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Imaging and Clinical Evaluation of the Lacrimal Drainage System

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The lacrimal drainage system is an intricate mucous membrane-lined conduit, the function of which depends on a complex interplay of anatomy and physiology. Appropriate drainage of tears depends on several factors, including the volume of tear production, eyelid position, normal pump mechanisms, anatomic status of the drainage passages, gravity, and nasal air convection currents. 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 therefore unable to handle normal tear production. Conversely, patients may have partial or complete blockage of the nasolacrimal system but experience no symptoms or have symptoms of dry eye if tear production is significantly reduced. The clinical picture of bothersome epiphora thus depends on the balance of tear production and tear drainage, not on the absolute function of either one.

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 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, such as tumors or stones. Physiologic etiologies result from failure of functional mechanisms despite normal anatomy. These types of dysfunction may result from anatomic deformity, such as punctal eversion or other eyelid malposition, or from lacrimal pump inadequacy from poor orbicularis tone or eyelid laxity.[1] Determining the type of dysfunction and the exact location of the anatomic blockage with physical examination and ancillary testing are 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 oftentimes 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. 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.

Clinical Diagnostic Tests

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 are used in selected patients. In most cases of epiphora, several tests must be used 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 can occasionally localize the site of obstruction 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 blockage at Hasner's membrane, whereas acquired epiphora in a child may have a very different etiology, such as canalicular obstruction. It is important to elicit a history of prior facial trauma or intranasal cautery, because this should prompt evaluation of the bony nasolacrimal canal. Prior use of ophthalmic medications (i.e., phospholine iodide), certain systemic chemotherapeutic agents, or orbital irradiation should lead the clinician to suspect canalicular obstruction. Previous sinus surgery, particularly intranasal antrostomy or ethmoidectomy should alert the surgeon to potential direct duct injury. History of a rapidly growing 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 from allergic rhinitis. Recurrent episodes of dacryocystitis may suggest lower nasolacrimal duct 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 hypersecre-

tion with resultant epiphora, even in the presence of a normally functioning drainage system. Blepharitis and allergic conjunctivitis will often trigger increased lacrimation. Eyelid malpositions such as entropion, with or without trichiasis, can produce corneal irritation and secondary reflex tearing. Lid laxity from aging or facial nerve palsy may lead to exposure keratitis and reflex epiphora. Lid laxity may also result in a weakened orbicularis pump mechanism or punctal eversion. The tear drainage system may be impaired by occlusion of the punctal opening from conjunctivochalasis or tight eyelid fissures with punctal opposition. Mass lesions in the medial canthal region 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 lower system obstruction. Examination of the nasal vestibule must be made, because hypertrophic mucosa or nasal polyps can obstruct the nasolacrimal ostium. Such findings during external examination will direct the clinician toward further specific diagnostic tests.

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 minutes. 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 true tear flow. The paper itself may stimulate reflex lacrimation. If the investigator is not careful to wipe the tear lake from the conjunctiva before 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. The fractional volume lost is in proportion to the adequacy of the drainage system and may be significantly more than the volume recorded. Normal values for the Schirmer I test range from 10 to 30 mm at 5 minutes, with values more than 25 mm typical of patients younger than age 30 and values 10 mm or less in those older than age 60.

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 must be performed in the dark, because light can stimulate reflex tearing. 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 tear function.

When the Schirmer I test results are 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.

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 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 on 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 bead 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. Viewing the corneal surface under slit-lamp magnification with cobalt blue illumination, the observer notes at what time dry spots appear in the tear film. Normal tear breakup time is between 15 and 30 seconds. A tear breakup time of less than 10 seconds indicates a probable mucin deficiency, which may result not only in the symptoms of dry eye syndrome but in reflex hypersecretion of the aqueous component and 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 minutes 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 lid overflow. Also, a sig-

nificant amount of dye may disappear in the presence of a large dilated sac mucocele and distal obstruction. The test cannot distinguish between physiologic and anatomic causes of drainage dysfunction, nor can it localize the site of mechanical blockage. The dye disappearance test has been shown to be positive in 95% of asymptomatic normal individuals and may be more sensitive than the primary Jones test.[2] Unlike the latter, it does not seem to be dependent on 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 frequently used procedures in the evaluation of epiphora. The primary Jones dye test (Jones I) is a true functional test and should be performed 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 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 minutes and again after 5 minutes. The test is positive if dye is recovered, and indicates patent anatomy and adequate physiologic 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 minutes allowed for the test. Testing conditions may alter results because transit time is influenced by factors such as blink rate, gravity, and fluorescein volume. Although a positive test strongly suggests a normal system, it does not completely rule out physiologic dysfunction or mild anatomic obstruction. More significantly, a negative test alone does not necessarily indicate abnormal drainage.

