive (dye in the nose), – negative (no dye in the nose)

Table 7.2 Results of primary and secondary Jones tests and probable sites of lacrimal system obstruction

Jones I	Jones II	Probable site of obstruction
+	+, dye in nose	Patent system, probably normal
–	+, dye in nose	Partial NLD obstruction vs. functional
–	+, saline in nose, no dye	Partial canalicular obstruction vs. functional
–	–, regurgitation of dye from opposite punctum	Complete lower NLD obstruction
–	–, regurgitation of saline from opposite punctum, no dye	Complete common canaliculus obstruction
–	–, regurgitation of dye from same punctum only	Complete opposite canalicular obstruction with lower NLD obstruction
–	–, regurgitation of saline from the same punctum, no dye	Complete canalicular obstruction

NLD nasolacrimal duct

procedures, including radiographic studies, may be required.

In the face of a normal Schirmer test of basic and reflex tear response, the dye disappearance test can be a sensitive, though subjective, indicator of gross drainage. With a normally draining system, fluorescein should be almost gone within 5 min. Epiphora due to physiologic dysfunction or partial anatomic obstruction will show prolonged presence of dye in the conjunctival sac, whereas epiphora resulting from oversecretion syndrome with normal drainage should yield normal or even rapid disappearance of dye. It is important to realize that the rate of dye clearance through the lacrimal system is strongly influenced by the pressure head from above. Even in the presence of decreased drainage function, a large volume of fluorescein augmented by increased reflex tear secretion from conjunctival irritation may result in an artifactually rapid dye disappearance. It is therefore important to administer this test under conditions as nearly physiologic as possible, with the patient in an upright position, blinking normally, and receiving only one drop of fluorescein. Increased voluntary blinking during the test can significantly shorten the test time, and can allow the use of a reduced concentration of fluorescein of 0.25 % [66].

When the dye disappearance test is abnormal or the history strongly suggests inadequate drainage, the primary Jones dye test is usually performed next. In interpreting the results of this test it is essential to keep in mind that in up to one-third of asymptomatic individuals, dye will not be recovered in the nose after only 5 min. It is also important to remember that this test correlates well with the results of the Schirmer test and therefore

with the volume of fluorescein placed into the conjunctival sac. Like the dye disappearance test, an artifactually positive Jones I test may result from volume overload even when epiphora is present under normal physiological conditions. To be meaningful, the test must be conducted under as close to normal physiological function as possible. Only a small volume of dye should be used, the patient should be in an upright position, and blinking should be normal. Variants of the Jones I test, such as the saccharin taste test, add little, and are difficult to interpret. When the primary Jones dye test is positive (dye is recovered in the nose), one may conclude that the system is grossly patent, although minor stenoses and physiological dysfunctions cannot be ruled out. When the test is negative (no dye in the nose), it is likely that anatomic or physiological pathology exists, but this test alone is not sufficient to document this conclusion.

When the dye disappearance test is prolonged and the primary Jones dye test is negative, the probability of drainage dysfunction is greater than would be indicated by a negative primary Jones dye test alone. The secondary Jones dye test is then performed. Careful interpretation of the test results will indicate the location of the block (Fig. 7.13). It is imperative to collect any irrigant that passes into the nose. The patient is asked to spit any fluid out onto a clean tissue. If the secondary Jones test is positive and dye passes into the nose without resistance or reflux from the puncta, then the lower NLD is grossly anatomically patent, and the proximal system (puncta and canaliculi) are normal since they allowed dye to pass into the sac during the primary test. When the secondary test is positive but only saline passes into the nose without dye, this indicates dysfunction of the proximal system, either anatomic or functional since dye never passed into the sac. It should be kept in mind that the secondary Jones test may be positive even in the presence of a low-grade partial obstruction or stenosis that can be overcome by increased hydrostatic pressure during irrigation. Failure of the lacrimal pump mechanism can also be responsible for a negative primary Jones test, delayed dye disappearance test, and a positive secondary Jones test with only saline entering the nose.

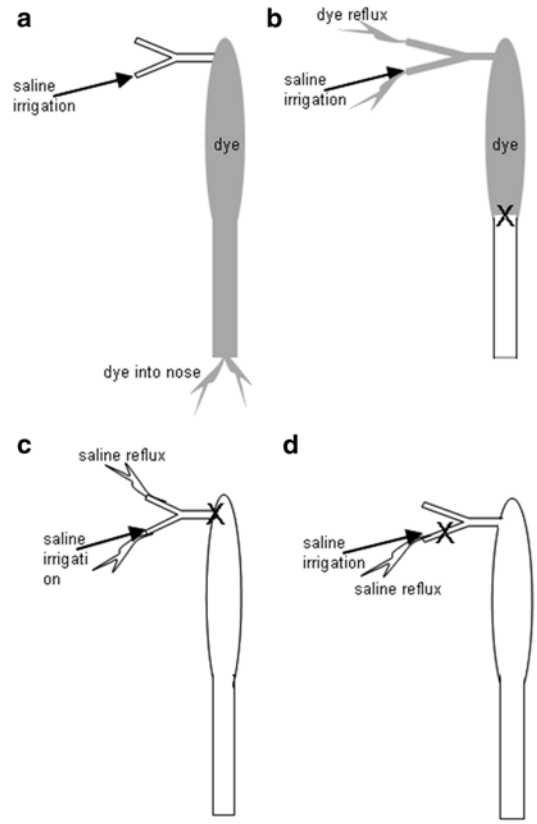

Fig. 7.13 Interpretation of the secondary Jones test. After the primary Jones test dye either passes into the lacrimal sac or not. (**a**) Normal patent NLD; irrigated saline pushes dye from the sac into the nose. (**b**) NLD obstruction; irrigated saline refluxes dye from the sac out the puncta. (**c**) Common canalicular obstruction; irrigated saline refluxes from the puncta without dye. (**d**) Canalicular obstruction; irrigated saline refluxes only from the same punctum without dye

If the secondary test is positive, but there is resistance to irrigation and some dye-stained irrigant regurgitates from the puncta, then there likely is a partial block in the distal system at the lower sac or duct. Remember that even in a normal system, retrograde flow out of the canaliculi may be seen with excessive injection pressures above 100 mmHg.

When the secondary Jones test is negative (no irrigant in the nose), it demonstrates a complete obstruction in the NLD system. If the secondary test is negative, but clear saline irrigated through the punctum causes dye-stained saline to regurgitate from the same and opposite puncta, then the

proximal system must be patent since the dye must have been in the sac. If only clear saline regurgitates from both puncta, the block is probably at the common canaliculus since no dye previously entered the sac. Confirmatory probing should encounter an obstruction at the distal canaliculus 6–9 mm from the puncta. If an obstruction or stenosis is not found, the test should be repeated. The eyelid must be pulled laterally to straighten the canaliculi during irrigation. However, if there is a lengthy delay between the primary and secondary tests, there may be too little dye remaining in the sac to stain the regurgitating fluid and this will cause a false test result of canalicular obstruction.

If the results of clinical testing are equivocal, or there is either a history of trauma, suspicion of tumor, recurrent epiphora following surgery, or persistent chronic dacryocystitis, then radiographic evaluation is indicated to image the anatomic structure of the system to pinpoint the site of obstruction. Dacryocystography clearly outlines the patent conduit of the lacrimal drainage system, but may not demonstrate low-grade stenoses that are easily opened when the distension technique is employed. Variations in normal anatomy include widened or narrowed sac or duct, diverticulum, angulations of the system, or occlusions of one canaliculus, all of which may give false-positive indications of pathology. The test does not easily visualize the canalicular system without intubation distension and subtraction, and gives no information concerning physiological function. Nevertheless, DCG gives the most reliable anatomic information of the sac and duct. In certain cases the addition of CT or MRI in conjunction with DCG will add useful information on soft tissue and bony abnormalities within and surrounding the nasolacrimal system that can affect management and help to plan surgical approach.

If clinical and radiographic evaluations fail to show an anatomic blockage, physiological dysfunction is probably responsible for the epiphora. Radionuclide dacryoscintigraphy is indicated here, especially when used with computer interfacing for qualitative evaluation of function. Subtle functional abnormalities may be uncovered, particularly in the proximal system. However, the physiology of lacrimal drainage is poorly understood. The function of Rosenmuller's and Hasner's valves is complex, their competency varies with age, and their patency is influenced by hydrostatic pressure and volume. The results of dacryoscintigraphy are influenced by head position, blinking, and volume overload. A significant number of asymptomatic individuals will show some dysfunction with this test, making interpretation in patients with epiphora more difficult.

In summary, most patients with epiphora can be evaluated adequately with a few relatively simple office procedures. A small number of cases will require more sophisticated studies to confirm the site of anatomic block or region of physiological dysfunction. With the range of tests available, appropriate medical or surgical management can be determined in the vast majority of patients with tear production and drainage imbalance.

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Primary External Dacryocystorhinostomy

8

Richard H. Hart, Matthew J. Allen, and Geoffrey E. Rose

The watering eye may be due to excessive tear production, abnormalities of lid position or movement, lacrimal canalicular pump failure, or obstruction of the outflow tract. With external dacryocystorhinostomy (DCR), the lacrimal sac is directly incorporated into the lateral wall of the nose, so that the canaliculi drain directly into the nasal cavity.

The aims of surgery are twofold: to eliminate fluid and mucus retention within the lacrimal sac and prevent sac enlargement (as a mucocoele)—the latter leading to intermittent viscous ocular discharge; to bypass the higher hydraulic resistance of the nasolacrimal duct, thereby increasing tear conductance and aiding the relief of epiphora.

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Indications for Surgery

1. Primary acquired nasolacrimal duct obstruction
2. Secondary acquired nasolacrimal duct obstruction due, for example, to dacryolithiasis, endonasal surgery, inflammatory nasal or sinus disease, or prior midfacial injury
3. Persistent congenital nasolacrimal duct obstruction, often after unsuccessful probing or intubation of the nasolacrimal duct
4. Functional obstruction of lacrimal outflow with decreased tear conductance due to
   (a) stenosis, but not occlusion, of the nasolacrimal duct
   (b) lacrimal canalicular pump failure from age-related laxity of the lower eyelid, or after facial nerve palsy
5. Acute or chronic dacryocystitis; the former group requiring initial treatment with systemic antibiotics

Surgical Principles

External DCR should establish a low-resistance drainage pathway between the conjunctival tear sac and the nasal cavity, by conversion of the lacrimal sac into part of the lateral nasal wall. Advantages of the external approach to DCR include

1. Sutured apposition and primary intention healing of mucosal flaps

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2. Preparation of a large osteotomy that facilitates future closed placement of glass canalicular bypass tubes, should this be required
3. Direct visualisation of abnormalities of the lacrimal sac—including stones, foreign bodies, or tumours
4. Provides ready access for the surgical management of canalicular disease; including canaliculo-DCR, retrograde canaliculostomy and intubation, or open placement of a canalicular bypass tube

Anaesthesia

External lacrimal surgery may be performed under local or general anaesthesia, usually as a daycase procedure, and both the patient and surgeon may have a preference for either technique.

Local Anaesthesia

Prior to the administration of local anaesthesia it is often beneficial to commence sedation in order to enhance the comfort of the patient. Sedation will also have the added benefit of reducing both the patient's heart rate and blood pressure throughout the procedure, thereby assisting with the control of haemostasis.

Sedation is provided by the anaesthetist and usually includes a benzodiazepine (such as midazolam) and an opiate (for example, alfentanil), which may then be combined with a low-dose target-controlled propofol infusion. The patient should receive supplemental oxygen and be closely monitored for signs of respiratory depression or airway obstruction, and those receiving sedation should be starved as for a general anaesthetic.

The anterior nasal space is then sprayed with 4 % lignocaine and packed with about 60 cm of 12 mm ribbon gauze pre-soaked in 2 mL of a 4 % (or 10 %) solution of cocaine; this pack providing effective nasal anaesthesia and mucosal vasoconstriction. Using angled nasal-packing forceps, successive loops of ribbon gauze are stacked anteriorly to each of the previously placed loops and the packing should be deliberately placed above, and in front of, the anterior end of the middle turbinate.

A mixture of 0.5 % bupivacaine with 1:100,000–1:200,000 epinephrine is used for local anaesthesia: 2–3 mL of this solution is placed in the orbicularis muscle of the medial one-third of the lower eyelid and about 2–3 mL infiltrated medially within the orbit, around the anterior ethmoidal branch of the nasociliary nerve. The intraorbital injection is given by passing a 27G needle through the skin at a point 5 mm above the medial canthus, and heading about 20° caudally from the axial plane—thereby reducing the risk of piercing the anterior ethmoidal vessels.

Giving the infiltrative local anaesthesia before the surgeon scrubs allows enough time for the epinephrine-mediated vasoconstriction to occur before the start of surgery and topical anaesthesia, such as proxymetacaine 1.0 % and tetracaine 0.5 % drops, are instilled into both eyes at the time of skin preparation.

Advantages of Local Anaesthesia

1. Haemostasis due to the vasoconstriction from injection of local anaesthetic solutions containing epinephrine
2. Avoidance of general anaesthetic risk in the elderly, or in patients with significant comorbidities

General Anaesthesia

General anaesthesia traditionally signalled a need for inpatient care, but, with the development of short-acting anaesthetic drugs, it has become possible to perform daycase surgery under general anaesthetic. Rapidly reversible anaesthesia and hypotension are beneficial for lacrimal surgery, especially in the daycase setting, and a number of well-tested techniques have been described.

With the advent of total intravenous anaesthesia, using a combination of propofol and remifentanil, it has become possible to readily provide ideal

operating conditions whilst enabling the patient to wake up quickly and smoothly following surgery with a lower incidence of postoperative nausea and vomiting. Remifentanil is a powerful, ultra short-acting, synthetic opiate which, in addition to providing profound analgesia, causes bradycardia and hypotension. Unless contraindicated, both the propofol and remifentanil infusions can be reliably adjusted to produce a state of controlled hypotension in order to minimise the presence of blood in the operative field. If the facilities or expertise do not exist for total intravenous anaesthesia then it would be reasonable to use a combination of volatile anaesthetic agent and opiate for maintenance.

After placement of ECG leads, noninvasive blood pressure monitoring and pulse oximetry, general anaesthesia can be induced. Following a dose of a suitable muscle relaxant, the patient can be intubated, ensuring that sufficient time has passed so that the patient is fully relaxed and unlikely to cough, as a rise in venous pressure at this stage encourages subsequent bleeding during surgery.

Endotracheal intubation is often employed due to the risk of pharyngeal soiling with blood during surgery, however, where a surgeon is well-versed in open lacrimal surgery (where bleeding might be minimal), the experienced anaesthetist may choose to place a laryngeal mask airway (LMA) as emergence from anaesthesia is often smoother; an LMA should be avoided in the obese patient, those with significant gastro-oesophageal reflux disease or those where there is a greater risk of haemorrhage—as with revisional surgery or the hypertensive patient.

The patient should be ventilated throughout the procedure with a mixture of air and oxygen to maintain a $PaCO_2$ of 4.0–4.5 kPa which will help reduce arteriolar vasodilatation.

The patient is placed on the operating table with a head-up tilt of at least 10–15° to reduce venous congestion at the operative site. After preparation of the sterile field, vasoconstriction of the nasal mucosa may be encouraged by the placement of three cotton-tip buds, moistened with 0.1 % epinephrine solution, anterior to the middle turbinate.

Universally it appears that bleeding during external lacrimal surgery becomes negligible once the systolic pressures drop below 80–90 mmHg. If required, additional means to reduce the blood pressure intraoperatively may be employed, such as the use of magnesium sulphate or a short-acting beta-blocker (such as labetolol), and other agents may also be considered (for example, hydralazine, clonidine or glyceryl trinitrate)—the choice of which is often personal. Local anaesthetic infiltration of the operative site prior to skin incision will reduce the noxious stimulation that normally raises systemic blood pressure; in the authors' experience, administration of local anaesthesia greatly reduces the requirement for systemic anaesthetic drugs, whilst simultaneously enhancing the ability of the anaesthetist to produce hypotension.

Prior to completing surgery it is very important that additional analgesia is given, as the remifentanil will not confer any analgesic benefit to the patient once the infusion has been terminated. These patients should, therefore, also receive intravenous paracetamol and a longer acting opiate such as fentanil (50–100 mcg) or morphine (5–10 mg). Nonsteroidal anti-inflammatory medications, such as diclofenac and ketorolac, are avoided because of their effects on platelet function that might increase the risk of postoperative bleeding.

Antiemetics are routinely given during surgery and often include dexamethasone (4–8 mg) and ondansetron (4–8 mg). By using the combination of these drugs with total intravenous anaesthesia, the incidence of postoperative nausea and vomiting is very low indeed.

At the end of surgery, the pharyngeal pack is removed and suction is applied with special attention given to the posterior nasopharynx. The patient is recovered in a semi-recumbent position and is extubated—or the LMA removed—once they are breathing spontaneously.

Advantages of General Anaesthesia

1. Controlled intraoperative hypotension with good control of operative bleeding

2. Preferred by many patients, who do not wish to be conscious during surgery, and helpful for the teaching of these procedures

Vasoconstriction and Haemostasis

Successful lacrimal surgery depends on a good, blood-free visualisation of tissues to permit accurate bone removal, mucosal apposition, and careful attention to the common canalicular opening to remove obstructive membranes or negotiate a retrograde canaliculostomy.

Several techniques help to encourage vasoconstriction and improve haemostasis:

1. With local anaesthesia
   (a) A nasal pack moistened with a 4 % or 10 % cocaine solution produces mucosal vasoconstriction, the pack being best left in place until the time of nasal mucosal suturing.
   (b) Supplementary intramucosal injection of local anaesthetic with 1:200,000 epinephrine may be used, but is rarely necessary during the procedure.
2. With general anaesthesia
   (a) Three intranasal cotton-tip buds moistened with 1:1,000 epinephrine and placed at, and above, the anterior end of the middle turbinate produces mucosal vasoconstriction in the operative field
   (b) Infiltration of local anaesthetic at the site of the skin incision
   (c) Controlled systemic hypotension, with typical pressures of 90/60 mmHg
3. General measures
   (a) Head-elevated (reverse Trendelenberg) posture reduces venous congestion
   (b) Use of a continuous suction device in the non-dominant hand helps maintain a blood-free field, viewing of tissues, and the displacement and protection of neighbouring structures during surgery
   (c) The careful handling of tissues, gentle diathermy of cut edges, suturing of mucosal flaps, and respect for surgical planes
   (d) The judicious use of bone wax for persistent haemorrhage from the cut edges of bone

Surgical Technique

A standard surgical skin cleansing and sterile draping is performed with access to the eye and nose; for local anaesthesia, the whole face can be exposed after complete facial cleansing.

Using a #15 blade to cut skin alone, a 12 mm incision—slightly shorter in children—is placed on the flat area alongside the nasion, beginning just above the level of the medial canthal tendon (MCT); positioning of a straight incision in the thicker paranasal skin helps prevent the late scar contracture and bridging often seen with posteriorly placed incisions. Lifting the lateral skin-edge anteriorly, the skin is separated from the underlying orbicularis muscle using blunt-tipped scissors until the MCT is evident (Fig. 8.1a). The union between preseptal and pretarsal orbicularis fibres is evident at the bony attachment of the anterior limb of the MCT, lateral to the angular vessels, and the two groups of fibres should be separated along this avascular junction using a Rollett's rougine (Fig. 8.1a). The surgical assistant should use a squint hook to anteriorly retract the preseptal orbicularis and angular vessels, whilst the surgeon uses the rougine to incise the periosteum—starting by disinsertion of the anterior limb of the MCT and continuing down the anterior lacrimal crest, using the sharp bone edge as a cutting edge beneath the instrument. The periosteum is raised widely—anteriorly alongside the nose—and posteriorly to elevate the lacrimal sac laterally within the lacrimal sac fossa (Fig. 8.1b). Using a right-angled periosteal elevator, the thin bone between the sac and anterior ethmoids is perforated at the suture line between the lacrimal bone and the frontal process of the maxilla. Occasionally the bone in the fossa is exceptionally strong and it may be necessary to thin the bone with a drill, trephine, or hammer and chisel prior to perforation; an alternative in this situation is to raise the periosteum to beyond the posterior lacrimal crest and then perforate the very thin lamina papyracea just behind the posterior lacrimal crest.

Once bone has been breached, bone removal should proceed anteriorly across the anterior lacrimal crest and this can be most readily achieved with a Kerrison-style rongeur, crossing the crest

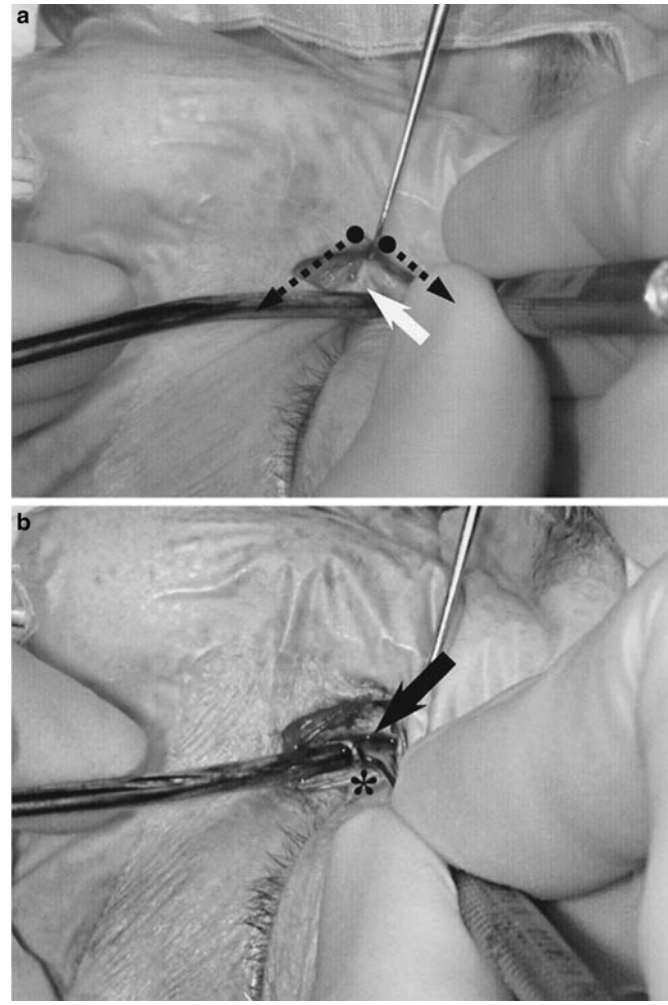

Fig. 8.1 (**a**) The left medial canthal tendon is readily evident (*white arrow*) after undermining the skin and the pretarsal and preseptal orbicularis fibres separated superolaterally and inferolaterally (*broken arrows*). (**b**) A rougine is passed behind the anterior lacrimal crest (*arrow*) to displace the lacrimal sac (*) laterally from its bony fossa

close to the skull base—this being the thinnest bone on the crest and also reducing the chance of damage to the nasal mucosa (Fig. 8.2a); a periosteal elevator should be swept around the bone edge (every two or three bites) to separate the nasal mucosa from underlying bone. Nasal mucosa is reached as the anterior lacrimal crest is crossed and, at this point, it is best to slightly withdraw the epinephrine-moistened cotton buds and they may be readvanced to the apex of the nasal space once the bone removal is complete. Once across the anterior crest, bone removal should be directed inferiorly to the level of the inferior orbital rim—creating an 'L'-shaped rhinostomy. The remaining bone of the frontal process of the maxilla is removed, either with down-cutting rongeurs or straight (Jensen) bone-nibblers, the lacrimal sac tissues being protected by displacing it laterally with the sucker held in the non-dominant hand. The thin hamular process of the lacrimal bone, between the upper part of the nasolacrimal duct and nasal mucosa, is removed with bone-nibblers and the upper part of the rhinostomy is extended to the skull base, although care should be taken here to avoid shearing forces that may fracture the cribriform plate and cause a cerebrospinal fluid (CSF) leak. At this stage, the rhinostomy should be about 12–18 mm diameter and extend from the fundus of the sac at the skull base, up to 10 mm in front of the anterior lacrimal crest, and inferiorly to expose the upper part of the nasolacrimal duct (Fig. 8.2b).

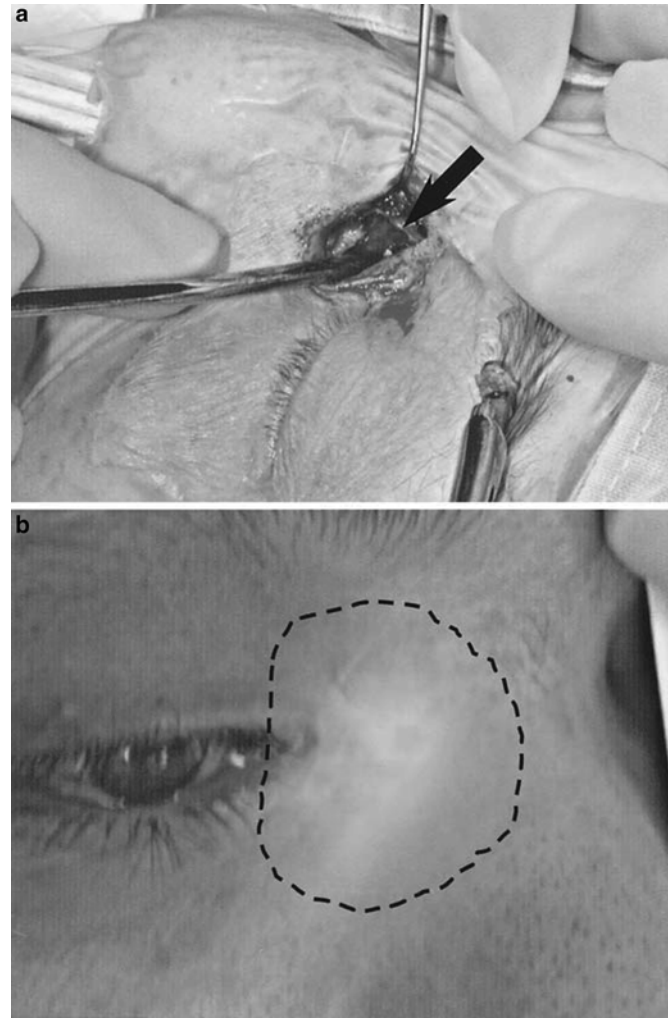

Fig. 8.2 (**a**) A large rhinostomy is being created during left DCR, after having creating a defect across the anterior lacrimal crest; the anterior cut edge of bone is evident (*arrow*). Note the presence of epinephrine-moistened cotton tips in the nasal space. (**b**) The final size of a typical osteotomy is outlined by endonasal transillumination

Anterior ethmoidectomy should be performed, using non-toothed forceps or a fine artery clip to palpate and avulse the fragment of bone and mucosa, as this creates a wide-open space that facilitates easy apposition and suture of the posterior mucosal anastomosis.

A '00' Bowman probe is passed into the lacrimal sac through the lower canaliculus, and the assistant maintains gentle medial pressure to "tent" the medial wall of the sac whilst the medial face of the sac is opened with a #11 blade; this blade should be directed away from the internal opening of the common canaliculus (Fig. 8.3a). Once in the sac, the closed blades of a Westcott spring scissor should *easily* pass into the lumen of the sac and duct (Fig. 8.3b); difficult passage commonly indicates that lacrimal fascia alone has been opened and the blades have entered the resistant sub-mucosal (extraluminal) plane. The entire sac is opened by extension of the blade incision in both directions (Fig. 8.3c)—from the fundus down to the duct and the sac is further opened with relieving incisions at the skull base above and the nasolacrimal duct below (Fig. 8.3d); cautery of the sac–duct junction is advisable before the relieving incisions, as there is a rich vascular plexus at this site.

The internal opening of the common canaliculus should be clearly visible and deliberately inspected (Fig. 8.3d): Where membranous

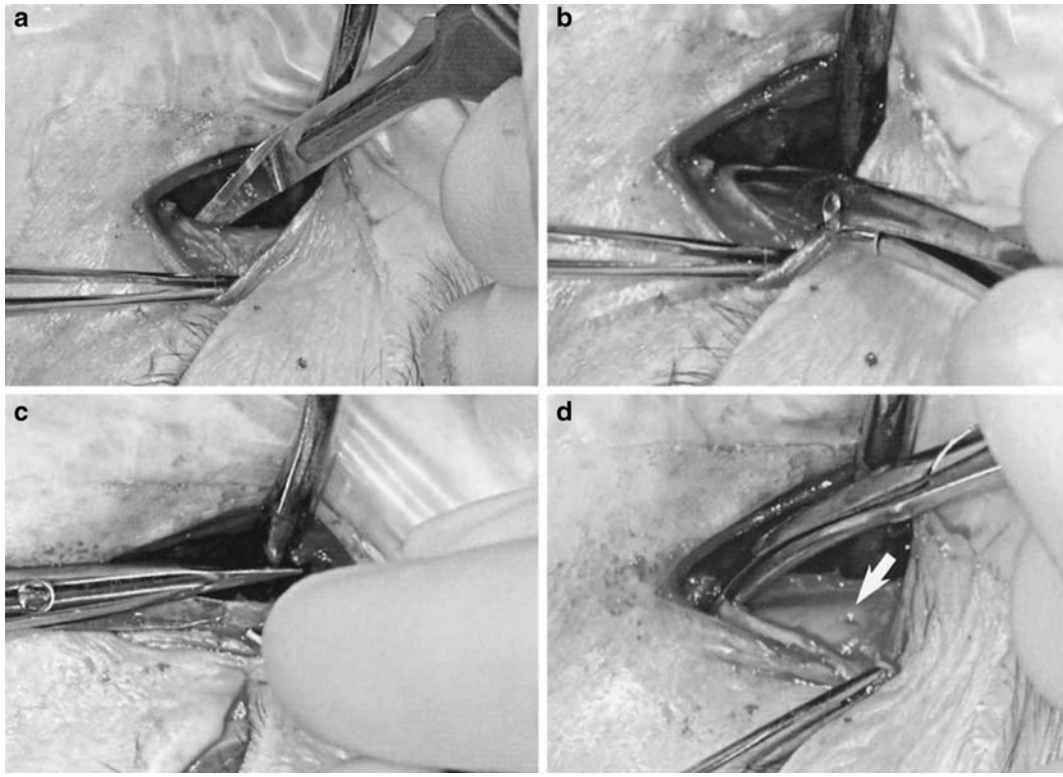

Fig. 8.3 (**a**) A #11 blade is used to make a small incision, below the level of the common canalicular opening, during left DCR. (**b**) The nasolacrimal duct is "sounded" with the closed spring scissors and the mucosal incision continued inferiorly into the upper end of the duct. (**c**) After likewise "sounding" upwards to the fundus of the sac, the mucosa is incised up to the skull base. (**d**) Relieving incisions are performed at the sac/duct junction and at the skull base, this leaving the sac opened widely and the internal opening of the common canaliculus readily evident (*arrow*)

obstruction is present, the adherent Valve of Rosenmuller should be excised by grasping it with a pair of fine, toothed forceps and excising about 1 mm^2 using a #11 blade. Likewise, biopsy of suspicious lesions within the sac, or removal of any debris (such as stones), is readily accomplished with the sac opened widely.

Using the #11 blade with the cotton buds protecting the nasal septum, the nasal mucosa is opened in a superior–inferior direction and the incision placed 3–4 mm anterior to the "arch" formed by the inflexion of the nasal mucosa into anterior insertion of the middle turbinate; this arch only being evident after anterior ethmoidectomy. The anterior flap is created by superior and inferior positioned relieving incisions (Fig. 8.4a) and the posterior flap similarly created after mucosal cautery. A 6-0 soluble suture (e.g., Vicryl W9756; Ethicon) is passed through the orbicularis muscle on the anterior lip of the incision and then through the middle of the free edge of the anterior nasal flap (Fig. 8.4b), the suture being clipped and draped across nasal bridge—this keeping the anterior flaps out of the surgical field during posterior suturing.

The posterior mucosal flaps are apposed—from the skull base (Fig. 8.5) to the entrance of the nasolacrimal duct—with a locked continuous 6-0 Vicryl suture and the suture secured by a triple locking throw. Silicone tubes are passed through the upper and lower canaliculi, retrieved through the incision using a curved haemostat, the metal bodkins removed, and the tubes tied over the shank of the closed haemostat resting across the incision (Fig. 8.6a). While the assistant holds both tubes elevated, a 2-0 silk ligature is

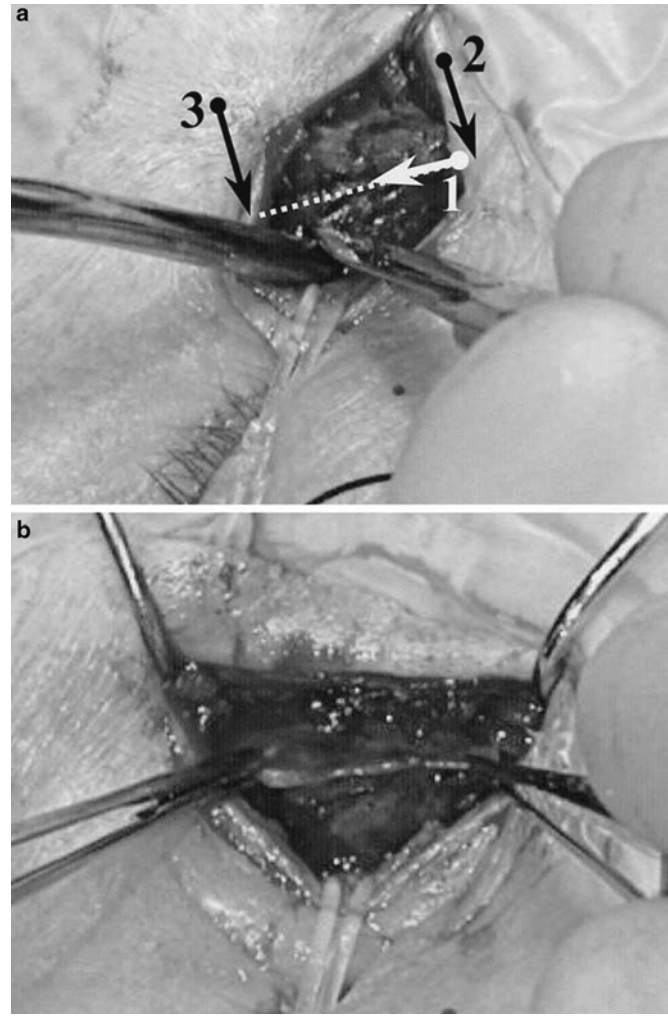

Fig. 8.4 (**a**) Fashioning a large anterior flap of nasal mucosa: the first incision—made using a #11 blade against intranasal cotton tips—is (anatomically) vertical, and the other two incisions pass anteroposteriorly along the edges of the osteotomy. (**b**) The resulting large nasal mucosal flap should be hung aside by a weighted suture placed across the nasal bridge

tied just above the silicone knot and the ends left about 15 mm long to facilitate identification within the nose; the tube ends are then passed into the nose and retrieved with a curved haemostat passed from the nasal entrance (Fig. 8.6b).

Closure of the anterior mucosal flaps is best accomplished with three 6-0 Vicryl sutures using "suspension" from the orbicularis fibres: The most superior suture is passed successively through the medial orbicularis (avoiding the angular vessels), the edge of the anterior nasal flap, the edge of the anterior sac flap and finally through the anterior limb of the medial canthal tendon (Fig. 8.7a); the middle suture has already been passed through the anterior structures and only need be passed through the anterior sac mucosa; the inferior suture is finally passed through the various layers and the sutures all tied to close both the mucosa and the orbicularis in one manoeuvre. The skin is then closed with a running mattress 6-0 nylon suture (Fig. 8.7b), antibiotic ointment instilled in the eye and a firm, non-adhesive pad placed on the incision for 12–24 h. The silicone tubes are left long and taped to the dressing, until trimmed just prior to hospital discharge—this permitting easier nasal packing if necessary in the unlikely event of primary haemorrhage.

If no contraindications exist, cefuroxime (typically 750 mg) is given intravenously during surgery to reduce the risk of postoperative wound infection.

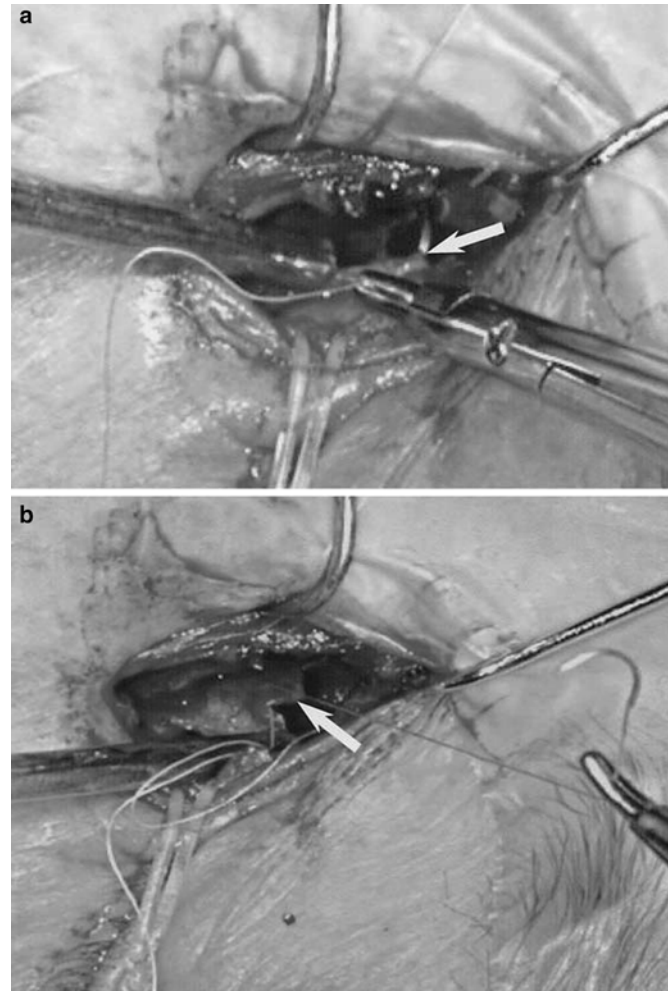

Fig. 8.5 (**a**) Prior anterior ethmoidectomy facilitates suturing of the posterior mucosal flaps using an 8 mm diameter, half-circle needle—here being passed through the upper end of the posterior sac flap (*arrow*). (**b**) The posterior nasal flap (*arrow*) has just been engaged to start the sutured anastomosis that should extend from the skull base to the sac/duct junction

Postoperative Care

The patient should rest for a few hours after surgery, seated half-reclining to reduce nasal venous congestion, and hot drinks and food avoided for about 12 h to reduce the chance of epistaxis due to heat-induced nasal vasodilation.

The dressing may be removed at home on the first postoperative day and a combined topical antibiotic/steroid used 3–4 times a day. To reduce the low risk of secondary haemorrhage, the patient is asked to avoid nose blowing for a week. The skin sutures are removed at about 1 week and the silicone stent at about 4–5 weeks, when epithelial healing is complete (Fig. 8.8).

