Quantitative lacrimal scintillography
II. Lacrimal pathology

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In the paper on page 308 (Hurwitz, Maisey, and Welham, 1975) the technique of quantitative lacrimal scintillography was described, and normal values for parameters in assessing flow through the lacrimal excretory system were presented. The method was found to be useful in elucidating the dynamics of normal lacrimal drainage.

This report concerns the use of the same method in assessing patients with pathology of the lacrimal drainage apparatus.

Material and methods
Thirty-six patients were studied using the scintillographic technique. In 29 of these patients, quantitation was performed using a computer interfaced to a gamma camera. All patients in this study had had intubation macro-dacryocystography (Lloyd, Jones, and Welham, 1972), performed before the quantitative lacrimal scintillography (QLS). Of the 36 patients examined, 19 had unilateral symptomatology only, with normal history, physical examination, and dacryocystography on the non-involved side. Altogether 53 abnormal naso-lacrimal systems were examined in this study.

All examinations were performed in the upright position with the patient 10-2 cm from the pinhole of an Anger gamma camera. 0.013 ml of Technetium 99 M sulphur colloid with specific activity of approximately 10 mCi/ml was dropped on to the marginal tear strip of each lower lid. The tracer distribution was imaged serially as it passed down the lacrimal drainage system. The data from the gamma camera were recorded simultaneously on to the magnetic disc of the computer for subsequent quantitative analysis (Hurwitz and others, 1975).

Four regions of interest are studied in each lacrimal system (Fig. I). Six criteria of normal drainage have been established previously, and by quantitative analysis values for a particular patient can be related to these (Table I).

The distribution of the abnormalities in the cases studied is seen in Table II.

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Table I: Normal values

<table>
<thead>
<tr>
<th>Values</th>
<th>Mean (sec)</th>
<th>Standard deviation (sec)</th>
<th>Range (sec)</th>
</tr>
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<tbody>
<tr>
<td>T</td>
<td>palpebral aperture</td>
<td>4.1</td>
<td>1.3</td>
</tr>
<tr>
<td>T</td>
<td>sac</td>
<td>6.6</td>
<td>2.5</td>
</tr>
<tr>
<td>T</td>
<td>duct</td>
<td>7.6</td>
<td>2.9</td>
</tr>
<tr>
<td>T</td>
<td>max sac</td>
<td>5.2</td>
<td>3.5</td>
</tr>
<tr>
<td>T</td>
<td>max duct</td>
<td>11.2</td>
<td>4.3</td>
</tr>
<tr>
<td>T</td>
<td>nose</td>
<td>1.1</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Table II: Patients examined