The fluorescein appearance test, described by Flach,[3] is a modification of the primary Jones dye test. It is designed to avoid the difficulty and variability involved in recovering dye from the inferior meatus. Two percent fluorescein is placed in the conjunctival sac and the oropharynx is examined with ultraviolet light, beginning at 5 minutes and continuing up to 1 hour if necessary. With this technique, 90% of normal individuals are said to show oropharyngeal fluorescence within 30 minutes, and 100% within 60 minutes. This procedure is best used as a supplement to a negative primary Jones test and can be performed 20–30 minutes later. Because of the persistence of fluorescence, only one eye can be tested by this technique during a single office visit.

In 1973, Hornblass[4] elaborated on a variation of the primary Jones dye test originally mentioned by Lipsius.[5] 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 minutes, with

65% of normal individuals reporting a positive test within 6 minutes, and 90% reporting positive results within 15 minutes. Transit times in excess of 15 minutes 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 dysfunction from anatomic obstruction. The secondary Jones dye test (Jones II) evaluates anatomic patency of the system in such cases. Residual fluorescein is flushed from the conjunctival sac and a topical anesthetic is instilled. The patient sits with head tilted forward while clear saline is irrigated into one canaliculus through a cannula. The patient is instructed to blow or spit any fluid that passes into the nose or pharynx onto a clean tissue. The presence of any fluid in the nose indicates gross anatomic patency of the nasolacrimal passages. In this situation, complete obstruction is not present because saline did traverse the system under pressure. Recovery of dye-stained saline demonstrates normal punctal and canalicular anatomy, because the dye must have passed freely into the sac during the previous Jones I test. Such a result is compatible with a partial anatomic block at the level of the lower sac or duct. Recovery of clear saline without fluorescein suggests punctal or canalicular stenosis, with failure of dye from the primary Jones test to enter the lacrimal sac. If fluid does not reach the nose at all but regurgitates from the opposite punctum, a high-grade obstruction is likely. 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 confirms the presence 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. However, a sac that is contracted and fibrotic because of chronic inflammation may 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 physiologic dysfunction and epiphora

resulting from partial anatomic obstruction. When a primary Jones test is positive, 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, but would rule out complete blockage. Negative results on both the primary and secondary tests confirm high-grade obstruction.

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. 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.