Complications

1. Intraoperative
   (a) Haemorrhage
      - For troublesome intraoperative haemorrhage, use cautery to soft tissues and wax on the cut edge of bone
      - If persistent, try pressure packing the operative site for 5 min with an epinephrine-moistened gauze
      - Consider packing the nasal space with an absorbable surgical cellulose sponge
   (b) Canalicular injury
      - May be avoided by gentle handling of probes and stents during surgery

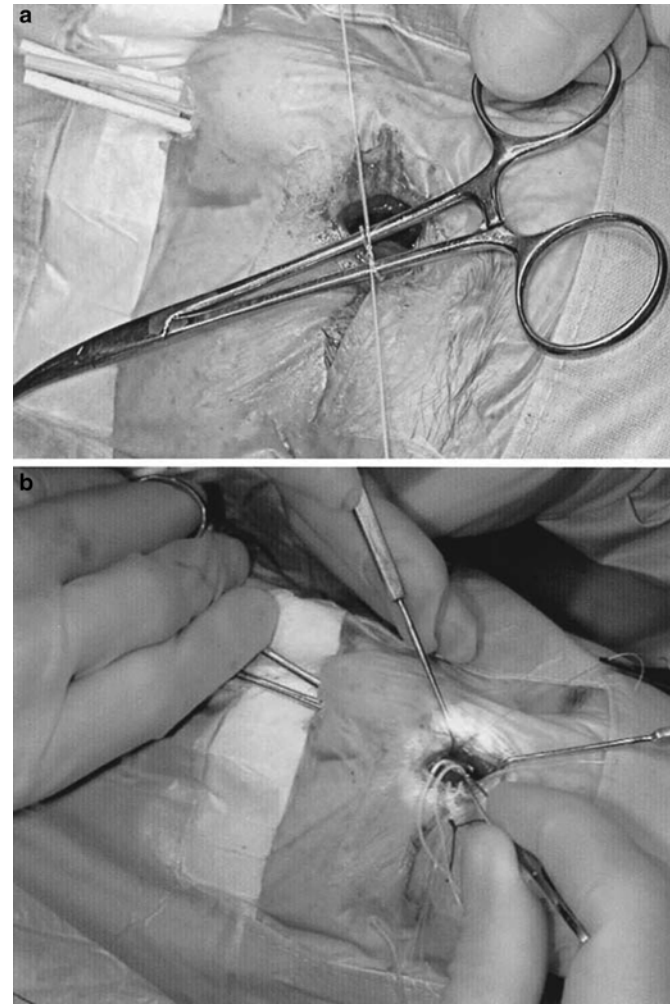

Fig. 8.6 (**a**) Postoperative ride-up of intubation is almost unknown if the intubation is passed through the section and tied over the shank of an instrument. (**b**) The tied tubes are then retrieved in the jaws of an artery clip passed into the anterior nasal space

- When passing a probe or tube, ensure that the eyelid is held taut, to avoid a "concertina" effect in the canaliculus and creation of a false passage

(c) Cerebrospinal fluid leak
- Inadvertent fracture of the cribriform plate may rarely result in CSF leak
- Small leaks may be sealed by occlusion with a tiny slip of orbicularis muscle fibres
- Postoperative antibiotics should be administered and vigilance maintained for symptoms and signs of meningitis; a neurosurgical opinion might be sought in certain circumstances

(d) Inadvertent orbital entry
- Orbital fat prolapse may occur during ethmoidectomy or incision of the sac
- Traction on the orbital fat should be avoided to reduce the risk of motility disturbance or, more rarely, orbital haemorrhage

2. Postoperative

(a) Haemorrhage
- Simple measures, such as a head-up posture and nasal ice-packs, may be all that is required

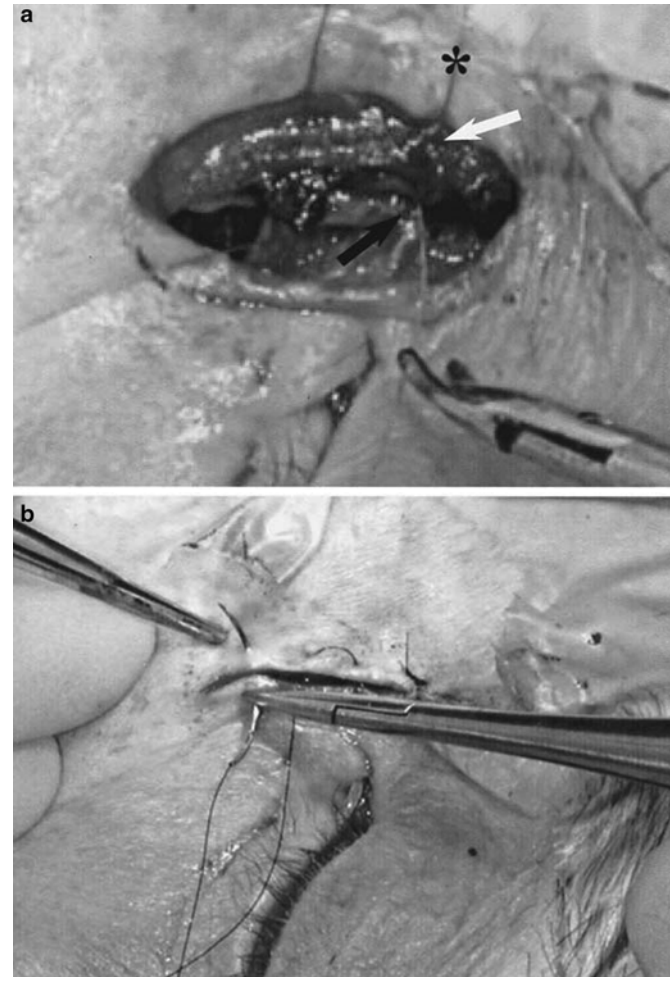

Fig. 8.7 (**a**) Three sutures are used to suspend the anterior mucosal union from the orbicularis muscle fibres: here the uppermost suture (*) has been passed through the anterior, preseptal orbicularis (*white arrow*), through the upper end of the anterior nasal and sac mucosa (*dark arrow*) and finally through the medial canthal tendon. (**b**) After suture of the deep tissues, the skin is closed with mattress 6/0 nylon

- If haemorrhage continues, pack the nose either with a commercial nasal tampon, or else with 12 mm ribbon gauze moistened in 1:1,000 epinephrine, and leave the pack undisturbed for 5 days. Oral antibiotics should be given for a week after haemorrhage

(b) Wound infection
- Prophylactic systemic antibiotics reduce the risk of wound infection
- A single intraoperative dose of a broad-spectrum antibiotic is as effective as a postoperative course of oral antibiotics
- Consider using postoperative antibiotics in the setting of preoperative infection, simultaneous bilateral surgery, with placement of a nasal tamponade, or with postoperative epistaxis

(c) Wound necrosis and fistula formation
- May occur in the setting of previous radiotherapy or overwhelming skin infections

(d) Stent prolapse or canalicular "cheese-wiring"
- With tying over the handle of forceps, prolapse is almost never encountered
- If prolapse should occur, the silicone tubes can be retrieved with nasal endoscopy in almost all cases
- Medial migration ("cheese-wiring") of stent arises where it is not passing

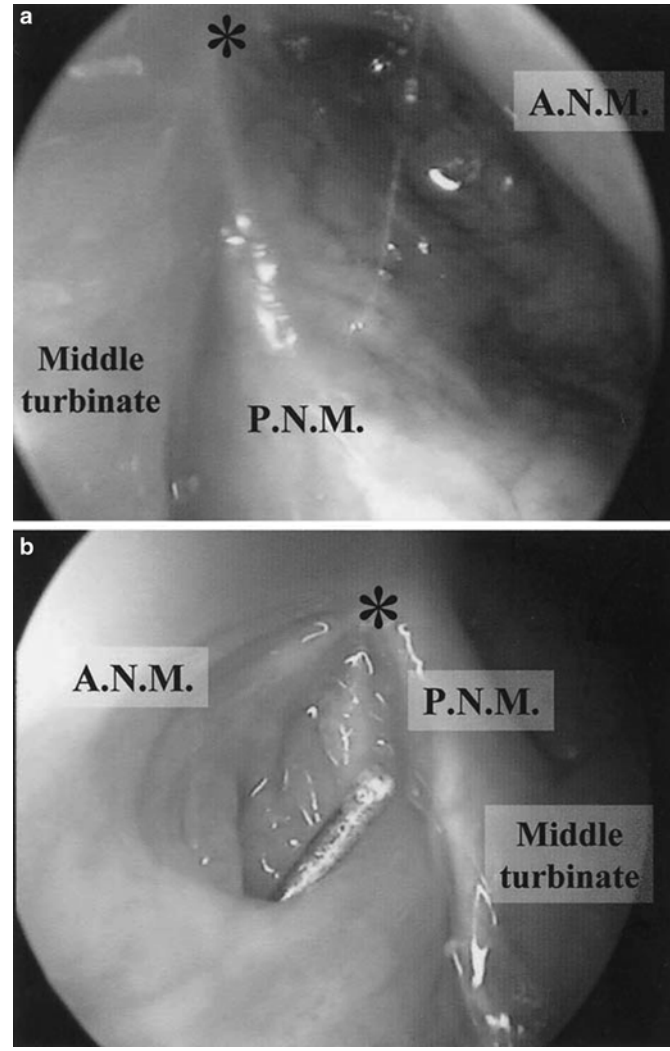

Fig. 8.8 Healed external DCR, showing (**a**) the left lacrimal sac opened widely to the nasal space and (**b**) a successful right-sided anastomosis, with intracanalicular probe. P.N.M. denotes posterior nasal mucosa; A.N.M. denotes anterior nasal mucosa; asterisk marks the area of secondary intention healing on the skull base

through the fibrous annulus of a lacrimal punctum—as, for example, after punctoplasty or retrograde canaliculostomy

(e) Hypertrophic scar or bowing of the incision
- Generally due to a posteriorly placed incision, in the concavity of the inner canthus (Fig. 8.9)
- May be exacerbated by excessive diathermy or placement of large numbers of subcutaneous sutures

(f) Failure of drainage
- Most often due to fibrosis at the site of a too small soft-tissue anastomosis
- If due to fibrous obstruction at the internal opening of the common canaliculus, this may be treated by transcanalicular trephination and intubation
- A redo-DCR may be required if there has been inadequate bone removal
- Failure due to canalicular obstruction at a more proximal level usually requires placement of a glass canalicular bypass (Lester Jones) tube

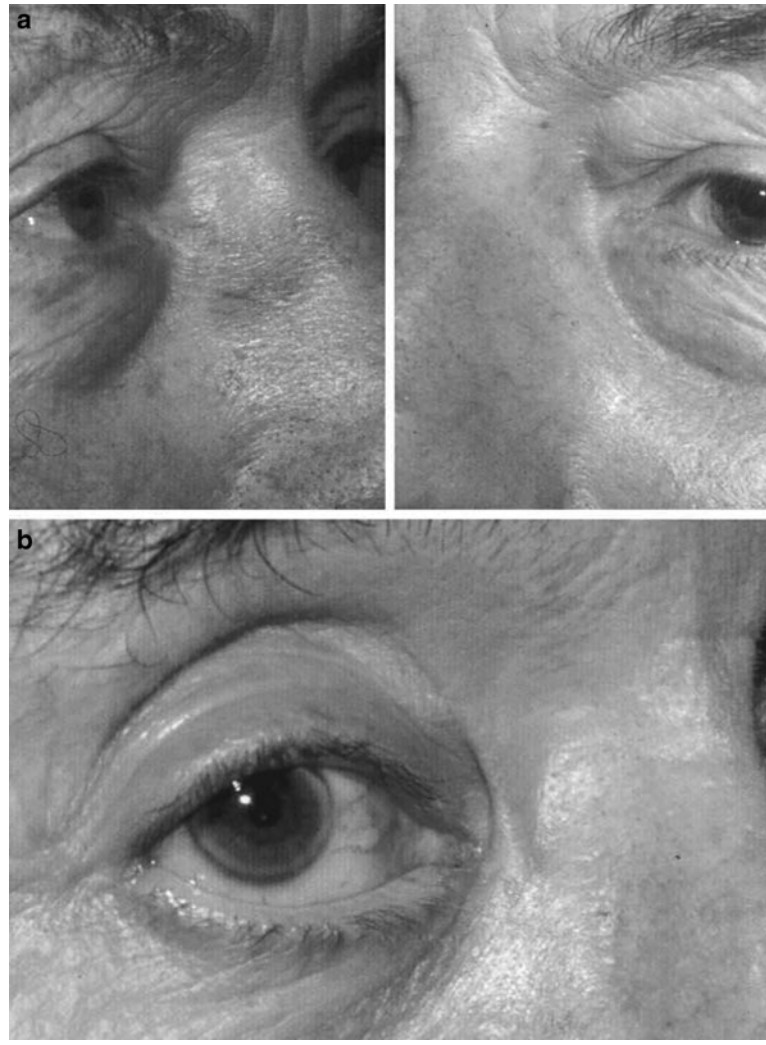

Fig. 8.9 (**a**) Well-placed incision for external DCR, with an "invisible" scar at 1 year after right-sided surgery. (**b**) Bowing of a DCR scar in the convexity of the inner canthus; this bowing being common with superior and posterior placement of the incision

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Radiofrequency Dacryocystorhinostomy

9

Reynaldo M. Javate and Ferdinand G. Pamintuan

Surgical specialists worldwide are rapidly acquiring expertise in radiosurgery or radiofrequency surgery. Many praise its superior results over conventional scalpel surgery. It is a, particularly, gaining ground in the field of ophthalmic oculoplastic and orbital surgery. The authors, for instance, have utilized radiosurgery in repair of upper lid retraction in thyroid eye disease, transconjunctival blepharoplasty, ptosis repair, endoscopic forehead lift, biopsy excisions, and orbital surgeries including procedures involving optic nerve gliomas, among others [1]. In this chapter, emphasis is given to the authors' evolving approaches to radiofrequency-assisted dacryocystorhinostomy (DCR) surgery.

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History

Ancient Egyptians evidently used heated metal instruments for surgical tissue destruction and hemostasis. Over recent centuries, electrosurgery emerged as a method to cut and coagulate tissues. The electrically heated, traditional platinum electrode wire produced residual tissue destruction, third-degree burns, prolonged healing, and poor cosmetic results. Low-frequency alternating current also caused muscle contractions in humans (the Faraday effect). In the late 1800s, Jacques d'Arsonval used high-frequency (>10,000 Hz) currents and a solenoid coil to heat tissues while avoiding the muscle spasms. In the 1920s, surgeon, George Wyeth, first used incisional electrosurgery, while William Bovie, a Harvard physicist, designed a machine for simultaneous cutting and coagulation of tissues. Today, the Bovie Cautery or Diathermy machine exists in practically every operating theater. Modern electrosurgical or diathermy machines have "step up" transformers to generate voltages higher than household, commercial current, and electric oscillating circuits to increase electric circuit oscillations.

In standard diathermy, a high-frequency electric current is passed through the patient. A "passive" electrode (large plate) is moistened and strapped to the patient's leg or back, and an "active" electrode is used to touch tissues. The electrical "density" of tissues determines the

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heating effect: current spread over a large surface area generates minimum heat, but current concentrated at a small point, produces enough heat to cut, coagulate, or destroy tissue. Dr. Irving Ellman, in 1975, patented a lightweight, solid-state radiosurgery instrument to filter fully rectified waves. Its handpiece transmitted a pure frequency signal of 3,800,000 cycles per second. Maness et al. confirmed that a filtered wave produces less tissue alterations and that the optimum frequency for cutting soft tissues was 3.8 million cycles per second (MHz) and this frequency is still used in modern radio-units.

Definition of Radiosurgery

High-frequency (500 kHz and 4 MHz) radio waves are transmitted through soft tissue from a handpiece (thin wire tungsten "active" electrode) and focused through soft tissues by a passive electrode (insulated ground plate/antenna plate that does not need contact with the patient) [2]. Water molecules in tissues exert a natural resistance to the passing radio signals, generating heat to volatize the cells. Sebben et al. described this sudden expansion of microbubbles of steam within the tissues, in effect, the passing electrode tip leaves a trail of cellular dehydration and destruction with virtually no hemostasis [3]. This cutting effect (electrosection) exerts no manual pressure or crushing since soft tissues split apart with razor-sharp precision. Alternatively, a coagulating current produces molecular oscillations to induce heat buildup that coagulates and dehydrates tissue without volatilization. This electrocoagulation is important for surgical hemostasis.

Comparison with Electrocautery, CO_2 Laser Surgery, and Incisional Surgery

Incisional surgery with the scalpel still remains the gold standard. It produces no thermal damage but does not provide hemostasis. Radiosurgery has been shown to be superior over electrocautery since it results in less lateral thermal damage to tissues. It also produces significantly less tissue damage than KTP, YAG or pulse CO_2 laser surgeries. An added advantage is that the electrodes are also self-sterilizing. Sebben et al. differentiated the two high-frequency modalities. In electrocautery, the filament resists an electric current passing through it and becomes red-hot. This heat (not the electric current) transfers from filament to the tissues. In electrosurgery (radiosurgery), electromagnetic radiation is passed to the patient and converted to heat due to the resistance offered by the tissue cells. While electrocautery operates optimally within the frequency range of 0.5–1.5 MHz, radiosurgery obtains best results within 3.8–4.0 MHz. There is less trauma to cells, less fibrous scarring, and less postoperative discomfort since a radiofrequency of 4 MHz is very gentle on the tissues with the active electrode remaining cold [2].

Radiosurgery Waveforms

A transformer in all radiosurgery units changes the main voltage input to a high-voltage, high-frequency current. Further filtering and rectification produces any of the following waveforms. A micro-smooth pure cut (fully filtered, fully rectified, 90 % cut/10 % coagulation) waveform is ideal for initial skin incisions, grafting, and biopsies where excess bleeding is not expected. This waveform gives the least tissue damage from lateral heat. A blended current (fully rectified 50 % cut/50 % coagulation) cut/coagulation waveform balances the minimal tissue injury of a pure cut with the hemostasis induced by coagulation as needed for subcutaneous dissections and lesion excisions (e.g., of verrucae, nevi, skin tags, papillomas, keloids, and keratoses) where slight bleeding is expected.

The authors, likewise, reserve this waveform for transconjunctival blepharoplasty. Direct/indirect, spot coagulation with minimal lateral heat spread requires a partially rectified (10 % cut/90 % coagulation) waveform to adequately control bleeding vessels up to 2 mm in diameter. The authors use this waveform in resection of orbicularis muscle and orbital fat in procedures

such as blepharoplasty, ptosis repair, correction of lid retractions, and lesions excisions (e.g., telangiectasias and spider veins). This is also used in external, mini-incision and endonasal dacryocystorhinostomy. Fulguration uses a spark gap current which generates significant lateral heat (similar to unipolar diathermy [Hyfrecator]) mainly used for electro-desiccation as in superficial hemostasis and destruction of small basal cell carcinomas or cysts. The bipolar waveform (1.7 MHz), which avoids tissue adherence to the forceps tip, is ideal for wet-field cautery, very precise hemostasis, and for control of individual bleeding vessels in microsurgery.

Electrodes

There are different types of electrodes available for use with the radiosurgery units. The choice of electrode is dependent on type of surgery to be performed, anticipated bleeding, and desired cosmetic results. There are extra fine empire electrodes (for thin skin incisions with very minimal scarring), fine wire electrodes (for extremely fine excisions and incisions), round loop electrodes (for excision of small lid neoplasms/biopsy specimens from bigger neoplasms), triangular or oval loop electrodes (for excision of pedunculated and raised skin lesions), and ball electrodes (for coagulation).

The authors use the endoscopic forehead lift electrode for endoscopic radiofrequency-assisted forehead (ERAF) lift. The Javate DCR electrodes (Fig. 9.1), on the other hand, are preferred for endonasal DCR, while the fine wire electrodes and extra fine wire empire electrodes are preferred for mini-incision DCR, and standard-external DCR [4, 5].

Radiosurgery in DCR

The authors use the Ellman Surgitron Dual RF (3333 Royal Avenue, Oceanside, NY) and all settings and waveforms refer to this machine. For over 10 years, the initial techniques have undergone several modifications that have helped achieve surgical success [6].

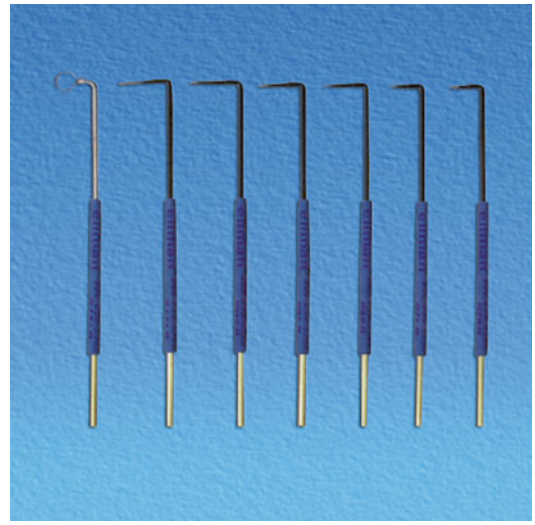

Fig. 9.1 The Javate DCR electrodes (from Javate et al. [5])

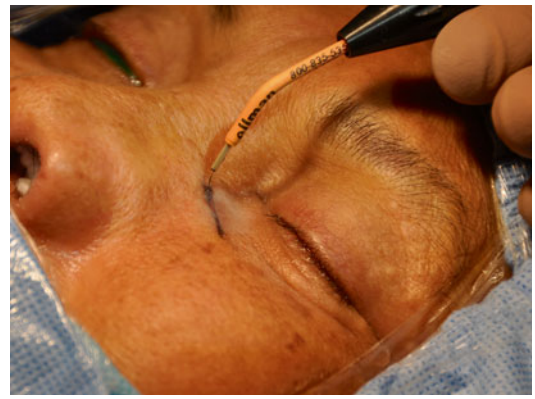

Fig. 9.2 Skin incision using fine wire electrode in the cut mode (from Javate et al. [5])

External DCR and Mini-incision DCR with the Radiofrequency Unit

In external DCR, the authors reserve radiosurgery for skin incisions, creation of lacrimal sac and nasal mucosal flaps, and hemostasis. They recently introduced the mini-incision DCR [7] for better cosmetic results. The Javate DCR electrode (attached to the Surgitron unit, set in the cut mode) is used to make an 8–10 mm incision set about 7–8 mm below the lower lid margin (Fig. 9.2). It starts from at a point slightly inferior to the medial canthal tendon, extending just into the anterior lacrimal crest, and continuing laterally in a

horizontal direction following the periorbital relaxed skin tension lines. This offers less bowstringing and postoperative scarring in contrast to incisions positioned 3–4 mm beneath the lower lid margin which can cause ectropion from wound contracture or orbital fat prolapse when incisions are placed just above the orbital septum [8]. Radiofrequency also provides excellent hemostasis since individual bleeding points are controlled by the electrodes. Tissue anatomy is not obscured by hemorrhage, thereby providing better visualization and shortened operative time. Patients wearing spectacles also report greater comfort immediately after mini-incision DCR surgery. This is not only due to less postoperative pain and inflammation but also the spectacle nose-pads usually do not rest on the resulting incision site. The rapid postoperative recovery allows an earlier return to normal daily activities and work.

Blunt scissors are then used to dissect down to the anterior lacrimal crest. Bleeders are coagulated to markedly decrease postoperative periorbital ecchymosis. The DCR electrode is then used to incise through the periosteum overlying the anterior lacrimal crest. After the osteotomy is created, the nasal mucosal flaps are made using the electrode set in coagulation mode.

The posterior flaps of the sac and nasal mucosa are apposed with one or two interrupted sutures using 6-0 polygalactin sutures (Vicryl). The suture is set in place with a backhand throw from the lacrimal sac to the nasal mucosal posterior flap.

Once the posterior flap is prepared, a bicanalicular silicone tube Crawford Bicanaliculus Intubation Set (S1-1270u, FCI, 20–22 rue Louis Armand, 75015 Paris, France) is needed to intubate the nasolacrimal fistulae (Fig. 9.3). The ends of the tube are secured in place by a series of two square knots followed by silk 5-0 sutures; after which, the ends are trimmed to appropriate length without extending beyond the nose orifices [5]. Recently, the FCI Nunchaku Self-retaining Bicanalicular Nasal Intubation (S1-1371 Nunchaku105mm, FCI, 20–22 rue Louis Armand, 75015 Paris, France) is used for bicanalicular silicone intubation. The FCI Nunchaku is a pushed silicone self-retaining bicanaliculus intubation stent that acts like a conformer, allowing tears to be drained by capillary. From a technical perspective, pushed nasolacrimal intubation is much simpler than the traditional pulled types of nasolacrimal intubation. The metallic guide is located inside the lumen, not as an extension of the stent as in conventional intubation sets (Fig. 9.4). The stability is guaranteed by the design of the silicone tubes. What's great about it is no knots, sutures, or retinal buckles that collect dirt and form incrustation with mucoid material are needed at the end of the procedure (Fig. 9.5a, b) and no retrieval from the nose is needed.

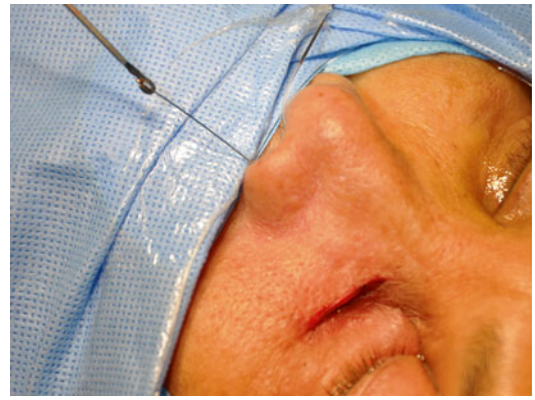

Fig. 9.3 Stent retrieval using a Crawford hook (S1-1270u, FCI, 20–22 rue Louis Armand, 75015 Paris, France) (from Javate et al. [5])

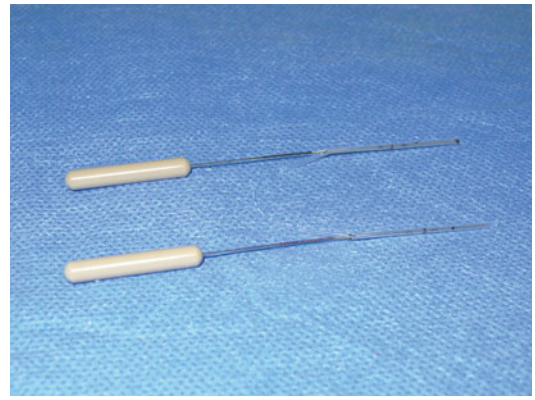

Fig. 9.4 The FCI Nunchaku Self-retaining Bicanalicular Nasal Intubation. The metallic guide is located inside the lumen which gives rigidity to the Nunchaku tubes (S1-1371 Nunchaku105mm, FCI, 20–22 rue Louis Armand, 75015 Paris, France)

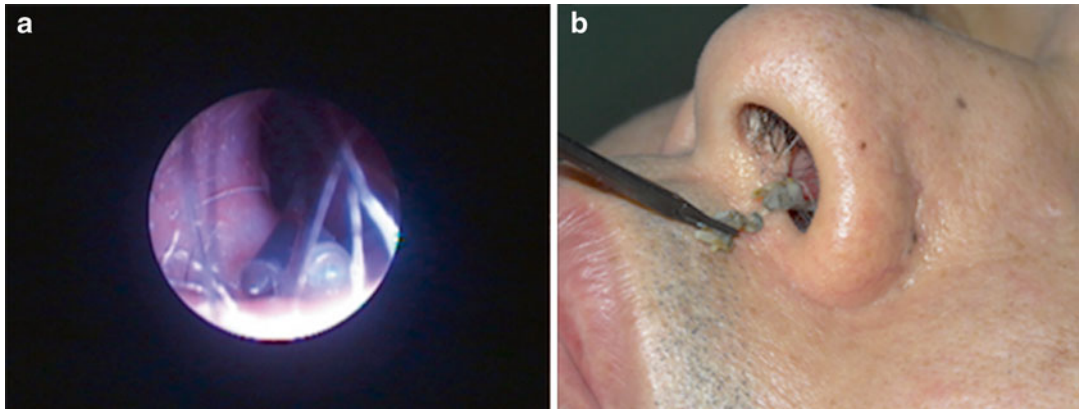

Fig. 9.5 Ends of the FCI Nunchaku Self-retaining Bicanalicular Nasal Intubation. No need to make knots and sutures in the nasal fossa (**a**). Ends of the conventional intubation set in the nasal fossa secured by 5-0 silk sutures with incrustation with mucoid material (**b**)

Anastomosis of the anterior flaps created from the nasal mucosa and the lacrimal sac is performed using 5-0 polygalactin sutures (Vicryl). A 6-0 nylon suture is used for closure of the skin incision using either continuous running or subcuticular suturing.

Postoperative Care in Mini-incision DCR

The patient's incisional wound is covered with a steri-strip. An ice compress is applied continuously over the operative site for 24 h postsurgery. Oral antibiotics are prescribed for 7 days and topical antibiotic-steroid eye drops instilled four times a day for 2 months. On the second to sixth postoperative month, silicone tubes are removed on a case-to-case basis.

Endoscopic Follow-Up Documentation After Mini-incision DCR

Postoperative healing of the intranasal ostium following mini-incision DCR can be properly documented with endoscopic imaging using HOPKINS II Rhinoscopes 0° and 30° (Karl Storz GmbH and Co., Tuttlingen, Germany) and Karl Storz Medi Pack NTSC 200431 20, all in one camera system, during postoperative follow-up of patients (Fig. 9.6a, b) [5].

Endoscopic Radiofrequency-Assisted Dacryocystorhinostomy (ERA-DCR)

A patient undergoing ERA-DCR is placed in a supine position with the head slightly elevated to decrease venous pressure at the operative site. Although local anesthesia is an option, general endotracheal anesthesia is preferred because of the copious volume of irrigation used to completely irrigate the mitomycin from the nasal passage. Nasal preparation includes packing with cotton soaked in 0.05 % oxymethazoline hydrochloride along the lateral nasal wall to initiate mucosal decongestion. A 4-mm 0° rigid Karl Storz Hopkins endoscope (Karl Storz GmbH and Co., Tuttlingen, Germany) is used for visualization as submucosal injection of 2 % lidocaine hydrochloride with epinephrine (1:100,000) is placed in the middle turbinate and the lateral nasal wall just anterior to the attachment of the turbinate. In some patients, the middle turbinate limits access to the lacrimal sac fossa. In such patients, the middle turbinate is infractured medially instead of removing its anterior portion. The entire procedure is performed with a video camera attached to the endoscope. The assisting surgeon is able to observe the surgery on a video monitor.

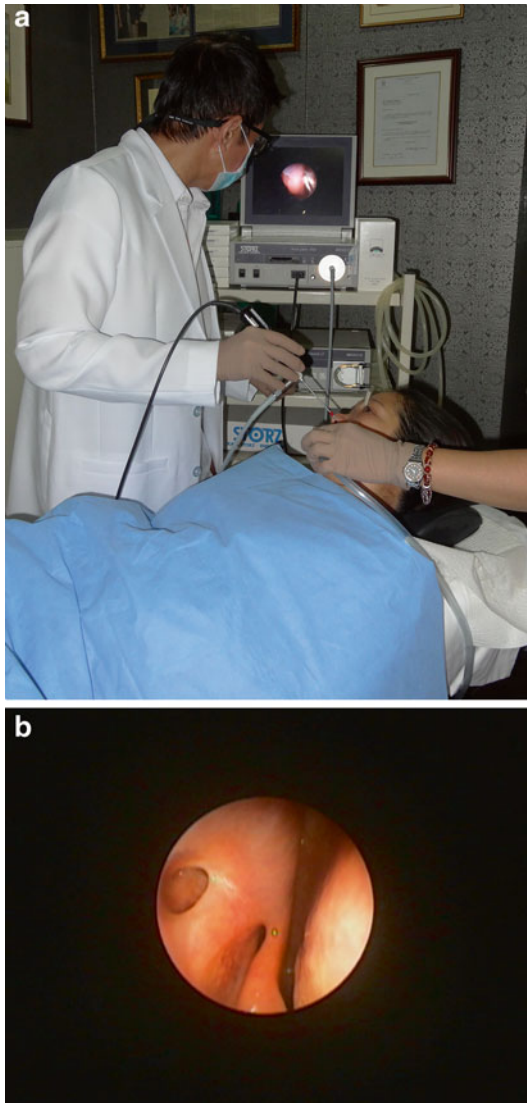

Fig. 9.6 Postoperative follow-up using rigid HOPKINS II endoscope and Karl Storz Medi Pack NTSC 200431 20, all in one camera system (Karl Storz GmbH and Co., Tuttlingen, Germany) to visualize intranasal ostium (**a**). Endoscopic view of the intranasal ostium 6 months postoperatively (**b**)

A 20-G retinal light pipe lubricated with antibiotic ointment is inserted through the dilated superior canaliculus. In order to ensure that its tip reaches the most inferodependent portion of the lacrimal sac a 0° or 30° rigid Karl Storz Hopkins endoscope is introduced into the nose to visualize the area anterior to the middle turbinate. The light from the endoscope is then kept at minimum setting to enhance the illumination visualized from the retinal light pipe. A diffuse glow indicates inadequate apposition of the light pipe to the lacrimal bone. A discrete area of light marks the intended area of rhinostomy along the lateral nasal wall. When the glow from the tip is adequately positioned at the posteroinferior wall of the sac (where the overlying bone is thinnest), the light pipe is held in place using sterile tape. The overlying mucosa is injected with the lidocaine–bupivacaine–epinephrine solution under endoscopic guidance. A 20-mm area of this nasal mucosa is incised using an assortment of electrode points of varying lengths (Javate DCR electrodes) with the Surgitron Dual RF, set in coagulation mode at a power setting of 50–60 (Fig. 9.7). In the past, the authors used the straight electrode for this step. However, they have recently adapted the loop electrode for scraping the nasal mucosa with greater facility. The incised mucosa is then lifted off with a Freer periosteal elevator.

The initial puncture into the intended rhinostomy site is made with a curette and the ostium is further enlarged to a 10- to 15-mm diameter size using a Kerrison punch. This rhinostomy includes part of the frontal process of the maxilla (anterior lacrimal crest).

A retinal light pipe inserted into the lacrimal sac facilitates the demarcation of the posterior–inferior and anterior–inferior walls of the sac through visible indentations. These indentations ensure that incisions in these areas made with the Javate DCR electrodes will create the ideal 5–10 mm openings. A lacrimal sac that is difficult to visualize (e.g., because of cicatrization) is dilated with Aquagel Lubricating Gel (Parker Laboratories, Inc., Fairfield, NJ, USA) introduced through the canaliculus to help prevent injury to the common canaliculus during incision. Shorter DCR electrodes are used for normal-sized or enlarged lacrimal sacs, whereas the longer electrodes are necessary to reach cicatrized lacrimal sacs. Additional marginal sac tissue is removed with a Blakesley nasal forceps. The Javate DCR electrodes and the Blakesley nasal forceps, when used under endoscopic visualization, permit the direct biopsy of the lacrimal sac, not possible in cases performed with laser DCR.

Fig. 9.7 A 4-mm 0° rigid Karl Storz Hopkins endoscope is introduced into the nose to visualize the area anterior to the middle turbinate. Javate DCR electrode connected to Surgitron Dual RF is used to incise a 20-mm area of nasal mucosa (from Javate et al. [5])

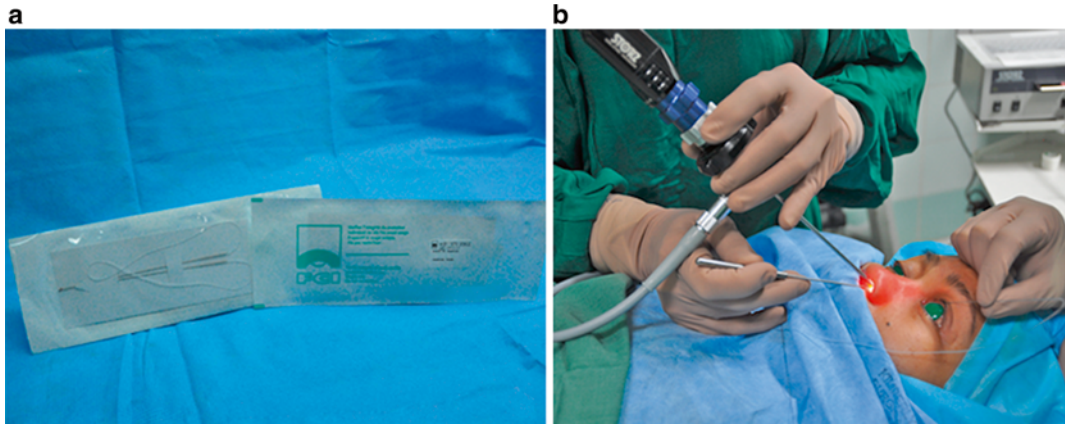

Fig. 9.8 A Crawford bicanaliculus intubation set (S1-1270u, FCI, 20–22 rue Louis Armand, 75015 Paris, France) is utilized for bicanalicular silicone intubation of the nasolacrimal fistula (**a**). Bicanalicular silicone intubation through the superior and inferior canaliculi (**b**) (from Javate et al. [5])

Once the nasal mucosa, rhinostomy, and lacrimal sac openings are judged adequate in size, cotton balls soaked in a 0.5 mg/mL solution of mitomycin-C are applied for three minutes over the surrounding mucosa with the purpose of inhibiting fibroblastic proliferation. Residual mitomycin is then copiously irrigated from the operative site and nasal cavity with sterile normal saline [4, 9]. Bicanalicular intubation of the nasolacrimal fistula is completed using a Crawford Bicanaliculus Intubation Set (S1-1270u, FCI, 20–22 rue Louis Armand, 75015 Paris, France) with a retriever device to bring the tubes out through the external nares (Fig. 9.8a, b). A Griffiths nasal catheter (Griffiths Nasal Catheter 5206), with the probes of the canalicular tubes passed through it, is pushed superiorly through the nostril to straddle the bony opening using alligator forceps [10]. This is a nasolacrimal catheter designed for

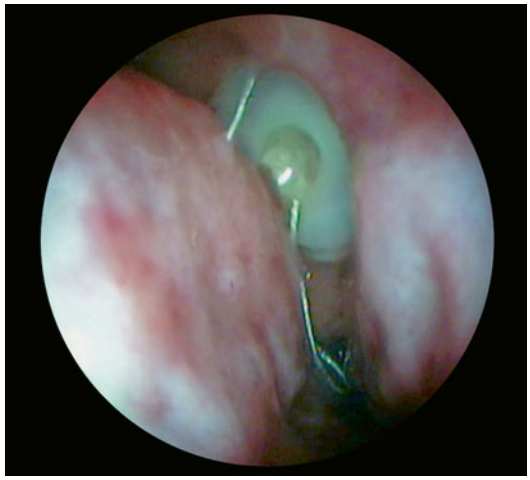

Fig. 9.9 Endoscopic photograph showing bicana licular silocone tubes emerging from the central lumen of the Griffiths nasal catheter

temporary retention in the lacrimal fossa to ensure the patency of the intranasal ostium (Fig. 9.9). The canalicular tubes are tied into two square knots, further secured by a 5-0 silk suture, and cut to an appropriate length within the nose. Patency of the fistula is then confirmed endoscopically through visualization of lacrimal irrigation around the silicone stents in the nose. Oxidized, regenerated cellulose is placed at the tip of the middle turbinate with a bayonet forceps to control operative and postoperative hemorrhage. The material absorbs spontaneously. Table 9.1 details the different instruments that the authors use for a usual case of ERA-DCR.

