REVIEW ARTICLE

Modern Lacrimal Duct Surgery From the Ophthalmological Perspective

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SUMMARY

Background: From the 1990's onward, it has been possible to assess changes in the lacrimal duct by direct, minimally invasive diagnostic inspection with the aid of miniaturized endoscopes originally used in gastroduodenal surgery. It has been shown in this way that mechanical lacrimal duct stenosis often develops gradually as the result of recurrent chronic inflammation. Absolute stenoses are often located at a single point rather than extending over a longer segment of the duct.

Methods: Advances in lacrimal duct surgery are presented through a selective review of the relevant literature.

Results: Roughly 70% to 80% of all mechanical stenoses of the lacrimal duct can be reopened during endoscopic surgery with the use of a laser or a miniaturized drill.

Conclusion: With the methods described here, it is now possible for the first time to perform surgery that obviates the need for a bypass procedure and maintains or restores the normal physiological function of the lacrimal system.

Excessive tearing of the eye ("epiphora") is a common problem in everyday ophthalmological practice, and its differential diagnostic evaluation is not always a simple matter (2, 17). Since the early 1990's, there has been continuing technical progress in the development of endoscopes that were originally intended for use in gastroduodenoscopy and endoscopic retrograde cholangiopancreatography, including instrument miniaturization, residual light intensification, and the introduction of a camera. Thus, it has become possible to employ such a system inside the efferent lacrimal pathway, which is only a millimeter in diameter (1, 4).

It is now feasible (*Figures 1–4*) to visualize the mucosa of the lacrimal duct and any structural changes within it directly, as if under magnification through a microscope. A better understanding has thereby been gained of the morphological changes in mechanical lacrimal duct stenosis. Soon after the introduction of lacrimal duct endoscopy for diagnostic purposes, minimally invasive therapy became possible as well, with the aid of either a laser (laser dacryoplasty, LDP) or a drill (microdrill dacryoplasty, MDP) (4, 21). Thus, surgery on the lacrimal duct can now be performed in such a way that the structural integrity and normal physiological function of the entire efferent lacrimal pathway are preserved (5, 8, 10, 21).

The authors provide an overview of the classification and results of modern lacrimal duct surgery on the basis of their own experience in the field and a selective review of the literature. Our purpose is to acquaint physicians from all specialties with the recent developments in minimally invasive lacrimal duct surgery and with the benefits that this form of treatment can bring.

Anatomy, physiology, pathophysiology

The efferent lacrimal pathway is a system of anatomical structures connecting the surface of the eye to the eyelids and nose (*Figure 4*). Tear fluid is produced by the lacrimal gland, the accessory lacrimal glands, and parts of the lids and forms the tear film, whose quantity and composition are subject to regulatory control by the efferent lacrimal pathway system. Outflow is mainly actuated by the pumping effect of the orbicularis oculi muscle (muscle of Horner) on the lacrimal sac. The mechanism of outflow remains incompletely understood

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even today. Active epithelial surfaces with kinocilia, as well as the surrounding, spirally shaped cavernous system of contractile veins and muscular and connective tissue fibers that are arrayed around the lacrimal sac, propel the tear fluid onward through the nasolacrimal duct and out under the inferior nasal concha. Some of the tear fluid is probably also resorbed through the mucosa of the lacrimal pathway itself. The generation of tear fluid and its outflow are coupled to each other through multiple feedback mechanisms. Thus, the entire system can be considered to be a functional unit (13, 19).

Mucosal inflammation/infection in the lacrimal pathway and in the nose, leading to histological changes in the epithelial surfaces, mucous-producing cells, connective tissue fibers, and blood vessels, can impair the outflow of tears and cause mechanical obstruction by narrowing the lacrimal pathway or promoting membrane formation within it. Stenosis or complete obstruction may arise as a result at any point along the system, from the lacrimal punctum to the canaliculi, lacrimal sac, and lacrimal duct.

Nonetheless, because the system normally has a number of characteristic bends and narrow spots, stenoses tend to arise at certain sites of predilection: at the entrance to, and exit from, the sac, as well as within it. The clinical manifestations and course of acute and chronic inflammation/infection are highly variable, depending on the particular causative organism.

The congenital lacrimal duct stenoses seen in children are usually due to developmental anomalies of various types: aplasia, atresia, or malformation of the budding lacrimal pathway, leading to the formation of pathologically doubled structures, fistulae, and diverticula. The most common anomaly is a persistent Hasner's membrane at the end of the nasolacrimal duct, which produces excessive tearing in infancy. This condition can usually be treated simply, with tear duct probing and irrigation (2, 3, 12).

