

Lacrimal scintigraphy. III.

Physiological aspects of lacrimal drainage

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SUMMARY Lacrimal scintigraphy (LS) was performed on asymptomatic lacrimal drainage systems and the results were evaluated to understand the physiology of lacrimal drainage. It was found that a physiological obstruction can exist at the level of the nasolacrimal duct in normal asymptomatic individuals, and it is suggested that this obstruction is due to the resistance offered by the valve of Hasner, which in turn is dependent on (a) the volume of fluid in the lacrimal sac and the nasolacrimal duct, and (b) the anatomical integrity of the valve. The LS observations are taken into account to postulate a mechanism of drainage from the lacrimal sac into the nose, which hitherto has not been very clear. It is also suggested that reflux can occur between the various compartments of the lacrimal drainage system and that the various valves in the membranous passageway can become incompetent in an obstructed system.

Tear fluid produced by the lacrimal glands is secreted into the conjunctival sac, from where it is transported to the nose through the lacrimal drainage system (LDS). The mechanism by which this transfer occurs is not clearly understood and accounts of it are controversial. With the introduction of lacrimal scintigraphy (LS) in 1972 by Rossomondo *et al.*¹ it became possible to study the dynamics of lacrimal drainage by visualising the passage of a tracer through the LDS with the help of a gamma camera. Since then LS has been used to study the normal and pathological lacrimal drainage and also to measure the rate of tear flow in normals.² It was our impression that studies on asymptomatic systems could contribute towards a better understanding of the mechanism of lacrimal drainage and help in resolving some of the controversy that surrounds the subject. In this paper we describe the results of such a study and present our observations on the physiology of lacrimal drainage.

Material and methods

We studied the lacrimal drainage in the opposite asymptomatic eye of 226 patients who were referred

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to the Lacrimal Scintigraphy Clinic with unilateral epiphora. In 10 of the patients the LS was repeated once, and in two the LS was performed 3 times. In addition the lacrimal drainage was studied in 12 other asymptomatic subjects, so that altogether 264 asymptomatic systems were investigated in 238 subjects. The technique of lacrimal scintigraphy has been described elsewhere in detail.³

Results

The results of investigations are described in Table 1. Although there were no symptoms of epiphora in the

Table 1 Results of investigations in asymptomatic lacrimal drainage systems

Complete canalicular obstruction	12	(4.5%)
Partial canalicular obstruction	28	(10.5%)
Complete obstruction at lower end of lacrimal sac	29	(10.5%)
Partial obstruction at lower end of lacrimal sac	11	(4%)
Complete obstruction of nasolacrimal duct	21	(8%)
Partial obstruction of nasolacrimal duct	3	(1%)
Functional obstruction	3	(1%)
Patent dacryocystorhinostomy (DCR)	7	(2.5%)
Blocked DCR anastomosis	1	
Normal drainage with no demonstrable obstruction	69	(26%)
Normal drainage with physiological obstruction	80	(30%)
Total	264	
		systems

systems an abnormality in the lacrimal drainage system was found in about 40% of systems. Only 26% of the systems studied had a completely normal lacrimal drainage. A very high percentage of the systems showed a physiological obstruction below the lacrimal sac, resulting in either a hold-up at the level of nasolacrimal duct and absent flow into the nose or the presence of high levels of tracer in the sac and nasolacrimal duct despite evidence of flow into the nose. Seven of the 8 systems in which a dacryocystorhinostomy had been performed to relieve the symptoms of epiphora were patent and showed a drainage through the anastomosis. In the eighth system there was no obvious flow into the nose in spite of the addition of saline drops to overload the tear film, and yet this side was asymptomatic.