Table 9.1 Instruments used in ERA-DCR

1. Headlight (Karl Storz Tuttlingen, Germany)	11. Retinal light pipe
2. Bayonet forceps	12. Javate DCR electrodes (3333 Royal Avenue, Oceanside, NY)
3. Nasal speculum	13. Suction machine (Vapor-Vac Ellman International, Inc.) with tip
4. Cotton balls	14. Bone curette
5. Oxymethazoline hydrochloride 0.05 % solution	15. Kerrison punch
6. Spinal anesthesia needle	16. Crawford bicanaliculus intubation set (S1-1270u, FCI, 20–22 rue Louis Armand, 75015 Paris, France)
7. Lidocaine 2 % with epinephrine (1:100,000) solution; lidocaine 4 % solution; bupivacaine 0.75 % solution	17. Mitomycin-C solution (2 mg/mL)
8. Karl Storz Hopkins 0° and 30° Rigid Endoscopes (Karl Storz GmbH and Co., Tuttlingen, Germany)	18. Corneal eyeshields
9. Karl Storz Blakesley nasal forceps	19. Griffiths Nasal Catheter No. 5206; Visitec
10. Aquagel (Lubricating gel, Parker Laboratories, Inc., Fairfield, NJ, USA)	20. Collagen absorbable hemostat 21. Suction tip

Postoperative Care

Postoperative regimen following both external DCR, mini-incision DCR, and ERA-DCR includes a broad spectrum oral antibiotic, antibiotic ophthalmic solution (Ofloxacin; Santen Pharmaceutical Co., Ltd. Osaka, Japan) applied topically four times daily, and nasal saline irrigation three times daily.

The postoperative care of patients after external DCR procedures is simpler, consisting of 3–4 follow-up visits where skin sutures and silicone tubes are removed at appropriate times. In contrast, endonasal DCR needs more frequent postoperative visits at intervals of 1–2 weeks. Lacrimal saline irrigation and meticulous endoscopic-guided removal of nasal debris and mucus at the rhinostomy site are performed when indicated. Steroid nasal spray (Fluticasone propionate Nasal Spray; Glaxo Smith Kline, Philippines), is during the first postoperative week. The Griffiths nasal catheter is removed 2–3 months after surgery, while the silicone tubes are removed 3–6 months after surgery (Fig. 9.10). Postoperative ostium patency is assessed by lacrimal irrigation and by endoscopic documentation of fluorescein dye flowing from the tear meniscus into the nose through the surgical

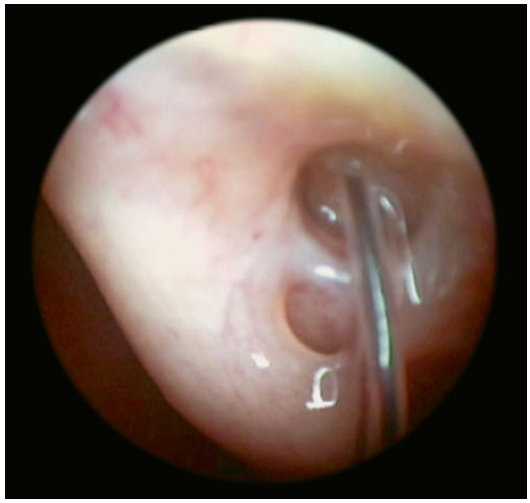

Fig. 9.10 Endoscopic photograph showing large, healed, intranasal ostium 2 months after removal of Griffiths nasal catheter and with bicanalicular silicone tube still in place

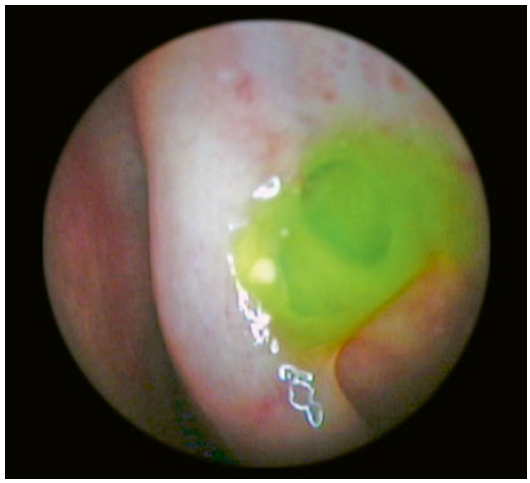

Fig. 9.11 Endoscopic photograph taken 1 year postoperatively showing fluorescein dye flowing through the surgical ostium after lacrimal irrigation

ostium (Fig. 9.11). Surgical success is further based on the relief of preoperative signs and symptoms of nasolacrimal obstruction.

The primary advantages of endoscopic lacrimal surgery (ERA-DCR) are elimination of external scarring and limited injury to the nasolacrimal fistula. Other advantages include less surgical trauma and bleeding, minimal operative and postoperative morbidity, rapid recovery, and patients' earlier return to work or school. ERA-DCR, likewise, allows the identification and correction of any intranasal pathology that may cause DCR failure, lacrimal sac biopsy under direct visualization, and success rates approaching 98 % [11] for long-term patency of the intranasal ostium.

Postoperative Complications

Any DCR procedure may present with possible complications. Epistaxis or infections in the nose or orbit are possible with the latter may requiring antibiotics. Adhesions between the intranasal ostium, the middle turbinate, and the nasal septum may be avoided by meticulous surgery and regular cleaning of the intranasal cavity at the site of the ostium created during endonasal DCR. Placement of the Griffiths nasal catheter, likewise, may lessen the incidence of these adhesions. Though ERA-DCR with the Griffiths nasal catheter may be complicated by granulation tissue formation between the nasal mucosa and the edge of the distal flange of the button, this is not necessarily associated with ostium occlusion. Cheese wiring of the canaliculi may occur if the stenting is too tight, necessitating stent loosening or removal. If the stent is too loose, however, prolapse of the stent onto the eye may occur, but may be avoided by tightening of the stent. Sump syndrome may occur if the rhinostomy is too small in size and high up in the lacrimal sac, causing tears and mucus to accumulate in the sac and to discharge onto the eye. Pyogenic granuloma may form at the puncta or the rhinostomy site if the tubing is left in place too long. This necessitates tube removal. Persistent watering or epiphora may indicate scarring of the rhinostomy and reoperation may be necessary.

Precautions in the Use of Radiofrequency Units

The radiosurgical instrument should never be used in the presence of flammable or explosive liquids or gases. It is contraindicated in patients

with pacemakers, unless prior clearance is given by their primary physicians or cardiologists and steps are taken to ensure that the pacemaker is shielded from the high-frequency interference. Whenever the electrode is changed, always remember to deactivate the handpiece by releasing pressure on the foot pedal avoiding injury to the surgeon, the patient, and other personnel.

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Primary Endonasal Dacryocystorhinostomy

10

Francois Codere and David W. Rossman

External dacryocystorhinostomy (DCR) has been the procedure of choice for many decades to treat nasolacrimal duct obstruction. The procedure, first described by Toti [1] at the turn of the century, has been refined over the years and is still currently adopted by most ophthalmologists. It consistently yields excellent results and can be routinely done under local anesthesia on an outpatient basis using minimal instrumentation. The intranasal approach to lacrimal surgery was first described by Caldwell in 1893 [2]; however, it quickly fell out of favor due to difficulties viewing the intranasal anatomy through the nose. Attention returned to the intranasal approach after Heermann in 1958 [3] introduced a direct technique for endonasal lacrimal surgery using an operating microscope which produced very good results [4]. Routine utilization of endoscopes by ENT surgeons led to renewed interest in approaching the lacrimal duct from the nose. The first modern endonasal DCR procedures using endoscopes were described by McDonogh and Meiring in 1989 [5]. Especially in America, early endonasal DCR techniques frequently included the use of lasers to burn through the mucosa and create the osteotomy [6]. However, the laser-assisted endonasal DCR yielded inferior results compared to the external route. This was likely due to the generation of excess granulation tissue and char around the ostium in the postoperative period [7]. Careful compliance to endoscopic surgical techniques with minimal tissue damage, the preservation of mucosa, and the creation of mucosal flaps has enabled this technique, in most cases, to become a positive alternative to external DCR with comparable outcomes [8].

Endonasal DCR has significant advantages over external DCR. It avoids a skin incision and scar, especially important in younger individuals or in patients with a history of keloid formation. Dissection is limited to the inner wall of the lacrimal fossa leaving intact the medial canthal anatomy and lacrimal pump function and avoiding a surgical site that goes from the skin to the nasal cavity. Postoperative pain is minimal, if at all present, and most patients can resume their normal activities a few days after surgery. The surgery requires less tissue dissection resulting often in less intraoperative bleeding and a shorter surgical time than external techniques [9]. Endonasal DCR can also be performed early to manage definitively acute dacryocystitis with abscess formation, minimizing the need to decompress the sac from the skin side [10].

There are also limitations. An anterior diverticulum arising from the lacrimal sac may not be

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effectively managed via the endonasal approach. Patients with a history of midfacial trauma may have altered anatomy involving the bones surrounding the lacrimal sac, making endonasal DCR hazardous with less predictable outcome. A lacrimal sac neoplasm is best treated with an external DCR. Finally, there is a steep learning curve with using the nasal endoscope that may hamper early success if proper training has not been obtained [9].

Patient Selection

The most frequent indication for endonasal DCR is chronic epiphora due to acquired dacryostenosis. Other indications include acute or chronic dacryocystitis with or without the presence of a dacryolith. The technique is useful in children with recurrent dacryostenosis despite probing and lacrimal intubation. In addition, endonasal DCR has produced good results in patients with functional nasolacrimal duct obstruction as determined by dacryocystography and lacrimal scintillography [11].

The investigation of the lacrimal system begins with the examination of the punctum to exclude agenesis, stenosis, ectropion, or any other abnormality. The medial canthal area is palpated to look for any firm mass that might represent a mucocele, dacryolith, or a tumor. If tumor is suspected or there is a history of midfacial trauma, further evaluation with CT-scan and or bone subtraction dacryocystography is necessary. Lacrimal system irrigation will confirm obstruction and allows the assessment of the common canaliculus and internal punctum as exploration of the common canaliculus cannot be performed easily during endonasal DCR.

Careful evaluation of the nasal cavity using an endoscope is crucial to assess the nasal access to the lacrimal sac. A large medial turbinate, nasal polyps, granular inflamed mucosa, tight nostrils, and septal deviations are all potential problems that can make endonasal DCR more difficult or impossible.

Preparation of the Nose

Preoperative vasoconstriction of the nasal cavity using a long acting nasal decongestant 2 h and 1 h prior to the operation helps visualization and minimizes intraoperative bleeding. Patients with seasonal allergies or with upper respiratory tract infections should wait for remission of their nasal congestion before having surgery. In cases of severe septal deviations, corrective surgery may be necessary before lacrimal surgery, either as a combined procedure or as a separate operation. However, in those patients with septal anomalies or tight nostrils, an external DCR is an excellent option that should be considered in most cases.

Anesthesia

Endonasal DCR can be performed safely under local or general anesthesia. Conditions favoring general anesthetic include acute dacryocystitis, prior surgery in the lacrimal area, difficult nasal anatomy with a tight access, and patient preference. However, in experienced hands and a normal nasal anatomy, local anesthesia can be offered making the procedure particularly suitable to an ambulatory care unit without a full recovery room.

In both types of anesthesia the lateral wall of the nose and middle turbinate are infiltrated with a solution of lidocaine 2 % with epinephrine 1:100,000 and the nostril is then packed with gauze soaked in either 5 % cocaine or a solution of neosynephrine 0.25 %–lidocaine 3 %. This induces long-lasting vasoconstriction and decongestion of the nasal mucosa allowing optimal visualization and minimizing bleeding. With local anesthesia, an anterior ethmoidal block from the orbital side along the medial orbital wall, 1–1.5 cm behind the medial canthal tendon, provides deep anesthesia of the sac area, the anterior ethmoids, and surrounding bones. The superficial tissues around the medial aspects of the lids should also be infiltrated and the cornea anesthetized with topical eye drops.

Surgical Equipment

It is mandatory when performing nasal endoscopic procedures to use proper high-quality instruments. A 4 mm, zero degree endoscope is the instrument most often used, although a 30° tip is useful for certain situations where an oblique view is necessary. A high-powered light source (Xenon) is essential to keep visualization at an optimal level. A high-resolution monitor at least 19 in. wide should be placed at the head of the patient and at eye level of the surgeon. A secondary light source is also necessary to transilluminate the lacrimal sac with a fiber optic probe.

Surgical Technique

The puncta are dilated and the fiber optic probe is gently inserted through the upper canaliculus and pass through the internal punctum into the lacrimal sac. The light probe will transilluminate the lacrimal sac through the thin lacrimal bone. The thicker frontal process of the maxilla does not transilluminate as well so that the anterior part of the transillumination corresponds to the lacrimal suture line. The position of the middle turbinate should be appreciated in relation to the position of the sac.

In some cases, the middle turbinate may be displaced medially using a Freer elevator to enhance exposure to the lateral nasal wall over the lacrimal area. A small ridge formed by the projection of the frontal process of the maxilla can usually be seen. A mucosal incision is made with a crescent blade or the sharp edge of the Freer elevator just anterior to that ridge below the insertion of the turbinate (Fig. 10.1). The incision is extended inferiorly for 10 mm and should go down to the bone and involve the mucoperiosteum. A Freer periosteal elevator is then used to elevate the nasal flap. To avoid damaging the mucosa, the Freer must be kept in continuous firm contact with maxillary bone while dissecting under the mucoperiosteum. Posterior incisions are then made at the superior and inferior margin of the mucosal flap using Yasargill scissors

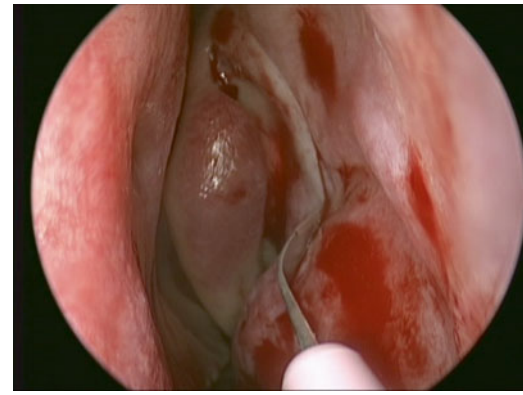

Fig. 10.1 Incision of the nasal mucosa with a crescent knife

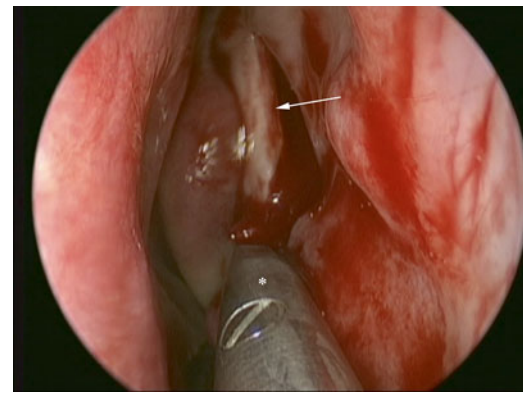

Fig. 10.2 Inferior incision with scissors. The superior incision has been done

(Fig. 10.2). Using the Freer elevator, the mucosal flap is elevated and displaced medially to the middle turbinate to expose the thin lacrimal bone and the area of transillumination. The thicker bone of the frontal process of the maxilla is anterior and does not transilluminate well. The suture line between the lacrimal bone and the frontal process of the maxilla is easily seen. The osteotomy is started by removing the frontal process of the maxilla with a 2 mm Kerrison rongeur (Fig. 10.3). The lacrimal bone does not need to be removed at this stage. With the tip of the rongeur, the edge formed by the thick maxillary bone can be felt and the rongeur is inserted just under it pushing the lacrimal bone toward the sac. Usually 5–6 bites are necessary to uncover the anterior part of the lacrimal cylinder. Care is taken to slip

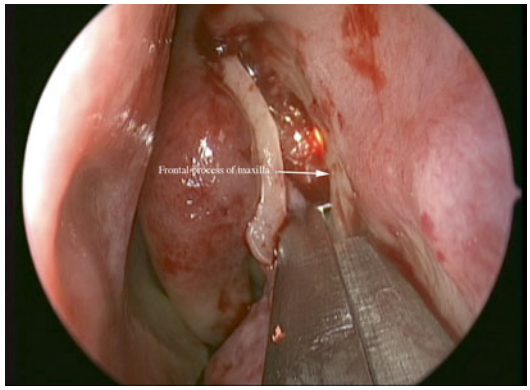

Fig. 10.3 Osteotomy of the frontal process of the maxilla

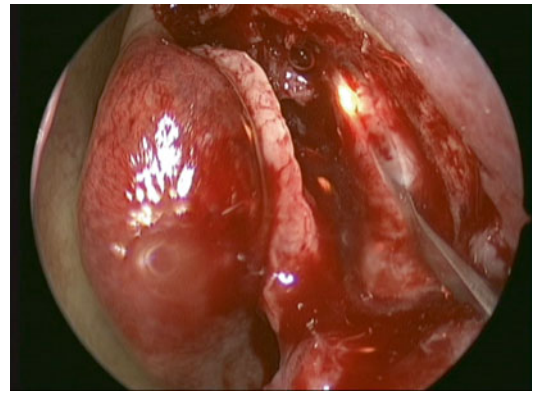

Fig. 10.5 Incision of sac with light probe showing through in upper portion of the sac

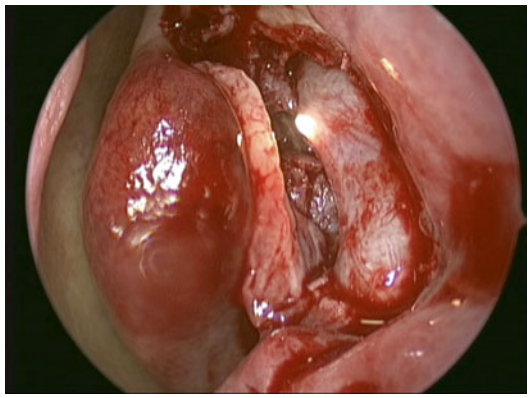

Fig. 10.4 Lacrimal sac exposed after completion of osteotomy with light probe in the superior portion

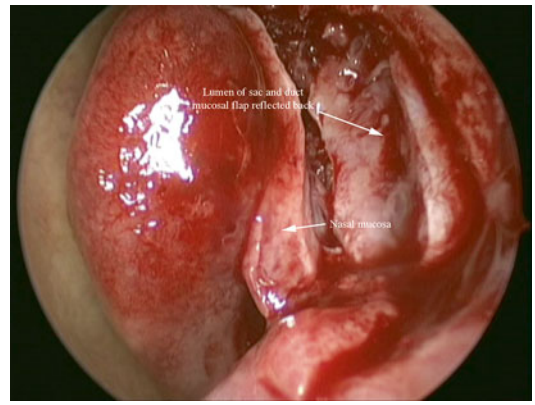

Fig. 10.6 Lacrimal sac and duct opened with lacrimal mucosal flap reflected posteriorly. The nasal mucosal flap is seen medially and will be brought back to make contact with the lacrimal mucosa

the instrument between the bone and the lacrimal mucosa to avoid undue bleeding and early opening of the sac. The posterior aspect of the lacrimal sac and duct is exposed by removing the lacrimal bone (Fig. 10.4). Using a Freer elevator, the thin sheets of lacrimal bone are lifted carefully from the lacrimal mucosa and then removed with microethmoid forceps. When the sac is scarred and has a small lumen, a more superior osteotomy is required. This is more easily done with a 45° tip Kerrison rongeur. Superiorly, the frontal process of the maxilla often has a more posterior projection and removal of the uncinate process may be necessary.

The lacrimal sac is then filled with a viscous solution of methylcellulose. The transillumination probe can be used to tent up the lacrimal sac. A straightened crescent knife is used to create a vertical incision in the anterior portion of the lacrimal cylinder. The incision is directed posteriorly at the superior and inferior end allowing the large lacrimal mucosal flap to be hinged posteriorly (Fig. 10.5). Massage of the sac at the inner canthus allows for visualization of the fundus of the sac and removal of any dacryolith that may have caused obstruction. The lacrimal mucosa can also be biopsied and sent for histopathologic examination if it is felt to be abnormal.

A Freer elevator is used to mobilize the nasal mucosal flap laterally to come in contact with the posteriorly directed lacrimal sac flap (Fig. 10.6). Having the flap edges in close apposition on the

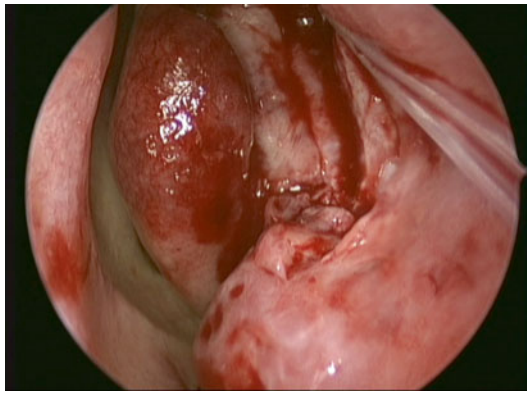

Fig. 10.7 Apposition of lacrimal and nasal mucosal flaps with silicone tubing going through the internal punctum in the lumen of the sac and duct

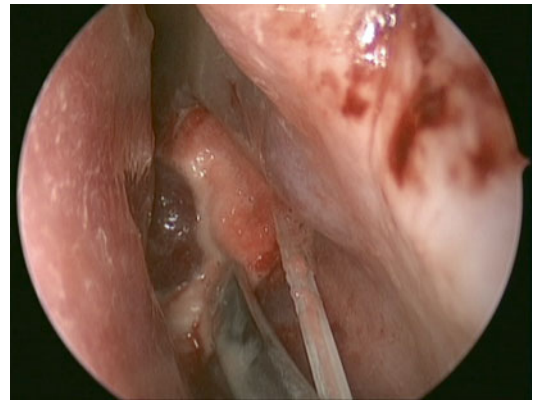

Fig. 10.8 Gelfoam packing soaked in steroid solution and slip over lacrimal silicone tubes and being positioned over the mucosal flps with the tip of a Freer elevator

lateral nasal wall allows for fusion of the mucosal flaps when healing creating a mucosal lined fistula from the sac to the nose [12]. This resembles flap creation in external DCR. At the end of surgery, bicanalicular intubation is done with silicone tubes and the ends are retrieved from the nose with straight microethmoid forceps. Lastly, a small piece of Gelfoam soaked in methylprednisolone 40 mg/cm^3 is slipped over the tubes down on the mucosal flaps to stabilize them and encourage stabilization of the flaps in contact with each other (Fig. 10.7).

Postoperative Care

Patients are instructed to avoid nose blowing for 10 days. Prophylactic systemic antibiotics are used only if significant infection is present. Washing of the nostril with saline sprayed in the nose is done for 1 week, three or four times daily. An antibiotic–steroid combination eye drop is used for a week in the operated eye. The lacrimal system is irrigated at 1 week and at 1 month. The tube is removed at 1 month. Endoscopy can be performed at 1 week if cleaning of the nostril is felt to be necessary and at 1 month to confirm adequate healing of the surgical site (Fig. 10.8). A final follow-up is done at 3 months to confirm the patency of the lacrimal passage and rehabilitation of the nasal anatomy (Fig. 10.9).

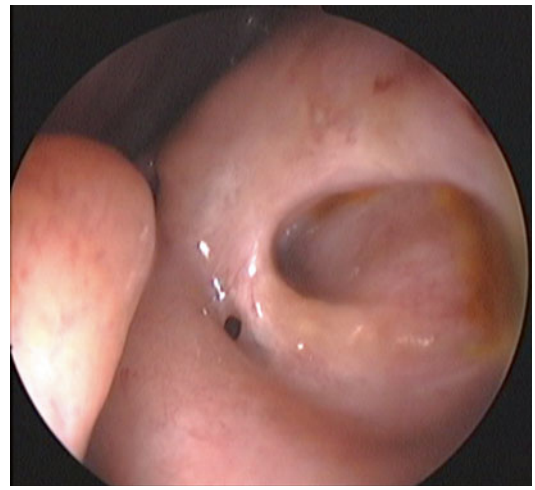

Fig. 10.9 At 3 months, the dye test is frankly positive at 1 min and the mucosa now is back to a normal appearance with good continuity of the mucosal flaps

Complications

Intraoperative or early postoperative bleeding is one of the chief concerns with endonasal DCR surgery. Prevention is the key and involves patients stopping systemic anticoagulants and adequate preoperative preparation to obtain maximum vasoconstriction of the nasal mucosa. Minimal bleeding during the operation is managed with suction. With moderate intraoperative bleeding the area can be packed with neurosurgical

sponges and the suction can be used as well to draw blood into the sponges further drying the field. If profuse, uncontrollable bleeding occurs obscuring visualization, the surgeon should consider aborting the operation instead of pursuing the dissection blindly. In the rare instance when significant bleeding occurs in the early postoperative period, the nose is packed overnight and packing removed 24–36 h later. Patients are given instructions to avoid aspirin containing compounds and to avoid heavy exercise or Valsalva during the first 10 days after surgery.

Invading adjacent structures is a known complication of endoscopic nasal surgery. Confirming surgical landmarks at every step of the operation will prevent deep invasion of surrounding structures. Temporally, the orbit can be violated leading to damage of the orbital fat or medial rectus and inferior oblique muscles [13]. A hemorrhage could also result from this complication and any hematoma under tension in the deep medial orbit should be considered for evacuation in extreme cases. Injury to the skull base should not be a risk as long as the proper landmarks are respected. The placement of the light probe in the sac determines the superior landmark, which should be at the level of the internal punctum. However, despite this measure, should a CSF leak occur, the dissection should be stopped and the patient should be placed on the appropriate antibiotics prophylactically. Bed rest, and in some cases, a lumbar shunt may be necessary to collapse the leak.

Postoperative synechia between different structures in the nose can create problems [14]. The most frequent is a small adhesion between the tip of the middle turbinate and the lateral nasal wall in cases with tight nostrils. Allowing the synechia to mature and then cutting it with scissors a few months later is often all that is necessary. However, excessive dissection and trauma to the nasal mucosa can lead to more extensive synechiae formation. In these difficult cases, more extensive revision with application of anti-fibroblastic agents such as Mitomycin may be the only solution [9]. Granulation tissue may form at the inner ostium of the DCR site in the early postoperative period resulting in obstruction of the lacrimal drainage system and epiphora. Using the endoscope, the granulation tissue can be removed from the ostium site with straight microethmoid forceps relieving the blockage. This complication may occur if direct damage to the mucosal lining of the sac is done at the time of the initial surgery.

Conclusion

Endonasal DCR has increasingly been shown to be as successful as external DCR to treat nasolacrimal duct obstruction [11]. Creation of mucosal flaps at the time of surgery is most likely responsible for these excellent results. The mucosa healing without granulation promotes the formation of a predictable mucosal lined fistula into the nose similar to an external DCR. Endonasal DCR has numerous advantages over external DCR. It is a minimally invasive procedure, which, with experience, can be performed faster than an external DCR [15]. Therefore, in appropriate patients, the endonasal DCR has become the procedure of choice for nasolacrimal duct obstruction.

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Powered Endoscopic Dacryocystorhinostomy

11

Joseph Brunworth and Peter John Wormald

Endoscopic dacryocystorhinostomy (DCR) was first described by McDonogh and Meiring in 1989 [1]. In that chapter they describe the identification of the frontal process–lacrimal bone junction as the key landmark for identification of the lacrimal sac. The technique in that chapter involved the removal of as much of the bone of the frontal process as possible before opening the lacrimal sac. There was no attempt to achieve full lacrimal sac exposure or nasal and lacrimal sac mucosal apposition. The sac was then carefully sutured to the mucosa of the lining of the nose achieving apposition of the lacrimal and nasal mucosa.

Other authors subsequently have described the use of punches and chisels for bone removal [2, 3]. The success rate for these techniques was also around 80 % [1–4]. In contrast, external DCR by dedicated oculoplastic surgeons could achieve success rates of between 90 and 95 % [3, 5]. It is also apparent with review of the literature that one of the keys to success for external DCR surgery is the creation of the largest possible bony ostium with full exposure of the lacrimal sac [6, 7].

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To enable these principles to be achieved via an endoscopic route, the intranasal relationships of the lacrimal sac and nasal anatomy needed to be better understood [8]. This was achieved by a study in our department using computed axial tomography dacryocystography (CT DCG) to define the limits of the lacrimal sac and to establish the relationship of the lacrimal sac with the middle turbinate [8]. Descriptions in the past have shown that the lacrimal sac sits anterior to the middle turbinate and the fundus of the sac ends just above the insertion of the middle turbinate onto the lateral nasal wall [1–4]. This insertion is termed the axilla of the middle turbinate [8]. The CT study showed that the lacrimal sac extended between 8 and 10 mm above the axilla of the middle turbinate [8]. In addition the axial scans revealed that the bone of the frontal process of the maxilla progressively thickened toward the fundus of the sac and reached up to 15 mm in some patients. Initial cadaver dissections indicated it was not possible in the majority of patients to remove the bone above the axilla with a punch. Chisels were not reliable and could damage the underlying skin.

Fortunately the understanding of the anatomy of the lacrimal sac and the need for precise bone removal coincided with the development of the powered instruments for standard sinus surgery. Powered instruments were first used for sinus surgery in the late 1980s. As the technology improved and the torque of the motor driving the instruments improved, drills were implemented.

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DOI 10.1007/978-3-319-10332-7_11,

Initially cutting burrs were used and although they quickly and aggressively removed the bone overlying the lacrimal sac, any contact between the burr and the mucosa of medial lacrimal sac wall tended to damage the wall. Often this resulted in a significant defect of the medial wall of the sac.

The goal of the new surgical technique is to preserve all sac mucosa so that the sac can be marsupialized into the lateral nasal wall. To avoid such damage, a rough diamond DCR burr was developed for powered endoscopic DCR surgery [9]. The technique, described below, has been specifically designed to duplicate the external DCR technique with complete exposure of the lacrimal sac so that the sac stands above the lateral nasal wall [9, 10]. The sac is opened by an H-incision, which preserves all the lacrimal sac mucosa and allows approximation of the lacrimal mucosa with the preserved mucosa of the nasal cavity. This achieves first intention healing rather than secondary intention healing which is similar to that achieved with an external DCR with suturing of the lacrimal flaps [9, 10].

Surgical Technique [9, 10]

A decongestant solution is prepared with 2 mm of 10 % cocaine solution, 1 mL of 1:1,000 epinephrine, and 4 mL of 0.9 % saline. Half of this solution is used to soak six neurosurgical cottonoids (2×1 cm) and the other half placed on four cottonoids for use during the surgery if bleeding is problematic. After the patient has been anesthetized but before the patient has been draped, one of the six cottonoids is placed between the middle turbinate and septum, one under the middle turbinate, one above the middle turbinate, and the remaining three anterior to the middle turbinate. If the procedure is to be done under local anesthetic, these packs are placed for 10 min before infiltration of the anesthetic is performed.

Local anesthetic infiltration is done using a dental syringe with 2 % lidocaine and 1:800,000 epinephrine. If the patient is under general anesthetic, 2 mm is used to infiltrate the lateral nasal wall above and anterior to the middle turbinate and the anterior end of the middle turbinate. If the procedure is to be performed under local anesthetic, the lacrimal sac, nasal septum, and upper lip are also infiltrated.

After nasal decongestion but before surgery, the surgeon needs to assess the access to the region anterior and above the insertion of middle turbinate. The less experienced the surgeon, the larger amount of space required. If the septum is deviated toward this region and compromises access, a limited septoplasty should be performed prior to the DCR. The septum is accessed via a Killian's incision placed about a centimeter behind the anterior mucocutaneous junction. A mucoperichondrial flap is raised, and the cartilaginous bony junction of the septum identified. The suction Freer is used to separate the cartilage from the bone and a mucoperiosteal flap is formed on both sides of the bone. The deviated bony septum is resected until sufficient access to the middle turbinate insertion on the lateral nasal wall is achieved. After the DCR has been completed, a 3-0 Vicryl Rapide® (Ethicon, Somerville, NJ, USA) plication suture is placed through the septum. This obliterates the potential space created by raising the flaps and prevents a postoperative septal hematoma from forming.

The first and one of the most important steps in powered endoscopic DCR is the mucosal incision. The incision is performed with a number 15 blade on a number 7 handle and starts 8–10 mm above and behind the insertion of the middle turbinate into the lateral nasal wall (the so-called axilla of the middle turbinate). The incision is brought horizontally forward 8–10 mm anterior to the axilla of the middle turbinate. The blade is turned vertically and the incision is carried down the prominent frontal process of the maxilla until the insertion of the inferior turbinate into the lateral nasal wall. This is about two-thirds of the way down the anterior edge of the middle turbinate (Fig. 11.1a).

The blade is turned horizontally and the incision continued posteriorly until the insertion of the uncinate process is reached. If this incision is properly placed, it provides accurate margins for the correctly sized bony ostium and for complete exposure of the lacrimal sac. A 30° endoscope can be employed so that the view captures the

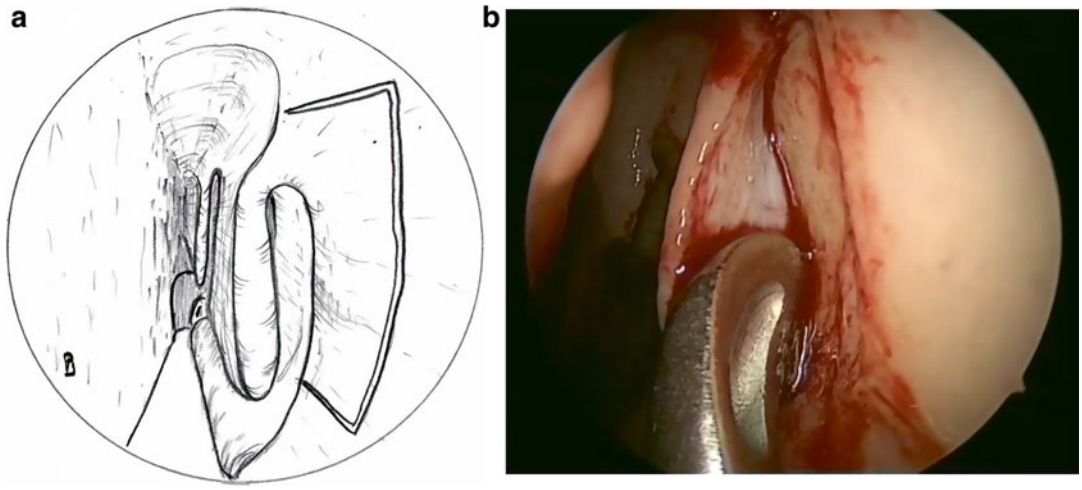

Fig. 11.1 (**a**) The mucosal incisions on the left lateral nasal wall are shown for endoscopic DCR. (**b**) The nasal mucosal flap is elevated by a suction dissector with exposure of the lacrimal bone

lateral nasal wall. The endoscope is pushed high into the nasal vestibule and all instruments are passed under the endoscope. At no time should the endoscope and instruments cross.

A suction Freer is used to elevate the mucosal flap, making sure that the tip of the Freer is on bone at all times during this process (Fig. 11.1b). The frontal process is rounded and its posterior aspect falls away, and if care is not taken to maintain contact between the bone and the elevator the surgical plane will be lost. The 30° endoscope allows the tip of the Freer to be visualized as the dissection proceeds around the frontal process of the maxilla toward the insertion of the uncinate. The flap is elevated up to the insertion of the uncinate but no further. The thin lacrimal bone is sought between the insertion of the uncinate and the posterior aspect (otology instrument from ear instrument set) of the frontal process of the maxilla. A round blade is used to palpate the hard bone of the frontal process of the maxilla until the soft lacrimal bone is clearly identified. This palpation is best done in the region directly above the insertion of the inferior turbinate into the lateral nasal wall in the inferior aspect of the raised flap. The round blade is used to elevate the thin lacrimal bone over the posterior inferior aspect of the lacrimal sac. This allows the forward biting Hajek Koefler punch (Karl Storz, Tutlingham, Germany) to be inserted. The tip of this instrument is placed on the exposed sac where the lacrimal bone had been removed and as the instrument is engaged, the tip pushes the lacrimal sac away and allows the bone over the anterior inferior aspect of the lacrimal sac to be removed (Fig. 11.2a).

Removal of bone is continued superiorly until the punch can no longer be seated. At this point (about half way up toward the superior incision) the bone becomes too thick for the punch to be able to grip. A powered 25° endoscopic DCR burr is attached to a microdebrider handpiece (Medtronic Xomed, Jacksonville, FL, USA) and used to remove the residual bone covering the lacrimal sac (Fig. 11.2b).

First, the residual bone exposed by elevation of the flap is thinned. Once the bone is thin, then the burr is moved to the bone–lacrimal sac junction and the remaining lacrimal sac is exposed. Care should be taken not to push the burr too far under the edge of the bone as this creates significant pressure on the lacrimal sac and the burr will create a hole in the sac. However, the sac wall is able to withstand light pressure as long as the entire burr can be visualized during the dissection. As the bone is removed in the region of the posterior superior sac, the underlying mucosa of the agger nasi cell is exposed. This is routinely done as the superior portion of the lacrimal sac is

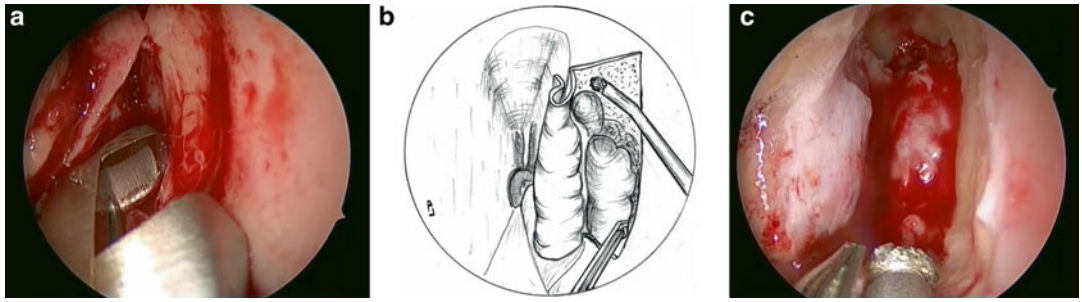

Fig. 11.2 (**a**) The Hajek Koefler punch is used to remove the bone over the anterior inferior aspect of the lacrimal sac. After the first bite the anteroinferior lacrimal sac is seen. (**b**) A rough diamond DCR burr is used to remove all bone over the remaining lacrimal sac up to the superior incision. (**c**) Intraoperative photo of the diamond bur in use. Note that the sac is beginning to stand proud of the lateral nasal wall

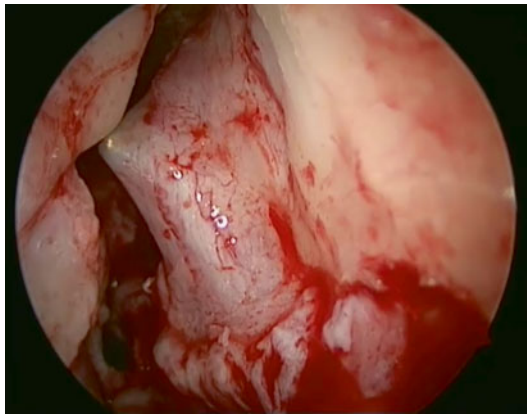

Fig. 11.3 Bowman lacrimal probe is used to tent the medial wall of the lacrimal sac

constantly related to the agger nasi cell. In addition a small amount of skin is routinely exposed just anterior to lacrimal sac indicating complete bony removal and defining the anterior aspect of the lacrimal sac. Once the bony removal is complete, the lacrimal sac should stand proud of the lateral nasal wall (Fig. 11.2c). This allows the sac to be completely marsupialized into the lateral nasal wall. A Bowman's lacrimal probe is placed into the lacrimal sac and the medial wall of the sac is tented (Fig. 11.3).