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Pathology</th>
<th>Fellow eye</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sac diverticulum</td>
<td>Normal</td>
</tr>
<tr>
<td>2</td>
<td>Lower sac obstruction</td>
<td>Normal</td>
</tr>
<tr>
<td>3</td>
<td>Lower sac stenosis</td>
<td>Normal</td>
</tr>
<tr>
<td>4</td>
<td>Intermittent mucococele</td>
<td>Normal</td>
</tr>
<tr>
<td>5</td>
<td>Lower sac obstruction and</td>
<td>Normal</td>
</tr>
<tr>
<td>6</td>
<td>previous cc obstruction</td>
<td>Normal</td>
</tr>
<tr>
<td>7</td>
<td>Stenosis cc</td>
<td>Normal</td>
</tr>
<tr>
<td>8</td>
<td>Stenosis cc (a)</td>
<td>Asymptomatic cc stenosis (b)</td>
</tr>
<tr>
<td>9</td>
<td>Stenosis cc</td>
<td>Normal</td>
</tr>
<tr>
<td>10</td>
<td>Stenosis cc (a)</td>
<td>Normal DCR (b)</td>
</tr>
<tr>
<td>11</td>
<td>Stenosis cc</td>
<td>Normal</td>
</tr>
<tr>
<td>12</td>
<td>Lower canaliculus obstruction</td>
<td>Normal</td>
</tr>
<tr>
<td>13</td>
<td>Lower canaliculus stenosis</td>
<td>Normal</td>
</tr>
<tr>
<td>14</td>
<td>Upper and lower puncta absent</td>
<td>Normal</td>
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<tr>
<td>15</td>
<td>Surgically occluded puncta</td>
<td>Normal</td>
</tr>
<tr>
<td>16</td>
<td>Gelatin rods upper and lower</td>
<td>Surgically occluded puncta (b)</td>
</tr>
<tr>
<td>17</td>
<td>Loose lid (a)</td>
<td>Asymptomatic loose lid (b)</td>
</tr>
<tr>
<td>18</td>
<td>Loose lid (a)</td>
<td>Normal</td>
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<tr>
<td>19</td>
<td>Ectropion (a)</td>
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<td>Medial canthal deformity (a)</td>
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<tr>
<td>21</td>
<td>Medial canthal deformity (a)</td>
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<tr>
<td>22</td>
<td>Bell’s palsy</td>
<td>Normal DCR (b)</td>
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<td>23</td>
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<td>24</td>
<td>Facial nerve palsy</td>
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<td>25</td>
<td>Functional block (a)</td>
<td>Normal DCR (b)</td>
</tr>
<tr>
<td>26</td>
<td>Functional block (b)</td>
<td>Normal DCR (b)</td>
</tr>
<tr>
<td>27</td>
<td>Obstructed DCR</td>
<td>Normal DCR (b)</td>
</tr>
<tr>
<td>28</td>
<td>Obstructed intubation DCR (a)</td>
<td>Normal DCR (b)</td>
</tr>
<tr>
<td>29</td>
<td>Canalicular-DRC stenosed</td>
<td>Normal DCR (b)</td>
</tr>
<tr>
<td>30</td>
<td>Fails DCR with blocked lower</td>
<td>Normal DCR (b)</td>
</tr>
<tr>
<td>31</td>
<td>Canaliculus</td>
<td>Normal DCR (b)</td>
</tr>
<tr>
<td>32</td>
<td>Obstructed canaliculus DCR</td>
<td>Normal DCR (b)</td>
</tr>
<tr>
<td>33</td>
<td>Normal DCR</td>
<td>Normal DCR (b)</td>
</tr>
<tr>
<td>34</td>
<td>Dysthyroid (a)</td>
<td>Normal DCR (b)</td>
</tr>
<tr>
<td>35</td>
<td>Dysthyroid (a)</td>
<td>Normal DCR (b)</td>
</tr>
<tr>
<td>36</td>
<td>Normal (a)</td>
<td>Normal DCR (b)</td>
</tr>
</tbody>
</table>

* No quantitation.

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Results

All QLS values in each normal system fell within the range of normal (Hurwitz and others, 1975) although the fellow eyes were pathological.

Lacrimal sac pathology

Patients 1 to 6 had abnormalities of the lacrimal sac.

Patient 1, a 19-year-old girl had left-sided epiphora. The system was patent to syringing. Dacryocystography (DCG) showed an inferior diverticulum of the lacrimal sac, the naso-lacrimal duct being patent (Fig. 2). Because this may be seen in an asymptomatic patient, scintillography was performed to determine whether the symptoms could be attributed to this abnormality. Marked residual tracer was seen in the left palpebral aperture, and pooling was present in the sac (Fig. 3). On the basis of the scintillography findings a dacryocystorhinostomy (DCR) was successfully performed.

Patient 2, a 34-year-old woman had a complete left lower sac obstruction as seen on DCG (Fig. 4). On QLS, tracer reached a maximum in the sac at 28 min, and the T½ for the sac was 29 min. Although scintillographic studies are not necessary in diagnosis or management of such a patient, it is interesting to note that functionally, the sac fills with tracer, although a complete obstruction is present. The patient was cured with a DCR.

Patient 3, a 42-year-old woman had epiphora for 3 years. Syringing showed patency of the system on six separate occasions. Subtraction DCG showed a patent system with the possibility of some lacrimal sac dilatation (Fig. 5). QLS was performed to determine the function of the possibly pathological sac. On the 25 min gamma camera image (Fig. 6), there appears to be increased counts in the sac. In Fig. 7 the curve from the normal sac (B) shows normal excretion with a T½ sac of 5 min, but the curve from the abnormal sac (A) shows poor excretion with a T½ of 40 min. On the involved side, the T max duct is 31 min
and tracer only enters the nose at 4 min. In view of these findings a DCR is to be performed.