Discussion

Jones⁴ studied the anatomical attachments of the medial palpebral ligament and the palpebral part of the orbicularis muscle and introduced the concept of a lacrimal pump, which consists of the superficial and deep heads of the pretarsal muscles, the deep head of the preseptal muscle, and the lacrimal diaphragm. According to his concept the lacrimal pump, which functions with the blinking movements of the eyelids, is responsible for the movements of the lacrimal fluid. He postulated that fluid is attracted by capillarity into the lacrimal puncta, and as the eyelids close the contraction of the pretarsal muscles which shorten the canaliculi, and simultaneous contraction of the preseptal muscle which pulls the lateral wall of the lacrimal sac laterally, create a negative pressure and suck the tear fluid into the sac. When the eyelids open again the lacrimal diaphragm returns to its previous state, and thus by compressing the sac it forces the tears into the nose. From pressure recordings obtained through a catheter introduced in the nasolacrimal duct Rosengren⁵ showed that during blinking movements the canaliculi were compressed and a uniform volume of fluid was squirted into the lacrimal sac. The rise of pressure in the conjunctival sac prevented any reflux from the canaliculi, and he therefore concluded that a canalicular pump did exist but felt that the function of the lacrimal sac was secondary. Support for the existence of a canalicular pump on lid closure also came from similar experimental work carried out by other workers.⁶

However, other investigators⁷ were unable to confirm any direct attachments of any part of the orbicularis into the lacrimal fascia or to the canaliculi in their anatomical studies and considered it highly improbable that closure of the eyelids could produce a compression of these structures. They held the view that the canaliculi are entirely open and accessible

ducts whether the eye is open or closed and that a pressure rise in the conjunctival sac brought about by closure of the eyelids was the sole propelling force driving tear fluid into the lacrimal sac. Similarly, François and Neetens⁸ too did not find any muscle fibres around the sac on anatomical dissection, but by observing the passage of lipiodol through the LDS they noted that the lacrimal sac and the canaliculi collapsed during blinking and expanded when the eyelids opened, creating a suction which together with capillarity was responsible for the entry of tears into the lacrimal sac. They also observed that the collapse of the tear sac was dependent on the intensity of the contractions and that several blinking movements were necessary to empty the sac.

There are thus basically 2 different but diametrically opposite theories of lacrimal drainage based on whether the lacrimal sac expands or collapses during blinking. In a study carried out to examine the role of the lacrimal sac with the help of LS⁹ the authors demonstrated that the tracer continues to accumulate in the sac if the eyelids are kept closed and descends into the nasolacrimal duct only when the eyelids open. They attributed the concentration of the tracer to a negative pressure in the lacrimal sac and a proof of the lacrimal pump theory. The significance of these observations is unclear, since it is difficult to understand how a negative pressure could prevail throughout the 3–5 minutes during which the eyelids were kept closed in this study. From our own studies we have gained the impression that tracer can enter the lacrimal sac, albeit in small quantities, even when the eyelids are kept open after the instillation of radioactive drops. Similarly there can be a long delay before the tracer leaves the lacrimal sac despite repeated blinking (Fig. 1) in normal individuals. Lacrimal scintigraphy has also shown that a physiological obstruction exists at the distal end of the nasolacrimal duct in asymptomatic eyes,¹⁰ which can delay the transit of tracer into the nose by as much as 30 minutes or longer. These findings are difficult to explain on the basis of Jones's lacrimal pump theory, which also postulates that the lateral and medial walls of the lacrimal sac are in contact with each other when in a state of rest. Even the role of gravity is not clear, since, although Hurwitz *et al.*¹¹ thought that gravity did have a significant role in the transport of tears, other workers¹² did not find any such influence in their studies.