The tip of the probe should be clearly visualized before incision of the sac is attempted. If the tip of the probe is at the common canaliculus entry to the sac, it may appear as if the probe is in the sac, as the sac will still move when the probe is moved. Incision in this scenario can potentially injure the common canaliculus' opening into the sac. The sac is opened using a DCR spear knife (Medtronic Xomed, Jacksonville, FL, USA). The knife is introduced into the sac lumen directly under the tip of the probe and the sac opened by rotating the spear knife (Fig. 11.4a). Do not insert the whole blade into the sac lumen, rather only the cutting edge. The sac is opened from top to bottom. The DCR mini-sickle knife (Medtronic Xomed, Jacksonville, FL, USA) is used to create releasing incision at the superior and inferior extent of the vertical incision allowing the anterior lacrimal mucosal flap to be rolled anteriorly toward the anterior nasal mucosal incision (Fig. 11.4b). Microscissors are used to make posterior releasing incisions at the top and bottom of the vertical incision. This allows the posterior lacrimal flap to be rolled posteriorly with complete marsupialization of the lacrimal sac. A standard sickle knife is used to make a vertical incision into the mucosa of the agger nasi cell and to roll this mucosa anteriorly until it meets the mucosa of the posterior lacrimal flap with mucosa-to-mucosa apposition. The original nasal mucosal flap is trimmed with pediatric through-biting forceps creating a superior limb of mucosa the same size as the space between the superior incision and the lacrimal mucosa (Fig. 11.5).

In addition the nasal mucosa is trimmed until it approximates the posterior lacrimal flap. An inferior limb can also be created if there is a space between the lower portion of the opened lacrimal sac and the inferior incision. This should

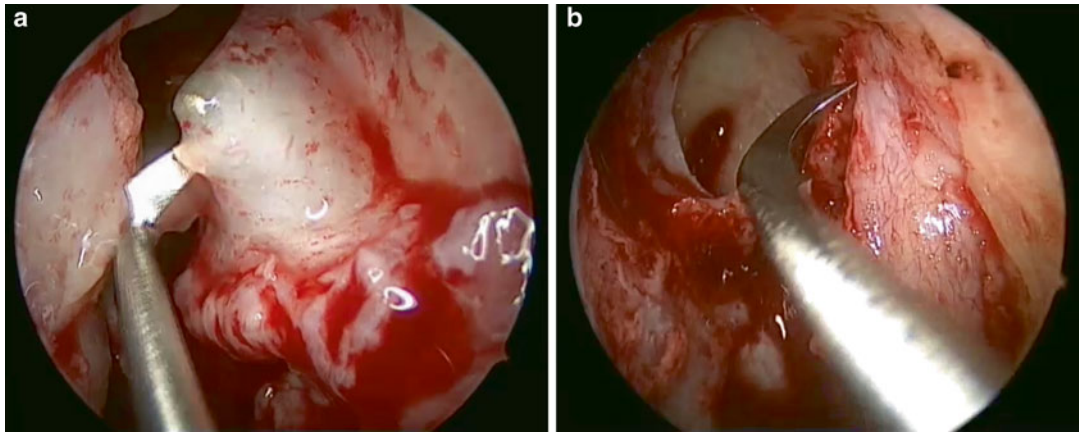

Fig. 11.4 (**a**) The DCR spear knife is used to make the initial incision into the lacrimal sac. Note the Bowman's probe tenting the sac wall. (**b**) The mini-sickle knife is used to make anterior superior and inferior releasing incisions to enable the anterior lacrimal mucosal flap to be rolled out

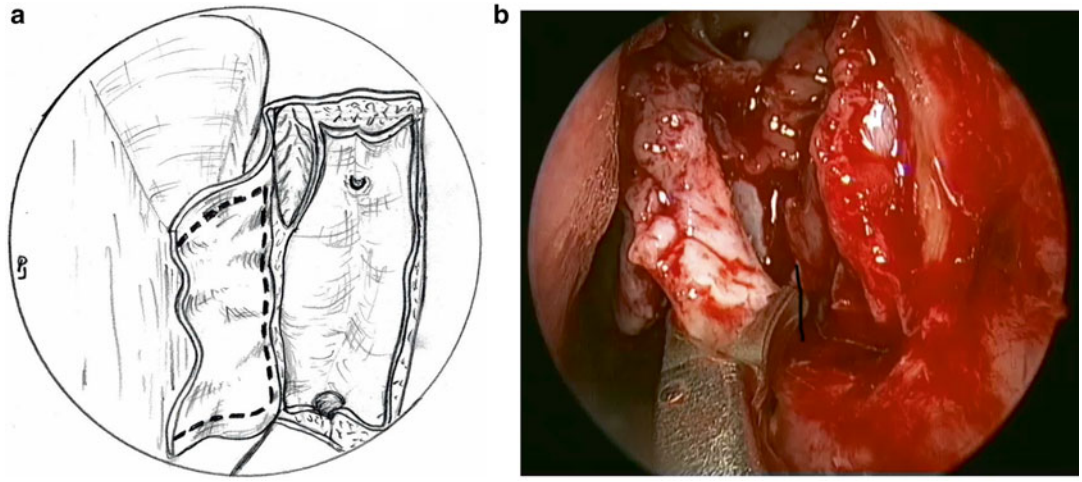

Fig. 11.5 (**a**) The pediatric through-biting Blakesley is used to trim the nasal mucosal flap to allow apposition with the lacrimal sac mucosa (*dotted line*). Mucosal apposition is achieved superiorly between the nasal mucosa and lacrimal mucosa, posterosuperiorly between the agger nasi cell mucosa and lacrimal mucosa, posteroinferiorly and inferiorly between the nasal and lacrimal mucosa. A small gap will often remain anteriorly. (**b**) Intraoperative photo showing the use of the pediatric through-biting Blakesley in use

allow approximation of nasal mucosa and lacrimal mucosa superiorly, posteriorly, and inferiorly. The only area where lacrimal and nasal mucosa will usually not be approximated is the anteriorly where the anterior lacrimal mucosa will often fall a few millimeters short of the anterior incision. If the common canaliculus grips the Bowman's canaliculi probe tightly, it is assumed that there is tightness of the valve of Rosenmuller. In these circumstances silastic O'Donaghue lacrimal intubation tubes are placed through the upper and lower canaliculus into the nose. These tubes are left for 4 weeks before removal. This dilates the valve of Rosenmuller allowing freer drainage of tears from the conjunctiva to the nose. If the Bowman's probe is loose in the valve then silastic tubes are not placed. If silastic tubes are placed, a 4 mm silastic tube cut to 0.5 cm is

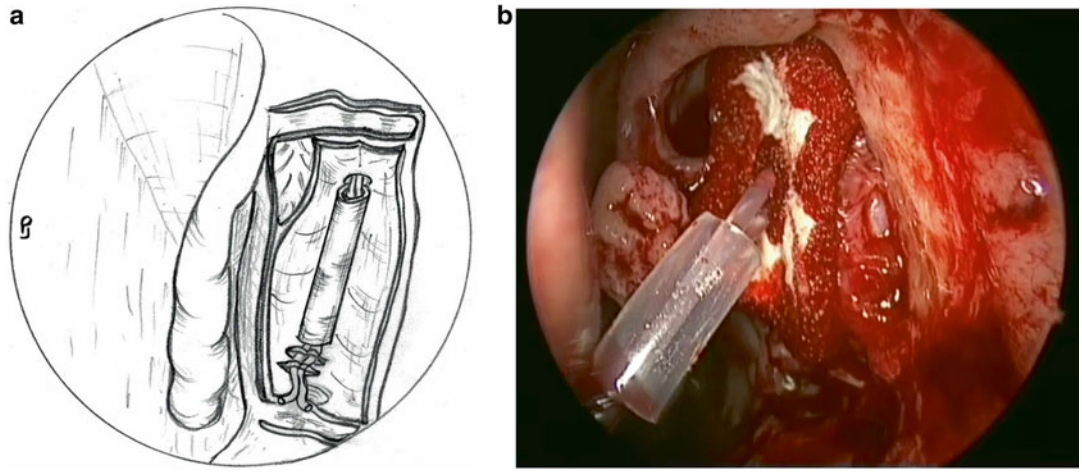

Fig. 11.6 (**a**) Silastic tubes are in place and the spacer (silastic tubing) has been secured. (**b**) Gelfoam® is slid over the silastic tubes, and the position of the flaps is checked before the Gelfoam® is replaced

slid over the O'Donaghue tubes to act as a spacer (Fig. 11.6a). A loop of silastic tubing is pulled in the medial canthal region to ensure that there is no tension on the tubing. If the tubes are tight, they can cheese wire through the superior and inferior puncta. Once the silastic tubing is tension free, Liga clips® are placed endoscopically behind the silastic spacer. A rectangular piece of Gelfoam® (Pharmacia & Upjohn, Kalamazoo, MI, USA) is slid up the tubes onto the lacrimal mucosa. The silastic tubes are cut. Gelfoam® is lifted and the position of the flaps verified before the Gelfoam® is replaced (Fig. 11.6b). The operation is complete.

Post-operative Care

All patients receive systemic antibiotics (amoxicillin/clavulanic acid or cefuroxime) for 5 days as well as antibiotic eye drops (Chloromycetin), 1–2 drops four times per day for 3 weeks. Nasal saline spray and douche is started within 24 h of surgery. This helps to remove blood clots from the nose and creates a clear nasal passage. It also prevents mucous from accumulating around the O'Donaghue tubes, which can create a medium for secondary infection. The patient is reviewed at 4 weeks and if present the O'Donaghue tubes are removed. A nasal endoscopy is performed and the lacrimal ostium observed. In most cases it is well healed. However, if there are any granulations present these are removed. Fluorescein is placed in the conjunctiva and nasal penetration confirmed.

Results

The results of lacrimal surgery should be reported with reference to patient symptoms as well as to the anatomical surgical success of creating a functioning pathway between the conjunctiva and the nose. For a patient to be deemed to have a successful powered endoscopic DCR in our department, the patient needs to be asymptomatic with a functioning patent lacrimal ostium. This is confirmed endoscopically by the immediate draining of fluorescein from the conjunctiva into the healed lacrimal ostium. These criteria classify any patient with residual symptoms as a failure irrespective of an improvement in symptoms or the state of the lacrimal ostium. In addition, if the patient was completely asymptomatic and did not have an endoscopically visible ostium and there was no fluorescein visible in the nose, the patient was considered a failure. Using these strict outcome criteria, the results of powered endoscopic DCR have been reported in a number of publications.

Primary DCR [9–11]

In a recent analysis of 128 consecutive DCRs, the overall success rate was 95 %. Of the failures there were three DCRs that had no visible lacrimal ostium and no fluorescein in the nose. Four of the failures had a patent lacrimal sac with a free flow of fluorescein from the conjunctiva to the nose but were still symptomatic. All these patients said that their symptoms had improved following surgery. If the patients are divided into patients who had an anatomical nasolacrimal obstruction as defined by an obstructed DCG and scintigraphy ($n=87$), the success rate was 98 % [11]. Only two patients in this group failed with obstruction of the lacrimal ostium. Those patients with a functional obstruction, defined by a patent system on DCG and impeded or absent nasal penetration on scintigraphy ($n=41$), had a success rate of 88 % [11]. Five of these patients failed. Of the four patients who had a patent lacrimal ostium, all felt that their symptoms had significantly improved. One patient with an anatomical failure was asymptomatic but was classified as a failure. The other anatomical failures all had significant symptoms and went on to have revision surgery.

Revision DCRs

If the results of patients undergoing powered endoscopic revision DCR are reviewed ($n=17$), we note that the success rate drops to 76.5 %. We also found that the failures in this group were largely those patients that had undergone two or more previous DCRs. This is thought to result from the scarring and cicatrization of the lacrimal sac and the increased difficulty of achieving a marsupialized lacrimal sac with good nasal and lacrimal mucosa apposition.

Pediatric DCRs

Pediatric DCR was defined as a patient less than 13 years of age undergoing an endoscopic powered DCR. The average age of the patients was 6.5 years (range 2–13 years, SD = 3.3). All patients had been diagnosed as having congenital nasolacrimal duct obstruction. The success rate was 14 out of 16 (89 %). The two failures occurred in a patient who had bilateral congenital nasolacrimal duct obstruction and had undergone three previous external DCRs on each side.

Adjuvant DCR Techniques

Since its inception, the endoscopic DCR has gained in popularity as techniques are refined and success rates continually improve. With the incorporation of powered instrumentation and precision drilling giving the largest possible bony ostium with full exposure of the lacrimal sac, the results have rivaled if not exceeded those of the external approach. Further developments will inevitably arise as techniques evolve and new instrumentation becomes available. For example, following studies in our department, we have found that we can achieve comparable results without the use of routine canalicular intubation [12, 13]. Other studies have looked at the use of mitomycin C as an adjuvant to reduce stricture or closure of the osteotomy; however, its use is not recommended in primary DCR, as one needs to expose a large number of patients to get potentially a very small improvement in patency. It may have some limited use in revision DCR where the success rate of revision surgery is less than that seen in primary surgery [14]. Further implications for endoscopic DCR are also on the horizon as well such as the high success rates reported in its use for acute dacryocystitis [15].

Conclusions

Powered endoscopic DCR allows the lacrimal sac to be fully exposed so that it stands proud of the lateral nasal wall after dissection. By fully preserving all the lacrimal mucosa during opening of the sac, the sac can be marsupialized into the lateral nasal wall becoming part of the lateral nasal wall. This marsupialization is different from creating an ostium into the sac. Complete marsupilization decreases the likelihood of closure of the sac. In addition preservation of the

nasal mucosa allows this mucosal flap to be trimmed so that the nasal and lacrimal mucosa can be opposed to ensure primary intention healing rather than secondary intention healing and potentially lessens the risk of fibrosis and subsequent closure of the lacrimal ostium. Results of this procedure have proved to be reliable in primary, revision, and in pediatric DCRs.

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Laser-Assisted Endonasal Dacryocystorhinostomy

12

Sangeeta Kapur Maini, Vamsidhar Vallamkondu, and Bhaskar Ram

Introduction

Laser dacryocystorhinostomy (DCR) techniques can be classified into endolaser DCR (surgery entirely by laser) and endolaser-assisted surgical DCR (surgery using laser and cold steel instruments).

Various laser systems (carbon dioxide, holmium: YAG, neodymium YAG, KTP, erbium, and diode) have been utilized successfully for rhinostomy creation in endolaser DCR, however it is unclear based on current data whether particular laser constitutes a significant advantage with respect to clinical outcomes [1, 2].

An important consideration in laser-assisted surgery is the response of tissues to laser energy, which is influenced by laser delivery method (contact vs. noncontact), application mode (continuous vs. pulsed), power/energy density, and tissue properties [3–7].

Questions arise about the effectiveness of endolaser DCR compared with endosurgical DCR. These concern success rates, operative time, cost-effectiveness, and ease of procedure.

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Studies have suggested delayed re-epithelialization and prolonged inflammation in laser-treated tissues, which may have implications with respect to postoperative rhinostomy patency and wound healing [7, 8]. Maini et al. [9] conducted a study which revealed no statistically significant difference between endolaser DCR and endosurgical DCR. However there was a trend towards falling success rate with time in endolaser DCR which could have reflected increased post-laser fibrosis and scarring as compared to the cold steel technique [9].

Surgical Technique

The procedure is generally done under general anaesthesia, although local anaesthesia may be used. A combined team approach with otolaryngologist and ophthalmologist is recommended.

Position

Patient is placed in the supine position with 15° head elevation. Both eyes are lubricated with petroleum-based ointment and the contralateral eye is taped. Corneal shields may also be used. General anaesthesia with TIVA-remifentanyl and sevoflurane is routinely used and blood pressure is kept around systolic levels of 100 mmHg.

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Nasal Preparation

Five percent of cocaine solution is prepared and the nasal cavity sprayed using the atomiser jet insufflation, 15 min prior to the procedure in the anaesthetic room. Once patient is placed on the operating table under general anaesthetic, the middle turbinate and the lateral nasal wall just anterior to the middle turbinate is infiltrated with 2 % lignocaine and 1:80,000 adrenaline (lignospan). Middle meatus is packed with medium-sized neurosurgical patties soaked in 1:1,000 adrenaline.

Procedure

Posterior-based mucosal flap is created with a vertical incision at the level of the anterior maxillary crest, superior incision 8 mm above the axilla of the middle turbinate and inferior incision up to the level of the midportion of the middle turbinate (Fig. 12.1). Mucoperiosteum is elevated using a suction freer elevator/dissector and folded posteriorly.

Bone Removal and Rhinostomy

The endonasal laser technique is carried out with the assistance of a potassium titanyl phosphate (KTP) laser, after suitable laser protection of the patient and staff. The laser settings recommended are 5.0 W, 0.5 s duration, and 0.5 s interval. The laser is used to resect the mucosa and thin bone. Superiorly and anteriorly where the bone becomes thick, a 15° curved 2.9 mm endonasal DCR coarse diamond burr (Medtronic, Jacksonville, FL, USA) is used for removing the hard bone anteriorly over the maxillary bone and above the axilla (Fig. 12.2).

Once wide bone removal, at least 1.5 cm in diameter, has been achieved, the sac should be easily identified with adequate exposure. The lacrimal puncta is dilated with a lacrimal punctal dilator and the lower canaliculus, dilated with a Bowman canalicular lacrimal probe (Fig. 12.3). The lacrimal sac is thus made to tent medially. A vertical incision is made along the lacrimal sac using the KTP laser at 5 W continuous mode (Fig. 12.4). The lacrimal sac is opened with the formation of anterior and posterior flaps.

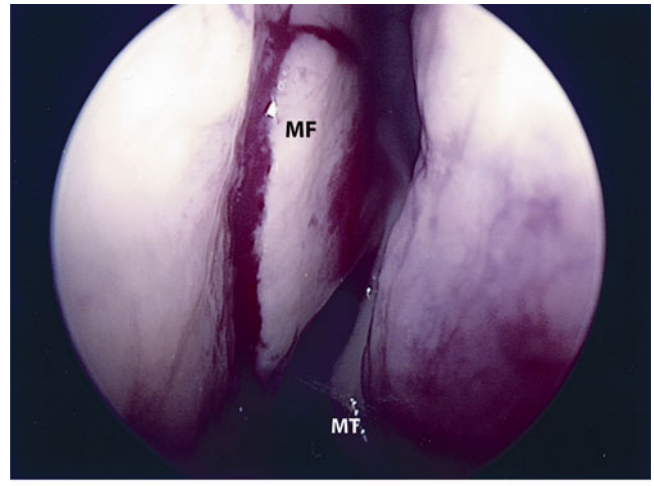

Fig. 12.1 Vertical incision and horizontal incisions for mucosal flap

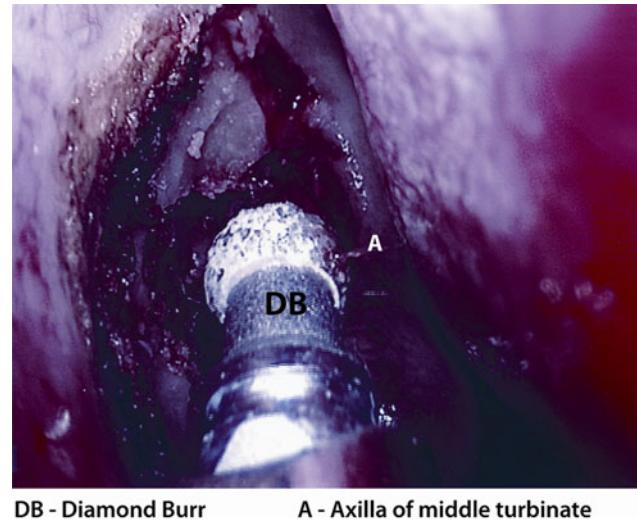

Fig. 12.2 Endonasal DCR coarse diamond burr is used for removing the hard bone

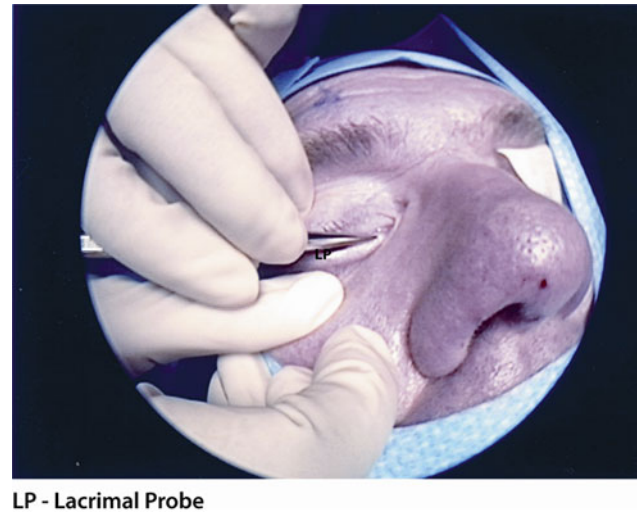

Fig. 12.3 Lacrimal puncta is dilated with a dilator

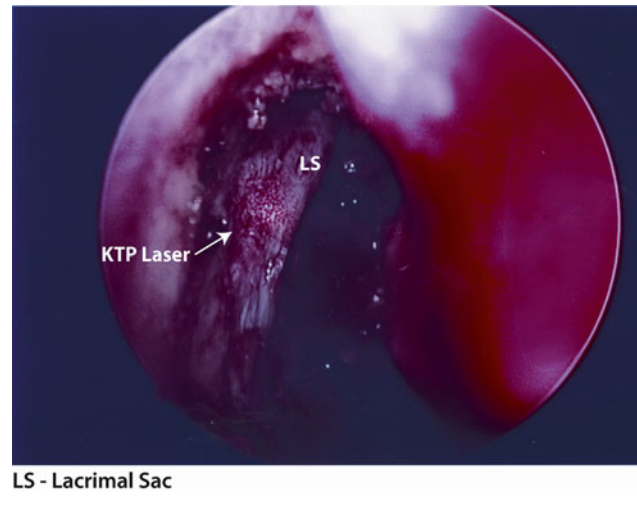

Fig. 12.4 A vertical incision is made along the lacrimal sac using the KTP laser

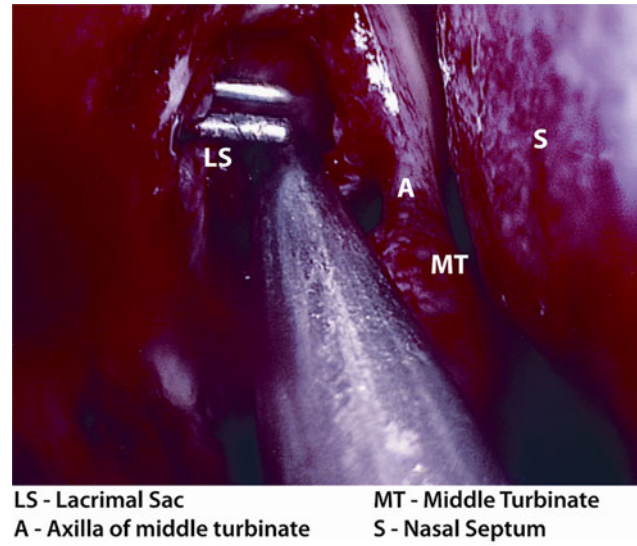

Fig. 12.5 O'Donoghue silastic stents are placed via both upper and lower canaliculi

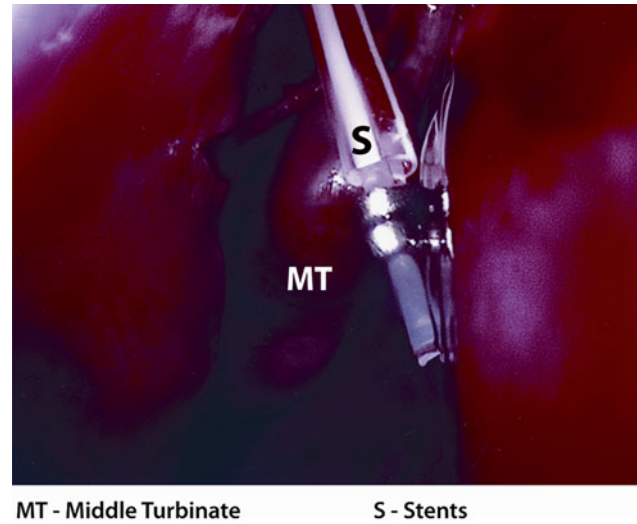

Fig. 12.6 Endonasal retrieving of stents and tightening over a silastic tubing

Horizontal incisions are then placed in the posterior flap using KTP laser superiorly and inferiorly and the midportion of the sac is vaporized thus achieving a wide rhinostomy. O'Donoghue silastic stents are then placed via both upper and lower canaliculi (Fig. 12.5), retrieved endonasally and tightened over a silastic tubing to prevent upward migration of the stent knot (Fig. 12.6). The stent loop is ensured not to be too tight as it may cheese wire through the puncta.

The eye is lubricated with chloramphenicol drops and nasal cavity packed loosely with small absorbable dressings soaked in topical steroid drops. Patient is advised not to blow their nose in the immediate postoperative period. Topical nasal saline douching and topical chloramphenicol eye drops are advised for 2 weeks.

Follow-Up

Patients are seen at 3 weeks, 3 months, and 12 months. Stents are removed in the outpatient clinic at 3 months and patency is checked with fluorescein dye test. Any granulation tissue seen around the stents are removed.

Key Points

Adequate nasal preparation
Adequate lacrimal bone removal using KTP laser and coarse diamond burr
Creation of wide rhinostomy (1.5 cm)
Stents in situ for 3 months

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Transcanalicular Dacryocystorhinostomy

13

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Anatomic and Pathophysiological Basics

The tear film has a complex consistence of exudate of the lacrimal gland, the accessory lacrimal glands, the goblet cells in the conjunctiva, and the lid margin glands. The lacrimal drainage system is an anatomic structure, which connects the lids, the surface of the eye ball, and the nose and regulates the drainage of the lacrimal fluid. Starting with the lacrimal punctum the drainage is mainly carried out by the muscle pump of the M. orbicularis oculi (Horner muscle), into the lacrimal sac. The exact mechanism of this isn't fully determined yet. Epithelia with kinocilium, the surrounding, spiral cavernous system of locking veins and the muscle fibers and connective tissue fibers which are arranged around the lacrimal sac are actively leading the lacrimal fluid from the lacrimal duct via the ductus nasolacrimalis to the efferent duct under the lower nasal concha. It is assumed that a part of the lacrimal fluid is absorbed by the lacrimal mucosa. As there are various feedback mechanisms between formation and drainage of the lacrimal fluid, the whole system is also called lacrimal unit [1–3].

A disorder of the lacrimal drainage is reflected in the primary symptom epiphora (tearing eye). The causes for such a dysfunction are inflammation of the lacrimal mucosa and nasal mucosa with histological alterations of epithelia, mucosa forming cells and connective tissue fibers as well as alterations of the blood vessels. Here it comes to a consecutive constriction of the lacrimal system or the formation of a membrane up to complete stenosis of the lacrimal drainage system. This stenosis can occur in any section of the lacrimal system, from the lacrimal punctum over the canaliculi and the saccus up to the ductus nasolacrimalis. Due to the anatomical structure with corners and narrow points the aditus of the way into and out of the saccus and the nasolacrimal duct are most likely for the formation of a stenosis. Depending on the pathogenic agent acute as well as chronic inflammations show different symptoms and progresses.

A special form is the congenital lacrimal duct stenosis in children. Generally they are caused by development abnormalities such as double structures, fistulas, and diverticulum. Most commonly the persistence of the Hasner membrane is observed at the end of the ductus nasolacrimalis. It leads to the symptom of tearing eye in babies and is normally treated by a simple flush at the age of 4–9 month [1–6].

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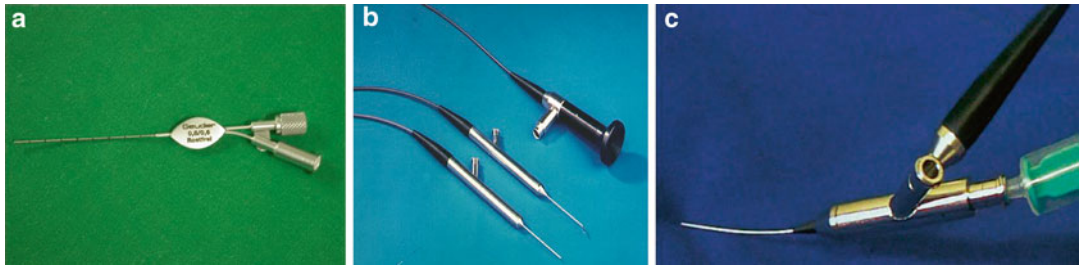

Fig. 13.1 Development of the dacryoendoscopes. (**a**) Modified Juenemann probe, 3,000 pixels. (**b**) Rigid dacryoendoscope (Vitroptic), 6,000 pixels. (**c**) Flexible Vitroptic T, 6,000 pixels

Imaging procedures such as dacryocystography, computed tomography, magnetic resonance imaging, high-resolution ultrasound, and scintigraphy are of great importance in diagnosing mechanical dacryostenosis. The aim is locating the mechanical stenosis and allowing for selection of a suitable operative procedure to eliminate the lacrimal obstruction. However, none of the imaging procedures enable direct visualization of pathologic changes such as mucosal or neoplastic changes, dacryoliths, or foreign bodies. The use of rigid endoscopes for preoperative endonasal assessment of the nasal mucosa or for postoperative evaluation has yielded important results for diagnosis and management of diseases of the lacrimal passage for many years.

Dacryoendoscopy

The need to directly visualize pathologic changes in the lacrimal passages led to the development of rigid and flexible endocanalicular endoscopes [7]. Because of the narrow lumen of the canaliculus, which is barely more than 1 mm in diameter, the first endoscopes could not provide a satisfactory image quality and thus did not represent a true advancement in diagnostics. Superfine flexible endoscopes (with a diameter of 0.3–0.7 mm) resulting as a modification of gastroduodenal endoscopes were developed for transcanalicular diagnostics [8, 9]. With a diameter of 0.3 mm, an image of 1,500 pixels could be transmitted with fair quality, but details could not be interpreted and only a rough outline could be attained. By extending the diameter to 0.5 or 0.7 mm, 3,000 or 6,000 pixels could be transmitted, resulting in a much better image.

Technical Equipment

A modified Juenemann probe was used as the first flexible diagnostic endoscope (Fig. 13.1) along with an irrigation channel [8, 10]. The exterior diameter was 0.9 mm. The endoscope had a 70° angle view and a 0° direction view. It was illuminated by a Xenon cold light source (Fig. 13.2) and was connected to a camera by a TV adapter. The camera had a residual light amplification and a high shutter speed of up to 1/2,000,000 of a second. The picture was visible on a high-performance monitor and recorded simultaneously through a video output and documented on a video recorder. It is important to understand that the quality of the actual video picture is much better than the pictures in the text, which were taken from a still video picture. With the exception of the configuration of the endoscopes, e.g., the Vitroptic (Fig. 13.1c), the system is unchanged. Future digitalization of the picture may improve its quality.

Performing Dacryoendoscopy

Before performing dacryoendoscopy, the puncta must be dilated (Fig. 13.3). Using an astringent solution, the passage is irrigated gently and the endoscope is inserted via the upper or lower

Fig. 13.2 Endoscopic system (from the top to the bottom): monitor and camera, Xenon light source, erbium:YAG laser, video recorder

canaliculus. The endoscope is advanced forward as far as possible to reach the stenosis or the inferior turbinate. It is then retracted, allowing for a complete evaluation of the lacrimal passage. Retracting and advancing the endoscope with simultaneous irrigation requires a certain amount of practice to obtain quality images. An unobstructed view demonstrates the normal anatomic sequence of transcanalicular endoscopy, showing canaliculus, lacrimal sac, nasolacrimal duct, and nasal mucosa of the inferior turbinate.

The canalicular mucosa appears white and is quite different from the reddish color of the mucosa of the lacrimal sac. The nasolacrimal duct can be recognized by its narrow shape and its reddish color. The nasal cavity is an intensively red structure, with a smooth surface and large width (Fig. 13.4).

Endoscopy permits differentiation of abnormal findings such as membranes, scars, acute or chronic mucosal inflammation, and foreign bodies. Even small blood deposits on the mucosa resulting from manipulation of the lacrimal passage are obvious (Fig. 13.5).

From the results of the endoscopy, an appropriate operative procedure can be selected. In Germany, some centers have performed more than 10,000 endoscopic procedures. Injuries caused by the endoscope are comparable to other surgical interventions of the lacrimal passage, such as irrigation or intubation. In general, it is possible to perform a dacryoendoscopy with anesthetizing eye drops, irrigation of the lacrimal passage with 4 % cocaine solution, and an anesthetizing nose spray. Most endoscopy procedures are performed under general anesthesia.

Pediatric Endoscopy

In children under the age of 2 years, a purely diagnostic dacryoendoscopy should only be performed in exceptional cases, because the small diameter of the lacrimal passage increases the risk of injury. Diseases of the lacrimal system in newborns and infants are mainly deformational in nature and in these cases, endoscopy does not provide any essential information. Only in cases of failure after prior procedures will endoscopy with simultaneous endoscopic therapy be performed to attempt to avoid a pediatric dacryocystorhinostomy (DCR).

Minimally Invasive Procedures

The desire for lacrimal surgery without scars led to the endonasal DCR technique. Over the years, diverse modifications have been developed. The introduction of microscopes and flexible nasal endoscopes were valuable contributions to this field. The combined approach of anterograde imaging and illumination of the lacrimal system with simultaneous endoscopically controlled nasal surgery provided excellent results [11]. To minimize operative trauma, these endonasal techniques were supplemented by the use of various lasers such as Holmium, potassium titanyl phosphate (KTP), or carbon dioxide.

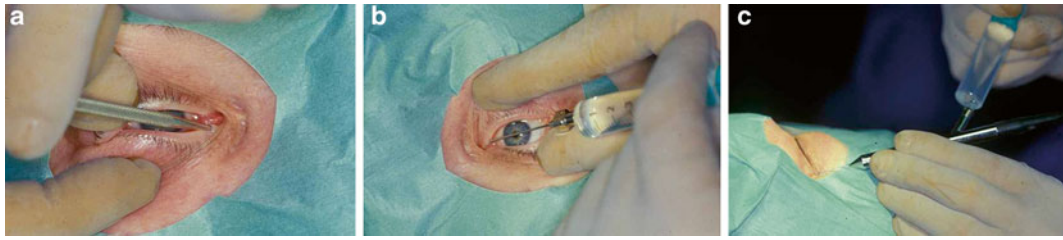

Fig. 13.3 Steps of dacryoendoscopy. (**a**) Dilating punctum. (**b**) Irrigation. (**c**) Endoscopy and irrigation

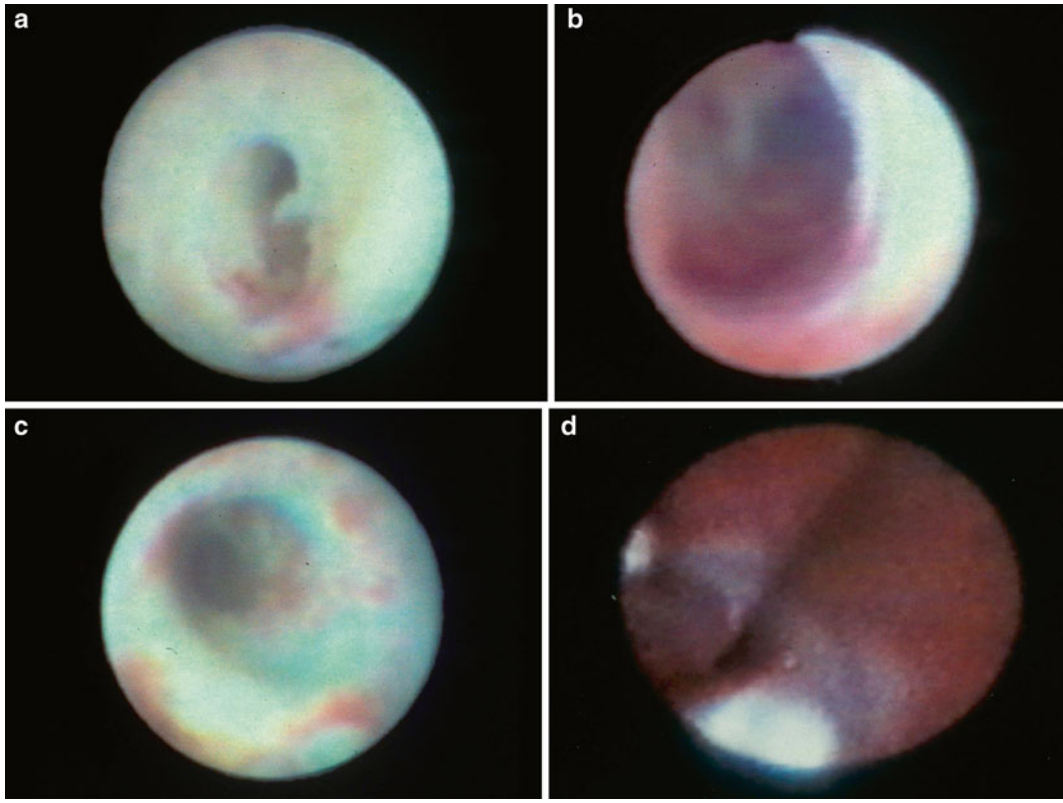

Fig. 13.4 Endoscopic view of the normal anatomy of the lacrimal passage. (**a**) Canaliculus. (**b**) Rosenmueller's valve. (**c**) Passage from sac to nasolacrimal duct. (**d**) Nasal cavity and inferior turbinate

Laser Dacryoplasty

Holmium:YAG Laser

First attempts of a laser canaliculoplasty were performed using a holmium:YAG laser [6]. Without being linked to an endoscope, a 1-mm cross-sectional connection to the nose was created in the case of canalicular stenosis. The laser had an energy level of 100 mJ, which was delivered by a quartz fiber. After 6 months, the postoperative success rate resulted in an improvement in 57 % in 17 examined.