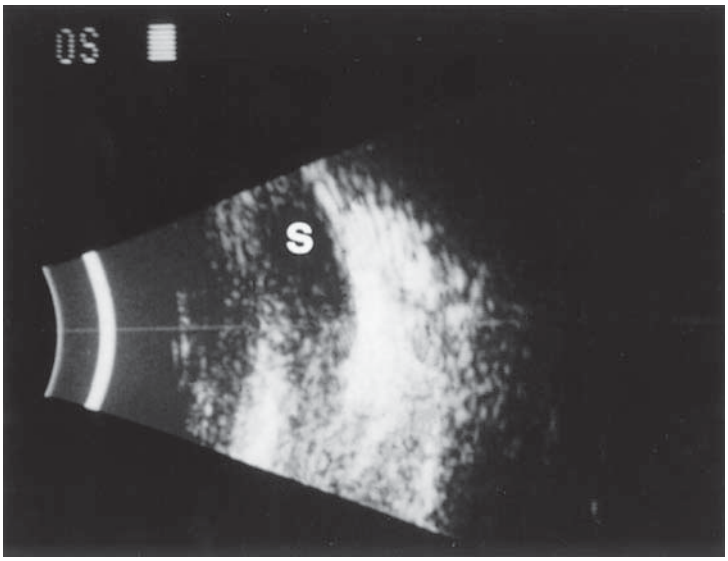
Diagnostic Imaging Techniques

Diagnostic Ultrasonography

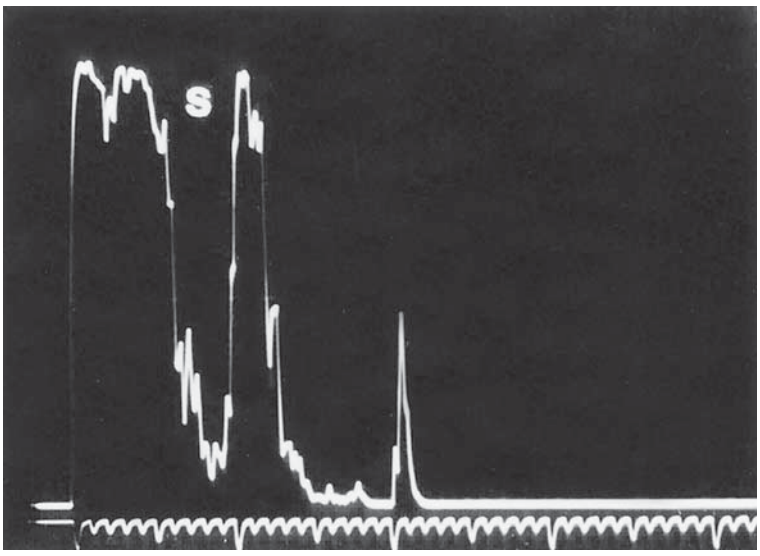
The techniques of A- and B-mode ultrasonography provide a simple, noninvasive method of evaluating gross anatomic abnormalities of the lacrimal drainage system (Figures 7.1A and B, and 7.2A and B). Physiologic dysfunction cannot be evaluated, nor can the precise site of anatomic obstruction be localized. However, a dilated lacrimal sac can easily be distinguished from one of normal dimensions. It is also possible to differentiate air from mucus or solid masses, making the identification of lacrimal sac neoplasms possible.[6]

With the B-mode probe oriented vertically, placed in the medial canthus, 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 dilated. The diameter of the sac and upper duct may be evaluated and the thickness of the walls can often be appreciated. Diverticula may also be identified and a variety of echogenic densities within the system, such as inflammatory membranes, tumors, and stones, can be detected. The position and size of a surgically created ostium (Figure 7.3) may also be imaged with this technique, although its patency cannot easily be evaluated.

For precise measurements of the sac and evaluation of the internal reflectivity of sac contents, A-mode scanning must be used. The probe is first oriented as for a periocular orbital study, but with the beam aimed just behind the anterior lacrimal crest toward the sac fossa. An oblique anterolateral–posteromedial cut of the sac is thus obtained. If



A



B

FIGURE 7.1. (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.

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 high-density, 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. This technique gives an approximate horizontal cross-section of the sac. The average dimensions of the sac in normal individuals are 2.5 mm (SD = 0.95 mm) in horizontal diameter and 4.0 mm (SD = 1.49 mm) in anteroposterior extent.[7] A sac more than 4.5 mm wide or 7.0 mm deep should be considered abnormally dilated.