In our study 30% of the asymptomatic systems had a physiological obstruction in the nasolacrimal duct, a figure which compares favourably with that found by Chavis *et al.*¹⁰ A careful study of the pattern of the drainage in the systems showing such a physiological obstruction would suggest that this is due to the resistance offered by the valve of Hasner. The force

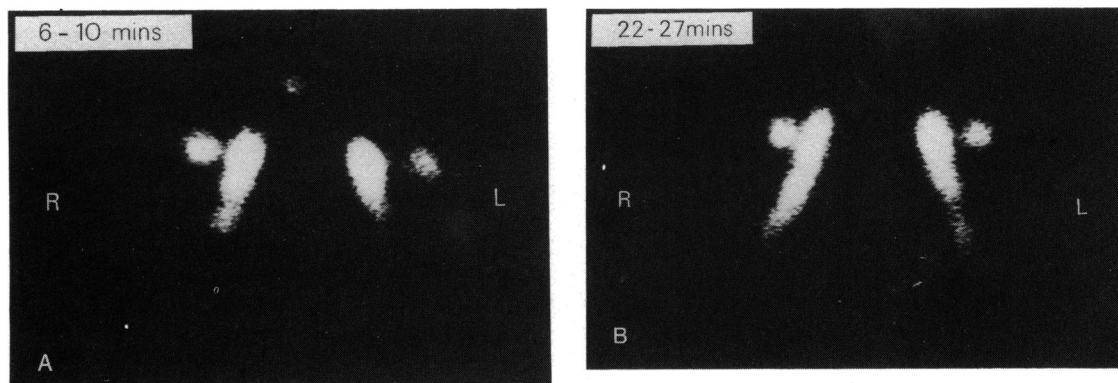
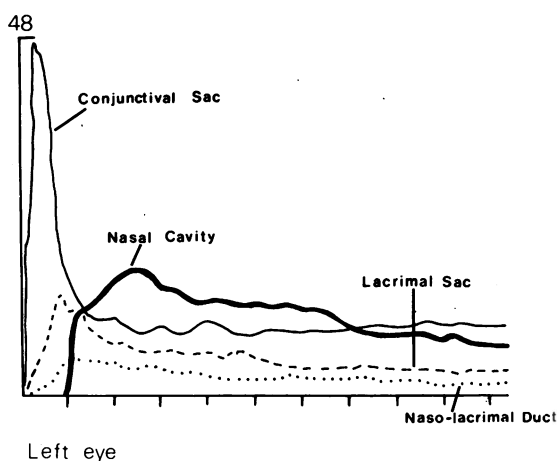


Fig. 1 (A and B) Lacrimal drainage in an asymptomatic individual showing that flow into nose can be delayed for as long as 27 minutes in normals.

necessary to overcome this resistance is in turn dependent on the volume of the fluid in the lacrimal sac and nasolacrimal duct and on the anatomical integrity of the mucous membrane structure. In some individuals, particularly the elderly, where presumably the valve is incompetent, the tracer passes rapidly into the nose within a few seconds of instillation (Fig. 2), whereas in others, especially the young, where the valve is efficient and functioning normally, the resistance is higher, and, unless the valve opened spontaneously, flow will occur only if the volume of fluid in the nasolacrimal duct is increased (Fig. 3). Although capillarity and blinking movements of the eyelids may have a role in the transport of tears from the conjunctival sac into the lacrimal sac, we feel that the sac does not empty with each blink but that tear fluid continues to accumulate in it until the volume is sufficient to open the valve of

Hasner and drain into the nose (Fig. 4). This being the case, one would expect that in situations where lacrimal flow did not exist because of a complete distal block it would be impossible for any more fluid to enter the lacrimal sac once it had filled up to its capacity. This, however, is not the case, and we find it very puzzling that tracer can easily gain access to the lacrimal sac in patients in whom there is an obstruction at its lower end (Fig. 5). There can be only 2 explanations for this. Either the lacrimal sac does not fill up to its capacity when it is obstructed at its exit, which is highly unlikely, or fluid from the sac flows in the opposite direction, allowing a free interchange and mixing to occur between the tracer in the conjunctival sac and tear fluid in the lacrimal sac. Our experimental studies have shown¹³ that reflux can occur between the various compartments of the LDS, and it is therefore very likely that in disease the valve of Rosenmuller and possibly the valve of Krause,



Left eye
Fig. 2 Dynamic curves for the asymptomatic left eye demonstrating the flow of tracer into the nose as early as one minute in a patient with right-sided epiphora.