Potassium Titanyl Phosphate Laser

The KTP laser is a very powerful solid-state laser and provides a maximum energy of 10 W, delivered by a 0.3-mm semiflexible fiber that can be connected to an endoscope. The energy released

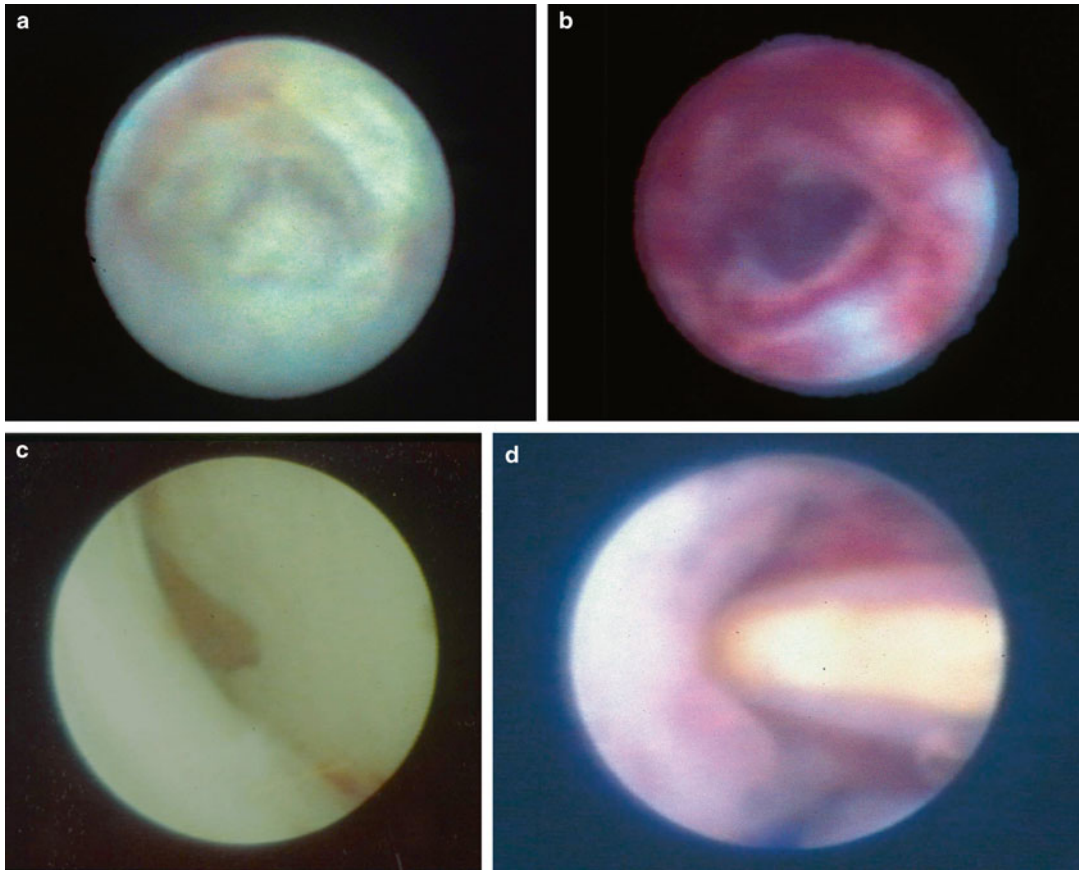

Fig. 13.5 Endoscopic view to pathologic findings. (**a**) Chronic dacryocystitis, submucosal scars. (**b**) Lacrimal sac stenosis with acute inflammation. (**c**) Mucocele. (**d**) Residual silicone tube after incomplete removal

from it is sufficient for creating holes in bones [12]. This laser has been used in a small number of patients and is not frequently used at this time.

Erbium:YAG Laser

A modified, miniaturized erbium:YAG laser [9, 10, 13] often used for glaucoma surgery has been in use since 1996 (Fig. 13.6). A 375-µm sapphire fiber delivers at most 50 mJ with 1–3 Hz.

Miniaturized handpiece	Yes
Wavelength	294 µm
Energy	Maximum 100 mJ
Frequency	1–3 Hz
Fiber length	11 cm
Zone of necrosis	10–20µm

The erbium:YAG laser is a photoablative laser, and its maximum absorption occurs in water. Mucosal cells have a water content of 77 % so ablation results quickly, but the main effect on a stenotic lacrimal passage is the resulting cavitation blister and not tissue ablation. This blister can extend over several millimeters, allowing for punctal stenoses to be opened with just a few pulses. The energy penetrates the tissue for only a few microns and its low thermal effect creates small necrosis zones of 10–20 µm, making it unsuitable for ablation of bone.

After changing the diagnostic probe from a two to a three working-channel handpiece, therapeutic interventions could be performed. Since 1996, an additional short tip of 4 cm has been developed for treating canalicular stenoses (Fig. 13.6c).

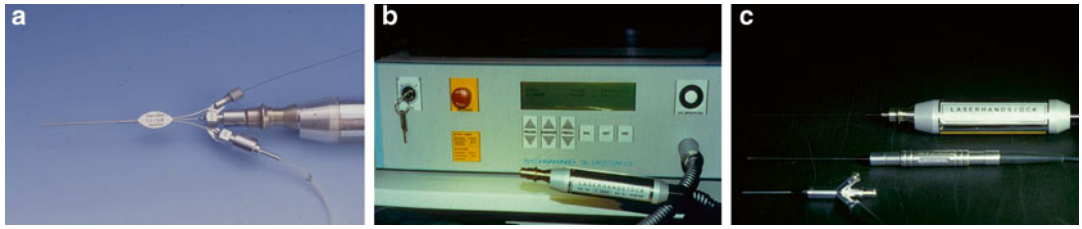

Fig. 13.6 Erbium:YAG laser components. (**a**) Miniaturized handpiece and early version of a probe. (**b**) Erbium:YAG laser. (**c**) Canaliculus tip

Technique of Laser Dacryoplasty

Initially, a diagnostic endoscopy is performed using the same probe, Vitroptic T (Fig. 13.6), before the laser application takes place. The procedure is continued until free irrigation without resistance is present and the endoscopic image confirms an opening of the mechanical stenosis. Then, bicanalicular intubation using a silicone tube is performed for preventing postoperative adhesions of the mucosa. The tube stays in place for at least 3 months. Alternatively, in cases of isolated canalicular stenosis, a monocanalicular probe can be used according to the methods of Bernard and Fayet [9]. The postoperative therapy is the same as following bicanalicular intubation in other cases.

Results of Laser Dacryoplasty

The success rate of laser dacryoplasty (LDP), judged as reduction of epiphora, is 60–70 % for all cases ($n=184$). The postoperative follow-up was 20.4 months. Considering all canalicular stenoses ($n=44$, follow-up more than 12 months), the success rate is 68 %, and it increases to 86 % for common canaliculus stenosis. These results are better when compared with those after microsurgical procedures performed without endoscopy [13, 14].

Indications for Laser Dacryoplasty

An LDP is indicated in cases of canalicular stenosis, intra- and/or postlacrimal sac lesions, and membranous occlusions after failed DCR. It has been mostly performed on canalicular and lacrimal sac stenoses with chronic infections. Unsuitable scenarios for LDP are acute dacryocystitis, mucoceles, widespread adhesions after viral infections, or stenosis caused by bone displacement after midface fractures.

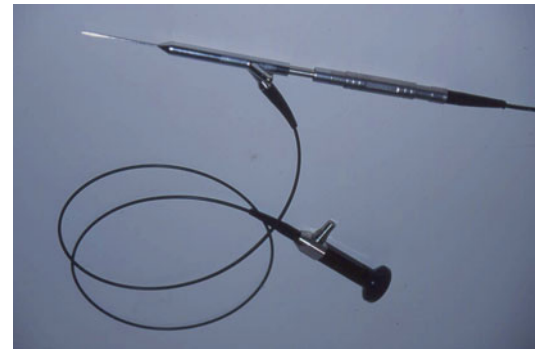

Fig. 13.7 Microdrill and Vitroptic T

Microdrill Dacryoplasty

Soon after the development of the LDP, a second technique was introduced for endoscopic transcanalicular manipulation using a microdrill, according to Busse [15] (Fig. 13.7). The microdrill, connected to the Vitroptic T, consists of a stainless steel probe with a diameter of 0.3 mm, a drill driven by a shaft, and a battery-operated motor with 50 rpm. The drill is controlled by a foot pedal. After inserting the Vitroptic T into the lacrimal passage and advancing to the location of the stenosis, the drill is pulled forward under continuous irrigation. This allows the drill to be visualized throughout the procedure. After clearing

the obstruction, patency is assessed by irrigation and endoscopy. The postoperative regimen (intubation and medical therapy) is the same as after LDP.

Results

The success rate of microdrill dacryoplasty ($n=168$) for reduction of epiphora with the follow-up of more than 12 months is almost 78 % [14, 16].

Indications

The microdrill is suitable for membranes, dacryoliths, or other mechanical obstructions, especially subtotal button-holed-style stenosis at the end of the lacrimal sac 18–20 mm distal to the punctum. The drill performs a kind of mucosal curettage; therefore, canalicular stenosis is not suitable for treatment with the microdrill system. The microdrill cannot be used to perform a DCR.

Conclusion

Transcanalicular dacryoendoscopy combined with simultaneous minimally invasive therapy is a great step forward in diagnostic and operative choices. It has considerably reduced the rate of DCRs that would otherwise have been necessary to perform.

Transcanalicular endoscopy enables new insights into the pathology of the diseases of the lacrimal system. Today, one can directly visualize lesions and decide immediately on appropriate interventions, whereas in the past, only indirect imaging was available.

Technique and Results of Transcanalicular Laser-DCR

Introduction

Transcanalicular microendoscopic surgical techniques with lacrimal duct stenoses have been established as "first step procedure" in lacrimal surgery since the invention of lacrimal duct endoscopy and the rechanneling of the revulsive lacrimal duct through microdrill dacryoplasty or laser dacryoplasty [9, 17] (Fig. 13.8).

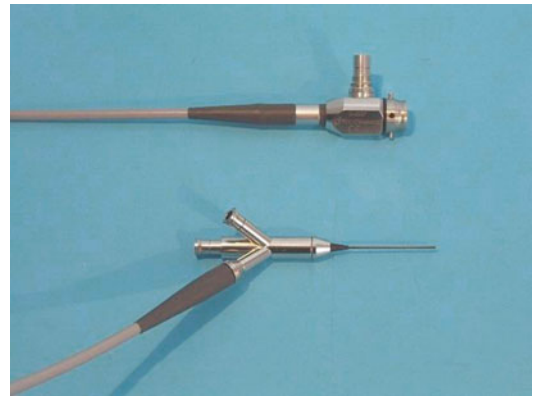

Fig. 13.8 Vitroptic T

The success rate of these operations is about 80 %. If such an microendoscopic surgical technique hasn't achieved success, in principle all other lacrimal surgery can be done, as no anatomic proportions have been changed; especially an external or endonasal dacryorhinostomy can be done in all cases, if necessary.

But before, due to persisting troubles, a DCR [18] with a prolonged time of postoperative recovery is done, there is, as already showed, the possibility to do a transcanalicular DCR through a transcanalicular osteotomie with a diode laser (Fig. 13.9) [19, 20]. To ensure the rate of success of this procedure and at the same time to avoid unnecessary trauma with the application of high laser energy, with the technique shown here, the osteotomie is widened by balloon dilatation up to a diameter of 5 mm.

Material and Methods

The transcanlicular laser DCR with following ballon dilatation is performed under general anaesthesia, as microdrilldacryoplasty or laserdacrypolasty as well. After a dacryoendoscopy with validation of the diagnoses an osteotomie with the diode laser is performed under the ear cap (laser energy 9.1 W, pulse length 20 ms, pulse rate 4 ms) (Fig. 13.10) under endonasal

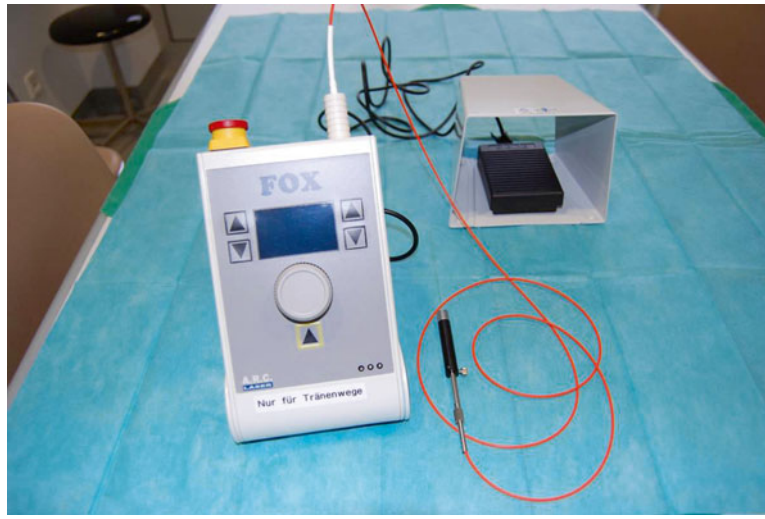

Fig. 13.9 Fox Laser

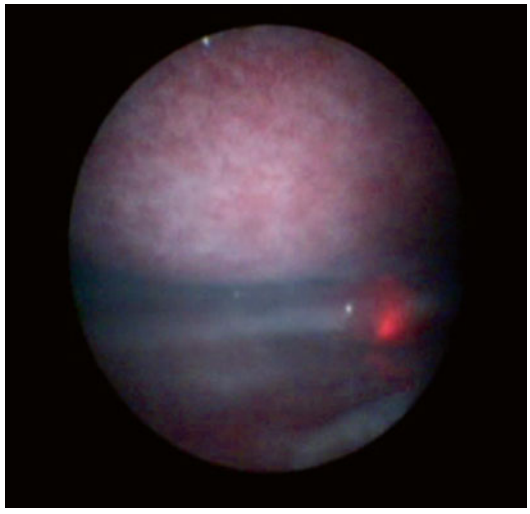

Fig. 13.10 Laserfiber with pilot beam with transcanalicular DCR, endonasal

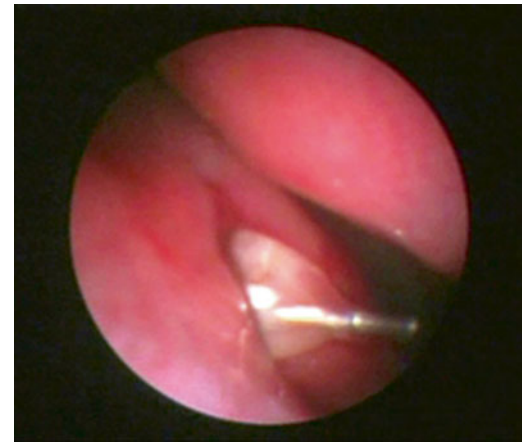

Fig. 13.11 Endonasal figure of a LacriCath balloon while dilatation

endoscopic control with a rigid endoscope (Endognost®, Polytech).

After the osteotomie the anastomosis is widened with a balloon catheter up to a diameter of 5 mm for the duration of 2×90 s with 8 atm high pressure (Fig. 13.11).

Following that a bicanalicular intubation of the nose is done under free flushing patency (Figs. 13.12, 13.13, and 13.14).

In posttreatment for 3 weeks a three-way therapy is applied with a combination medicine (antibiotic and cortisone eye drops), decongestant eye drops and decongestant nose drops. A control with the removal of the tube is done after 3 months.

Discussion

New developments in lacrimal surgery aspire to reach the results of DCR with less effort. The

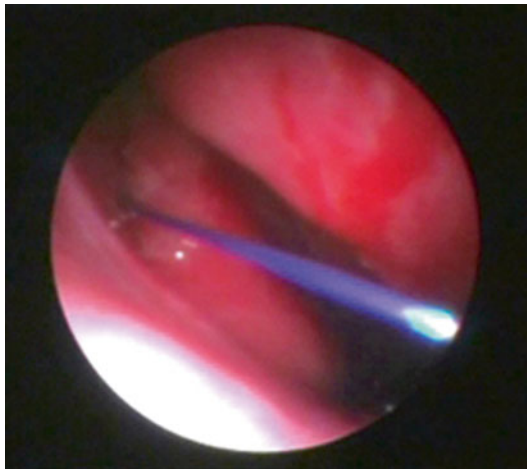

Fig. 13.12 Endonasal figure with provided prolene fiber for intubation (Seldinger Technique)

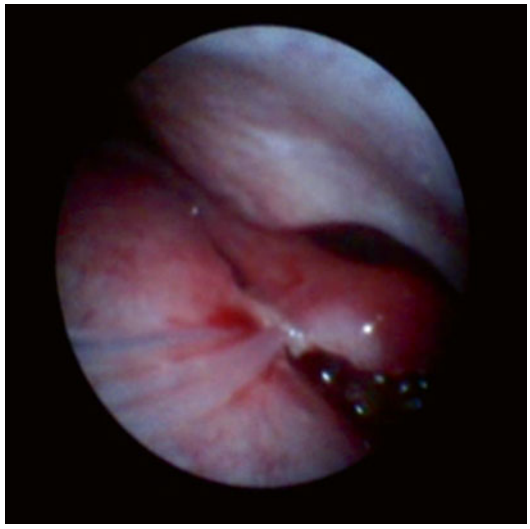

Fig. 13.13 Endonasal figure with lying silicone intubation with bicanalicular intubation

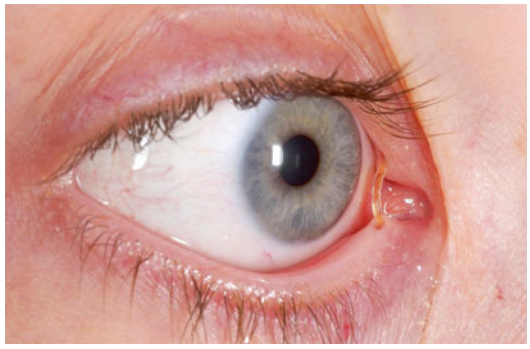

Fig. 13.14 Bicanalicular intubation

duration of the surgical procedure is to be as short as possible, the convalescence is to be reached as soon as possible, visible and invisible scars are to be avoided. With all considerations the rate of complications has to be as low as possible.

A huge step on this way is the successful introduction of transcanalicular microendoscopy (dacryoendoscopy) and the subsequent minimal invasive surgical technique [21, 22]. This way since 1995 it could be shown that a great percentage of patients who had to be treated with DCR could be successfully treated with significant less invasive procedures, the laser dacryoplasty and the microdrill dacrypolasty [14]. With the surgical technique which is presented here, the transcanalicular dacryocystorhinotomy, which is based upon transcanalicular microendoscopy, these procedures should be completed. Indication for this is e.g., failure of therapy, in which already a rechanneling procedure has been done without success. The procedure of transcanalicular DCR is therefore an additional procedure which is significantly less invasive as DCR.

The first results of the study presented here are encouraging, the procedure is, technically and considering the risk profile, practical. The presented rate of success has to be reviewed in a larger group of patients, but it is a good basis for the performance of this procedure.

Conclusion

The transcanalicular, endoscopic laser dacryocystorhinostomy is, in addition with the 5 mm balloon dacryoplasty a new, technically good to perform, procedure in lacrimal surgery with a minimal invasive profile. This procedure especially seems to be perfect to close the gap between rechanneling surgical procedures—laser dacryoplasty and microdrill dacryoplasty—and external or internal DCR.

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Conjunctivodacryocystorhinostomy 14

Eric A. Steele and Roger A. Dailey

Procedure

This surgery is typically performed using infiltration of local anesthetic with monitored anesthesia care (MAC). The local anesthetic used is a 1:1 mixture of 1 % lidocaine with 1:100,000 epinephrine and 0.5 % bupivacaine. The vasoconstrictive properties of the epinephrine are important for hemostasis, and the anesthesiologist or certified registered nurse anesthetist monitors the patient and administers oxygen and intravenous sedation to keep the patient comfortable and avoid excessive elevation of blood pressure. The naris is packed with neurosurgical cottonoids saturated in either cocaine hydrochloride 4 % solution or adrenaline 1:1,000 solution (mixed with fluorescein dye so there is no confusion as to what this otherwise clear liquid is) to vasoconstrict the nasal mucosa.

After parenteral sedation is administered, topical proparacaine is instilled in the eye, and the local anesthetic is infiltrated subcutaneously in the medial canthal area, taking care to avoid intravascular injection into the angular vessels. The cottonoids are placed in the nose with a bayonet forceps in the area just anterior to the attachment of the middle turbinate.

The skin incision is made 11 mm medial to the medial commissure, with the superior border in the plane of the medial canthal tendon and extending approximately 18 mm inferiorly and slightly laterally (Fig. 14.1). A sharp Stevens scissors is used to divide the remaining subcutaneous tissue, and an Agricola self-retaining retractor is placed. A Freer or Cottle elevator is used to dissect to the maxillary bone anterior to the lacrimal crest. The angular vessels are typically encountered during this process and can be avoided or cauterized at the surgeon's discretion. The authors typically use a handheld battery cautery unit for hemostasis, although monopolar or bipolar cautery also works well.

The elevator is used to lift the periosteum posteriorly to expose the anterior lacrimal crest. There is often a small vessel in a bony groove just anterior to the crest that is cauterized. The periosteum is lifted in the lacrimal sac fossa, and down as far as possible in the nasolacrimal canal (Fig. 14.2).

At this point, local anesthetic is infiltrated in the lacrimal sac. A small cottonoid with adrenaline or cocaine is placed in the space between the lacrimal sac and the fossa, and the intranasal cottonoids are removed to avoid damage to these mucosal tissues during the next step of bone removal.

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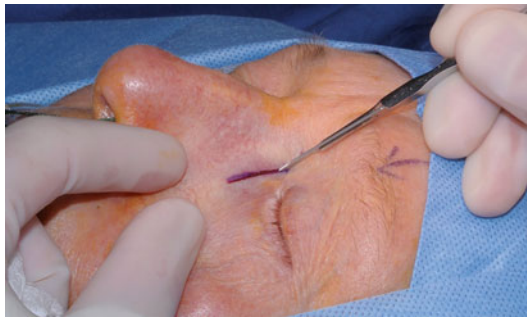

Fig. 14.1 The superior aspect of the skin incision is 11 mm medial to the medial commissure, extending inferiorly and slightly laterally for approximately 18 mm

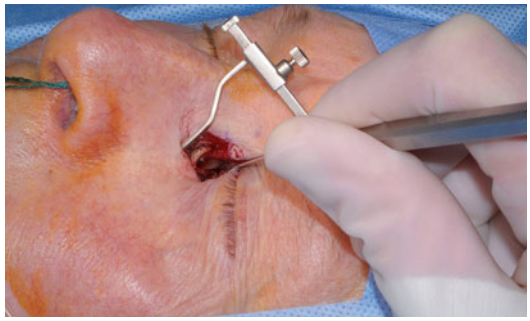

Fig. 14.2 After the frontal process of the maxillary bone is exposed anterior to the lacrimal crest, the periosteum is lifted from the lacrimal sac fossa and down as far as possible in the superior aspect of the nasolacrimal canal

The Agricola retractor is replaced with a Goldstein retractor, which has longer teeth to provide better exposure. A 4 mm burr on a high speed drill is used to remove an oval window of bone anterior to the lacrimal crest, taking care not to damage the nasal mucosa. The nasal mucosa is infiltrated with local anesthetic, and a dental burnisher is passed through the bony window to separate the nasal mucoperiosteum from the underside of the bone (Fig. 14.3).

A 45° Kerrison rongeur is used to enlarge the bony opening to include removal of the anterior lacrimal crest, and the entire lacrimal sac fossa from the level of the medial canthal tendon superiorly and including the superior aspect of the nasolacrimal canal inferiorly. The medial canthal tendon is left intact, with care taken to remove enough bone in this area to provide at least a

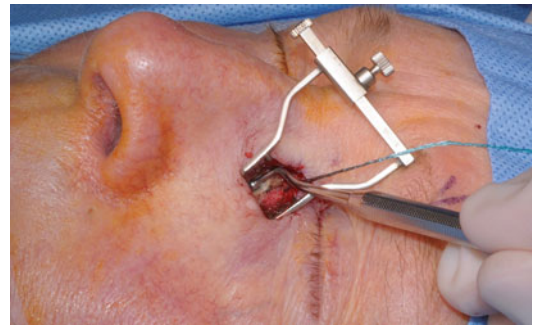

Fig. 14.3 After the nasal mucosa is infiltrated with local anesthesic, a dental burnisher is passed through the bony window to separate the nasal mucoperiosteum from the underside of the bone

5 mm distance from the level of the common canaliculus. Occasionally during this process there will be an anteriorly placed ethmoid air cell that is removed.

The lacrimal sac is then vertically incised along its entire length with a #11 blade, and anterior and posterior flaps are created. A corresponding vertical incision is made through the nasal mucosa, with creation of anterior and posterior flaps. Both posterior flaps are then excised.

Attention is then directed to the caruncle. If it is prominent, it is conservatively debulked with a scissors. A sharp Stevens scissors is inserted in the area of the caruncle and gently advanced in a slightly downward trajectory into the previously created opening into the nose, taking care to angle anterior to the middle turbinate. If the middle turbinate interferes, the anterior tip can be judiciously resected. The scissors are slightly opened, and a Bowman probe with the appropriate length Jones Tube in place is passed immediately anterior to the scissors. The scissors are slowly removed, with the blades still slightly open, as the Jones Tube (Gunther Weiss Scientific Glass Blowing Company, Portland, Oregon) is pressed forward using a forceps (Fig. 14.4). The tip of the tube of the tube is inspected, and must rest halfway between the lateral wall of the nose and the septum, or should be replaced with a tube of a different length. The anterior mucosal flaps are then sutured together anterior to the Jones Tube using 5–0 polyglactin on a small curved needle.

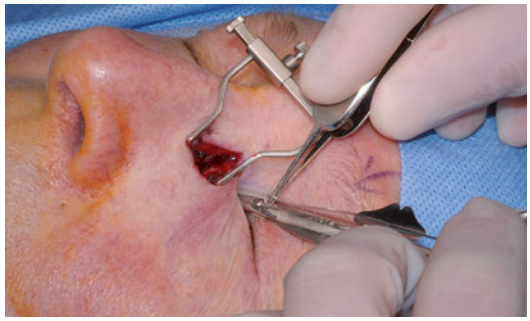

Fig. 14.4 The Jones Tube has been "loaded" on a Bowman probe, with the probe passed into the tract and resting between the open blades of the scissors. The scissors are slowly removed, with the blades still slightly open, as the Jones Tube is pressed forward using a forceps

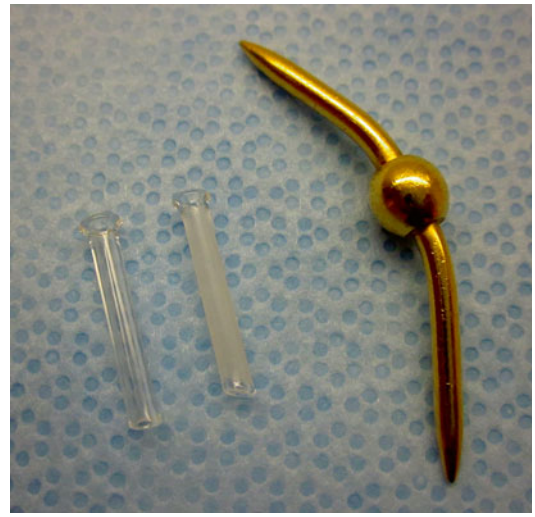

Fig. 14.5 The Weiss gold dilator. This is placed in the CDCR tract when the Jones Tube is removed for cleaning to allow the tube to be easily replaced. The dilator also comes in a small size, which can be used to progressively dilate the tract in the case of tube extrusion. Pictured to the left of the dilator are standard (*left*) and frosted (*middle*) Jones Tubes

The orbicularis is closed with a running 6–0 polyglactin suture, followed by closure of the skin with a running 6–0 fast absorbing gut suture. A 6–0 polyglactin suture is secured to the medial canthal tissue and wrapped around the collar of the tube to prevent migration of the tube in the early postoperative period. A 4 mm collar is typically placed initially to prevent inward migration of the tube, and can be replaced at a postoperative visit if the collar is causing irritation of the ocular surface or if the appearance is cosmetically objectionable to the patient.

Postoperative Care

The Jones Tube is prone to develop obstruction due to deposition of tear salts or mucus crusting over time, and requires some maintenance for optimum function. Patients are instructed to place an artificial tear in the eye on a daily basis and "snuff" it through the tube by pinching their nose and inspiring. This irrigates the internal aspect of the tube to prevent build up of debris. Similarly, the patient can use saline nasal irrigation if they have issues with nasal crusting.

Patients are scheduled for routine cleaning of the Jones Tube on a semiannual or annual basis, or can be performed on an as-needed basis if the tube becomes obstructed. This is performed in the office and is well tolerated. After instillation of topical anesthetic, the Jones Tube collar is grasped with a forceps and removed. A Weiss (gold) dilator (Gunther Weiss Scientific Glass Blowing Company, Portland, Oregon) (Fig. 14.5) is immediately placed in the tract to avoid contracture while the tube is being cleaned. The tube is cleaned by rubbing the tube under running water or with an alcohol wipe. The internal aspect of the tube is cleaned by pressing a small piece of alcohol-soaked cotton through with a Bowman probe. Alternatively, ultrasonic cleaning may be used. The tube is then "loaded" on a Bowman probe. The Weiss dilator is removed and the Bowman probe is passed into the nose, followed by gentle pressure with a forceps to advance the Jones Tube into proper position. Proper placement in the nose is confirmed by examination with a headlight and a nasal speculum.

The tube can extrude if the patient blows his nose or sneezes, and so patients are taught to keep their eyes closed during these maneuvers, or even to press their finger in the medial canthal area if necessary. If the tube completely extrudes, the patient is instructed to call to be seen as soon as possible to try to replace the tube.

Within the first 24 h, it is usually possible to dilate the tract with the Weiss (gold) dilators and replace the tube. If the dilators cannot be passed, an attempt can be made to reestablish the tract using local anesthetic in the office, or a new tract can be created in the operating room with Monitored Anesthesia Care for patient comfort. The use of a Frosted Jones Tube can decrease the likelihood of tube migration, and has a similar safety and efficacy profile as the original non-Frosted tubes.

Problems with Jones Tubes

Jones Tubes are not tolerated by all patients, and occasionally have to be removed. The most common issue is related to the bidirectional nature of the tube. Some patients are bothered by air puffing onto their eye when they blow their nose, or even get splattering of tears on their glasses. The use of a CPAP machine by patients with Obstructive sleep apnea can be especially problematic in this regard. Attempts can be made to adjust the type of mask or settings on the CPAP machine, but sometimes this does not provide a satisfactory solution. A mask that fits over both the nose and the tube (so the air pressure is the same on either side of the tube) can sometimes be beneficial.

Occasionally, the patient will develop a chronic conjunctivitis in the medial canthal area, or even granuloma formation around the tube. This usually is the result of a crusty deposit on the outside of the tube that can be scraped off of the tube during the routine cleaning process, with resolution of the patient's symptoms. The conjunctivitis will typically respond nicely to a 2-week course of an antibiotic/steroid drop administered two times per day.

In summary, external conjunctivodacryocystorhinostomy with placement of a Jones Tube continues to be an excellent option in the treatment of patients with upper lacrimal obstruction.

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Endoscopic Conjunctivodacryocystorhinostomy

15

Geoffrey J. Gladstone and Brian G. Brazzo

Preoperative Evaluation

The evaluation of a patient with excess tearing involves thorough investigation of the causes as well as determination of the location of lacrimal outflow obstruction. Numerous causes of excess tearing include dry eye syndrome, entropion, ectropion, retraction, trichiasis, distichiasis, and other causes of ocular irritation. Idiopathic hypersecretion is a diagnosis of exclusion and should be considered in all cases where there is no other apparent cause of excess tearing.

Slit lamp examination of the conjunctiva for signs of symblepharon, inflammation, or infection must be performed. The surgeon should also inspect the eyelids and eyelashes for abnormal positioning and check closely for entropion, ectropion, trichiasis, districhiasis, and eyelid notching.

Probing and irrigation of the lacrimal system is a very important technique for evaluating and determining the blockage location of the lacrimal system. The traditional Jones 1 and Jones 2 testing is rarely performed. Probing and irrigation of the tear duct system with a #23- or 25-gauge lacrimal canula is regularly used to probe the upper and lower canaliculi. It is important for the surgeon to note any blockage or stenosis that is encountered along the path of the proximal canalicular system. Irrigation with water or saline is then attempted when the canula is stabilized within the canaliculus. The ease of irrigation of fluid into the nasopharynx and the amount of reflux from the canalicular system back to the eye is noted. Significant blockage or stenosis of a canaliculus is an indication for endoscopic conjunctivodacryocystorhinostomy (CDCR).

When the surgeon is considering whether to perform endoscopic CDCR, the caruncle and medial canthus must also be closely evaluated. There must be an appropriate place for the proximal end of the tube to rest. If the patient has previously had a medial tarsorrhaphy or other surgical or traumatic event in that area, surgical correction should first be performed in order to restore normal anatomical position of the eyelid and conjunctiva.

Nasal endoscopy should be performed to evaluate the space between the septum and lateral nasal wall. The presence or absence of intranasal lesions or unusual anatomic positioning should be noted. Intranasal tumors or lesions can cause an outflow obstruction and should be treated appropriately. A deviated nasal septum or narrow nasal cavity can make endoscopic surgery difficult or impossible. Additionally, the distal end of

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the tube must rest in a space between the septum and lateral nasal wall. If this space is insufficient, a septoplasty should be performed prior to endoscopic CDCR in order to allow proper outflow of the tube.

Gladstone-Putterman Modified Jones Tube

The original Jones tube is susceptible to internal and external migration, as well as to ejection following sneezing, coughing, and nose blowing. An additional flange was added to the Jones tube in order to alleviate this problem. An internal flange was placed 4 mm distal to the external flange. This modification acts as an arrowhead, locking the tube in position (Fig. 15.1). The modification of this tube is known as the Gladstone-Putterman tube and it is inserted in a similar manner as the original Jones tube.

Indications for Endoscopic CDCR

Canalicular stenosis is the most common indication for endoscopic CDCR. This blockage may be secondary to trauma, prior surgery, systemic chemotherapeutic agents such as Taxotere or 5-FU, or chronic use of topical ophthalmic medications that can cause a low-grade or high-grade allergic conjunctivitis. Unicanalicular or bicanalicular blockage, in addition to significant common canalicular stenosis, can cause epiphora.

When any type of canalicular stenosis is identified, treatment can involve silastic intubation. Often, monocanalicular intubation is performed. If this treatment fails to eliminate the symptoms, then endoscopic CDCR should be considered. When canalicular stenosis is present, dacryocystorhinostomy (DCR), will not be effective in alleviating the symptoms. In this situation, tears will not progress to the lacrimal sac and complete bypass of the lacrimal outflow tract with a modified Jones tube must be considered.

Following Bell's palsy and other types of facial weakness and paralysis, lacrimal pump failure often occurs. This situation is common after removal of acoustic neuromas and squamous cell carcinomas. A normal probing and irrigation of the lacrimal system may be completed, and the flow of fluid into the nasopharynx may be normal. However, a dye retention test may be abnormal and a large amount of dye will remain in the enlarged tear film. In these conditions, the surgeon will often detect significant ectropion, lagophthalmos, and corneal staining in the preoperative evaluation. It is important to

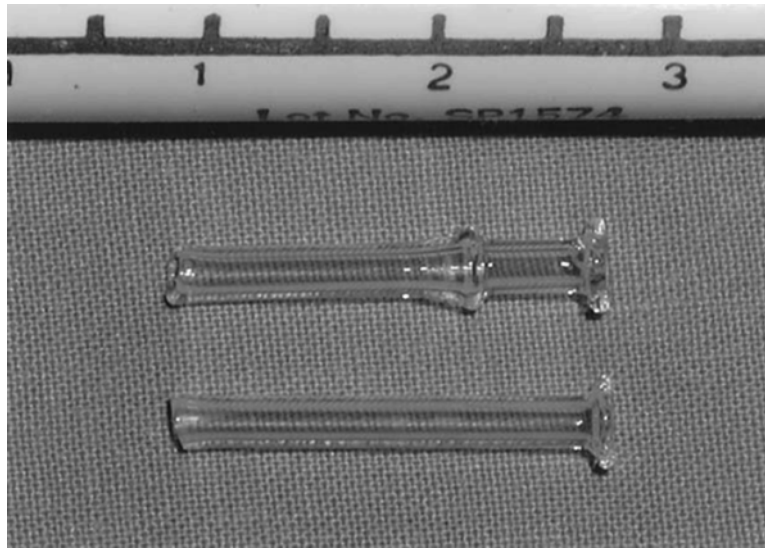

Fig. 15.1 Comparison of Gladstone-Putterman tube (*above*) and Jones tube (*below*)

exclude these causes of tearing before proceeding with surgery.

In normal eyelids, the lower lid and punctum move medially with each blink. This can be seen easily during slit lamp examination if the upper eyelid is held open and the patient is asked to blink. The absence of movement of the lower eyelid can be an indication of an old facial paralysis that has not completely resolved.

A final indication for endoscopic CDCR is idiopathic hypersecretion. This diagnosis of exclusion is suggested when the outflow tract is normal and there are no identifiable factors causing increased lacrimal gland secretion. The Shirmer 1 will be much higher than normal. Referral to an external disease consultant should be considered prior to arranging surgery. In these cases, the modified Jones tube provides an additional and larger outflow tract to accommodate the increased tear production.

Advantages of Endoscopic Technique

Endoscopic CDCR has several advantages over traditional external CDCR. Among the advantages are the absence of a scar, absence of edema, and ecchymosis, and minimal surgical manipulation of the medial canthus tissue. It also allows improved visualization of the modified Jones tube and adjacent nasal structures once the tube has been inserted into the nose. With minimal external tissue manipulation, ecchymosis and edema of the skin and canthus are rarely present.

Because no medial canthal skin incision is necessary with the endoscopic technique, no dissection of deep subcutaneous tissue is performed. This lack of tissue manipulation contributes to a more rapid healing process, and improves the chance that a properly placed modified Jones tube will remain in position. With the traditional external technique, there is greater chance of tube migration in the healing phase. This change can lead to malposition of the proximal end of the tube or alteration of the angle of the tube. The tube should maintain an approximate 45° downward angle at all times. If this angle is modified, tear drainage can diminish.

Endoscopic intranasal inspection of the distal end of the modified Jones tube is performed immediately after it is placed. This process allows accurate assessment and identification of potential problems. If the tube is too short and does not protrude far enough from the lateral nasal wall, it is at risk for being covered during the healing phase by nasal mucosa. Also, a tube that is too long may touch the nasal septum, causing pain and leading to external extrusion with poor drainage. These problems are easily correctable at the time of surgery by reinserting a different size tube. Therefore it is imperative that the surgeon recognize the problem intraoperatively, when it can easily be corrected.

The relationship of the distal end of the tube to the middle turbinate is also evaluated endoscopically. The middle turbinate must often be infractured early during the surgical procedure to provide appropriate access to the uncinate process. Postoperatively, the turbinate will often migrate to its preoperative position, and may touch or block the distal end of the modified Jones tube. If the surgeon believes that turbinate movement will result in blockage of the tube, a partial turbinectomy should be performed at the time of surgery.

Surgical Technique

Twenty to thirty minutes prior to the beginning of surgery, the patient is asked to blow the nose, and is then given two sprays of 0.05 % oxymetazoline in the ipsilateral nasal cavity of the planned procedure. This process is repeated 5 min later. Endoscopic CDCR may be performed under monitored intravenous sedation with local anesthesia or general anesthesia, depending on the preferences of the patient and surgeon. After induction of anesthesia, the nasal cavity is packed with approximately 18 in. of 0.5-in. plain gauze soaked in 4 % cocaine solution. If cocaine solution is not available, the surgeon may substitute a mixture of oxymetazoline and 2 % lidocaine with epinephrine. The packing is removed after 5 min.

