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Quantitative lacrimal scintillography

I. Method and physiological application

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Anatomical assessment of the lacrimal drainage apparatus is precise using subtraction macro-dacryocystography with canalicular catheterization (Lloyd, 1973), but provides only limited information about the dynamics of the system. A technique using a radioactive tracer instilled into the conjunctival sac and visualization with an Anger gamma camera is a more sensitive method for evaluating the dynamics of lacrimal drainage (Rossomondo, Carlton, Trueblood, and Thomas, 1972). The purpose of the present study was to improve the diagnostic value by including quantitative criteria for lacrimal drainage by utilizing a computer interfaced to the gamma camera.

Material and methods

The patient sits erect with the head fixed in front of an Anger gamma camera (Ohio Nuclear Series 100) fitted with a standard 3 mm pinhole collimator. The nasion is located centrally towards the upper margin of the field of view and 10·2 cm from the pinhole. The gamma camera is interfaced with an image display and analysis system (DEC Gamma 11). Two automatic pipettes (Finnpipettes) are used to deliver 0·013 ml of tracer simultaneously on to the lower marginal tear strip beneath the inferior limbus of the cornea. The tracer used is Technetium 99 M (^{99m}Tc) sulphur colloid, with a specific activity of 10 mCi/ml. This has a viscosity of 1·21 centipoise at 20°C, and 0·87 centipoise at 37°C, thus simulating the viscosity of tears (Hamano and Mitsunagu, 1973). The patient is instructed to blink normally. The distribution of the tracer is imaged serially as it passes down the lacrimal drainage systems. Images are taken every 10 s for 1 min, then every 3 min for 10 min, and finally every 5 min until 30 min after instillation, at which time the study is discontinued. The data from the gamma camera are recorded simultaneously on to the magnetic disc of the computer system for subsequent quantitative analysis.

ANALYSIS

When the digitized images are redisplayed on the Gamma 11 persistence oscilloscope, optimized images of the regional distribution of tracer are produced using background subtraction, contrast enhancement, and frame arithmetic. Areas of interest are then superimposed on these images by the use of a remote 'joy stick' device. Time activity curves for the entire study are then displayed for these designated areas. Four areas of interest are chosen in each lacrimal system, namely: the inner canthus of the palpebral aperture, the lacrimal sac, the lacrimal duct, and that region just beneath the lacrimal duct in the inferior meatus (Fig. 1).

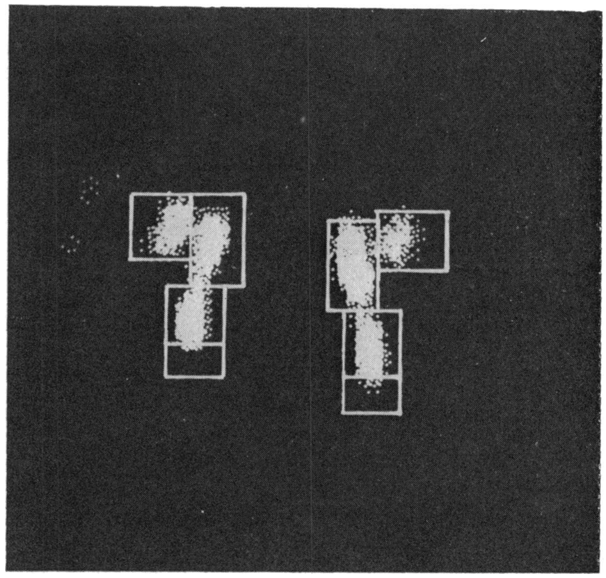

FIG. 1 *Regions of interest outlined on computer oscilloscope*

Fig. 2 shows the typical curves from the inner canthus, the sac, and the naso-lacrimal duct.

The T½ values for the inner canthus are measured directly (Fig. 3). However, to obtain the absolute values for the sacs, the changes in the inner canthus are subtracted from the sac values at each point (Fig. 4). Likewise the change in activity in the sac was subtracted from the duct counts (at each point) before the T½ for the duct was calculated (Fig. 5). The mean transit times (T max) can be determined for the sacs and ducts as the time at

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which maximal counts are present in these areas. The flow time to the nose is the earliest time of significant counts above background in the inferior meatus (Fig. 6).