Patient 4, a 19-year-old girl with three previous attacks of acute dacryocystitis and mucocele was referred at a time when epiphora was not present. Dacryocystography showed a possible constriction at the lower end of the sac (Fig. 8). It was found on QLS examination that tracer entered the sac quickly (Ti inner canthus = 2 min) and the sac emptied slowly (Ti sac = 13 min). Tracer reached the nose at 3 min (compared with 15 s on the contralateral side). The drainage was therefore abnormal, and a DCR is indicated to prevent further attacks.

Patient 5, a 44-year-old man with a complete medial (mucosal) common canaliculus (cc) obstruction on DCG, was admitted for surgery, but on admission was found to have a patent system and no epiphora. QLS demonstrated a reasonable emptying of the palpebral aperture (Ti inner canthus = 10 min) but Ti sac was infinity and negligible tracer entered the duct. This confirms the hypothesis that a mucosal level cc obstruction is secondary to a sac obstruction (Welham, 1973). If symptoms recur, a DCR with removal of the partially perforated cc membrane, and temporary intubation of the system (3 months) will be performed (Jones and Corrigan, 1969).

Patient 6, a 57-year-old man had a cc stenosis on x ray (Fig. 9). The gamma camera picture at 27 min shows a pooling of tracer at the left inner canthus (Fig. 10). At 70 min, there is still pooling present, as well as a possible delay in the sac (Fig. 11). Curves from the palpebral aperture show a delayed emptying of the left palpebral aperture (Ti inner canthus = 15.5 min). Fig. 12. But
FIG. 9 Case 6: DCG demonstrating a common canaliculus stenosis

the Ti sac is also markedly delayed (54 min), indicating severe sac pathology. The surgical procedure indicated is a DCR with exploration of the cc, and temporary intubation of the system.

FIG. 10 Case 6: Gamma camera picture at 27 min demonstrates pooling in left inner canthus

FIG. 11 Case 6: Gamma camera picture at 70 min shows residual tracer at left inner canthus

FIG. 12 Case 6: Normal delay from right inner canthus (lower curve), and delay at left inner canthus, (upper curve)

Common canalicular disease

It is often difficult to diagnose stenosis of the cc on DCG, and therefore in Cases 7 to 11 QLS was performed to determine whether or not there was a delay in transit at this level. In each case of suspected cc stenosis, there was a pooling of tracer in the palpebral aperture, and slow entry to the sac and lower system. Case 8 is a typical example.

Patient 8, a 48-year-old woman had epiphora on the left side. There was cc stenosis on the DCG (Fig. 13), and the system was patent. QLS showed a clear area between the palpebral aperture and sac on the right side (characteristically seen in normal patients), but no clear area on the left (Fig. 14). The left inner canthus also appears to have more tracer present, and this is confirmed by quantitation as the Ti inner canthus is 34 min. Entry to the sac is delayed (T max sac = 48 min). Sac emptying is normal. This patient was cured with a canaliculo-DCR (Jones, 1960).

In complete obstruction of the cc as was found in the fellow eye of Patient 6 (Table II), no tracer entered the sac or canaliculi.
Quantitative lacrimal scintillography. II

FIG. 13 Case 8: Left common canaliculus stenosis on DCG

FIG. 14 Case 8: Computer image from 45 to 60 s demonstrating a clear area between inner canthus and lacrimal sac on right, and a filling in of this area on left

Upper and/or lower canalicular lesions

Cases 12 to 15 had lesions of the upper and/or lower canaliculus.

Patient 12, a 48-year-old man had a laceration of the lower canaliculus, which had been repaired, but remained totally occluded. The upper canaliculus and remaining system were normal, QLS enabled the flow through the upper canaliculus to be determined. The T inner canthus on the involved side was 10·1 and T max sac was 13·2 min. On the normal side, T inner canthus was 2·5 and T max sac was 3·0. These values indicate that there is a much greater flow through the upper and lower canaliculi together, when compared with the upper alone. With a normal upper canaliculus, the epiphora can be cured by a DCR (Jones, 1960).

Patient 13, a 60-year-old patient had a lower canalicular stenosis and occluded upper canaliculus on DCG. QLS showed a markedly delayed outflow from the palpebral aperture (T inner canthus = 90 min). Because the level of the stenosis is only 5 mm from the punctum, a glass bypass tube is indicated (Welham, 1973).