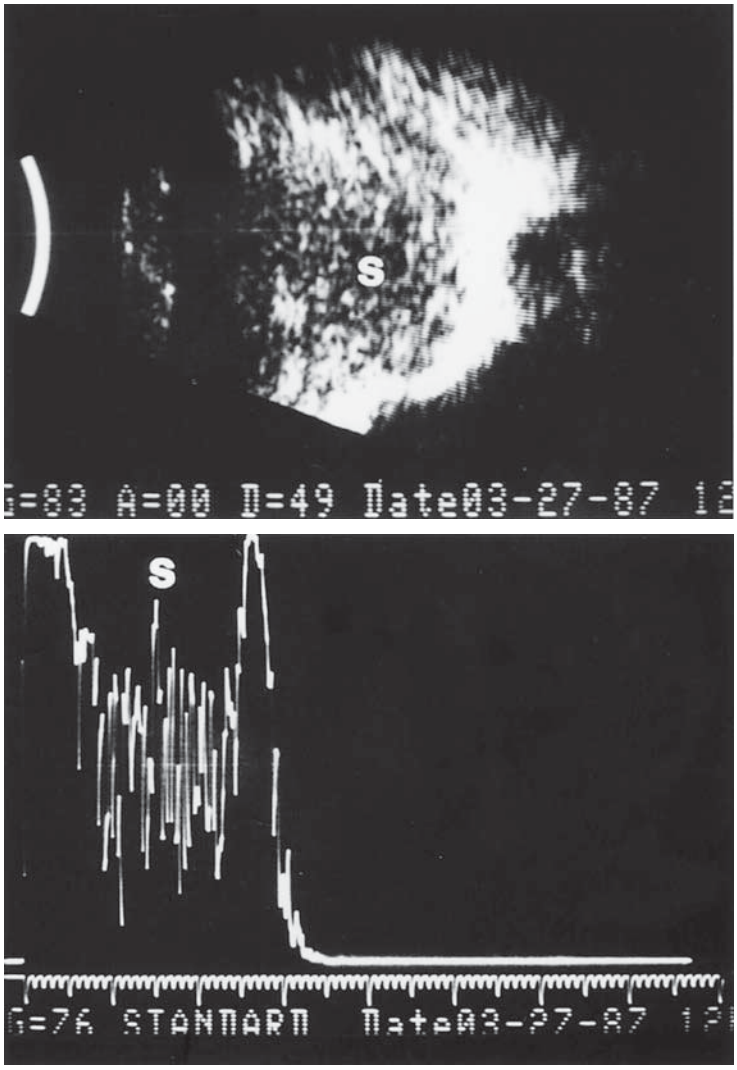


FIGURE 7.2. (A) B-scan ultrasound of a patient with acute dacryocystitis demonstrating a massively enlarged nasolacrimal sac (S) and thickened anterior and posterior walls. **(B)** A-scan ultrasound of the same patient as in part A showing dilated nasolacrimal sac (S) with irregular, medium reflectivity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

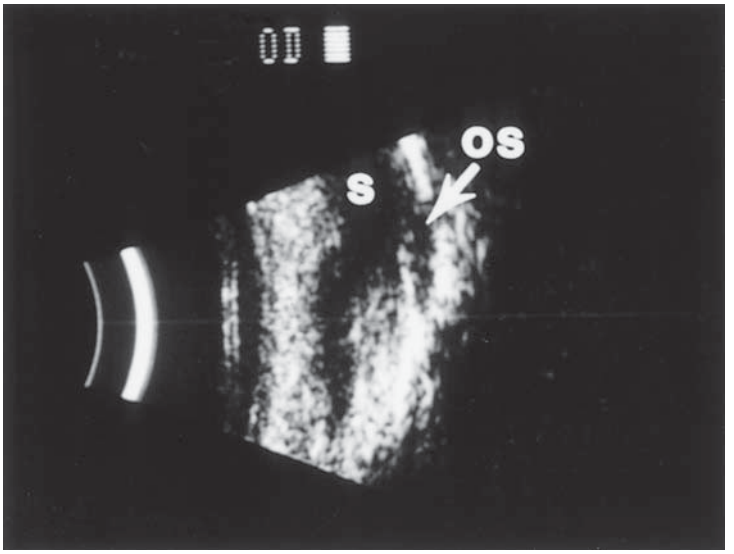


FIGURE 7.3. Postdacryocystorhinostomy B-scan ultrasonography showing the surgically created lacrimal–nasal ostium (OS). The lacrimal sac (S) is somewhat dilated because of soft tissue closure of the ostium.

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 and 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 minutes and upright films may be taken to evaluate the effects of gravity on lacrimal drainage. DCG can also be combined with computed tomography (CT) or magnetic resonance imaging (MRI) to give further information on the nasolacrimal system.

In 1968, Iba and Hanafee[8] described the technique of distension DCG, first used by Barrie Jones in 1959. 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 intravenous catheter tubing. This method provides maximum visualization of the anatomic structure of the system and, because of the backpressure, gives good filling of the canaliculi. It is the best technique for demonstration of fistulae,