Diagnostic evaluation

Excessive tearing can result from a wide variety of causes. Specialized diagnostic evaluation is required so that the appropriate treatment can be provided. The conditions producing epiphora as their main manifestation are classified into three groups according to their etiology:

- hypersecretion, i.e., the increased production of tear fluid (usually due to an ocular disease, such as an affection of the conjunctiva or cornea);
- functional stenosis, i.e., the occurrence of epiphora even though the efferent tear pathway is anatomically intact (e.g., because of a malpositioned lid with medial ectropion);
- mechanical obstruction (e.g., by a stenosing or occluding adhesion somewhere along the course of the efferent pathway) (3, 12, 16, 18, 25).

These three categories of diseases causing epiphora can be distinguished from one another through careful history-taking and an ophthalmological examination.

Figure 1: Lacrimal duct endoscopy and intubation: a) bougie dilatation; b) lacrimal duct irrigation; c) lacrimal duct endoscopy; d) intubation

The following studies should be performed (2, 18):

- inspection (lids, lacrimal puncta, conjunctiva, cornea)
- testing of the tear pumping mechanism
- a dye test, where indicated (i.e., an active functional test)
- irrigation and probing
- indirect imaging techniques (x-ray with contrast medium, computerized tomography [CT], magnetic resonance imaging [MRI])
- direct techniques (rhinoscopy, lacrimal duct endoscopy).

Whenever a mechanical stenosis is suspected, the ophthalmological examination must be followed by consultation with an otorhinolaryngologist (17, 18, 20) for nasal endoscopy and examination of the paranasal sinuses. These studies yield information about the anatomical structures of the nose, the nasal conchae, and the ostium of the nasolacrimal duct, as well as any

Figure 2: Endoscopic views of the anatomy of the efferent lacrimal pathway: a) canaliculus with a small mucosal polyp; b) fold of Rosenmüller, lacrimal sac; c) transition to the nasolacrimal duct, with blood residue; d) inferior nasal concha

Figure 3:

Pathological findings in lacrimal duct anatomy:
a) membranous canalicular stenosis;
b) intrasaccular stenosis in chronic dacryocystitis;
c) acute dacryocystitis;
d) remnant of an incompletely removed silicone tube

pathological changes that may be present, such as chronic inflammation of the nasal cavity and paranasal sinuses, tumors (e.g., polyps), traumatic changes, ridge and spur formation, and septal deviation. The examination may reveal an indication for an intervention by the ENT surgeon. In some cases, there will be nasal pathology that should be addressed by the ENT surgeon before the ophthalmologist treats the lacrimal duct abnormalities.

Radiological diagnosis

Radiological diagnostic studies provide valuable additional information (2, 17) for therapeutic decision-making; they can reveal causative conditions such as sinusitis or tumors, when these are present. The standard studies include conventional imaging of the efferent lacrimal pathway with lipid or water-soluble contrast medium and digital subtraction dacryocystography with water-soluble, iodinated contrast medium. Conventional imaging with lipid contrast medium gives the lacrimal duct surgeon very useful information; our personal experience (ca. 250 such

studies each year for more than 20 years) indicates that the risk of mucosal granuloma formation with this technique is not as great as commonly supposed. Further imaging studies such as CT, MRI, and their recent variations, like 3-D rotation dacryocystography, may be indicated in some cases, mainly when a tumor is suspected.

Lacrimal duct endoscopy

The development and application of dacryoendoscopy, starting in the 1990s, have led to major advances in the diagnostic assessment of diseases of the efferent tear pathway and, above all, in our understanding of the pathophysiological changes affecting it (1, 4–6, 18, 22). Lacrimal duct endoscopy is the first technique that makes it possible to visualize pathological changes of the mucosa not just indirectly (as in contrast x-ray techniques), but directly and with a high degree of magnification, comparable to that of nasal endoscopy. Thus, it makes not just the normal anatomy visible, but also pathological changes such as epithelial changes, polyps, inflammation, lacrimal sac concretions, and foreign bodies in the sac (*Figures 2 and 3*).

Endoscopic technique

The endoscopic procedure is usually performed under general anesthesia, because it is combined, in most cases, with a minimally invasive treatment employing a laser or drill, or with some other therapeutic measure. After dilatation of the superior and inferior lacrimal puncta and irrigation with an astringent fluid, the endoscope is introduced and advanced all the way to the floor of the nasal cavity, or else until a mechanical impediment to further advancement is reached. The endoscopic image becomes visible on the monitor when the endoscope is pulled back and the lacrimal pathway is simultaneously irrigated (*Figure 1*). Although microendoscopic techniques have already reached quite a high degree of sophistication, it should be remembered that the 6000-pixel image obtainable through an endoscope that is 0.5 mm in diameter is not of comparable quality to the images one sees through larger nasal endoscopes. Nonetheless, the dacryoendoscopic image is good enough to enable treatments to be performed effectively through the endoscope, and is thus a valuable aid to improved patient care.

Minimally invasive treatment

Minimally invasive therapeutic techniques were introduced only a short time after diagnostic endoscopy became available (7–9, 11, 23). A third treatment channel was added to the diagnostic instrument for therapeutic purposes. The earliest treatments involved energy from an erbium-YAG laser applied through a rigid sapphire fiber. The authors currently use a diode laser with wavelength 980 nm and power 7–9 watts.