Patient 14, a 13-year-old girl lacked an upper canaliculus but had a normal lower canaliculus on the right side. The T inner canthus is 6·5 min (upper limit of normal), and the T max sac is relatively normal (2 min). On the left, both puncta were absent at birth and had been canalized. However, epiphora persisted. QLS results of T inner canthus = 10·5, T sac = 20·5 indicated a sac abnormality, and a DCG subsequently demonstrated stenosis at the lower end of the sac.

Patient 15, a 17-year-old girl had had the lacrimal gland totally removed because of a benign mixed-cell tumour. She subsequently developed a dry eye with marked corneal staining. Gelatin rods were inserted (Wright, 1971) but staining persisted. Because of this both puncta were occluded, but this unfortunately resulted in epiphora. Scintillography confirmed that no tracer passed through the puncta. A canaliculotomy is indicated.

Patient 16, a 60-year-old patient with keratoconjunctivitis sicca was studied because of the outcome in Patient 15. The right upper and lower puncta had been completely occluded, surgically, and no tracer left the palpebral
aperture. However, the left side had a trial of gelatin rods before permanent surgical occlusion, and symptoms were slightly relieved. The rods were inserted 48 hours before the scintillography examination. This showed that the tracer entered the left sac in 10 s, reached the nose by 2 min, and disappeared from the palpebral aperture normally. This indicates that gelatin rods as a trial of puntal occlusion are unsatisfactory, and reliance should not be placed on the results of their use. In this patient only one punctum (lower) was occluded surgically, and the symptoms resolved.

Lid abnormalities

Patients 17 and 18 had marked horizontal lid laxity, and epiphora. There were no puntal abnormalities. The DCGs were completely normal. Both patients were over 60 years old. The T\(\frac{1}{4}\) inner canthus, T\(\frac{1}{4}\) sac, T max sac, and T max duct were abnormal, suggesting abnormalities of the lacrimal pump mechanism (Jones, 1962). One patient subsequently had a Bick procedure where a wedge of full thickness lid is resected laterally (Bick, 1966), and the epiphora resolved. Subsequent QLS showed that surgery had decreased the T\(\frac{1}{4}\) inner canthus value from 37.0 to 19.2 min.

Patients 19 to 21 had positional deformities of the lids. Examination with QLS was useful in determining the amount of flow through malpositioned puncta. One patient, although only 19 years old, had increased laxity of the lids because of congenital medial canthal abnormalities. The T\(\frac{1}{4}\) inner canthus was 24 min on the more affected side, and 9.5 on the other. A Bick procedure is planned for the worse side. Another patient with poor lid-globe apposition and a T\(\frac{1}{4}\) inner canthus of 38 min had a DCR to promote drainage through the system. Postoperatively, tracer entered the nose in 5 s, and T\(\frac{1}{4}\) inner canthus fell to 6.5 min.

Facial palsy

Patients 22 to 24 had facial palsies. Two had epiphora, normal DCGs, and no demonstrable lid weakness. In Patient 22, there was a hold-up of tracer in the inner canthus (T\(\frac{1}{4}\) = 20.5), and slow entry to the sac (T max sac = 351), with normal emptying of the sac. These findings indicate that a lacrimal pump dysfunction (Veirs, 1955) is responsible for the epiphora. In Patient 23 the results were normal. A gustatory relationship of his symptoms was present and he was considered to have 'crocodile tears'. Patient 24 is 14 years old and has marked lid laxity and orbicularis weakness. The T\(\frac{1}{4}\) inner canthus = 40 and T max sac is 27. He is to have a lid-shortening procedure.

'Functional block'

The original definition of 'functional block' included those patients with epiphora, and normal classical dacryocystography (Demorest and Milder, 1955). However, with intubation DCG, many of these cases are found to have anatomical abnormalities (Welham, 1973).

Patients 25 to 26, each with bilateral epiphora and over the age of 50, demonstrated slow exit of tracer from the palpebral apertures, delayed entry into the sacs, and slow emptying of the sacs. This 'upper functional abnormality' (Hurwitz and others, 1975), should be managed by a lid-tightening procedure in the first instance (Bick, 1966) and only if this fails should recourse be made to a bypass procedure.