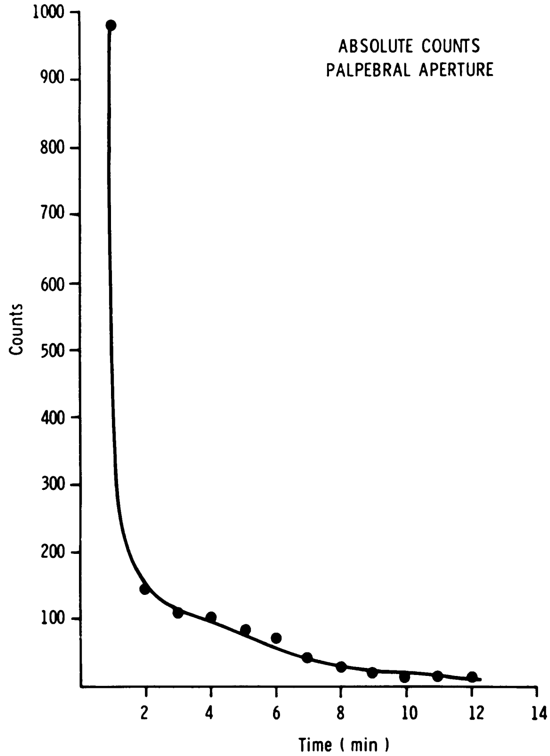

FIG. 2 (*a*) *Typical curve from inner canthus*

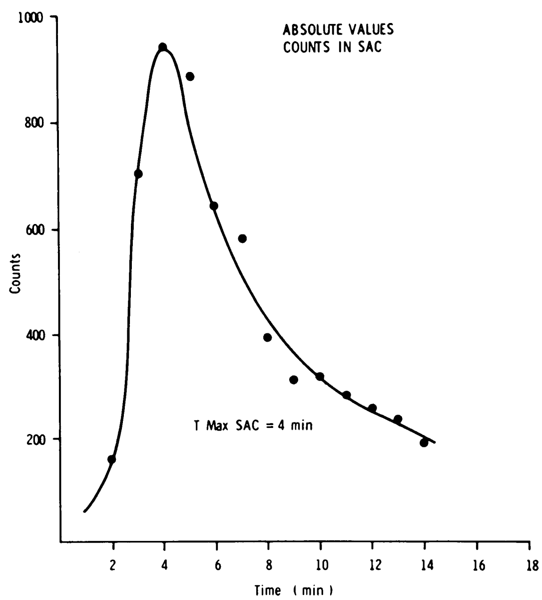

FIG. 2 (*b*) *Typical curve from lacrimal sac*

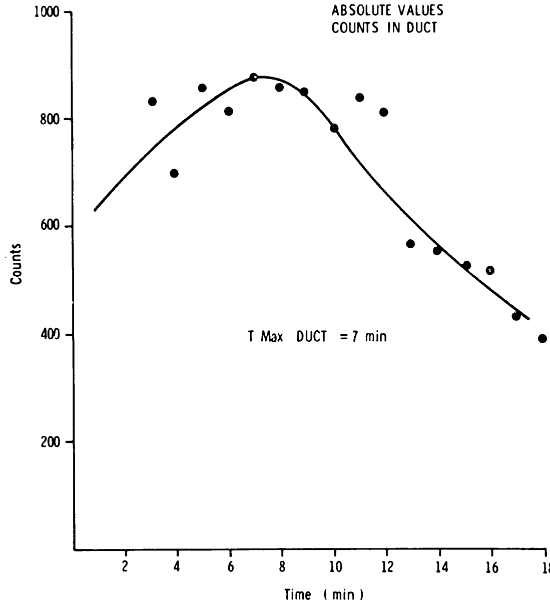

FIG. 2 (*c*) *Typical curve from naso-lacrimal duct*

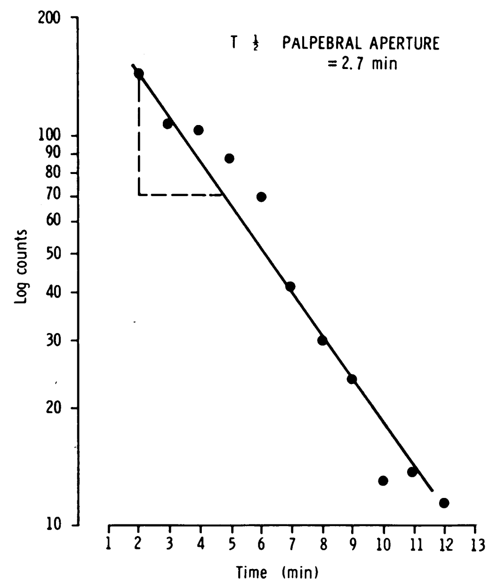

FIG. 3 *Semilogarithmic plot of palpebral aperture, from which T½ PA is calculated*

SUBJECTS

Seven completely normal patients with an age range of 25 to 40 years were studied (fourteen systems) in the erect position. A few weeks later they were all re-examined, six of these lying down, and one lying down with eyes completely closed. One other patient was studied lying down with eyes closed for 15 min followed by normal blinking for 15 min. Two others had this same procedure, but in the erect position.