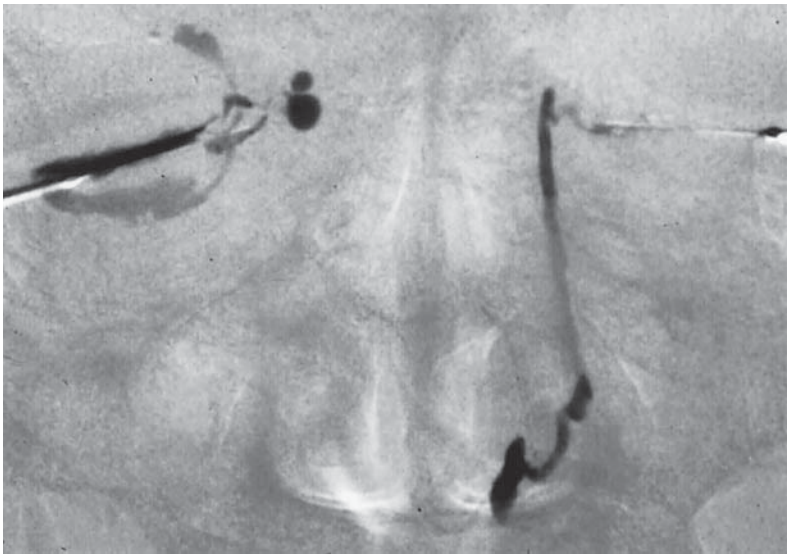


FIGURE 7.4. Digital subtraction contrast dacryocystogram. Patient with normal passage of contrast through the left nasolacrimal system and complete blockage of the right proximal nasolacrimal duct and mild dilation of the right nasolacrimal sac.

diverticula, supernumerary canaliculi, and the presence of stones 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 can be obtained with a technique adopted from subtraction angiography (Figure 7.4) that eliminates confusing bony shadows. 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.[8,9]

The dacryocystogram of a normal lacrimal drainage system will usually show the canaliculi when less viscous aqueous contrast media are used. The sac appears as a smooth, straight, or gently curved passage with the concavity facing laterally. The anteroposterior dimension is wider than the transverse. There is usually a constriction at the sac–duct junction caused by the split fascia of the orbicularis muscle as it passes around the system. 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 midportion 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 physiologic 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 MRI studies to obtain a complete picture of the nasolacrimal system and the surrounding anatomy.

Computed Tomography

In selected cases, CT of the lacrimal system can be extremely useful in the evaluation of epiphora. In axial scans through the lower orbit (Figure 7.5), the lacrimal sac fossa appears as a depression in the antero-

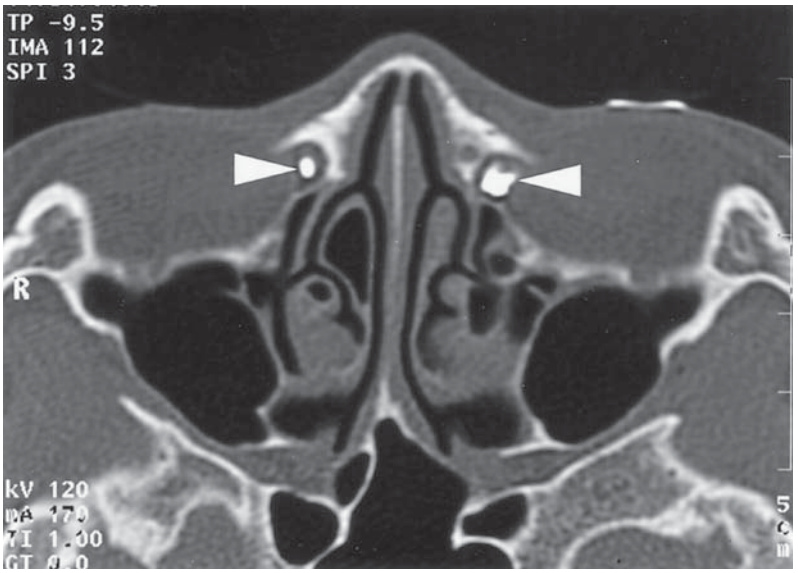


FIGURE 7.5. Axial CT–DCG demonstrating contrast-filled lacrimal sacs (arrowheads). The left system is dilated compared with the right. (Courtesy of Susan K. Freitag, MD, reprinted with permission from Lippincott, Williams & Wilkins ©2002.)

medial wall. 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 because the line of section is oriented downward and obliquely backward. Parasagittal reformatted images will reveal the entire length of the system in longitudinal section.

Although dilatation of the sac and dacryocystitis can be seen, these are more easily and inexpensively studied by other techniques. When epiphora follows trauma and subsequent clinical studies indicate nasolacrimal duct obstruction, CT may reveal orbital rim or maxillary fractures compressing the sac or duct. 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 sac from a meningocele. 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 of the sac or adjacent paranasal sinuses. MRI is more sensitive for soft tissue abnormalities but does not image the bony structures well.