Normal DCR

Two cases of normally functioning DCRs (fellow eyes of Patients 10 and 28) were studied. Tracer was seen to enter the middle meatus in each case at 5 s (Fig. 15). The T\(\frac{1}{4}\)
inner canthus values were between 3–4 min. These are values against which an abnormally functioning DCR may be compared.

A third patient with a normal DCR was studied with the eyes closed upon instillation of the tracer. With the eyes closed, the Tiinner canthus was infinity, which fell to 7.5 when blinking began. The Tiinner sac was infinity with eyes closed, and this fell to 3.2 upon blinking. These are important observations regarding the mechanism of flow through a DCR.

**Postoperative cases of epiphora**

**Patients 27 to 32** had non-functioning lacrimal excretory systems following previous surgery.

**Patient 27, a 40-year-old man** who had a DCR for a lower sac obstruction. Epiphora persisted, and the system was not patent to syringing. The DCG showed a sac obstruction (Fig. 15). No tracer entered the sac or nose, but pooled at the inner canthus with a Tiinner canthus of 34.

**Patient 28, a 14-year-old boy** who had a DCR with temporary intubation of the system to treat a mucosal obstruction. However, the tube was prematurely removed at one week, and epiphora has persisted. QLS showed a Tiinner canthus of 21, T max sac of 23, and Tiinner sac of infinity. The system was patent to syringing. Re-operations are indicated for both these patients.

**Patient 29, a 52-year-old patient** had a canaliculo-DCR on the right side which had failed, and a poorly functioning DCR on the left, because of a 'sump syndrome' (Welham and Henderson, 1973). On the right, Tiinner canthus is 43, and negligible counts are seen in the nose. On the left Tiinner canthus is 28 min with entry to the nose at 20 min. However, there is a hold-up in the 'sump' which has a Ti value of 48 min. Re-operations are indicated bilaterally.

**Patients 30 and 31.** The former had a failed canaliculo-DCR with a blocked lower canaliculus, and the latter had a failed DCR with a blocked lower canaliculus. Both had epiphora, with patent, yet somewhat stenotic upper canaliculi, and the fluorescein dye tests gave equivocal information. The DCGs showed 'normal' rhinostomies. However, when QLS was performed, no tracer passed through the upper canaliculus in either case. The delay at the inner canthus in Patient 30 is seen in Fig. 16. The Tiinner canthus (upper curve Fig. 17) is infinity, as compared to the other asymptomatic side (lower curve) where the Tiinner canthus is 6.0. These patients are to have Lester Jones tubes inserted.

**Patient 32, a 38-year-old man** had a canaliculo-DCR but epiphora persisted in spite of patency to syringing. A DCG demonstrated stenosis of the fistula to the nose, (Fig. 18). QLS showed no flow with a Tiinner canthus of 48 min.
Dysthyroid eye disease

**Patient 34, a 51-year-old woman** had bilateral epiphora. She was clinically dysthyroid, with bilateral lid lag and lid retraction. Exophthalmometer readings (Hertel) were 19 mm both for the right and left. The DCG was normal. The T₄ inner canthus values were 36 min on the right and 28 min on the left. The T max sac values were 27 min on the right and 19 min on the left. The rest of the drainage function was normal. The 20 min gamma camera image is seen in Fig. 19.

**Canalicular disease**

In cases of complete occlusion of an individual canaliculus, the results in Patients 12 to 14 suggest that the lower canaliculus is functionally more important in the conduction of tears.

Discussion

Quantitative lacrimal scintillography is an excellent test for assessing the function of the lacrimal excretory system. Scintillography alone (Carlton, Trueblood, and Rossomondo, 1973; Chaudhuri, 1974) without quantitation gives limited information when compared with the technique described. QLS is complementary to intubation macro-dacryocystography and they should be interpreted together to gain the maximum possible clinical information:

**DCG interpretation**

QLS may clarify the cause of epiphora in certain conditions in which the DCG is difficult to interpret. This happens when the system is patent to contrast in the presence of a dilated and possible partially obstructed sac, or if there is a suggestion of canalicular stenosis. On the DCG, contrast normally passes quickly from the cc to the sac, and therefore it is difficult to see the normal cc (Henderson, 1973). In these circumstances QLS detects any delay in tear progress and determines whether any true abnormality exists. QLS may also determine whether an anatomical variation such as a sac diverticulum or an abnormal sac-duct junction is associated with delayed sac emptying. The normally 'clear area' where tracer is absent between the inner canthus and lacrimal sac (Rossomondo, Carlton, Trueblood, and Thomas, 1972) may be seen to be filled, when examined on the computer oscilloscope in a case of cc stenosis (Patient 8). This finding demonstrates that cc stenosis is present, and a canaliculo-DCR therefore indicated (Jones and Corrigan, 1969).

**Temporary and permanent iatrogenic punctal occlusion**

Surgical occlusion of the puncta is often performed in patients with dry eyes. Gelatin rods may be temporarily inserted into the canaliculi to predict the outcome of such a procedure (Wright, 1971). When scintillography was performed on a patient with gelatin rods in both canaliculi (Patient 16) it was evident that, in this particular case, the rods were not achieving their objective. Before proceeding with

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**Fig. 18** Case 32: DCG demonstrates stenosis of DCR

**Fig. 19** Case 34: 20-min gamma camera image shows hold-up in both palpebral apertures of dysthyroid patient
Lid abnormalities

Epiphora may occur in a patient with poor orbicularis function but an otherwise normal lacrimal excretory system, even with the punctum in its normal position (Lyle, 1956). QLS is useful in assessing this abnormality, and in determining the extent of improvement after a lid-tightening procedure (Bick, 1966).

A patient with a facial palsy may have epiphora for a number of reasons. Although an everted punctum is a common aetiological factor (Korchmáros, 1969), one may suffer from epiphora with a properly-positioned punctum (Veirs, 1955) presumably because of a poorly-functioning orbicularis. Epiphora may also be present with normal orbicularis function, because of a gusto-lacrimal reflex known as 'crocodile tears' (Jacklin, 1966). Normal QLS values suggest 'crocodile tears', whereas delayed emptying of the palpebral aperture suggests a lacrimal pump dysfunction.

Patients with so-called functional blocks have often been found to have anatomical abnormalities on intubation macro-dacryocystography or at exploratory surgery (Welham, 1973). In these patients without anatomical abnormalities, QLS has invariably shown a delay in emptying of the palpebral aperture and this presumably reflects malfunction of the lacrimal pump (Jones, 1960).

Normal DCR function

In two cases of normally-functioning DCRs, the tracer was present in the middle meatus by 5 s, with a normal T4 from the inner canthus.

A similar case studied showed no entry of tracer into the nose until blinking began 20 min later. This supports the theory that there is a 'canalicular pump' dependent on blinking (Brienen and Snell, 1969).

Postoperative epiphora

In those patients with persistent symptoms following previous lacrimal surgery, the method may provide invaluable quantitative information regarding flow through the system, as in these circumstances, interpretation of the x rays may be particularly difficult. An example of a 'sump syndrome' produced by inadequate drainage of the sac to the nose is seen in the fellow eye of Patient 29. Although the situation might be suggested radiologically (Welham, 1973), QLS confirms the pooling of tracer in the 'sump'.

Dysthyroid eye disease

The tearing often present in patients with dysthyroid eye disease has been blamed on a hypersecretion of tears (Roy, 1972). The QLS findings in the three cases with tearing, demonstrated pooling of tracer at the inner canthus. This suggests that the main problem is delayed excretion of tears. This may be because of the infrequent blinking in these patients (Blodi, 1974), or possibly because of the altered function of the punctum caused by increased orbital pressure (Riise, 1970). If hypersecretion were the only explanation, tracer would have passed normally through the system.

Screening

In patients suspected of an organic cause for epiphora QLS is the best method of excluding a normal lacrimal drainage system (Patient 36) before further radiological investigation.

Summary

Quantitative lacrimal scintillography is a useful clinical procedure in assessing lacrimal drainage function in patients with epiphora. Examples are presented of patients with canalicular disease, lid abnormalities, 'functional blocks', and dysthyroid disease, in which this technique was valuable. Information regarding the dynamics of a functioning and non-functioning dacryocystorhinostomy is elucidated with quantitative scintillography.

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