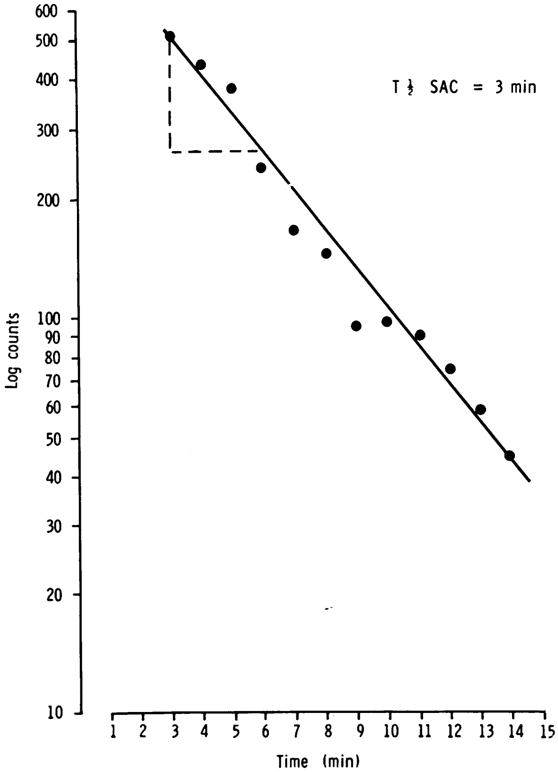

FIG. 4 *Semilogarithmic plot for sac, from which T½ sac is calculated*

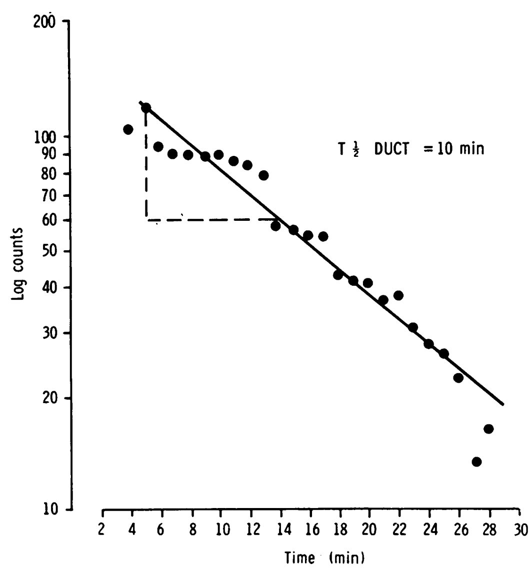

FIG. 5 *Semilogarithmic plot for duct, from which T½ duct is calculated*

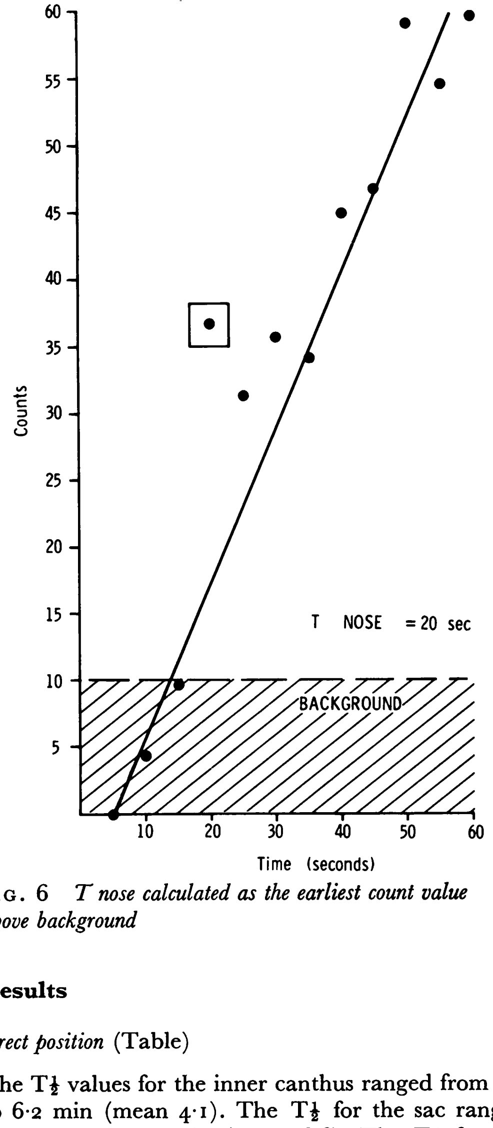

FIG. 6 *T nose calculated as the earliest count value above background*

Results

Erect position (Table)