The goal of so-called laser dacryoplasty (LDP) is the recanalization of punctate stenoses. Such stenoses can be found in the canaliculi as well as within and distal to the sac. The technique of LDP is similar to that of

The efferent lacrimal pathway (with kind permission of Georg Thieme Verlag)

FIGURE 4

diagnostic endoscopy (*Figure 1*). The stenosis is treated with a laser under endoscopic vision. The irrigation that is concomitantly performed provides a useful demonstration that the efferent system is functioning once again.

It remains to be shown by future studies whether the additional application of balloon dilatation can further improve functional outcomes. At present, a good outcome from laser dacryoplasty depends in large measure not just on the elimination of mechanical obstructions to outflow, but also on the intubation of the lacrimal duct at the same procedure with a silicon tube (stent), which remains in place for three to six months. This is done after all interventional procedures, because endoscopy has provided ample evidence that any intervention, no matter how gentle, causes some degree of mucosal hemorrhage, which can then become a starting point for the development of further adhesions.

One year after laser dacryoplasty, 87% of patients say that their main symptom, epiphora, is better than before (9, 14, 15, 17, 22). The 86% success rate of LDP in the treatment of canalicular stenosis is higher than that of all other surgical procedures described to date (9).

The use of a miniaturized drill (0.3 mm in diameter, 600 rpm) as part of the endoscopic system further broadens the possibilities for minimally invasive treatment. Microdrill dacryoplasty is performed analogously to laser dacryoplasty and has the following indications:

- the opening up of intra- and post-saccular stenoses and occlusions,
- the removal of membranes, folds, and polyps, and
- the debulking of dacryoliths.
- The success rate of MDP after one year, for all types of stenosis taken together, is 81% with respect to epiphora as the main clinical manifestation (10, 14, 15, 22).

Contraindications

The following are contraindications for all minimally invasive surgical procedures on the lacrimal pathways, i.e., LDP as well as MDP:

- acute dacryocystitis
- mucocele of the lacrimal sac
- traumatic outflow impairment after midface fractures (displaced anatomy)
- segmental rather than punctate scarring, e.g., after viral infection (herpes) (14, 15).

Summary

Minimally invasive lacrimal duct surgery is highly suitable for use as an initial treatment. It enables the surgeon to see the mucosa directly with almost microscopic vision, and thus to determine the cause of lacrimal duct stenosis and treat it immediately through the endoscope. In case this type of treatment fails, the option to perform any type of conventional surgery is still available as before. Despite these major advances in minimally invasive lacrimal duct surgery, direct external and endonasal dacryocystorhinostomy (DCR) pro-

FIGURE 5

Statistical breakdown of lacrimal duct operations at the Hagen and Darmstadt Clinics, 1995–2007 (total number of lacrimal duct operations in Germany: ca. 4000 per year); LD, lacrimil duct; DCR, dacryocystorhinostomy

cedures remain a highly successful option that has not yet become obsolete (20, 24). The authors' statistics (*Figure 5*) show, however, that there has been a marked decline of DCR in favor of endoscopic surgery (from 40% to 15%), i.e., some of the DCR procedures can now be done endoscopically. Debates about the optimal DCR approaches and techniques (ab externo vs. ab interno, endonasal or with the use of lasers) are as old as the procedures themselves and will not be discussed here in any greater detail.

Prospects

Where does the future lie for modern, minimally invasive lacrimal duct surgery? At present, disorders of the lacrimal pathway are treated both from above—i.e., from the side of the lacrimal puncta and the efferent system, in an endocanalicular procedure—and from below, i.e., from within the nose, sometimes in collaboration with colleagues from ENT surgery. Perhaps the application of fibrosis-inhibiting medications such as mitomycin will lower the rate of recanalization (24), but this cannot be conclusively judged at present. Initial experience is now being gathered with the use of transcanalicular laser DCR in combination with balloon dilatation. The future will bring not just technical improvements in surgical methods, but also a better understanding of the causes of epiphora and of ways to prevent it, as well as of the modulation of postoperative wound healing.

Conflict of interest statement

The authors declare that no conflict of interest exists according to the guidelines of the International Committee of Medical Journal Editors.

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KEY MESSAGES

- Miniaturized endoscopes originally developed for use in gastroduodenoscopy have been used since the 1990s for endoscopy of the efferent lacrimal pathway.
- Experience in lacrimal duct endoscopy has yielded new knowledge of the morphology of mechanical lacrimal duct stenosis.
- Diagnostic lacrimal duct endoscopy can now be extended to a minimally invasive lacrimal duct operation with the aid of a laser or a miniaturized drill.
- Minimally invasive lacrimal duct surgery can be used as the initial treatment in most cases of mechanical lacrimal duct stenosis.
- The future of lacrimal duct surgery lies in the further elucidation of the causes of lacrimal duct stenosis and of the modulation of wound healing.

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