When combined with DCG, CT scan is excellent at identifying bony structures around the nasolacrimal system (Figures 7.6 and 7.7). By using modern spiral CT techniques with topical contrast material, the surgeon can accurately identify obstructions in the nasolacrimal system. This can be especially useful in patients who have had facial trauma, prior sinus or lacrimal surgery, or tumors of the medial canthus.[10] Newer techniques using spiral CT and three-dimensional reconstruction technology have improved the diagnostic accuracy for patients with partial obstructions of the nasolacrimal system by allowing the surgeon to view a three-dimensional image of the entire system from multiple projections.[11]

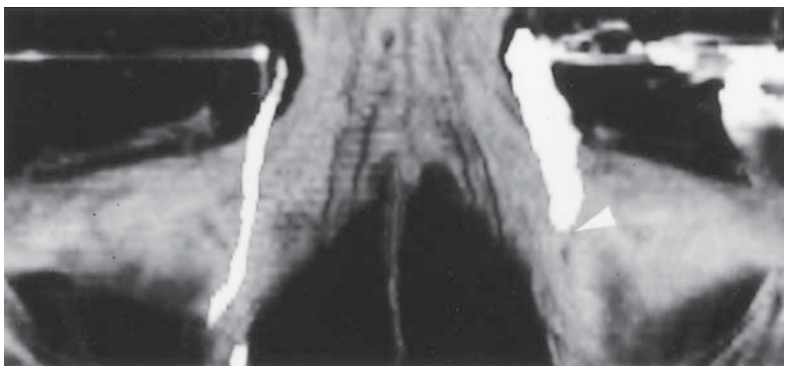


FIGURE 7.6. CT–DCG three-dimensional reconstruction in the left oblique projection confirms the left complete obstruction and proximal dilation. Right system is normal. (Courtesy of Susan K. Freitag, MD, reprinted with permission from Lippincott, Williams & Wilkins ©2002.)

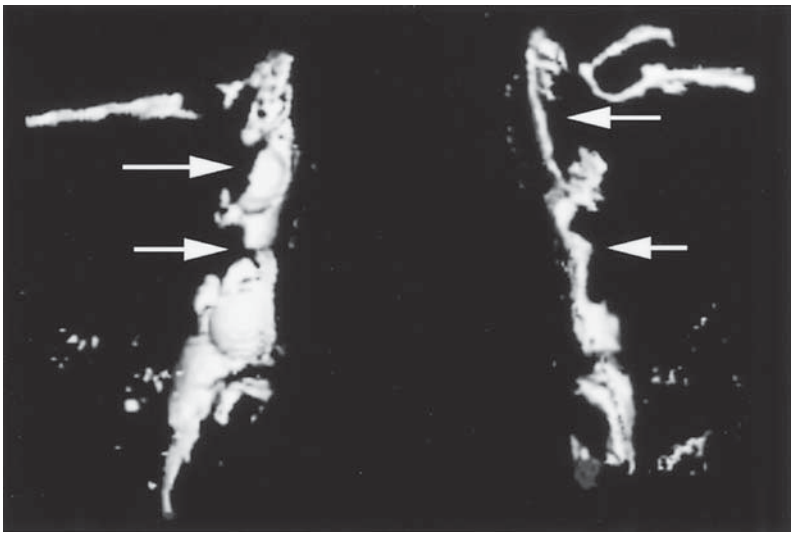


FIGURE 7.7. CT–DCG three-dimensional reconstruction demonstrates bilateral filling defects (arrows) in distorted and dilated lacrimal systems. (Courtesy of Susan K. Freitag, MD, reprinted with permission from Lippincott, Williams & Wilkins ©2002.)

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 and 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.

Magnetic Resonance Imaging

Since 1990, MRI has been used as an adjunctive diagnostic test in the evaluation of lacrimal system pathology that allows for excellent resolution of the nasolacrimal system.[12,13] When combined with a contrast agent, MRI offers several advantages over other imaging studies. Gadolinium can be given as a topical solution (Magnevist) diluted from 1:10 to 1:100 with normal saline, one drop to each eye per minute for 5 minutes. The patient should stay in an upright position until just before 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. Exposure to ionizing radiation is also avoided with this technique.