The T½ values for the inner canthus ranged from 2·3 to 6·2 min (mean 4·1). The T½ for the sac ranged from 1·5 to 14·0 min (mean 6·6). The T½ for the naso-lacrimal duct ranged from 4·0 to 15·0 min (mean 7·6).

Table I *Normal values—Erect*

Values	*Mean (min)*	*Standard deviation*	*Range (min)*
T½ palpebral aperture	4·1	1·3	2·3 –6·2
T½ sac	6·6	2·5	1·5 –14·0
T½ duct	7·6	2·9	4·0 –15·0
T max sac	5·2	3·5	1·0 –15·0
T max duct	11·2	4·3	3·0 –24·0
T nose	1·1	0·73	0·25– 3·0

The maximal (T max) sac counts ranged from a time of 1·0 to 15·0 min (mean 5·2). Every system had tracer in the lacrimal sac by 5 to 10 s. The T max for the naso-lacrimal duct was 3·0 to 24·0 min (mean 11·2). The time for the tracer to enter the nose ranged from 0·25 to 3 min (mean 1·1).

Supine (Table II)

The T½ for the palpebral aperture ranged from 5·2 to 90 min (mean 38 min). The palpebral aperture T½ in the supine position is 9·2 times as slow as in the erect position. The T½ for the sac ranged from 8·0 to 44 min (mean 27·5). The sac T½ in the supine position

Table II *Normal values—Supine*

Values	*Mean (min)*	*Standard deviation*	*Range (min)*
T½ palpebral aperture	38·0	23·0	5·2–90·0
T½ sac	27·5	6·0	8·0–44·0
T½ duct	18·0	8·5	3·7–38·0
T max sac	12·0	7·2	2·0–25·0
T max duct	12·5	5·7	5·0–25·0
T nose	8·0	7·5	0·9–28·0

is 4·2 times as slow as in the erect position. The T max for the sac ranged from 2·0 to 25·0 min (mean 12·0). The tracer first entered the nose in 0·9 to 26 min, (mean 8·0). This is 7·2 times as slow as in the erect position.

Erect with eyes closed

The T½ for the sac ranged from 20 min to infinity, and is much slower than the T½ for the sac in the erect blinking patient. Likewise the T max for the sac is 3 to 13 min which is 1·5 times as slow as when blinking occurs. Without blinking, no tracer reaches the duct or nose. When the subject begins to blink, the T½ values for the sac and palpebral aperture decrease, and tracer enters the duct and nose.

Supine with eyes closed

The T½ for the sac is 70–90 min (mean 38 min) which is nine times as slow as in the supine blinking patient. The T max of the sac is also much slower. No tracer enters the duct or nose, but when blinking begins, the T½ of the palpebral apertures and sac decrease and tracer enters the duct and proceeds inferiorly, reaching the nose after 15 min in two cases and not at all in the other two.

Variation between systems in the same individual

The results are shown in Table III. Examination in the erect position produces less difference between the two lacrimal drainage systems of the same individual than does examination while supine.

Twelve patients with unilateral epiphora had scintillography performed on their other, asymptomatic lacrimal excretory system. All of these patients had results for the six parameters which fell within the range of normal values. The pathological systems had values markedly different from these. These cases are presented in the paper that follows, see page 313.