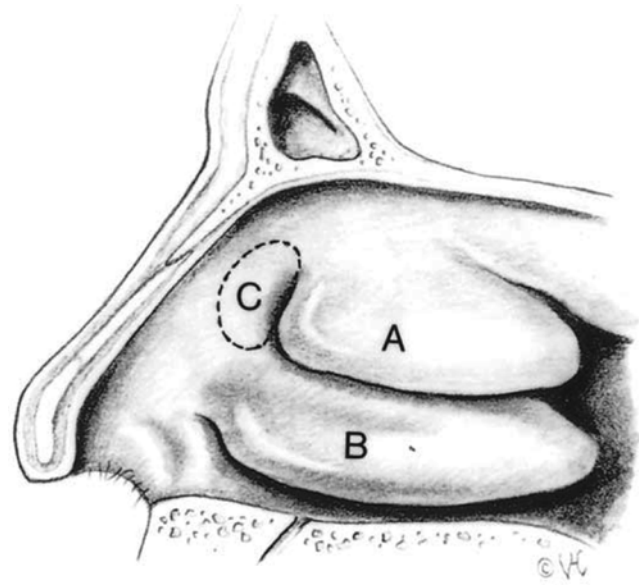

Fig. 15.2 Normal nasal anatomy. (*A*) Middle turbinate. (*B*) Inferior turbinate. (*C*) Bone and mucosa overlying lacrimal fossa

Under direct visualization, with a 0° rigid endoscope, local injection of 2 % lidocaine with 1:100,000 epinephrine mixed with an equal amount of bupivacaine 0.075 % with 1:200,000 epinephrine is administered to the submucosa of the anterior middle turbinate, uncinate process, and the area anterior and superior to the uncinate. Approximately 3 cc infiltrate is applied with 1.5 in. 25-gauge needle. The nasal cavity is repacked, carefully filling the space between the middle turbinate, and lateral nasal wall with the anesthesia-soaked gauze for another 5 min. This regimen of packing is important to obtain appropriate hemostasis. The face is prepped and draped in an appropriate manner. A sterile field is not necessary.

With endoscopic visualization, the middle turbinate and its position to the lateral nasal wall are inspected (Fig. 15.2). If the turbinate obstructs the view of the uncinate process, or if the surgeon believes that the turbinate will obstruct the osteotomy site in the postoperative phase, then the turbinate can be gently infractured with a blunt periosteal elevator. This same instrument may be used to make an incision at the border of the bone of the lateral nasal wall, and the uncinate process. The uncinate is identified as the first protrusion of the lateral nasal wall that is encountered under the middle turbinate.

The mucosa that overlies the lacrimal fossa is cauterized with monopolar cautery that is set in the coagulation mode (Fig. 15.3). The area of cauterization begins at the level of the anterior root of the middle turbinate, and broadly extends 10 mm anteriorly, inferiorly and superiorly. When cautery is completed, the charred mucosa is scraped from the underlying bone with a periosteal elevator. This tissue is then removed with Blakesley forceps.

Thorough removal of the mucosa is important to prevent bleeding during the next step of the procedure. A medium-sized Kerrison bone rongeur creates an osteotomy which corresponds to the area from which the mucosa was removed. The rongeur is placed on the bony edge that was exposed following removal of the uncinate process. Progressive bone removal extends superiorly and anteriorly. Usually four to five bites are needed to obtain an adequate opening. The lacrimal sac should be identifiable at this time.

The external track for the glass tube is next created. No excision of caruncle or conjunctiva needs to be performed. In fact, surgical manipulation of this tissue can promote inward migration of the modified Jones tube during the healing phase.

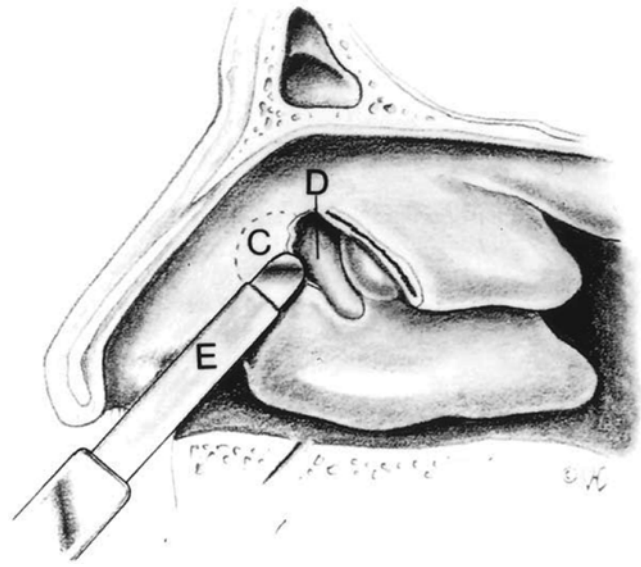

Fig. 15.3 Guarded monopolar cautery (*E*) applied to nasal mucosa (*C*) and lacrimal fossa bone (*D*)

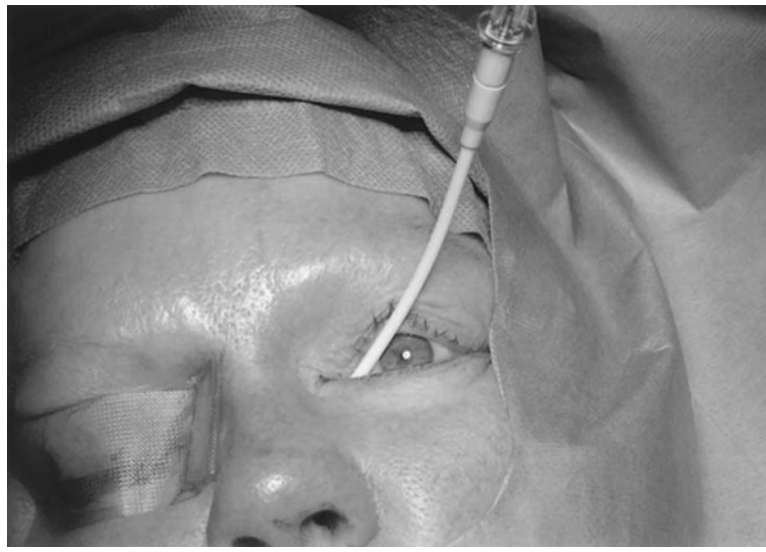

Fig. 15.4 A 12-gauge shielded intravenous catheter (Angiocath) is bent approximately 30° at its midpoint and advanced through the middle of the caruncle at a 45° angle. The catheter can be visualized entering the nasal cavity with an endoscope

A 12-gauge shielded intravenous catheter is bent approximately 30° at its midpoint. A smaller 14-gauge catheter can be used, but the passage of the Jones will be more difficult with the smaller catheter. Bending the catheter as described is intended to keep the distal end of the tube relatively anterior in the nasal cavity. The catheter enters the middle of the caruncle (Fig. 15.4). The shaft of the catheter is kept close to the eye as the catheter is advanced in the medial and inferior direction. A downward angle of 45° is attempted. The tip is visualized with the endoscope as it punctures the nasal mucosa. If the tip of the catheter does not appear in the predetermined location, it can be pulled back and redirected so that it exits through the osteotomy in the appropriate location. The metal needle is removed, leaving only the plastic sheath in position.

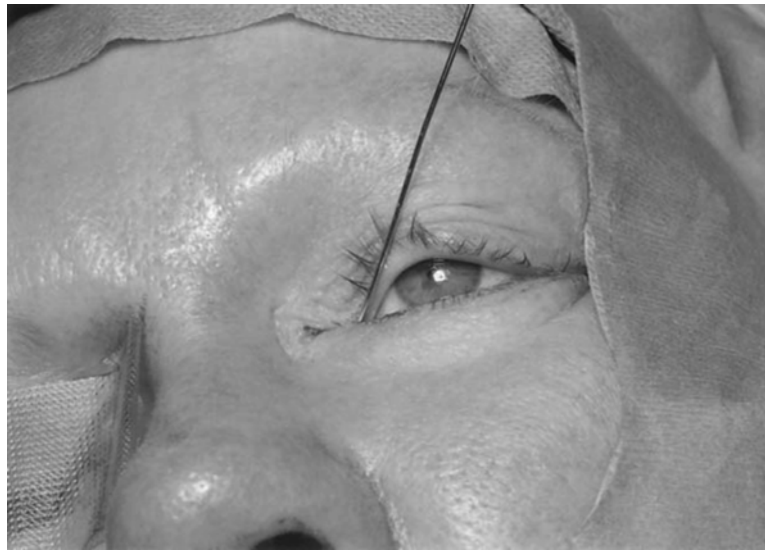

Fig. 15.5 A 9-in.-long piece of 20-gauge wire is passed through the plastic sheath and the sheath is removed, leaving only the wire in position. The wire acts as a guide for the glass tube placement

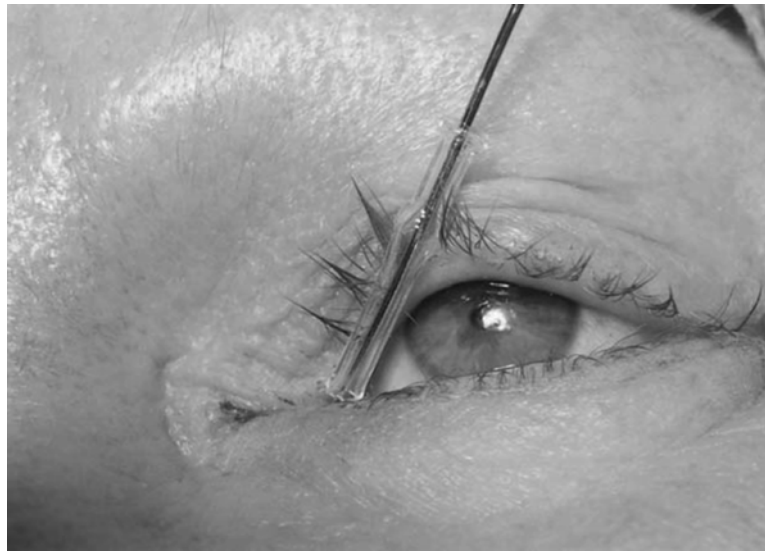

Fig. 15.6 A Gladstone-Putterman 4 × 19 mm tube is placed over the wire before it is pushed into proper position

A 9 in. long piece of 20-gauge wire is passed through the plastic sheath. The wire is stabilized and the sheath is then removed, leaving only the wire in position (Fig. 15.5). The wire will act as a guide to the glass tube, which is placed through the caruncle and conjunctiva. A 4 mm by 19 mm tube is placed over the wire and pushed into proper position (Fig. 15.6). When the flange of the tube encounters the medial canthus, increased resistance should be felt by the surgeon. Both of the surgeon's thumbnails are placed on the proximal end of the tube and used to push it firmly into position. The internal flange will lock the tube in position.

The length and position of the tube are identified through the endoscope. The tube ideally sits halfway between the nasal septum and the lateral nasal wall. If the position is not appropriate, the proximal end of the tube is grasped with tooth forceps, and the tube is removed, leaving the guidewire in place. A tube of different length can be inserted over the guidewire and placed into position as previously described. Once a tube of acceptable length is found, the guidewire is removed. A 6–0 double-armed silk or polyglactin suture is wrapped twice around the proximal end of the tube. Both needles are brought from the medial side in the tube through the conjunctiva and skin. The needles are passed through a small piece of sterile rubber band and are tied over the rubber band in a square knot. The rubber band bolster and sutures can be removed after 1 week.

Special Surgical Considerations

Following placement of the modified Jones tube, the distal end of the tube is inspected and its relationship to the middle turbinate is assessed. If the distal end of the tube is occluded by the middle turbinate, there is an increased possibility of external tube displacement or poor drainage of tears. A partial turbinectomy should be performed to reduce the chance of this complication. To perform this maneuver, an additional injection of local anesthetic is given directly into the turbinate. A small curved hemostat is applied perpendicular to the inferior border of the turbinate at the distal end to be removed. The curve of the hemostat is reversed and the instrument is applied along the superior border of the turbinate. Ideally, the tips of the crushed area on the turbinate will meet. The surgeon must be mindful not to dislodge or crush the Jones tube during insertion and closure of the hemostat. Endoscopic turbinate scissors are used to incise the tissue along the crushed areas. Blakesley forceps are used to twist and remove the turbinate section.

Preoperative evaluation should include evaluation of the intranasal region. If significant septal deviation is present, endoscopic surgery is much more difficult because insufficient space will not only make positioning and movement of instruments difficult, but will make it more difficult to place the tube in proper position.

In these situations, a septoplasty should be performed at a separate surgical visit, prior to endoscopic CDCR. Septoplasty can also be performed on the same day and immediately preceeding endoscopic CDCR. However, the septum medializes better if the tissues are allowed to contract for at least a month prior to endoscopic CDCR.

Postoperative Care

For at least several months following surgery, the patient should put a finger over the tube in the medial canthus during sneezing, nose blowing, and coughing. This preventative measure will reduce the change of external displacement of the tube. Once the medial canthus tissue has contracted around the tube and the flange, the tube becomes significantly more stable and there is less chance of external displacement.

Patients should also be reminded to tightly close their eyes whenever they perform the above maneuvers. Nose blowing is discouraged for the first postoperative week as this may also cause intranasal bleeding. After 1 week, a nasal saline rinse is used as much as desired to clean the nasal cavity.

Postoperative Evaluation and Management of Complications

An important aspect of the postoperative evaluation is the patient's subjective perception of how much their tearing has been reduced. This subjective evaluation is what patients consider in determining their satisfaction with the procedure. An objective evaluation of tube function has been devised.

The tear drainage is classified as Class I through IV. Several drops of water are placed in the medial canthal region with the patient's head leaning backwards. In Class I drainage, the water

drains spontaneously. In Class II drainage, the water drains with exaggerated nasal inspiration. Class III drainage is present when the water will not drain with inspiration but the tube can be irrigated with a canula. Class IV drainage is present when no irrigation is possible from the tube.

With Class I or Class II drainage, the patient generally has significant improvement in the symptoms and is typically satisfied. Class III and IV drainage problems need to be investigated and corrected, otherwise epiphora will continue. Poor drainage can be due to many factors including displacement of the tube in an anterior or posterior direction, displacement in an internal or external direction, and blockage of the tube either internally or externally.

A tube with the proximal end anteriorly displaced is not in position to allow tears to flow into the tube. This tube must be removed and replaced to a more posterior position. It is necessary to use the #12-guage catheter and enter the caruncle tissue more posteriorly than the original placement.

Removal of a modified Jones tube can be difficult since the medial canthal tissue contracts and holds the tube firmly in position. Tying a 2–0 silk suture around the neck of the tube will facilitate removal of the tube without risk of breakage. The chance of breaking the tube is much higher if large forceps are used to pull on the flange. Occasionally, it is necessary to use Westcott scissors to incise the adherent tissue. A posteriorly placed tube can irritate the eye or can become blocked at its proximal end by overgrowth of conjunctiva. Removal of the tube and placement more anteriorly will typically improve the tearing.

Internally migrated tubes are seen more commonly when a portion of the caruncle is removed intraoperatively, but can occasionally occur without caruncle manipulation. Usually, the tube can be palpated with forceps through the overlying tissue. Westcott scissors are used to incise the conjunctiva and scar tissue down to the proximal end of the tube. The surgeon should attempt to thread a 2–0 silk suture around the proximal flange. This suture is used to pull the tube laterally and remove it from the surrounding tissue. The canthal tissue should be allowed to heal prior to implanting another tube, otherwise internal migration will likely occur.

External displacement of the tube also places the proximal end of the tube in a position where tears cannot enter. The tube may irritate the globe and eyelid. Simple manual pressure on the proximal end of the tube may force it back into position, allowing the distal flange to lock properly in position. If simple manual pressure is not adequate, endoscopic examination of the distal end of the tube should be performed. The tube may be too long, and abut the nasal septum. In this situation, the tube must be removed and replaced with a new tube several millimeters shorter. Conversely, a tube that is too short may not be seen intranasally and should be replaced with a tube of longer length. If the tube abuts the middle turbinate and is obstructed, a partial turbinectomy should be performed.

A normally placed tube will often have its proximal end occluded by redundant conjunctiva. An injection of the conjunctival tissue with a depo steroid may improve the situation. If not, surgical excision of the excess conjunctiva can be performed under local anesthesia.

Obstruction of the distal end of the tube can be caused by the lateral nasal wall, nasal septum, or the middle turbinate. The treatment of these problems has previously been discussed.

Occasionally, a tube may appear to rest in perfect position and function appropriately, yet still cause irritation of the medial canthal tissues. Topical steroid may resolve this condition. If not, an injection of depo steroid can be considered.

16 Minimally Invasive Conjunctivodacryocystorhinostomy

Altug Cetinkaya and Martín H. Devoto

Dacryocystorhinostomy (DCR) is a long-time established surgery with high success rate in the treatment of distal nasolacrimal duct obstruction; however, it is not a good option when the proximal lacrimal drainage system is completely obstructed. The causes of complete upper lacrimal drainage system obstruction are various -and other than the idiopathic and congenital cases- it may include failed lacrimal surgery, trauma, infection, and inflammation, tumor, topical drop use, radiotherapy, chemotherapy and Stevens-Johnson syndrome [1, 5]. Less than 8 mm of healthy proximal canaliculus is considered non-reconstructible canalicular obstruction [6, 7] and in those cases conjunctivodacryocystorhinostomy (CDCR) with the insertion of Jones tube is accepted as the mainstay of therapy. CDCR was first described by Von Hoffman in 1904, and later modified by Kraupa and Goar [8]. Many modifications of this technique were unsuccessful for long-term patency, until Lester Jones suggested that the created fistulas would close without the insertion of a bypass tube. His technique relied on bypassing the normal lacrimal outflow with the help of a thin Pyrex tube for the management of complete bicanalicular obstruction [9]. His surgical technique involved a skin incision, opening of the lacrimal sac with flaps and a large osteotomy similar to the conventional dacryocystorhinostomy (DCR), and insertion of a glass tube between the conjunctiva and the nose through the osteotomy [2, 10–12]. Several investigators advocated a large bony opening to ensure the tube fixation by soft tissues [7, 9, 12]. On the other hand, Lee et al. have shown that successful outcome was achieved using a smaller osteotomy [13]. Overall success rate of CDCR was reported between 85 and 98.5 % [2–4].

The traditional technique of CDCR provided good success rates, however it is time consuming, technically difficult to perform, and requires long-term follow-up [14, 15]. Furthermore, the traditional surgery is associated with increased risk of intraoperative adjacent tissue injury, increased amount of bleeding, cutaneous scarring, longer recovery times, and increased postsurgical morbidity.

Despite high success rate with CDCR, patient-declared dissatisfaction was as high as 30 % in some reports and the complaints were most frequently related to persistence of overflow tearing in recumbent position, patient dissatisfaction with aesthetic outcome and having more complications than expected [5, 16]. Efforts to decrease the surgery duration and to refine the technique led investigators to the endonasal approach with no skin incision; however, this technique still involved a formal osteotomy [17, 18]. Successful

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application of holmium laser to perform the track was reported with low morbidity rates, however the use of laser increases the cost of the procedure [19, 20]. Other investigators used diode laser to open the track and insert the tube with endoscopic guidance, but the technique was associated with low long-term patency and high tube migration rate [21].

In the pursuit of short and effective surgery for CDCR, we applied the technique of minimally invasive CDCR (MICDCR) to 55 consecutive patients and published the results in 2006 [22]. This is a straightforward technique that relies on a 3 mm diameter communication between the conjunctiva and the nose, sparing the skin incision, flap dissection, and a large osteotomy. The procedure is technically easy to perform once the steps are mastered, takes a shorter time compared to the open-incision surgery and can be undertaken using local anesthesia. Our series revealed that the average surgery duration lasted 16 min compared to 59 min for the endoscopic technique and 74 min for the external technique as previously declared by other authors [17].

Surgical Technique

Patients are given preoperative nasal packing with 4 % lidocaine and 0.05 % oxymetazoline nasal spray. The nasal mucosa is injected intranasally with 3 ml of 2 % lidocaine with 1:100,000 epinephrine, using a 27-gauge spinal needle. The caruncle and inner canthal area are infiltrated with the same solution in patients undergoing the operation under general or local anesthesia to obtain hemostasis and anesthesia. The inferior third of the caruncle is excised. A 14-gauge intravenous catheter is inserted from the semilunar fold in the place where the caruncular excision was made, directed inferiorly and medially into the middle meatus through the thin lacrimal bone posterior to the anterior lacrimal crest, under endoscopic view, just anterior to the middle turbinate (Fig. 16.1). The surgeon performs this maneuver while an assistant holds the endoscope, attached to a video monitor, placed in such a way as to allow the surgeon to shift his or her attention from the middle meatus to the endonasal view. The angiocatheter is very slowly advanced through the tissues until the bone is felt. At this point, the instrument is further advanced at the slowest possible pace to avoid injury to the septum or the middle turbinate as the bone is breached. When this operation is done without the endoscope, the angiocatheter is advanced until the bone is felt to break and then, a nasal speculum is placed to have direct vision of the catheter as it is further advanced. If the needle does not go through the bone, it is withdrawn a few millimeters and angled more posteriorly to go through thinner bone. Once the distal end of the angiocatheter is visualized in the nose, the needle of the catheter is withdrawn, leaving the Teflon sheath in place (Fig. 16.2). An anterior middle turbinectomy may be performed during the same procedure, if needed, to ensure a wide space at the nasal end of the Jones tube (Fig. 16.3). At this point, the track needs to be slightly enlarged. The latest variation of this technique, utilizes a 10 G needle, inserted using the guide wire, and is gently advanced. This needle is inserted through the sheath, and the latter is removed. A Jones tube (Weiss Scientific Glass Blowing Company, Portland, Ore, USA.) is inserted, sliding it along the guide wire (Fig. 16.4), under endoscopic or direct endonasal visualization. The tube is checked for appropriate length and exchanged for a different one if needed, before removing the guide wire. The tube is then anchored in position

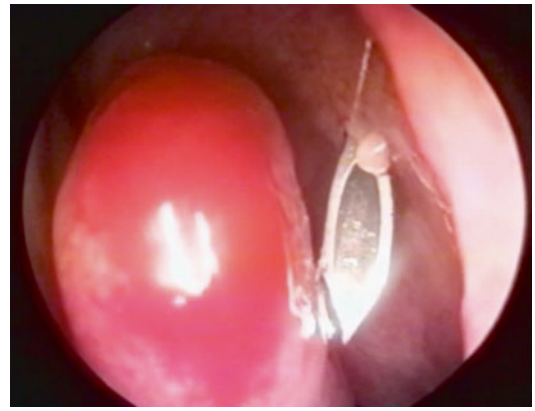

Fig. 16.1 A 14 G angiocath is inserted from the caruncular area, in an inferomedial direction and is visualized in the nose with the endoscope

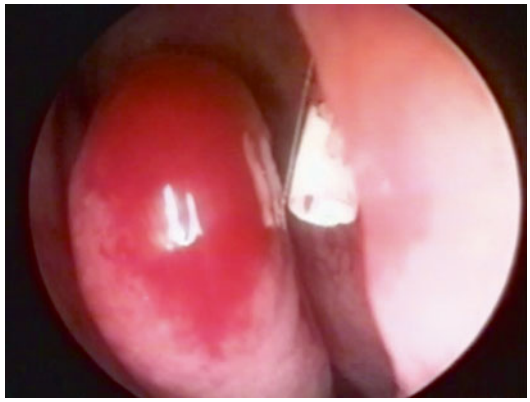

Fig. 16.2 The needle is pulled out and the Teflon sheath is left in

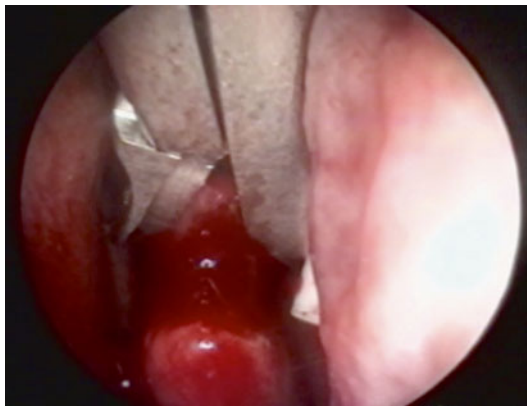

Fig. 16.3 A partial anterior turbinectomy is performed to enlarge the space where the Jones tube will end, if needed

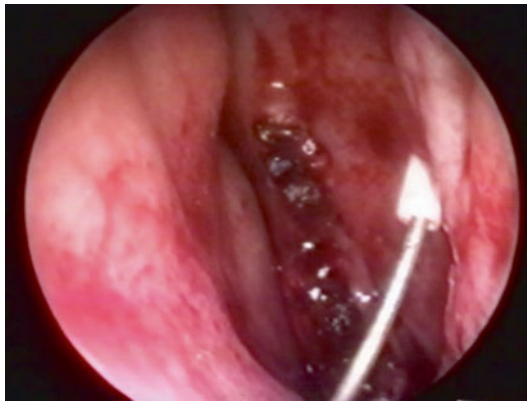

Fig. 16.4 A guide wire is introduced through the Teflon sheath. The Teflon sheath is withdrawn and the Jones tube is slid along the guide wire

with a double-armed, 5–0 nylon suture passed around the neck of the tube and then in full thickness through the skin. It is removed 10 days after the procedure.

This procedure can be conducted under endoscopic or direct visualization. We prefer to perform MICDCR under direct visualization using surgical loupes and a fiberoptic headlight; however, the use of an endoscope may be helpful in patients with difficult anatomy. The major benefit of performing under direct visualization is the ability to use both hands freely, which is especially valuable when bleeding compromises the surgical field. In such cases, the surgeon may hold the suction line in one hand and the surgical instrument in the other to continue performing the procedure without needing an assistant. However, the procedure may also be successfully undertaken using the endoscope, which provides good visibility of the surgical field and help proper placement of the tube. A recent report of endoscopic MICDCR in a series of 15 patients achieved 86.6 % success and no tube extrusion in any of the cases. The authors used straight Jones tube in 60 % of the patients and Gladstone-Putterman tube was preferred in 40 %; the mean tube length being 21 mm [23].

There are several benefits of MICDCR besides the shortened surgery duration. As the minimally invasive character implies, it causes minimal trauma to the patient. There is no skin incision and this is quite important for the young patients and the pigmented population who are at higher risk for keloid or scar formation. The surgery can be undertaken using simple and inexpensive equipment. Another advantage of this surgery is the ability to undertake the procedure using local anesthesia instead of general anesthesia owing to the shorter operative duration and the benefit of minimal blood loss.

Tube length and positioning is an important parameter for the success of surgery. Ideally, the medial end of the tube should not touch the nasal septum (approximately 2 mm from the septum).

The length of the tube depends on the patient anatomy; however, we found that 16 mm tube was appropriate for most of our patients [22]. The flange diameter is also important as the

larger diameter will prevent displacement of the tube, but larger tubes will be more irritating to the surrounding tissues including the globe. The standard Pyrex tubes have a 3.5 mm diameter and those are the ones we prefer during MICDCR; however, in a single case of extrusion, we needed to replace the standard tube with a 4.5 mm diameter tube that provided good stabilization.

Conventional CDCR was reported to have a high complication rate. In a series of 49 eyes operated with conventional CDCR between 1984 and 2002, complication rate was reported as 3.5 per patient and the most common complications included extrusion, malposition, medial migration, hypermobility, obstruction, infection, granuloma formation, discomfort, restrictive strabismus, and diplopia [1, 5, 14, 24, 25]. Surgical failure is commonly due to tube migration or incorrect tube positioning. Extrusion or dislocation of the tube was reported to occur as high as 51 % and 33 % respectively [5, 14].

The technique of MICDCR, on the other hand, is associated with few complications. The most common complication in our MICDCR series was tube migration towards the nose seen in 7 of 55 patients. Of these seven patients, successful repositioning was achieved in four patients in office conditions. The other three patients were diagnosed with permanent closure and the tubes were surgically repositioned under local anesthesia. Another patient had recurrent tube migration and was treated by the use of a larger, 4.5 mm flange tube with success. In such cases, the use of frosted tube or a Gladstone-Putterman tube has been recommended [26, 27]. Dailey et al. reported that the frosted tube (Weiss Scientific Glass Blowing Company, Portland, OR) improved stability and decreased extrusion in ten patients followed for 8 months [26]. Other customizable tubes such as the Teflon tube (Dupont, Wilmington, DE), silicone, polypropylene, and polyethylene were also shown to be less likely to migrate or extrude; however, poor capillary attraction with slower flow and higher likelihood of obstruction limited their success [28]. Some authors declared that high-density porous polyethylene (HDPP)-coated tear drain tubes (Medpor, Porex Surgical Inc, Newman, GA, USA) minimized tube extrusion rate [29, 30]. However, the use of Medpor-coated tubes was associated with increased conjunctival overgrowth (23 % compared to 5.7 % with conventional tubes) [29]. They are hard to replace if needed because of the fibrous ingrowth and they may incite conjunctival irritation. To solve the conjunctival irritation and discharge due to this type of material, Abdulhafez recommended modifying the tube by cutting the proximal portion of the HDPP coat, and by this technique, they showed successful outcome with no patient discomfort in a series of ten patients [31].

Massry and Larian described a different technique to manage recurrent tube extrusion in a 62-year-old lady who was reoperated by the authors and received a 17 mm frosted Jones tube which extruded again [32]. The authors decided to place a red rubber catheter around the distal end of the tube to provide mechanical stabilization and the patient was followed for 4 months without any further problems. However, the follow-up was short and then as the authors stated in their paper, this technique would prevent easy removal of the tube when the tube required cleansing or exchange in the future. In an unpublished case, one of the authors of this study (AC) used a similar mechanical plugging idea to provide stability for an early extruding tube; however, instead of an allogenic material, autologous fat was used to provide a snug fit between the mucosa and the distal end of the tube. This provides a natural integration with the mucosa and the autologous character prevents possible future adverse events associated with the foreign material. The fat was acquired from the posterior ear lobe of the patient through a tiny incision. The patient experienced no problems for more than 2 years after this revisional procedure.

Modifications of the tube according to the patient anatomy are definitely important for successful outcome; however, the best way to improve the stability of the tubes is probably through refining the surgical steps. Previous research stated that the main cause of CDCR failure was tube migration or incorrect tube positioning, and that success of surgery could be increased by reducing tube malposition [3, 33]. A number of

instruments were used to create the tract properly between the ocular surface and the nasal cavity including cannulae, Kirschner wire (K-wire), and the Cox system [34–36]. The main purpose of such instruments is to make a precise tube insertion; however, since the consecutive steps require removing the dilating instruments before the guide is placed, multiple tracts may be formed causing misdirection or malpositioning of the tube. A modified double component trochar using the Cox system was reported to be helpful to overcome this problem. The authors claimed that the double component trochar reduced operative time and risk of tube displacement [37].

Tube obstruction in the postoperative period is another possible complication associated with Jones tubes usually preventable by educating the patient about frequent cleansing and in-office cleaning by probes at regular intervals. In our series, we never encountered a clogged tube, but in case of severe obstruction that cannot be prevented or managed by conservative measure, tube exchange is mandated. Techniques of tube replacement or exchange may be various. Recently, Eloy et al. described an easy-to-perform in-office tube exchange procedure using the Seldinger technique [38]. In this technique, 3–0 prolene is passed through the tube, tube is removed, and the new tube is inserted over the prolene suture under local anesthesia in office conditions. The reason why MICDCR provides less clogging problem may be due to the more vertical positioning of the tube compared to the conventional technique and due to creating less inflammation and mucosal healing response by the less tissue distortion associated with this technique.

Damage to the middle turbinate or the septum is a possibility during any type of CDCR operation using bypass tubes. In conventional surgery, the Jones tube is angled 10–20° inferiorly, reaching a crowded region inside the nose where the septum and the lateral wall of the nose are in close anatomic proximity. This may cause septum or turbinate deformity either during the operation or postoperatively if the tube touches these structures. Middle turbinate usually requires partial resection to provide adequate space during surgery. This maneuver, however, may lead to nasal adhesions and scarring and therefore preservation of the turbinate has been recommended [39]. In our series however, we have never encountered any such problem due to partial resection of the middle turbinate. We believe that a limited middle turbinectomy that allows a wide space at the nasal end of the tube, performed with special care not to injure the septal mucosa is safe and greatly improves the outcome of the operation, reducing the incidence of reoperations to change the length of the tube.

Another complication we never observed was the postoperative diplopia in our series, while Ashenhurst et al. described eight diplopia cases following their modified CDCR technique in a series of 225 cases [40]. Their surgical technique was very similar to the MICDCR procedure that we described. In their paper, the patients reported diplopia several months to as long as 6 years after surgery. This complication was associated with conjunctival scarring and while symptoms resolved by topical application of corticosteroids in two patients, other six patients required surgical excision of scar tissue, which was successful in only two patients.

Other minor complications include pyogenic granuloma formation, conjunctival occlusion of the tube, and excessive secretions needing tube clearance are frequently observed in various techniques of CDCR.

Postoperative care is very important and the patients should be counselled prior to the surgery. Ultimately, patient compliance may define the surgical success and the possible complications. The patient has to be careful not to blow the nose for 2 weeks and tube cleaning should be done at regular intervals. The patient should be instructed on how to clear away the mucus and clean the tube by sniffing water or saline postoperatively. Retrograde air blowing may be a reason for patient dissatisfaction. A recent report declared the importance of detailed counselling of postoperative care in a patient who instead of sniffing eye drops down the tube, deliberately blew air up the tube postoperatively and ended up having periorbital emphysema and epiphora [41].

In summary, MICDCR is a successful modification of conventional CDCR surgery with several

benefits including simplified tube insertion, shortened operative times, and faster recovery period. This technique may be easily mastered using simple instruments and the postoperative course is less eventful with high patient satisfaction rate.

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Minimally Invasive Lacrimal Surgeries: Balloon Dacryoplasty

17

Mohammad Javed Ali

Introduction

Balloon dacryoplasty is a term used for a set of minimally invasive lacrimal procedures that utilize specially designed balloons, targeted at different points in the lacrimal system for a wide range of indications. Balloons were first used by Becker and Berry in 1989 [1]. Around the same time Munk et al. [2] reported balloon catheter dilatation for adults with epiphora using an angioplasty catheter under fluoroscopic guidance. This chapter would review the details of various balloons, instruments needed, indications in pediatric and adult populations, preoperative preparations, operative standards and procedures, and postoperative managements and outcomes.

Balloons and Instruments

A good nasal endoscopic set up is ideal for a balloon dacryoplasty (Fig. 17.1a). A typical Balloon dilatation set (Atrion Corporation, Allen, Texas, USA) (Fig. 17.1b) consists of the following:

(a) 2, 3, 5, or 9 mm balloon catheters
(b) Inflation device
(c) Lacrimal Probes
(d) Punctum dilator
(e) Dandy's Nerve hook
(f) Intubation set with retrieval device

Balloon catheters are specially designed with an inflatable balloon at one end of the catheter (Fig. 17.1c) and hub with luer-lock mechanism at the other which engages the inflation device (Fig. 17.1d). Two millimeter balloon catheters are named so since they have an outer diameter of 2 mm during an inflated stage. The length of this balloon is 13 mm. Similarly 3 mm balloon has an outer diameter of 3 mm but the length is 15 mm. The 5 mm (Fig. 17.2a) and 9 mm (Fig. 17.2b) balloons have outer diameters of 5 mm and 9 mm respectively but their length is 8 mm. Nine millimeter balloon catheter is much sturdier and is angulated at 120° focused within the balloon segment. Two important markings on the 2 and 3 mm catheters are the 10 and 15 mm black marks to serve as a guide when the catheters are within the nasolacrimal ducts (Fig. 17.2c).

The inflation device has a manometer which displays the pressure reading in atmospheres (Fig. 17.2d). Proximal end of the manometer has a tube with a luer-lock adaptor for attachment to the catheters and the distal end has a locking device and a knob. When the locking device is to the left, it indicates an unlocked stage, whereas if it is to right, it indicates a locked stage. The knob when rotated clockwise with the manometer in locked stage, steadily increases the pressure within the device and inflates the balloon whereas its anti-clockwise rotation reduces the pressure

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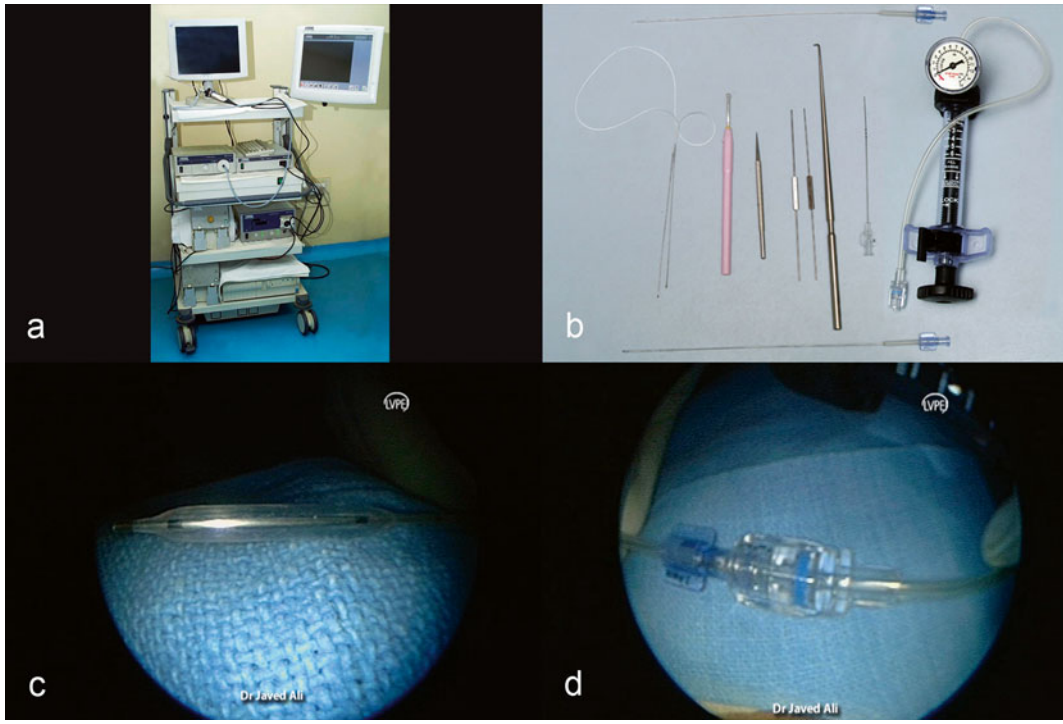

Fig. 17.1 (**a**) A Nasal Endoscopy set up. (**b**) A Balloon Dacryoplasty armamentarium. (**c**) The inflatable end of a 2 mm balloon catheter. (**d**) The hub of a 2 mm balloon catheter with luer-lock mechanism, which engages the inflation device

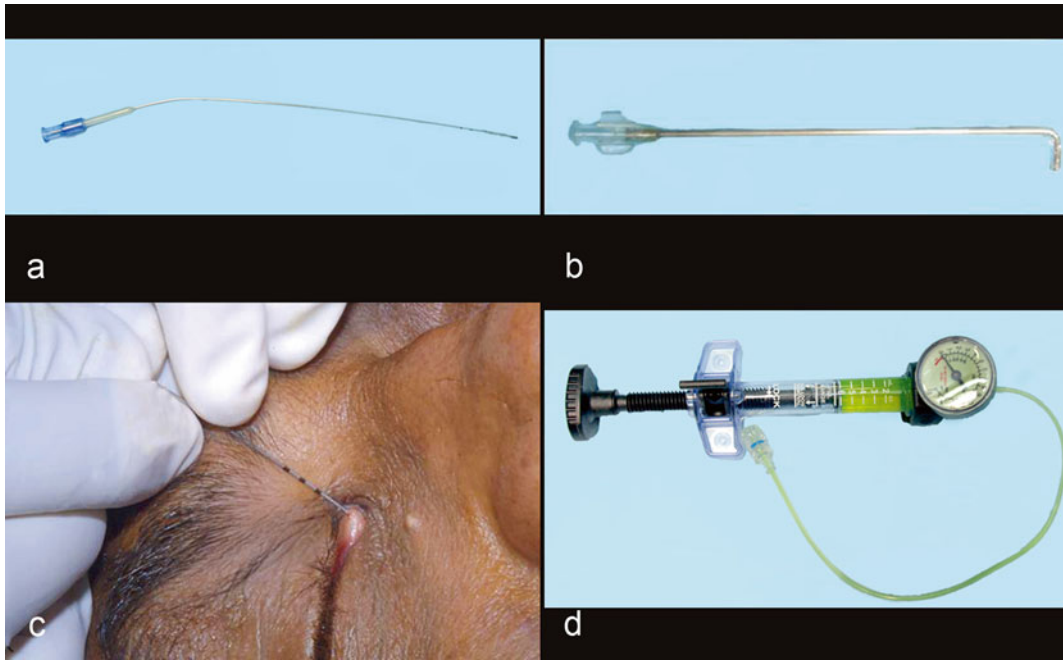

Fig. 17.2 (**a**) A 5 mm balloon catheter. It is a bit curved unlike the 2 and 3 mm ones which are straight. (**b**) A 9 mm balloon catheter. Note the robust body and 90° angulation near the balloon end. (**c**) Two important markings on the 2 and 3 mm catheters are the 10 and 15 mm black marks to serve as a guide when the catheters are within the nasolacrimal ducts. (**d**) Inflation device with the manometer at one end and locking device and the knob at the other end

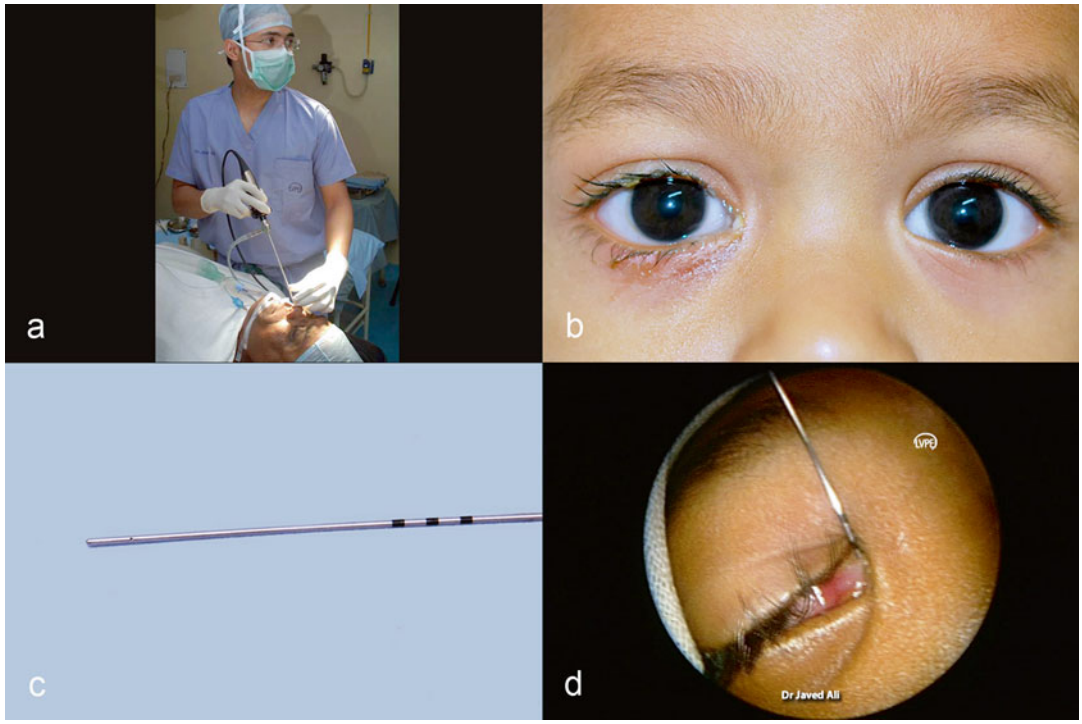

Fig. 17.3 (**a**) Nasal endoscopic examination before a balloon dacryoplasty procedure. (**b**) A child with right CNLD. Note the increased tear meniscus height as well as matting of lashes with discharge. (**c**) An I-Probe with black markings. Note the small opening on one side of the probe. (**d**) A balloon catheter in action. Note the markings which reflect the position of the balloon in the nasolacrimal duct

and thus deflates the balloon. Preoperative and Intraoperative nasal endoscopic examination is essential for these procedures (Fig. 17.3a).