MRI allows very fine resolution of soft tissue structures within and surrounding the nasolacrimal system compared with dacryoscintigra-

phy, DCG, and even CT.[14,15] 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.[16] Manipulation of signal intensities, repetition times, and tip angles, as well as the use of fat suppression algorithms, can oftentimes allow for differentiation of mucous or blood from solid neoplasms. Also, because of volumetric acquisition, magnetic resonance images can be viewed in any plane without degradation of the quality of images. 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 should not be used routinely. Other drawbacks include poor ability to image bony structures, and there can be artifact from the nearby ethmoidal 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 employed radioactive ^{198}Au and measured the buildup of activity over the sac and duct. Rossomondo et al.[17] introduced the first modern nuclear imaging technique for the lacrimal drainage system. They instilled a drop of saline with [^{99m}Tc] sodium pertechnetate, and imaged the system with a gamma camera. In the first clinical evaluation of the technique, Carlton et al.[18] demonstrated its value in visualizing the lacrimal system, and in measuring some physiologic parameters of tear flow. In their study of 28 asymptomatic volunteers, they recorded a transit time for the nuclide of 4–43 seconds to the sac, and 4–323 seconds to the nose. There is a high degree of correlation between dacryoscintigraphy and contrast DCG; however, the former is more sensitive to incomplete blocks, especially in the upper system. Because dacryoscintigraphy is a physiologic test, it is also very sensitive in finding abnormalities in patients with physiologic nasolacrimal duct obstruction and can often localize the site of blockage.[19]

The technique often employed today uses [^{99m}Tc]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 seconds for the first 2–3 minutes, and then late images are taken every 5 minutes for a total of 20 minutes (Figure 7.8). The specific activity of this dose is in the range of 50 to 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

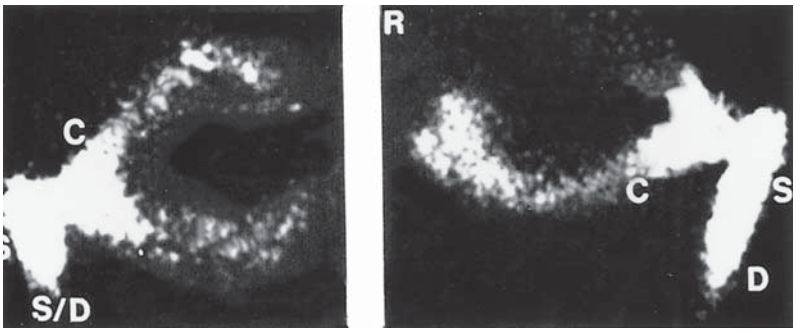


FIGURE 7.8. Dacryoscintigraphy in a patient with unilateral epiphora on the left side. The right lacrimal drainage system fills normally, with tracer concentrated in the canaliculi (C), sac (S), and duct (D). The left system shows no tracer below the sac–duct junction (S/D).

proximal canalicular system is usually poorly imaged unless it is dilated. The sac and duct are usually well outlined. Complete blocks in the sac or duct can be detected, although precise localization of the obstruction may be difficult. However, the procedure can yield considerable information concerning physiologic function. Generation of dynamic activity curves for specific regions of interest will demonstrate incomplete anatomic obstructions as well as a rather subtle degree of functional impairment.[20,21] 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 minutes. 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.

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 is not possible, and the concomitant presence of lower sac or duct pathology cannot be easily demonstrated unless echography is used to detect a dilated sac. In 1972, Putterman[22] 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

The use of chemiluminescent materials is 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 dibutylphthalate, which produce an intense cold light. This product is commercially used as a safety light. When these agents are injected into the lacrimal system, the glow is visible through the skin and clearly outlines the upper system. The lower duct is 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.[23] Chemiluminescence has not yet been used extensively enough to evaluate its clinical effectiveness as an alternative or adjunct to other procedures.

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°C.[24] 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.

Nasolacrimal Endoscopy

Direct visualization of the lacrimal drainage system has been attempted with rigid and flexible endoscopes, however, results have been mixed and these techniques are not recommended. No clinical evaluation of these instruments has been presented, and their reliability in evaluating nasolacrimal obstruction remains to be demonstrated.

Interpretation of Diagnostic Tests

As is the case with many diagnostic tests in medicine, most of those described above required some subjective interpretation 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 physiologic, does not indicate lacrimal dysfunction. Patients with significant degrees of partial or even com-

TABLE 7.1. Interpretation of clinical tests in the evaluation of epiphora.