Table III *Difference between fellow eyes*

Values	*Erect*		*Supine*	
	Range (min)	*Mean (min)*	*Range (min)*	*Mean (min)*
T½ palpebral aperture	0·1– 3·0	1·7	0·8–74·0	27·5
T½ sac	0–2·0	0·8	1·0– 9·0	5·3
T½ duct	1·0– 6·0	2·4	1·0–20·0	7·5
T max sac	0– 8·0	3·0	0–16·0	5·3
T max duct	0–14·0	3·7	0–11·0	3·5
T nose	0– 0·66	0·22	0– 5·5	2·5

Discussion

Quantitative lacrimal scintillography is a highly effective technique for investigating the lacrimal excretory system. It is easy to perform, and there is no morbidity. The radiation dose to the lens of the eye is less than 2 per cent of the radiation from an antero-posterior skull film (Rossomondo and others, 1972). If the tracer pools at the inner canthus, the sulphur colloid is removed from the palpebral aperture at the end of the procedure. It is well tolerated by the patient as the drops are non-irritant and no instrumentation of the lacrimal system is required. It is the most objective test of lacrimal function because quantitation decreases the need for subjective interpretation of the gamma camera images, which may be misleading. The procedure permits the establishment of normal quantitative criteria against which pathological cases can be compared. However, properly performed dacryocystography, and the anatomical information thereby obtained (Lloyd, 1973), is not likely to be replaced by scintillography, as others have claimed (Rossomondo and others, 1972; Chaudhuri, Saparoff, Dolan, and Chaudhuri, 1974), or even by quantitative lacrimal scintillography, because the two examinations are complementary.

Quantitative lacrimal scintillography is extremely valuable in investigating the physiology of the drainage of tears from the palpebral aperture to the nose. Some of the controversy surrounding lacrimal drainage may be resolved by this method. With lacrimal scintillography, the tracer may be seen to pass from the lateral aspect of the palpebral aperture medially where it pools at the inner canthus before entering the punctum. Tracer continues to pass from the palpebral aperture to the lacrimal sac even when the eyes are closed, although at a reduced rate. This supports the hypothesis that capillarity plays a major role for the passage of tears into the puncta (Norn, 1965). These observations suggest that tears, once through the punctum, are siphoned from the canaliculus into the sac (Jones, 1962). The lacrimal sac shows increasing activity the longer the eyes remain closed, which suggests that the lacrimal sac remains open when the eyes close, probably because of the orbicularis pulling on the lacrimal diaphragm and opening the sac (Jones, 1957). The sac does not release the tears with the eyes closed, because of a competent valve at the sac-duct junction, and because of an expanded sac. Opening the eyes releases the tension on the lacrimal diaphragm and tears pass down the system. The increased drainage times in the supine position and with the eyes closed show very clearly the importance of gravity and of the lacrimal pump mechanisms in the drainage of tears. The effect of gravity is not as important in transporting tears from the lacrimal sac to the nose as is the blinking mechanism, but it still plays a significant role.

These preliminary results show that quantitative lacrimal scintillography is not only an excellent physiological method for studying normal dynamics of the lacrimal drainage apparatus, but it is also an important clinical tool. With the normal values defined, pathology in the lacrimal drainage system may be detected. The procedure is particularly important in cases where the dacryocystogram is equivocal, as in patients with dilated sacs or common canalicular stenoses. Patients with 'functional blocks', that is, those having epiphora and normal dacryocystograms (Demorest and Milder, 1955), can be more satisfactorily assessed by this method. Quantitative lacrimal scintillography is invaluable in assessing patients with postoperative epiphora. Because of the low radiation, the negligible morbidity, and the ease of performing this procedure, quantitative lacrimal scintillography may prove to be an effective method in screening patients with epiphora.

Summary

Quantitative lacrimal scintillography, using ^{99m}Tc sulphur colloid, a high resolution gamma camera, and quantification using a digital computer, is a highly effective way of assessing lacrimal physiology, and of establishing normal flow and drainage values against which pathological cases may be compared.

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References

CHAUDHURI, T. K., SAPAROFF, G. R., DOLAN, K. D., and CHAUDHURI, T. K. (1974) *J. nucl. Med.*, **15**, 482
DEMOREST, B. H., and MILDER, B. (1955) *Arch. Ophthal. (Chicago)*, **54**, 410
HAMANO, H., and MITSUNAGU, S. (1973) *Folia ophthal. jap.*, **24**, 435
JONES, L. T. (1957) *Amer. J. Ophthal.*, **43**, 203
——— (1962) *Trans. Amer. Acad. Ophthal. Otolaryng.*, **66**, 506
LLOYD, G. A. S. (1973) *Trans. ophthal. Soc. U.K.*, **93**, 589
NORN, M. S. (1965) *Acta ophthal. (Kbh.)*, **43**, 557
ROSSOMONDO, R. M., CARLTON, W. H., TRUEBLOOD, J. H., and THOMAS, R. P. (1972) *Arch. Ophthal. (Chicago)*, **88**, 523