Balloon Dacryoplasty in Children

Syringing and Probing has been a standard of care for congenital nasolacrimal duct obstructions (CNLDO) (Fig. 17.3b). Although it is a very good procedure with high success rates, the same is not true for older children [3, 4]. Probing is less effective in older children because of complex blocks or diffused narrowing of the nasolacrimal duct [5, 6]. Silicone intubations are generally carried out in older children or those who fail probing but the drawbacks of these procedures in children including stent prolapse, second sitting for removal of tubes, and keeping them in situ for 2–3 months need to be taken into account [7].

Balloon dilatation came into vogue because it achieves true dilatations of narrowed segments, easier to perform than primary silicone intubation with good success rates. A 2 mm balloon is used for patients less than 30 months of age and 3 mm for children more than 30 months of age. The indications of balloon dacryoplasty for congenital nasolacrimal duct obstructions [1, 6, 8, 9] are:

(a) Failed Probing
(b) Failed intubation
(c) Older children (>12 months of age)
(d) Down's syndrome or any syndromic association with CNLDO

Operative Procedure

Preoperative preparation includes decongestion of the inferior meatus with 0.05 % Oxymetazoline. Two drops can be placed half an hour before the

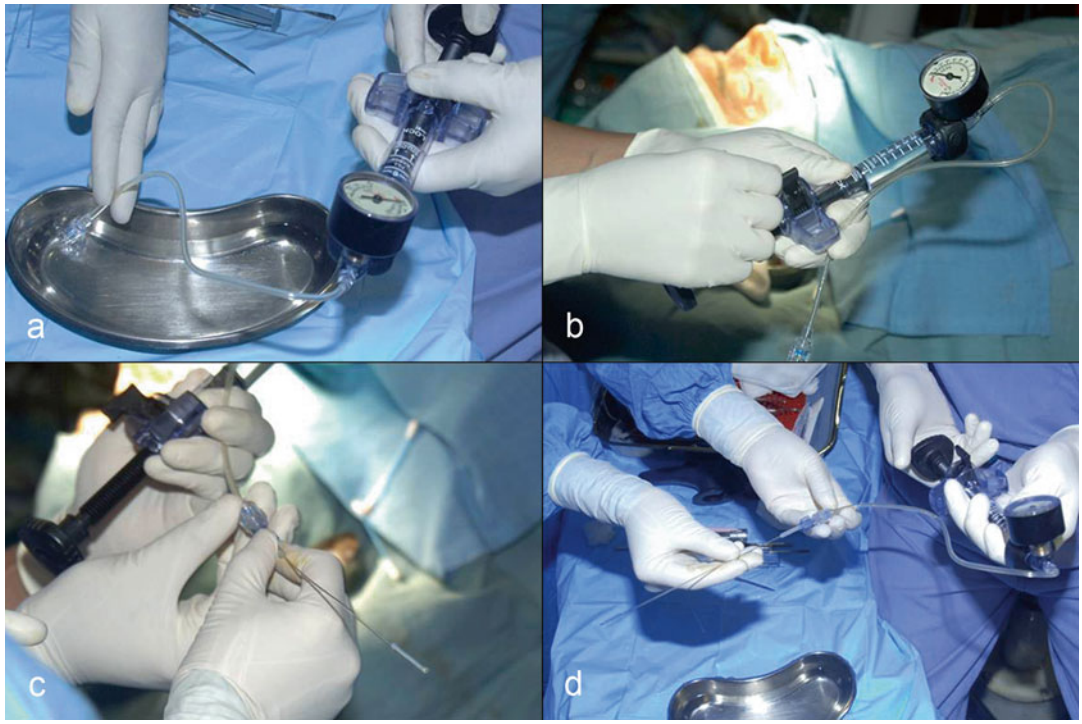

Fig. 17.4 (**a**) Saline filling of the inflation device. (**b**) Locking of the inflation device. (**c**) The hub of the balloon catheter engaging the inflation device by a luer-lock mechanism. (**d**) The final and complete assembly of catheter and inflation device

procedure or alternatively a cottonoid soaked with the drug can be placed in inferior meatus for 5 min before the procedure. Following dilatation of the puncta, a probing is performed as a standard procedure and the probe is inspected in the inferior meatus to confirm that all the blocks are overcome. An I-probe (Quest Medical Inc, Allen, Texas, USA) can be used which is similar to a bowman's probe with a small eyelet near the tip to wash off the debris following probing and also to reflect on the free flow following probing (Fig. 17.3c). Inferior turbinate medialization may occasionally be needed along with probing if it appears to be impacted to the lateral wall.

The sleeve of the balloon is removed, it is then lubricated with either a viscoelastic or a 1 % carboxymethycellulose drops and gently placed into the lacrimal system just like the procedure of probing and introduced further into the nasolacrimal duct till the 15 mm mark is adjoining the puncta (Fig. 17.3d) or the balloon exits just beyond the valve of Hasner as seen with nasal endoscopy. In the meantime the inflation device filled with saline or fluorescent-stained saline (Fig. 17.4a) should be ready in the locked position (Fig. 17.4b). The air should be removed from the device after saline filling. The luer-lock hub of the inflation device is connected to the catheter (Fig. 17.4c) and the knob is slowly rotated in the clockwise direction (Fig. 17.4d) by the assistant while the surgeon can be visualizing the dilatation of the balloon via the endoscope.

The balloons are inflated to 8 atm of pressure for a duration of 90 s (Fig. 17.5a). The inflated balloon should be under constant monitoring in the nose (Fig. 17.5b). The knob of the inflation device is then rotated in an anti-clockwise manner to deflate the balloon. Once deflated, without disturbing the catheters position, it is reinflated to 8 atm for 60 s. The balloon is again deflated (Fig. 17.5c) and pulled back till the 10 mm mark adjoins the punctum or the tip of the balloon is barely visible proximal to valve of Hasner (Fig. 17.5c). The two cycles of inflation and

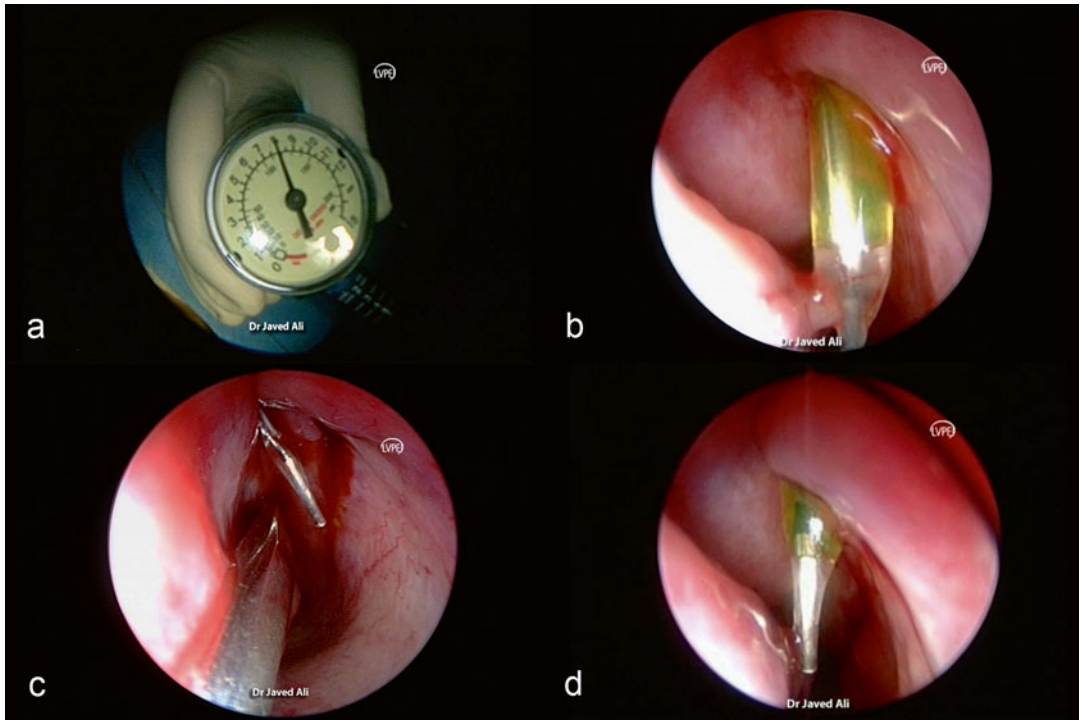

Fig. 17.5 (**a**) Manometer of the inflation device showing that the pressure of 8 atm has reached. (**b**) Endoscopic view showing the distal dilatation of the nasolacrimal duct. Note the inflated balloon. (**c**) Endoscopic view showing the deflated stage of the balloon catheter. (**d**) Endoscopic view showing the beginning of proximal dilatation of the nasolacrimal duct

deflation are carried out again in this position. The catheter and the inflation device are then disconnected followed by gentle withdrawal of the catheter from the lacrimal system. The lacrimal passages are then irrigated with either saline or fluorescein-stained saline (Fig. 17.6a). The fluid should flow easily and in copious amounts indicating success of the procedure. The saline from the inflation device is then emptied after unlocking the device (Fig. 17.6b).

The author practices the use of intravenous dexamethasone 4 mg during the postoperatively a topical steroid–antibiotic (Tobramycin–Fluormethalone) combinations are given in tapering doses over 2 weeks. Patients are examined at 6 weeks and 3 months and the outcome measures that are looked for is tear meniscus height, relief in symptoms, and occasional dye disappearance test. Numerous publications have classified the outcomes as excellent if the child has complete resolution of epiphora with normal tear drainage, good if the child has minimal residual symptoms with minimally delayed dye disappearance test, fair if there are moderate residual symptoms or delayed dye clearance and poor if there is no improvement [1–11].

Results

Balloon dacryoplasty for congenital nasolacrimal duct obstruction is a very effective treatment modality for specific indications as mentioned already. The success rates range from 76 to 83 % in various large case series [8–11]. Tien DR [8] following his study of 39 lacrimal systems observed that balloon catheter dilatation is simple and atraumatic and should be considered as an alternative to silicone intubation in patients who undergo probing. Tao S et al. [9] studied 73

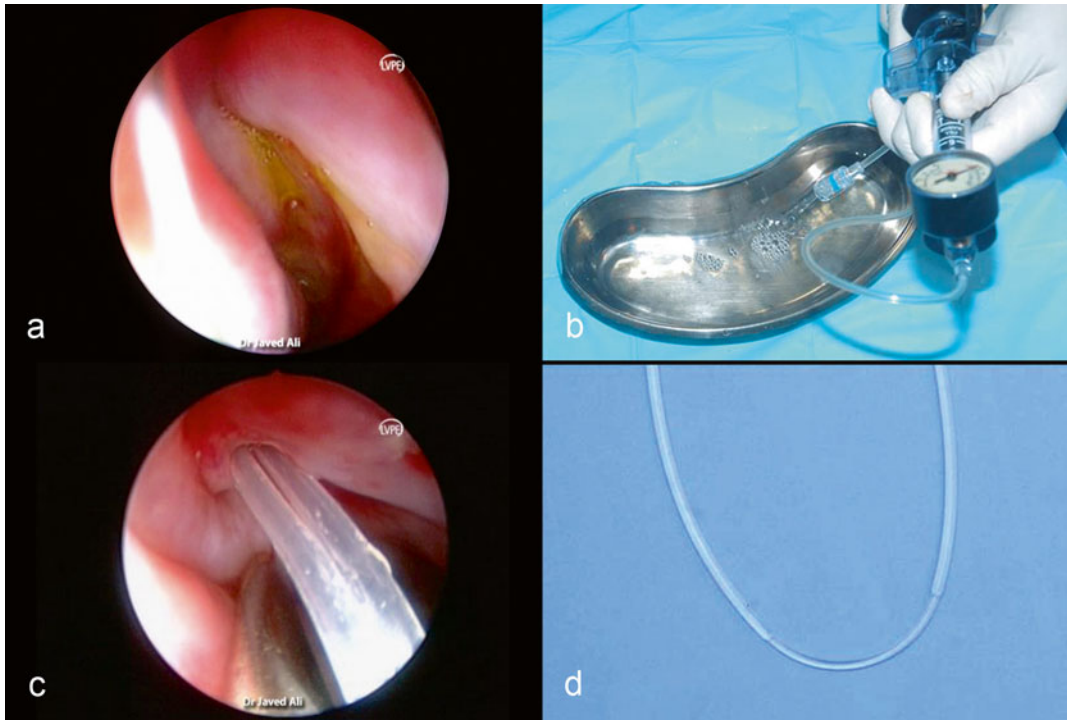

Fig. 17.6 (**a**) Endoscopic view showing fluorescein-stained saline freely flowing in the inferior meatus. (**b**) The saline from the inflation device being drained out at the end of the procedure. (**c**) Endoscopic view showing the dilated NLD as well as the silicone stent coming out of the NLD. Note the clearly seen NLD mucosa. (**d**) I-Stents. Note the thinner central segment contiguous with thicker segments on either side

lacrimal systems of CNLDO undergoing balloon catheter dilatation with patients whose mean age was 35.6 months. Thirty-nine (53 %) of these were failed probing or post silicone intubation. The overall success rate was 76.7 % but it was very interesting to note that children undergoing secondary dilatation following failed previous procedures did not show a statistically significant difference ($P=0.8165$) in outcomes when compared to the primary group. Therefore it was concluded that balloon catheter dilatation appears to be successful specially for older children who fail probing or silicone intubation. Leuder et al. [10] studied the outcomes of balloon dacryoplasty in 76 children above the age of 18 years. Though the procedure did not appear to benefit simple obstructions more than probing, it, however, was beneficial in 82 % ($n=28$) of the patients who had stenosis of the distal nasolacrimal duct. Leuder et al. [11] further studied the efficacy of balloon catheter dilatation in 32 children with persistant congenital nasolacrimal duct obstructions (CNLDO) following previous failed attempts at recanalization. Outcomes were found to be excellent and good in 28 % and 47 % of the patients respectively. Yuskel et al. [12] studied the efficacy of balloon dilatation in older children with a mean age of 43.9 months with a mean follow up of more than 25 months and reported success rates of close to 90 %. The concept of balloon dacryoplasty for older children specially post probing is steadily gaining a rapid ground as an alternative to silicone intubation and dacryocystorhinostomy. The authors of the present study are conducting a study in older children who failed probing earlier. A combination of balloon dilatation and silicone intubation is performed and the initial results appear to be promising; however, long-term results would ascertain its efficacy.

Balloon Dacryoplasty in Adults

There has been a renewed interest in using minimally invasive approaches for partial and complete nasolacrimal duct obstructions in adults. This led to increased attention to the use of balloon-assisted lacrimal surgeries in adults. We will discuss this under two headings, Partial NLD obstructions and complete NLD obstructions.

Partial NLD Obstructions

Incomplete NLDOs are usually managed with a dacryocystorhinostomy. With the advent of balloons several studies have looked at the efficacy of using 3 mm balloon dilatation in such cases. The procedure is similar to what has been described above for pediatric dacryoplasty except that probing needs to be much more meticulous to overcome the multiple blocks or diffuse narrowing of the nasolacrimal ducts. This is followed by a primary intubation under endoscopic guidance. The authors usually use Crawford tubes (Fig. 17.6c) or I-Stents (Fig. 17.6d) (Quest Medical Inc, Allen, Texas, USA) and retain them for 12 weeks before removal.

Perry JD et al. [13] reported a success rate of 73 % after treatment with balloon dilatation and intubation for partial obstructions in adults. Kuchar A et al. [14] reported an overall success of 90 % in improvement of symptoms in adults and 56 % experiencing complete resolution of epiphora. The authors in their unpublished study of 21 partially obstructed nasolacrimal ducts of 12 patients have shown an anatomical patency of 81 % and functional success of 76 %, 3 months after removal of stents. The latter parts of this study have shown an additional benefit of doing balloon dacryoplasty under dacryoendoscopic guidance.

Complete Obstructions: EBA DCR

For complete obstruction, Endoscopic Balloon-assisted Dacryocystorhinostomy (EBA–DCR) using the 5 mm or more commonly the 9 mm is an alternative to standard external or endonasal DCRs. One difference that needs to be kept in mind here is that unlike the 5 mm balloon which is used via the transcanalicular route, the 9 mm can only be used transnasally. The authors use 5 mm balloon catheter only for revision DCRs and the 9 mm balloon catheter for both primary and revision DCRs. There is very scanty literature on the use of 3 mm balloons targeting the completely obstructed nasolacrimal ducts in adults [14–16]. Song et al. [15] and Janssen et al. [16] found initial failure rates ranging from 41 to 44 %; however, others like Kuchar et al. [14] found a failure rate of 10.7 % at the end of 1 year. The clinical use of 3 mm balloons targeting the completely obstructed nasolacrimal ducts is very limited and generally not followed, but such patients are being increasingly managed by the 9 mm balloon-assisted primary endoscopic DCR.

9 mm Primary Endoscopic Balloon DCR

Primary endoscopic DCR using the 9 mm balloon catheter (Fig. 17.2b) is a good alternative to an external or endoscopic DCR. It was introduced and popularized by Silbert DI [17]. The advantages of this procedure include

(a) Reduced operative trauma
(b) Less bleeding
(c) Faster and less time consuming
(d) No need for powered endoscopic instruments
(e) Less postoperative morbidity
(f) Early rehabilitation
(g) High success rates

Operative Procedure

Good case selection is vital for the success of any surgery and so is true for 9 mm endoscopic balloon DCR. Suspicion of any lacrimal sac tumor, severe deviated nasal septum, and canalicular obstruction are contraindications, the former being an absolute and latter two being relative. Anesthesia can be general or monitored

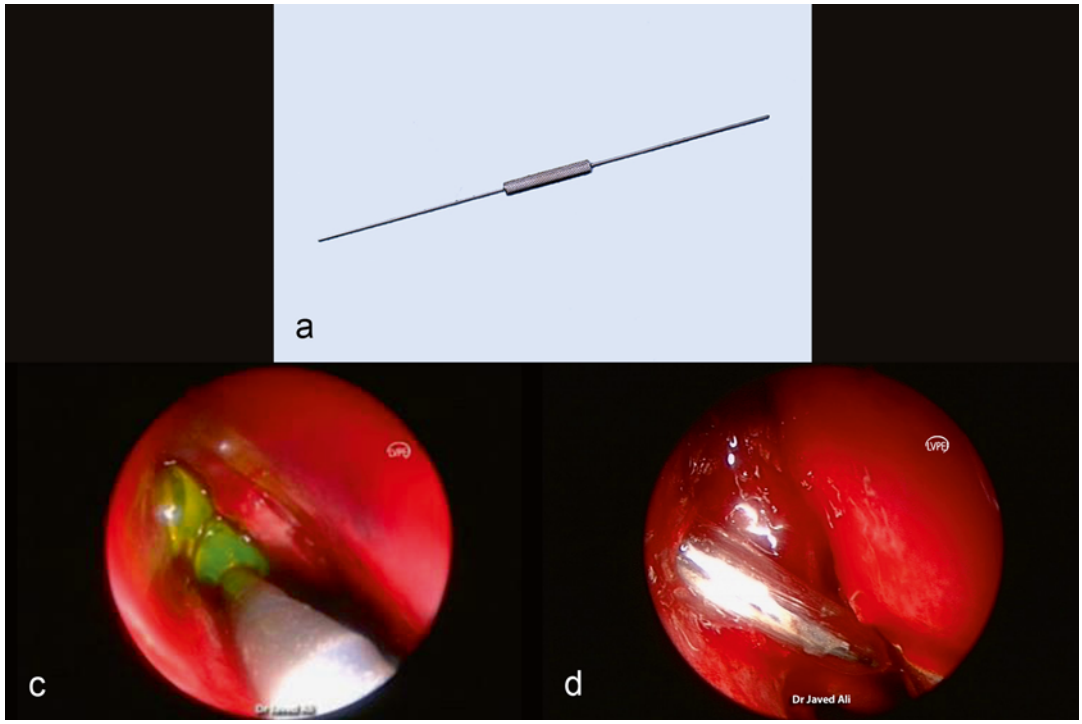

Fig. 17.7 (**a**) A reinforced Bowman's probe. (**b**) Endoscopic view of a 9 mm balloon enlarging an ostium. (**c**) Revision DCR with 5 mm balloon catheter. Note the inflated balloon dilating the stenotic DCR ostium

anesthesia care with sedation. Once the patient is under anesthesia, lidocaine 2 % with adrenaline combination is injected in nasal sub mucosal plane, 2–3 cm^3, anterior and inferior to the axilla of the middle turbinate. The nose is then packed with cottonoids soaked in 0.25 % Oxymetazoline, placed under the middle turbinate and in front of its insertion with the help of bayonet forceps, preferably under endoscopic guidance.

Once the patient is draped, the nasal pack is removed and the puncta are gently dilated progressively to allow number 3 or 4 reinforced bowman's probe (Fig. 17.7a) to be passed into the lacrimal sac. The probe is directed towards the infero-posterior part of the lacrimal fossa, since it is very thin and can be easily overcome. Once the bone is overcome, the position of the middle turbinate is assessed and if needed a mild medialization of the middle turbinate is carried out. The probe is then passed inferiorly and superiorly in a honeycomb pattern initially followed by opening of the lacrimal sac in a "filleting open" motion. A blakesly forceps is then introduced into this small opening and pulled back into the nose with its mouth wide opened. Bits of tissues around now can be gently removed. The 9 mm balloon catheter is now connected to the inflation device and introduced into the nose with the balloon end going in first. Under the guidance of the bowman's probe, the catheter is introduced into the newly made ostium and inflated to 8 atm for 90 s. It is then pulled into the nose backwards with the balloon still inflated (Fig. 17.7b). The balloon is deflated, introduced into the ostium again, and reinflated for 60 s and again pulled back in the inflated state. This makes the ostium very big and fragments of bone and mucosa are then removed. Once the ostium is of adequate size, intubation is carried out with Crawford tube or the specially designed large diameter Stent tubes. The nose is then packed using cellulose sponges.

Soon following the surgery a single intravenous dose of 8 mg dexamethasone is administered. Postoperatively the patient is placed on

systemic antibiotics, topical antibiotic-steroid combinations, nasal decongestant and saline nasal douching. The patient is reviewed at 1 day, 1 week, and 3 months. The tubes are retained for 12 weeks. The outcome measures that are looked for is tear meniscus height, relief in symptoms, and occasionally dye disappearance test. Routine syringing is not practiced by the authors unless patient complains of epiphora.

Results

The results of primary endoscopic 9 mm balloon DCRs in long term are appearing to be quite encouraging. Silbert DI [17] in a large case series of 97 patients reported success rates of 92 %. Among the eight cases which failed in this series, three underwent repeat surgery, one of them with 5 mm balloon and were successful [17]. Longer follow up with still larger number of patients will ascertain its efficacy in the long run.

Balloon-Assisted Revision DCRs

Revising a failed DCR is a challenging job. For primary external and endoscopic DCR, the failure rate has been reported to be 5–10 % or less and 10–20 % or less, respectively [18, 19]. The most common cause of a DCR failure is occlusion of the rhinostomy site by soft tissue or cicatricial closure of the ostium. The stenotic or occluded DCR fistula is amenable to balloon dilatation. It is of advantage since the occlusion is primarily a soft tissue and the bony window is usually adequate. The authors use both 5 and 9 mm balloon catheters for their failed external or endonasal cases. The 5 mm catheters (Fig. 17.2a) are usually used for very early failures where there is usually a stenotic fistula. A bowman's probe is passed to identify the area in front of the common canaliculus and to clear any soft tissue. The 5 mm balloon catheter is then inserted through the upper canaliculus and under endoscopic guidance, the DCR fistula is enlarged with the standard inflation (Fig. 17.7c) and deflation cycles are discussed already. Following dilatation of fistula, any soft tissues in the vicinity are gently removed, mitomycin c 0.04 % is applied, followed by Crawford intubation. The 9 mm balloon catheter is also used in the same fashion as already described for primary DCR. Though long-term studies are not available, the initial results in the unpublished author series look promising. What needs to be stressed is identification of all the etiological factors contributing to the DCR failure and addressing them adequately yields satisfying results.

Conclusions

Balloon dacryoplasty and Balloon-assisted primary and revision DCRs are speedily gaining grounds in minimally invasive lacrimal surgeries with increasing indications for their use. These techniques are essential in the armamentarium of a dacryologist. Careful patient selection and skillful nasal endoscopy are important factors for successful outcomes. A good clinical armamentarium along with constant innovative habits helps facing challenges thrown by lacrimal disorders thrilling and profitable!

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Revision Dacryocystorhinostomy

18

Suk-Woo Yang and Ji-Sun Paik

Dacryocystorhinostomy (DCR) is a procedure used to create a lacrimal drainage pathway into the nasal cavity to reestablish the permanent drainage of a previously obstructed excretory system. Revision DCR is indicated in patients in whom primary external or endoscopic DCR failed, and who meet the criteria for primary DCR. DCR is normally a successful operation, with a failure rate of <10 % in most studies. The two most common causes of failure are a common canalicular obstruction and an inappropriate size or location of the osteotomy [1, 2]. The osteotomy is closed in some cases by granulation tissue while in others this is attributed to new bone formation. Various features were shown to be associated with unsuccessful previous DCR cases. Several nasal pathologic conditions were found preoperatively, including nasal mucosal fibrosis, synechiae between the middle turbinate and anastomosis sites, transnasal synechiae, hypertrophic middle turbinate, granuloma, severe septal deviation, and nasal polyp. In the perioperative findings, the major cause of obstruction resulted from an inappropriately sized and/or localized osteum, while minor causes were fibrosis at the anastomosis site, canalicular or common canalicular obstruction, and the absence of an ostium [3–7]. Paik et al. reported recently in a comparison between endoscopic revision for failed primary external and endoscopic DCR that pathologic nasal findings, including as hypertrophic middle turbinate and severe septal deviation, were more frequently found in previous external DCR group, whereas a small-sized osterum or localized ostium was associated more often with the previous endoscopic treatment group [3]. Therefore, there were some differences in the surgical outcome related to the method of the previous DCR surgery (Table 18.1).

The endoscopic access for DCR is extremely precise in revision surgery, which permits the correction of associated nasal factors that may have been involved in the failure of previous surgery [3, 4, 8]. Common causes of failure in lacrimal drainage surgery are septal deviations, incomplete removal of the lacrimal bone, synechiae, and granulation tissues, which apply to both the external and endonasal approaches. These factors were easier to identify at the time of revision surgery and more accurately treated because of direct endoscopic visualization (Fig. 18.1).

El Guindy et al. performed endoscopic revision DCR on 18 patients with recurrent epiphora after external DCR, with an 83.3 % success rate [8]. Tsirbas et al. compared endoscopic and external approach methods in 17 and 13 revision cases, respectively, and reported success rates of 76.5 % and 84.6 %, respectively [9].

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Table 18.1 Causes of failure after previous external of endoscopic dacryocystorhinostomy (DCR)

	Previous external DCR (%)	Previous endoscopic DCR (%)	*P*-value
Preoperative nasal findings			
Nasal mucosal fibrosis	8 (32)	15 (26.3)	0.598
Synechiae between middle turbinate and anastomosis site	5 (25)	20 (35.1)	0.172
Transnasal synechiae	5 (25)	10 (17.5)	0.791
Hypertrophic middle turbinate	6 (26)	4 (7.0)	0.031*
Granuloma	7 (28)	10 (17.5)	0.819
Severe septal deviation	2 (8)	2 (3.5)	0.001*
Nasal polyp	8 (32)	1 (1.8)	0.166
Perioperative findings			
Inappropriately sized and/or localized ostium	2 (8)	17 (29.8)	0.031*
Fibrosis at the anastomosis site	15 (60)	25 (43.9)	0.178
Common canalicular obstruction	5 (25)	7 (12.3)	0.153
Membranous obstruction	5 (25)	23 (40.4)	0.199

Source: Clin Experiment Ophthalmal. 2013 Mar; 41(2):116–21
*Chi-square test: $p < 0.05$ was considered statistically significant

They concluded that the endoscopic method has a comparable success rate to the external method in revision cases. The reported success rate of revision endoscopic DCR in the literature ranges from 75 to 90.9 % [8–10].

Endonasal DCR has several advantages for revision cases: (a) absence of additional scarring; (b) maintenance of the mechanism of lacrimal pumping by the orbicular muscle; (c) reduction in injury to structures of the medial canthus; (d) less bleeding; (e) shorter hospitalization; (f) technical facility because of anterior removal of the lacrimal bone; (g) the possibility to correct other conditions during the same surgical procedure, including septal deviations, synechiae, granulation tissue, rhinosinusitis, nasal polyposis, and incomplete bone removal; and (h) direct visualization of the site and amplitude of the nasolacrimal fistula. The endoscope provides excellent intranasal visualization and enables the surgeon to open the lacrimal sac with relative ease from within the nasal cavity [3, 10].

Two different standard DCR surgical techniques are used in surgical revision cases, as described below. Both methods can be conducted under local or general anesthesia, depending on physician preference [9, 11–13].

External DCR Surgical Revision Technique

A standard skin incision and soft tissue dissection are performed to expose the lacrimal sac. A Bowman's lacrimal probe is placed into both the inferior and superior canaliculi, and an incision is made through existing scar and mucosa of the rhinostomy, creating a large anterior nasal flap. In most cases, the bony rhinostomy, sac, and/or duct are found to have been insufficiently opened to allow for an adequate rhinostomy. After the creation of an adequate bony osteum of at least 10–20 mm, the lacrimal and mucosal flaps are sutured. Silicone tubes are inserted if there is any canalicular pathology or if the sac is small, scarred, or inflamed. The tubes are removed 3–6 months postoperatively.

Endoscopic DCR Surgical Revision Technique

Mucoperiosteal flap surgery is performed under endoscopic visualization, in the projection of the lacrimal fossa to obtain a flap incision that is

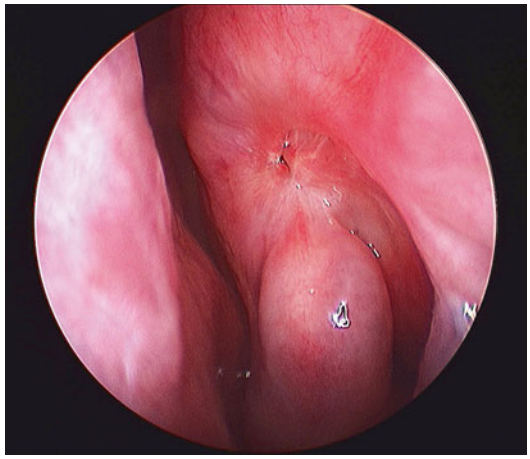

Fig. 18.1 The endoscopic photograph of obstructive rhinostomy of failed primary dacryocystorhinstomy: thick fibrotic mucosal membrane obscures bony rhinostomy

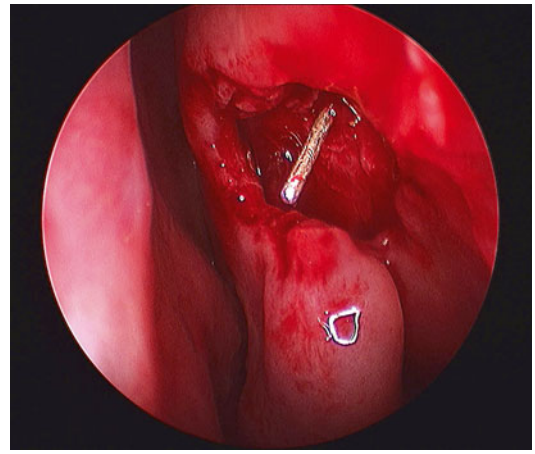

Fig. 18.2 The endoscopic photograph during endoscopic revision surgery case: thick mucosal membrane is reopened with a sickle-shaped or a number 12 blade knife and number 1 Bowman probe is placed through upper canaliculus to a newly formed rhinostomy site

slightly more anterior over the frontal process of the maxilla. This mucosal incision allows the correct surgical plane to be established for the dissection of the mucosal flap. The flap is undermined and resected, and the medial bone wall of the lacrimal sac or its remnant is removed by drilling or using a Kerrison rongeur until complete sac exposure is obtained. The lacrimal sac is located by inserting a stent into the lacrimal canaliculi and is opened along its full vertical length using a sickle knife. Silicone tubes are inserted into the nasal cavity via the superior and inferior puncta, and are removed 3–6 months postoperatively (Fig. 18.2).

Important Points in Revision Cases

The reason for the failure of previous surgery may be attributable to an inadequately opened bone window [6, 7, 14]. In the case of bone formation, a suitable method for the endoscopic localization of the sac is important to avoid the recurrence of epiphora. The sac is localized on the anterior–superior region of the connection point of the middle concha, and variations are rarely encountered. An osteotomy should be performed exactly over the sac and the sac should be opened from the middle aspect, and not from the upper or lower aspects. The development of postoperative adhesions is a further reason for failure. Nasal pathologies, including septal deviations, concha bollosa, or concha hypertrophy, and hyperpneumatized ethmoid cells are factors that enhance adhesions. When these intranasal pathologies result in the failure of the previous operation, the subsequent adhesions can be readily determined during endoscopic revision surgery and be repaired during the same operation session. Another important point in revision cases is the usage of stents, which is relatively controversial. Although it has been reported in some studies that leaving the stents for an extended period may induce granulation formation, some authors still propose long-term use, particularly in revision case. In a literature review of revision cases, especially endoscopic revision, most authors used silicone stents for 3–6 months postoperatively.

As indicated earlier, the cause of failure for external or endoscopic DCR include: septal deviations, incomplete removal of the lacrimal bone, and synechiae, granulation tissue, membrane and scar formation at rhinostomy. The most common cause of failure is excess scarring at the site of the lacrimal sac and soft tissue of the osteum. Primary success rates tend to be

significantly higher than for secondary, repeated surgery. Therefore, various adjuvant techniques have been attempted to improve the success rate of secondary DCR. The most popular adjuvant method in the current literature is topical mitomycin C (MMC) application [15–17] or the injection of corticosteroids (e.g., bethamethasone [18]). MMC is an alkylating agent that inhibits fibroblastic proliferation and scar formation when applied topically. Reported results for topical MMC are variable and remained controversial. In three reports on revision cases, a small piece of cotton soaked with 0.4 or 0.5 mg/ml MMC was applied topically to the nasolacrimal stroma site for 5 or 10 min. Penttilä et al. reported that adjunctive use of intraoperative MMC appeared to be safe and that this could increase the success rate of revision endoscopic DCR surgery [17]. Ragab et al. reported that MMC did not increase the success rate of revision endoscopic DCR, although it was a safe procedure and may be of value for patients inaccessible to strict follow-up [16]. Corticosteroids are known to have anti-inflammatory, immunosuppressive, and antimitogenic properties, which to date have proved useful in other areas of ophthalmic practice. Zeldovich and Ghabrial used betamethasone in revision DCR, injecting it at 5.7 mg/ml, using a bent 25-G needle into the soft tissue surrounding the osteum before completion of the surgery [18]. Anatomical patency was achieved in 84 % of cases and symptoms improved in 89 % of the enrolled patients. These authors also reported that revision endoscopic DCR, under assisted local anesthesia, had a high success rate (89 %) when the betamethasone injection was administered intraoperatively.