Dye disappearance test	Jones I	Jones II	Probing	Palpation	Diagnosis
Rapid	+	+	Normal	Normal	Probable oversecretion
+	+	+	Normal	Normal	Normal vs. functional
+	–	+	Normal	Normal	Normal vs. functional vs. mild NLD obstruction
+	–	+	Normal	Abnormal	Partial NLD obstruction with dilated sac
Slow	–	+	Normal	Normal	Mild NLD obstruction vs. functional
Slow or –	–	+	Normal	Abnormal	Partial NLD obstruction
–	–	–	Normal	Abnormal	Complete NLD obstruction
–	–	+	Stenotic	Normal	Partial canalicular obstruction
–	–	–	Stenotic	Abnormal	Combined NLD obstruction with canalicular obstruction
–	–	–	Blocked	Normal	Complete canalicular obstruction

NLD, nasolacrimal duct.

plete obstruction may be entirely asymptomatic as long as tear production and drainage balance are 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 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

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: normal vs. low-grade partial obstruction vs. functional (nonlocalizing)
–	+, Dye in nose	Partial NLD obstruction vs. functional
–	+, Saline in nose	Partial canalicular obstruction vs. functional
–	–, Regurgitation of dye from opposite punctum	Complete NLD obstruction
–	–, Regurgitation of saline from opposite punctum	Complete common canaliculus obstruction
–	–, Regurgitation of dye from same punctum	Complete opposite canalicular obstruction with NLD obstruction
–	–, Regurgitation of saline from same punctum	Complete canalicular obstruction

NLD, nasolacrimal duct.

should be almost gone within 5 minutes. Epiphora attributed 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.

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 5 minutes. 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. Similar to the dye disappearance test, an artifactually positive Jones I test may result from volume overload even when epiphora is present under normal physiologic conditions. 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, one may conclude that the system is grossly patent, although minor stenoses and physiologic dysfunctions cannot be ruled out. When the test is negative, it is likely that significant anatomic or physiologic 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 and, if negative, will demonstrate complete obstruction in the system. The results of the test will indicate the location of the block. When the secondary test is negative and saline irrigated through one punctum causes dye to regurgitate from the opposite punctum, then the dye must be left over from the primary Jones test. If only clear saline regurgitates from the opposite punctum, the block is probably at the common canaliculus. 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 with care. 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.

When the secondary Jones test is positive, a low-grade partial obstruction or stenosis may be present that can be overcome by increased hydrostatic pressure, or failure of the lacrimal pump mechanism may be responsible for the negative primary Jones test and delayed dye

disappearance test. Recovery of clear saline alone in the nose suggests partial canalicular obstruction because no dye entered the sac during the primary test. Appearance of dye-stained saline in the nose demonstrates free flow of fluorescein to the sac during the primary test and therefore an open canalicular system. The partial block is probably present in the distal system at the lower sac or duct. Retrograde flow out of the canaliculi may be seen even with a partially open duct if injection pressures are more than 100 mm Hg. A negative primary Jones test and positive secondary test could also be compatible with intact canalicular capillary action, but with pump failure in propulsion through the lower system.

When hypersecretion syndrome has been ruled out and the dye disappearance test and primary and secondary Jones tests are all negative, a complete anatomic blockage is present somewhere along the nasolacrimal system. The results of the secondary Jones test will usually indicate if the block is proximal, requiring canalicular repair or bypass, or distal enough to be corrected with a dacryocystorhinostomy. If the results are equivocal, and there is a history of trauma, suspicion of tumor, recurrent epiphora after surgery, or persistent chronic dacryocystitis, then radiographic evaluation may be indicated to image the anatomic structure of the system and to pinpoint the site of obstruction. DCG 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 used. 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 physiologic function. Nevertheless, DCG gives the most reliable anatomic information about 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 aid in planning a surgical approach.

When the primary Jones test is negative and the secondary test is positive, the surgeon must distinguish between physiologic dysfunction and partial anatomic obstruction. In the absence of obvious eyelid or punctal deformity or atonic orbicularis muscle, the problem is likely anatomic, and the secondary Jones test should indicate whether it is proximal or distal. Nevertheless, minor degrees of stenosis and functional failure caused by eyelid laxity, a dilated sac, a diverticulum, or a calculus cannot be differentiated with the above tests. DCG will usually demonstrate the presence of a stenotic segment.

If clinical and radiographic evaluation fails to show an anatomic blockage, physiologic 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, particu-

larly in the proximal system. However, the physiology of lacrimal drainage is poorly understood. The function of Rosenmüller'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 physiologic 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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