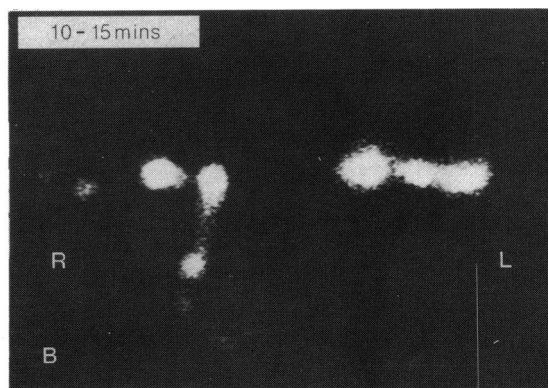
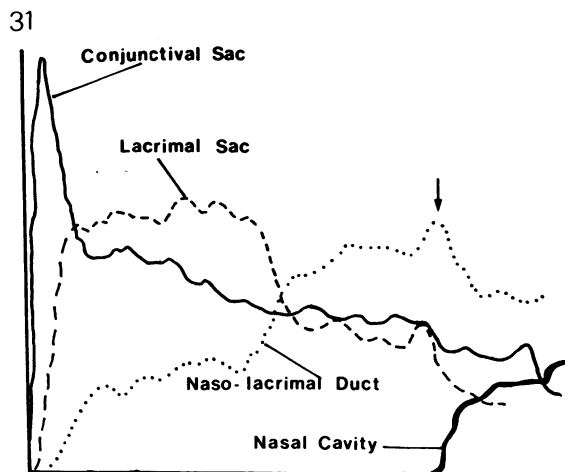


Fig. 3 Lacrimal scan showing flow into nose on overloading tear film with saline drops in a patient exhibiting a physiological obstruction on asymptomatic right side where there was no flow into nose after 10 minutes.



Left eye

Fig. 4 Normal drainage on left side in a patient with right epiphora showing that flow into nose starts when the level of tracer in nasolacrimal duct has reached a high level (arrow).

whose function in health is to prevent the reflux of tears, are rendered incompetent by a block in the membranous passageways and permit free reflux to occur between the nasolacrimal duct, lacrimal sac, and conjunctival sac. Even in normal individuals the valves are not always competent, for in some of them air can be shown to escape from the puncta when the nose is blown.¹⁴ Although Francois and Neetens⁸ observed no return flow from the nasal cavity to the nasolacrimal duct in their studies, they did consider that a suction from the duct into the sac existed.

We thank the technical staff of the Nuclear Medicine Department, Western Infirmary, Glasgow, for their help and co-operation in this study, Mrs M. Borg and the staff of the Department of Medical Illustration, District General Hospital, Great Yarmouth, for preparing the illustrations, and Mrs. R Brown for her invaluable secretarial assistance and for typing the manuscript.

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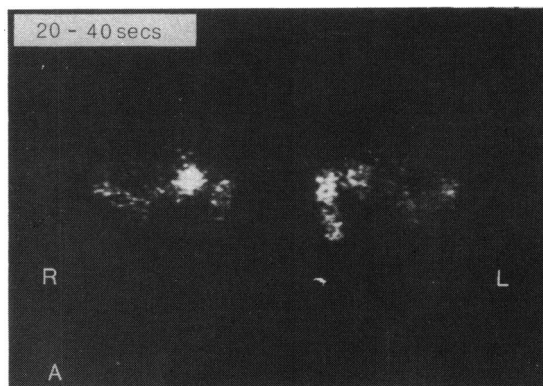


Fig. 5 Lacrimal scan of a patient with left epiphora due to blocked nasolacrimal duct at 20-40 seconds. Note that lacrimal sac on this side fills up earlier than the right side, which is patent and asymptomatic, and showed normal drainage.

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Br J Ophthalmol 1983 67: 729-732

doi: 10.1136/bjo.67.11.729

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