The transcanalicular approach normally creates smaller rhinostomies than the external and endonasal approaches, which is correlated with the low success rate of primary and secondary transcanalicular DCR. However, it allows a direct application of the laser energy to the obstructed site. Endonasal and transcanalicular revision surgeries have two major advantages over the external approach: avoidance of a skin incision in an already scarred surgical field and limited surgical trauma. Generally, the procedure can be performed under local anesthesia as an outpatient procedure in the office. Regrowth of bone at the rhinostomy site after DCR is limited or absent, while soft scar tissue is responsible for any failure. Endonasal or transcanalicular revision surgery has been particularly useful in failed external DCR revision in which a wide boneless window has already been created and no bone needs to be removed. Patel and associates employed this approach for revision DCR using a neodymium-doped yttrium–aluminum–garnet (Nd:YAG) laser [19]. They reported a 46 % success rate and therefore did not recommend it for revision DCR. In contrast, Woo and associates had an 83 % success rate after the first revision surgery, which increased 100 % following the second revision surgery [20]. They suggested that the discrepancy in their success rates with that of Patel et al. may have been differences in the origin of the nasolacrimal duct obstruction, because cases of DCR resulting from trauma, canalicular obstruction, radiation, sinus tumor, Wegener's granulomatosis, and Down's syndrome have lower surgical success rates. Narioka and Ohashi reported a good surgical outcome with an 80 % functional success rate (mean, 27.3 months after surgery) in revision cases using a semiconductor diode laser [21]. They suggested that the diode laser can achieve effective tissue dissection with minimal collateral damage external to the target zone, and these characteristics diminish the risk of retrograde damage.

In several specific cases of revision DCR surgery, we have to consider conjunctivo-DCR (CDCR)-as final potential surgical method for symptomatic epiphora. CDCR involves the creation of a fistula from the medial commissural conjunctiva into the nasal cavity. In most cases, a Pyrex glass tube (Jones tube) is inserted within this fistula to reestablish lacrimal drainage. Indications for CDCR are canalicular agenesis, canalicular obstruction, common canalicular obstruction, and lacrimal pump dysfunction (e.g., facial nerve palsy). Therefore, for canalicular obstruction or pump dysfunction in revision cases, we must consider the CDCR procedure [22].

Surgical Technique for CDCR

A rhinostomy can be formed using an external or endoscopic approach. The external approach involves a standard DCR incision, mobilization of the lacrimal sac, and removal of the medial wall of the lacrimal fossa. The rhinostomy can then be enlarged to allow appropriate positioning of the tube. An incision is made on the medial side of the lacrimal sac and the flaps are sutured to the nasal mucosal flaps. A passage is then created from the caruncle to the lacrimal sac.

The endonasal approach involves an endoscopic DCR, with or without prior passage of a 16-G needle as a positional guide. Further procedures may be required to increase the space within the nasal cavity, including an out-fracture or resection of the middle turbinate. Endoscopic visualization allows for accurate placement and measurement of the tube, even if the external approach is used to create the DCR [22–24].

Conclusion

Endoscopic and external revision DCR have similar outcomes when performed by surgeons with a specific interest in lacrimal surgery. To improve surgical outcome, topical application of MMC or a betamethasone injection can be considered as an adjunctive treatment of revision cases. In recent reports, laser-assisted canalicular DCR surgeries have shown improved success rates even in revision cases. CDCR may thus be indicated in several specific revision cases including proximal canalicular obstruction and intractable functional obstruction.

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Lacrimal Trauma

19

Balaji Perumal and Dale R. Meyer

Introduction

Injury to the lacrimal system is a relatively common occurrence following physical or thermal/chemical trauma to the periorbital region. Blunt trauma can cause lateral traction on the eyelid and lead to laceration of the canaliculus. The canaliculus or lacrimal sac can also be injured after a sharp, penetrating injury to the eyelids. Mawn et al. reported that 54 % of canalicular injuries occurred as a result of direct penetrating trauma and 46 % occurred secondary to blunt trauma. They postulated that the nasal bridge and superomedial orbital rim act as a "funnel" which makes it more likely for sharp objects to damage the medial canthal area [1]. Medial canthal tendon injury is a common occurrence in patients with canalicular lacerations, seen in 36 % of patients in one study [2]. One of the most common causes of canalicular lacerations is a dog bite; this often leads to a deep laceration without loss of soft tissue [3].

Nasoethmoidal fractures as well as soft tissue trauma in the deep medial canthal area should make one suspicious of a lacrimal sac injury. Fractures of the midface from blunt trauma including naso-orbitoethmoidal, LeFort II, and III fractures can disrupt the nasolacrimal duct/canal leading to obstruction of the lacrimal system [4]. These types of injuries occur most often after blunt trauma, such as after a motor vehicle accident [5]. One study found that 29 % of patients with naso-orbitoethmoidal fractures developed persistent epiphora secondary to nasolacrimal duct obstruction [6].

The puncta/canaliculi can also be injured secondary to thermal and chemical burns of the eyelids. There are a number of different mechanisms for eyelid burns including fire, molten metal, and alkali or acidic products. One study noted that 6 % of patients with eyelid burns developed epiphora secondary to canalicular scarring which was untreated [7].

Anatomy of the Lacrimal System

A good understanding of the lacrimal system anatomy is essential to diagnosing and treating injuries. The upper and lower puncta are the initial portions of the lacrimal drainage system. The canaliculi run 2 mm vertically initially, then turn 90° and extend medially 8–10 mm to join with the lacrimal sac. They run just underneath the surface of the eyelid margin and are usually encased within a small portion of orbicularis muscle. In 90 % of patients the upper and lower canaliculi join to form a common canaliculus. This structure enters the sac posterior and slightly superior to the anterior crus of the medial canthal tendon.

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The lacrimal sac is 12–15 mm in length which includes a 3–5 mm fundus superior to the medial canthal tendon. The sac is approximately 4–8 mm anterior to posterior and 3 mm in width. The anterior limb of the medial canthal tendon inserts on the anterior lacrimal crest and the posterior limb inserts on the posterior lacrimal crest.

The nasolacrimal duct consists of an approximately 12 mm intraosseous portion and a 2–5 mm membranous portion distally. Within the bony nasolacrimal canal the lining of the duct becomes more adherent to the bone and has a more fibrous quality. The duct empties into the nasal cavity just inferior to the inferior turbinate [8].

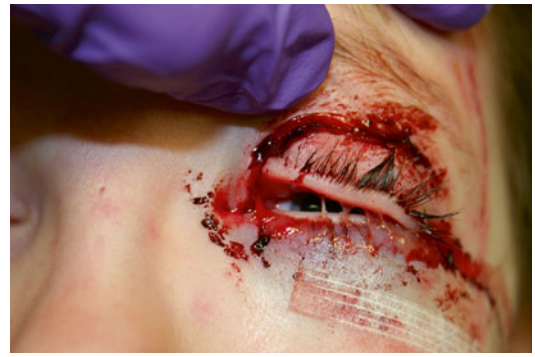

Fig. 19.1 Example of an upper canalicular laceration

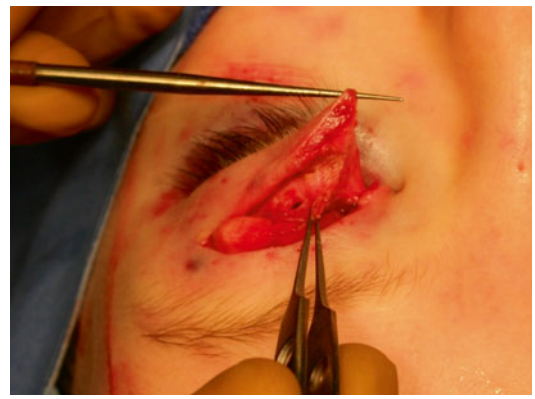

Fig. 19.2 Canalicular laceration with punctal dilator visualized in the wound after being placed through the punctum and proximal canaliculus

Examination

It is recommended that any patient with a suspected lacrimal system injury first receive a thorough ophthalmic examination. These patients often have other ocular injuries, such as a ruptured globe, which may take priority. For patients with blunt or sharp trauma to the eyelids, it is important to carefully examine the medial aspects of the lids. Any injury in this area puts the patient at high risk for lacrimal system injury, especially since the canaliculi run close to the skin (Fig. 19.1). Similarly, in patients with burns to the eyelids, punctal/canalicular involvement is a serious consideration if the medial aspects of the lids are involved.

In order to inspect the canaliculus the punctum is dilated first. A size "00" Bowman probe can then be passed through the punctum. A laceration can be confirmed if the dilator or probe is visualized distal to the punctum (Fig. 19.2). If there is difficulty in passing the probe, canalicular injury must be suspected as well. In addition, irrigation can be performed and flow of solution out through the open wound is highly suggestive of canalicular involvement. In patients with a laceration near the medial canthus, flow of irrigation fluid out through the wound can indicate a lacrimal sac laceration.

In a patient with burns to the eyelids, the authors recommend examination of the punctae to note any degree of stenosis. The punctae can then be dilated and a probe and irrigation of the canaliculus can be performed. This will help to determine if there is any degree of canalicular stenosis.

As mentioned previously patients with fractures of the midface are prone to disruption of the lacrimal sac and/or nasolacrimal canal/duct. The surgeon needs to review the imaging studies to determine if there may be any disruption of the lacrimal sac or nasolacrimal duct. These are patients in whom it may be beneficial to perform probing of the nasolacrimal duct soon after the trauma to assess the extent of injury, especially if the patient is acutely symptomatic; although caution is advised since probing can potentially cause further iatrogenic damage. These injuries are usually identified while the patient is under anesthesia and a proper probe and irrigation can be performed [4].

Management of Injuries

Canalicular Laceration

Repair of canalicular lacerations at one time always involved taking the patient to the operating room to place a bicanalicular stent and closure of the eyelid defect. More recently monocanalicular stents have been introduced which has allowed for repair of canalicular injuries under local anesthesia in the ER or office.

The use of oral antibiotics in these types of lacerations is somewhat controversial. The surgeon can consider prescribing a broad spectrum antibiotic for patients with "dirty" wounds such as a dog bite, although there is some evidence that this is not necessary in this situation [9].

The surgeon first needs to identify the medial end of the cut canaliculus in order to properly repair a canalicular laceration. This is often the most difficult part of the repair. The cut end usually appears as a glistening white ring with rolled edges. The canaliculus is easier to identify if the laceration is closer to the punctum. In patients with more medial lacerations the canalicular injury will be in the deeper tissue, often deep to the medial canthal tendon. A Bowman probe can be place through the punctum and intact canaliculus to help judge where the cut end may be. If the medial cut end still cannot be identified, fluorescein dyed saline can be injected in the intact canaliculus on the same side and the surgeon can attempt to determine where it exits the wound. Alternatively, air can be injected while the medial tissues are submerged under saline.

In order to properly repair the canaliculus we recommend that a stent be placed to keep the canaliculus open while it heals [10]. The standard for many years in the repair of canalicular lacerations was the use of bicanalicular intubation. This involves the use of nasal packing to obtain sufficient anesthesia along with intravenous sedation or general anesthetic. More recently monocanalicular stents have become popular. These can be inserted under local anesthesia. The disadvantage of these stents is that they are less secure and can become dislodged, especially in children. In addition, any disruption of the punctum generally precludes use of this stent because it will likely not seat properly.

For repair with a bicanalicular stent, the authors prefer the use of the Ritleng system (FCI Ophthalmics Inc.) (Fig. 19.3). After punctal

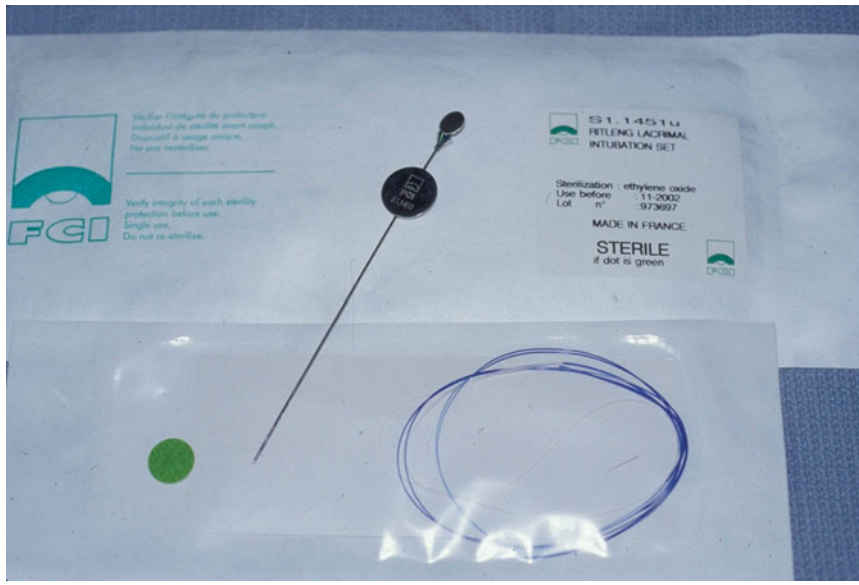

Fig. 19.3 Ritleng bicanalicular intubation system with the probe and thread guide

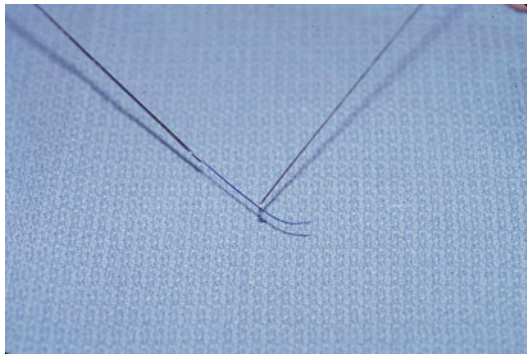

Fig. 19.4 Ritleng hook with thread guide

Fig. 19.5 Mini-Monoka monocanalicular stent. Notice the phalange which seats within the punctum

dilation the Ritleng probe is inserted into the proximal intact portion of the canaliculus. It is then passed through the medial cut end and then advanced until a hard stop is felt. The probe is then rotated superiorly along the brow and then passed through the nasolacrimal duct into the nasal cavity just below the inferior turbinate. The PolyEtherEtherKetones (PEEK) thread guide which is attached to the silicone stent is then passed through the Ritleng probe into the nasal cavity. The thread can be retrieved from the nose with a Ritleng hook (Fig. 19.4), which is then pulled through until the stent is identified in the nose. The probe can then be removed from the lacrimal system, leaving the stent in place. If the laceration is near the punctum, there is a risk for tearing the punctum when rotating the probe. In these instances the thread/stent can be passed through the punctum and proximal canaliculus first, and then pulled out through the wound. The probe can then be inserted into the medial cut end of the canaliculus. At this point the probe can be rotated superiorly and passed into the nasal passage without inducing a large amount of medial traction on the punctum. This procedure is performed again for the adjacent canaliculus. The PEEK threads are removed from both sides of the stent, and the stent is tied in the nose with a single square knot. The knot may or may not be secured to the wall of the nasal passage with a suture depending on surgeon preference.

The monocanalicular stent (Mini-Monoka, FCI Ophthalmics Inc.) is a short silicone tube with a phalange at the proximal end (Fig. 19.5). When using this stent for a canalicular laceration, it is initially passed through the punctum and proximal canaliculus so the phalange is seated appropriately within the punctum. This secures the stent into place. The stent can be pulled from the cut end of the canaliculus to help seat it properly. It is then threaded through the medial cut canaliculus into the lacrimal sac. It does not need to be advanced into the nasolacrimal duct; therefore it can be shortened if needed.

An additional option for intubation of the canaliculi, especially when the surgeon has difficulty identifying the medial cut end, is the use of a pigtail probe. Some centers have used this method primarily with good success [11]. The pigtail probe has an eyelet at its tip. The probe is passed through the intact canaliculus with the probe handle in the vertical position. It is rotated until the end of the probe is seen exiting the cut end of the opposite canaliculus. A 5-0 nylon suture is passed through the eyelet and the probe is rotated back out to bring the suture through the canaliculi. The opposite end of the probe is passed through the punctum of the cut canaliculus and into the wound. The nylon suture is then passed into the eyelet and the probe is removed. The nylon suture is threaded into a silicone tube and a clamp is placed on both. The unclamped suture is then pulled to bring the stent through both canaliculi. The stent is then shortened and the nylon is tied to itself creating a loop. The closed edges of the stent are then rotated into the

intact canaliculus. Without proper experience with this method the probe can cause iatrogenic injury to the canaliculus.

Soft tissue closure of the wound is similar whether a bicanalicular or monocanalicular stent, or pigtail probe system is used. If the medial canthal tendon has been avulsed, it can be reattached to the periosteum of the medial orbital wall just posterior to the lacrimal sac with 5-0 Vicryl suture. It is recommended that this procedure is performed after the stent is in place. If there is injury to the punctum it can be sutured around the silicone stent with a deep 7-0 Vicryl suture. The pericanalicular tissue can be closed with a single 7-0 Vicryl horizontal mattress suture to reapproximate the canaliculus. Direct suturing of the canaliculus may be unnecessary, and can cause unwanted scarring [12, 13]. The deep tissue can be closed with interrupted buried 5-0 Vicryl sutures and the skin can be closed with interrupted 6-0 fast absorbing gut suture.

Canalicular stents can be left in place for 6 weeks to 6 months; it can vary greatly depending on surgeon preference [14]. In order to remove a bicanalicular stent the stent can be partially pulled out through the canalicular side and then cut. If the stent is secured to the nasal mucosa this suture should be cut as well. The stent can then be removed through one of the puncta. It is preferable to pull it out through the uninjured punctum/canaliculus if the patient had a monocanalicular laceration. Alternatively, the stent can be pulled out through the nose if it can be easily identified. Cutting the stent and leaving it in place (assuming it will come out on its own) is not advisable. The stent may become lodged in the lacrimal duct and cause a granuloma [15].

Lacrimal Sac and Nasolacrimal Duct Injury

Primary repair of a lacrimal sac laceration can be considered depending on the type of laceration and related injuries. If the laceration is contiguous with the external medial canthal injury, repair of the sac with direct closure and bicanalicular silicone intubation (as described previously with the Ritleng system) is reasonable. The lacerated sac edges can be reapproximated with interrupted 5-0 Vicryl sutures. Once again the stent can be left in place for 6 weeks to 6 months. If the sac cannot be salvaged, a decision on primary versus delayed dacryocystorhinostomy (DCR) must be made. Bony disruption in some of these patients may complicate the repair. In the authors' opinion if the case lends itself to primary repair (taking into account concomitant injuries) and a sufficient amount of bone can be removed for a DCR, it is reasonable to perform primary surgery with a stent [4]. The disadvantage of delayed surgery is that there can be a large amount of scar tissue which forms and can make surgery more challenging.

When deciding on management of nasolacrimal duct injury, the surgeon can consider primary intubation of the lacrimal system if it is feasible. If the patient has symptomatic tearing, silicone intubation can be offered to the patient and can be performed concomitantly with repair of associated midfacial fractures [4]. Similar to canalicular and lacrimal sac lacerations, the stents for these injuries can be removed 6 weeks 6 months after repair. It is also reasonable to reassess the lacrimal system in approximately 2 weeks after the edema subsides. For patients who do not receive primary repair in the first few weeks after the injury, it is generally acceptable to perform a DCR later if needed.

Burns Involving the Punctum/Canaliculus

Patients with burns involving the medial eyelids who have identifiable puncta and easily probed canaliculi can be observed initially, though the authors recommend that these patients be followed closely (every 1–2 days for the first week) with subsequent fluorescein dye disappearance tests and potentially repeated dilation. Patients with more marked punctal stenosis and tight canaliculi may benefit from early surgical debridement with punctoplasty or canaliculoplasty and silicone intubation. Intubation can be performed with a bicanalicular or monocanalicular stent.

In these patients the lacrimal system is highly prone to complete closure secondary to scarring. Silicone tubing can be left in for 3–6 months, although 3 months appears to be sufficient to allow for full healing [7].

Summary

Lacrimal injuries can be a common feature of facial trauma. Injuries can include canalicular or lacrimal sac lacerations, nasolacrimal duct disruption, or chemical/thermal trauma to the punctum and canaliculus. Many of these are amenable to early treatment to preserve satisfactory tear drainage in affected patients. It is imperative that the surgeon take into account the patient's concomitant injuries when determining the best treatment plan.

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Application of Antimetabolites in Lacrimal Surgery

20

Chieh-Chih Tsai and Hui-Chuan Kau

The application of antimetabolites in ophthalmic surgery has been increasingly used to modulate the wound healing process and improve surgical outcome. Current applications in ophthalmic practice include glaucoma surgery, pterygium surgery, lacrimal surgery, refractive surgery, conjunctival-corneal intraepithelial neoplasia, and vitrectomy for proliferative vitreoretinopathy. The two most commonly studied and widely used antimetabolites in ophthalmology are mitomycin-C (MMC) and 5-fluorouracil (5-FU).

Mitomycin-C and 5-Fluorouracil

5-FU was first synthesized in 1957 by Dushinski et al. [1]. It is a pyrimidine analogue with a chemical structure related to thymine and uracil. Its mechanism of action is associated with inhibition of thymidylate synthetase and incorporation into DNA and RNA, then interferes with DNA and RNA synthesis [2]. MMC is originally isolated from the soil fungus *Streptomyces caespitosus*. It is usually classified as an alkylating agent. Under anaerobic conditions, the MMC intermediates could cross-link double stranded DNA and then inhibit DNA and RNA synthesis. In ophthalmic use, MMC has been shown to inhibit cell migration, extracellular matrix production, and modulate wound healing by blunting the proliferative phase of fibroblasts [3]. MMC is available in a vial (2 mg/ml) and is often reconstituted with normal saline (5 ml) to make 0.4 mg/ml or in 10 ml to make 0.2 mg/ml. It should be stored under refrigeration after reconstitution to keep its potency for 2 weeks [4]. The effect of MMC on fibroblasts has been shown to be more potent and prolonged duration than 5-FU, requiring single topical application doses of approximately 100-fold less than 5-FU. Cell culture experiments by Ali et al. found that the minimum effective concentration of MMC was 0.2 mg/ml for 3 min to prevent cell proliferation of human nasal mucosal fibroblasts [5].

Application of Antimetabolites in Lacrimal Surgery

Lacrimal outflow obstruction can occur at any level along the lacrimal outflow pathway including of punctum, canaliculus, lacrimal sac, or nasolacrimal duct. The primary reason of failure in lacrimal drainage surgery is closure of the surgical osteotomy due to scarring, fibrosis, or granulation tissues. Topical use of antimetabolite has

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been described in lacrimal drainage surgery or procedures to minimize postoperative fibrosis or granulations, and thus to inhibit such closure.

Topical MMC for Punctal Stenosis

Punctal stenosis, a common cause of symptomatic epiphora, may require punctal dilation or surgical procedures. Recurrent stenosis or scarring is a common problem in patients with punctual stenosis after these procedures. Application of topical MMC may minimize the adhesions and scar tissues around the new opening of punctum (Fig. 20.1). In a case report by Lam and Tessler, topical MMC was successfully used in the treatment of a patient with recurrent punctual stenosis [6]. They applied cellulose sponge soaking with 0.04 % MMC on the punctal opening 5 min in a patient who had two previous failed one-snip procedures. The punctum successfully remained open during the follow-up of 3 months. Ma'luf and associates investigated the efficacy of supplemental topical MMC in patients who underwent posterior punctectomy [7]. After posterior punctectomy procedure, they used a cotton applicator soaked with 0.5 mg/ml MMC over the punctal opening and changed every 1 min for a total of 5 min. Their findings showed complete absence of scarring in all cases where MMC was used (0 %), as compared to 19.2 % developing complete anatomic obstruction and scarring of their puncta after surgery in non–MMC group. No significant complications were observed.

Fig. 20.1 Application of topical MMC by using a cotton applicator soaked with 0.5 mg/ml MMC over the punctal opening to minimize the adhesions and scar tissues around the opening of punctum

Adjunctive MMC Irrigation in Lacrimal Probing

Nasolacrimal probing has proved effective for children with congenital NLD obstruction. However it shows a decline in success with increase in age due to longstanding blockage, chronic inflammation, and fibrosis of NLD. Tsai et al. in 2002 first used adjunctive MMC to improve the success rate of lacrimal probing for patients with NLD obstruction [8]. They introduced a Bowman 0- or 00-gauge probe into NLD and left in place for 30 s to minimize bleeding. After irrigating with normal saline to confirm duct patency, lacrimal irrigation was performed by introducing 1 ml of 0.02 % MMC into the duct with a syringe three times. To reduce systemic absorption of MMC, a cotton-tipped applicator was placed into the nasal cavity and patients were instructed not to swallow the solution. A following comparative randomized study by Sinha et al. showed an overall subjective improvement in 65 % of cases with MMC-adjunctive probing (1 ml of 0.2 mg/ml, once), as compared to 40 % of cases with probing alone [9].

Adjunctive MMC Irrigation in Balloon Dacryocystoplasty

In comparison to dacryocystorhinostomy, balloon dacryocystoplasty is associated with less morbidity and simple technique, but has a relative lower long-term success rate especially in cases with complete NLD obstruction. An analysis by Kim and associates showed that MMC irrigation at a concentration of 0.2 mg/ml in three different sessions (immediately, 1 week, and 1 month) after balloon dacryocystoplasty was effective in increasing the cumulative patency rate [10]. The balloon was soaked in MMC

solution (0.2 mg/ml) before use. In addition, MMC irrigation was only performed in the NLD that revealed patency by dacryocystography, which was performed just after balloon dacryocystoplasty. Irrigation was performed twice with 1.5 ml of MMC solution (0.2 mg/ml) by using a syringe through the lower punctum for 1 min. MMC irrigation after balloon dacryocystoplasty could be an alternative to stent placement, especially in cases of complete NLD obstruction.

Efficacy of MMC in External Dacryocystorhinostomy

In 1997, Kao and Liao first used MMC to maintain a larger osteotomy size [11]. A meta-analysis study of nine randomized controlled trials indicates that adjunctive intraoperative MMC application with primary external dacryocystorhinostomy had a significantly higher success rate than external dacryocystorhinostomy without MMC ($p=0.01$) [12]. Among which, two randomized controlled trials showed the mean osteotomy size 6 months postoperatively was significantly larger in the MMC group than in the control group [11, 13]. In most studies, a cotton pledget soaked in 0.2–1.0 mg/ml MMC was placed over the anastomosed posterior flaps and osteotomy site for approximately 2–30 min followed by copious irrigation with normal saline (Fig. 20.2). No complications except two cases with delayed healing of the external skin wound were noted in the MMC group of their systematic review [12].

Efficacy of MMC in Endoscopic Dacryocystorhinostomy

Adjunctive MMC has also been applied for primary or revision endoscopic dacryocystorhinostomy, transcanalicular laser-assisted dacryocystorhinostomy, or endonasal endoscopic laser-assisted dacryocystorhinostomy to enhance the success rate. However, these results are not completely consistent. A meta-analysis study by Cheng and associates revealed that the success rate of the patency of the nasolacrimal canal and symptomatic improvement was significantly higher in the group with adjunctive intraoperative MMC application in primary and revision endoscopic dacryocystorhinostomy, as compared to those without MMC ($p=0.041$) [14]. Among which, the mean ostium size in three studies was significantly bigger in MMC group than that in control group at 3 and 6 months postoperatively, though the difference was not significant at 12 months [15–17]. No MMC-associated complications were reported in their systematic review [14].

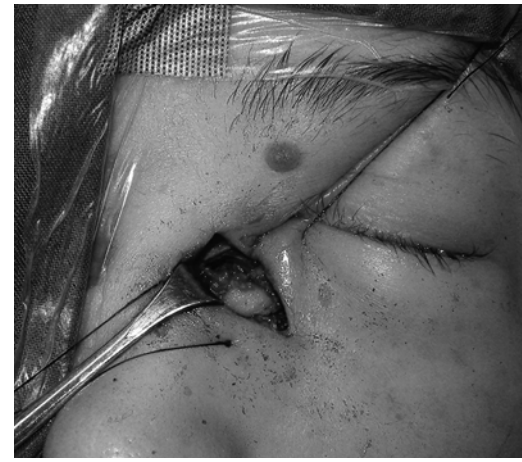

Fig. 20.2 A cotton pledget soaked with MMC was placed over the anastomosed posterior flaps and osteotomy site during external dacryocystorhinostomy

Efficacy of 5-FU in External Dacryocystorhinostomy and Endoscopic Dacryocystorhinostomy

There are limited studies to investigate the efficacy of 5-FU in lacrimal surgery. By observing the postoperative structural change of the intranasal ostium through endoscopy, Costa et al. suggested that adjunctive 5-FU in external dacryocystorhinostomy does not significantly influence the final size of the surgical fistula [18]. Bakri et al. also showed that intraoperative use of 5-FU failed to increase the patency rate in endonasal laser dacryocystorhinostomy [19].

Side Effect

Although MMC has proven efficacy, it also increases the risk of complications. Some complications caused by MMC application have been reported in ophthalmic practice such as pterygium surgery, glaucoma filtration surgery, and topical use for of conjunctival-corneal intraepithelial neoplasia. It includes secondary glaucoma or cataract, corneal ulcer, limbal stem cell deficiency, scleral melting, hypotony, and endophthalmitis and maculopathy [20–22]. Nevertheless, the application of MMC in lacrimal surgery appears to be safe, and there are very few MMC-related complications have been reported in the lacrimal surgery. One case with adjunctive MMC irrigation in balloon dacryocystoplasty developed superficial punctate keratitis which was transient and resolved promptly with the use of artificial tears [10]. Two cases with delayed wound healing were reported in the use of MMC in external dacryocystorhinostomy [23, 24]. Strategies to minimize the incidence of complications associated with antimetabolite use in lacrimal surgery include using minimum effective concentration of MMC (0.2 mg/ml) and irrigating with copious normal saline after use of MMC. Doctors should be always aware of the potential complications associated with its use.

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Ancillary Procedures

21

Alexander L. Grigalunas and Adam J. Cohen

Griffiths Nasal Catheter

Introduction

Since its initial description by Toti in 1904, numerous modifications in technique and technological advances have been made to dacryocystorhinostomy (DCR) surgery [1]. These include sutured and sutureless rhinostomy flaps, endoscopic approaches, various alloplastic stents [2], balloons, and implants such as the Griffiths Nasal Catheter (GNC) and Rains stent. These advances have focused on the prevention of cicatricial ostium closure leading to DCR failure.

The GNC is an implant that improves long-term patency of the fistula tract in primary and secondary procedures. Another device, a Modified Rains Stent, has increased DCR success rates in high risk patients with Wegener's granulomatosis, pemphigoid, sarcoidosis, and choanal atresia.

The GNC is a self-retaining alloplastic device shaped like a collar button (Fig. 21.1). Made from a thermoplastic, highly biocompatible elastomer called C-Flex (Saint-Gobain Performance Plastics, Clearwater, FL, USA), the GNC has low platelet adhesion and protein binding [3]. C-Flex is non-pyrogenic, non-cytotoxic, less permeable, higher in tensile strength, and has a greater degree of elasticity than silicone [4].

The GNC has a standard lumen diameter and is available in two collar sizes. A 12 mm collar diameter is primarily used for an external DCR in adult patients while an 8 mm collar diameter GNC may be useful in pediatric patients or when using an endonasal approach to DCR.

Technique

The GNC can be placed either by external or endonasal approaches [5, 6]. With the endonasal approach, once intubation is performed, the tubes are placed within the lumen of the catheter. The catheter is then advanced in the nostril with bayonet forceps until the proximal collar is in the lacrimal sac fossa. If an external approach is used, the catheter is placed into the rhinostomy without suturing of flaps.

The tubes and catheter may be removed in the office setting after remaining in place for 6 months. After removing the intubation tube, the catheter is grasped from the intranasal portion

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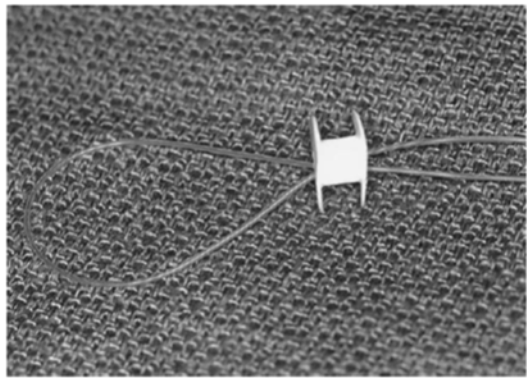

Fig. 21.1 Griffiths nasal catheter with silicone intubation tube

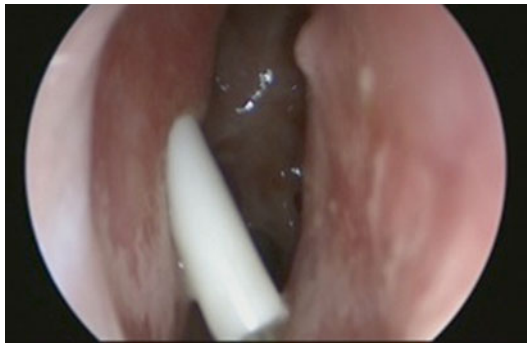

Fig. 21.2 Endoscopic view of Modified Rains Stent within the ostium. Notice the tip is well positioned away from the nasal septum. Image courtesy of Aaron Fey, M.D.

and removed from the nostril. Sedation may be needed for removal in pediatric patients, but topical anesthesia is usually sufficient for removal in adults.

Modified Rains Stent [7]

The Modified Rains Stent (MRS) is created from a silicone Rains frontal sinus stent. The top of the bulbous end is cut with scissors so the ribs are separated, but remain in a bulb shape to prevent dislodgment. The tubular portion is trimmed to a length that avoids contact with nasal septum (Fig. 21.2). Once in place, the bulb collects tears and directs them through the tube into the nasal cavity.

Technique

The MRS is placed using an external approach. The anterior portion of the lacrimal sac is opened, and a small hole is created in the posterior aspect of the sac. Once a 4 mm diameter ostium is created, the device is placed in the lacrimal sac and the tubular end is placed through the ostium. The anterior lacrimal sac incision is closed and the overlying surgical incision site is closed in normal fashion.

The MRS has been left in place for extended periods of time without complication. Regular endoscopic exams to look for possible mucosal erosion and debridement of the tube may be required.

Discussion

Previous reported success rates for primary and secondary DCR are 90–95 % [8, 9]. The GNC has been used in multiple studies for primary and secondary DCR with 100 % patency at 3 years and 98 % patency at 2.5 years respectively [6] without pyogenic granuloma formation in any cases.

The use of the GNC may also be indicated in patients with significant sinonasal disease or congenital nasolacrimal duct obstruction associated with craniofacial abnormalities, as these cases tend to develop cicatricial stenosis at higher rates than cases with relatively normal nasal mucosa.

The Modified Rains Stent, a potentially permanent silicone stent, has shown promise in these difficult cases with 8 of 9 patients asymptomatic at 2.5 years [7].

Summary

The GNC and MRS have been successful in maintaining ostium patency following DCR. Once the technique is learned, insertion of the GNC has more successful outcomes and reduces operative time versus suturing flaps. The biocompatibility and ease of in-office removal further supports the use of the GNC. Furthermore the GNC and the MRS can be useful in cases with

significant sinonasal disease or congenital nasolacrimal duct obstruction due to craniofacial abnormalities; however, in these difficult cases, the MRS has shown high success rates.

Canalicular Trephine

Introduction

There are many different techniques prior to intubation of canaliculi for canalicular obstructions including probing, balloon canaliculoplasty, endocanalicular laser, membranectomy, and punctoplasty. A technique using a microtrephine, first described by Sisler and Allarakhia in 1990 for distal canalicular obstructions, has been successful [10].

Device

The Sisler Lacrimal Canalicular Trephine (SLCT) is a steel microtrephine 38 mm in length and 0.80 mm in diameter. The SLCT has a plastic grip at one end and a cutting trephine at the other end. The SLCT comes prepackaged over a blunt-tipped advancing stylet that helps avoid damage to the surrounding tissues [11].

Technique

Topical anesthesia with viscous lidocaine is used along with a nasociliary nerve block. The canaliculus is dilated with a probe. The stylet within the SLCT is advanced into the canaliculus until the blockage is found. At this time, the stylet is removed and the SLCT is rotated and advanced until the lacrimal sac fossa is reached. Care must be taken not to create a false passage while advancing the trephine. A 5 mL syringe may be attached to the SLCT and the plunger is drawn back to collect any scar tissue or debris during trephination. Once the SLCT is within the lacrimal sac fossa, it is removed. Irrigation is performed to ensure canalicular patency. A standard silicone stent may then be placed through the canaliculus, albeit the authors prefer a mini-Monoka or bicanalicular stent (FCI Ophthalmics, Marshfield Hills, MA, USA) (Fig. 21.3). These stents allow for an in-office procedure versus need for use of an operating room for placement of traditional stents. Patients are then instructed

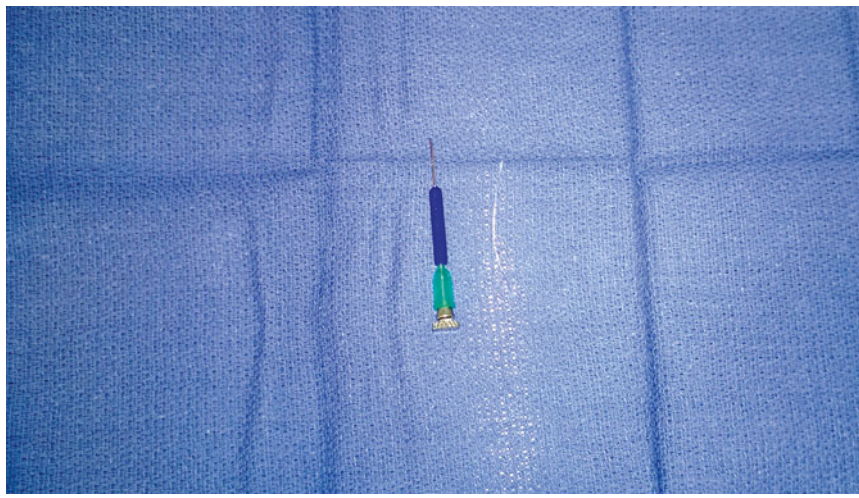

Fig. 21.3 Sisler Lacrimal Trephine on left and mini-Monoka stent tube on right

to use antibiotic/steroid drops for 2 weeks. The stent is removed at 2 months.

Discussion

Complete resolution of epiphora when using a microtrephine and stenting occurred in 49 % of patients in one study and partial relief in another 38 % [10]. Another study combined endoscopic DCR with lacrimal trephination and nasolacrimal intubation for distal and common canalicular obstruction [11]. They found an 80.6 % and 12.9 % complete and partial success rates respectively in 31 eyes.

The most common complication is trauma to the non-obstructed portion of the canaliculus [12]. Trauma, as well as the creation of false passages, may be avoided by dilation of the canaliculus and use of the blunt-tipped stylet. Additionally, re-occlusion may occur after removal of the stents. Adjuvant therapies, such as topical, low-dose mitomycin C, have been used in conjunction with silicone intubation during endoscopic DCR [13], and may be beneficial in reducing re-occlusion when combined a mini-Monoka stent.

Other modified lacrimal trephines using differing approaches have been used successfully as well [14]. As more options become available, more data will become available to assess the primary success rate, long-term patency, and risks of using microtrephines during repair of canalicular obstructions.

Summary

The SLCT has the potential to turn treatment of a distal canalicular obstruction from an operation in an operating room into an in-office procedure with little patient recovery time and healthcare cost savings. The ease of use, in combination with fairly high success in reducing epiphora, makes using the SLCT a strong option for distal and common canalicular obstructions.

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