Radiography in functional lacrimal testing

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I. Ultra-fluid Lipiodol

The clinician has at his disposal an excellent procedure for determining the anatomy of the lacrimal system, namely, dacryocystography. However, the tests of physiological function are often difficult to perform, or interpret, and require expensive equipment. Syringing of the lacrimal passages is often misleading, since although saline may pass to the pharynx, indicating patency, this by no means indicates the absence of abnormality (Doughman, 1973). The same may be said for the patency test using saccharin (Hornblass, 1973; Lipsius, 1956). The Jones fluorescein dye tests (Jones and Linn, 1969) are often difficult to perform. The primary dye test detects only 77 per cent of normal passages, and is therefore not reliable. The secondary dye test is not a test of physiological lacrimal function, but rather of patency. This test also depends on the tear flow rate (Zappia and Milder, 1972a). Likewise, instilling fluorescein into the tear film and its detection on a tissue after blowing the nose (Campbell, Smith, Richman, and Anderson, 1962) is only a test of patency. Tests using pressure transducers (Callahan, Forbath, and Besser, 1965) are difficult to perform, and require complicated equipment. The fluorescein dye disappearance test (Zappia and Milder, 1972b), whilst being easy to perform does not distinguish anatomic from functional defects.

Recently, radionuclide studies of the lacrimal system have been used to determine physiology (Carlton, Trueblood, and Rossomondo, 1973). We feel that it is necessary to use a digital computer in the scintillography testing to get the maximum physiological information, but these tests, although superb for physiology, are still not as precise as dacryocystography in detecting anatomical abnormalities (Hurwitz, Maissey, and Welham, 1975).

Dacryocystography has been used for a number of years to detect anatomical abnormalities of the lacrimal excretory system (Milder and Demorest, 1954). Iodized oil is injected by cannulation of the system and a radiograph taken. This method has had several modifications, to delineate more precisely the anatomical structures. Distension of the system (Iba and Hanafé, 1968), by injecting the contrast through a catheter, markedly decreases the pressure of injection, thus being more physiological, and, by taking radiographs while the system is distended, allows the anatomy to be better seen. The technique of macrography (Campbell, 1964) produces enlargement of the image, and a better view of structure. By performing subtraction studies with distension and macrography (Lloyd, 1973; Lloyd and Welham, 1974), the structure can be optimally appreciated. Anatomy is so well shown that the structures can be accurately measured (Henderson, 1973; Malik, Gupta, Chatterjee, Bhardwaj, and Saha, 1969).

The contrast media used in the above studies were forms of an iodized oil. The most suitable is a non-viscous fluid called 'ultra-fluid Lipiodol' (May and Baker), with a viscosity of 25 centipoises at 37°C (Lloyd, 1973). It is advisable to use Lipiodol because it is homogeneous, non-irritant, eventually absorbed if not discharged, and not toxic (Law, 1967). It is not necessary to guard against iodine idiosyncrasy because of the small amount used (May and Baker). Ultra-fluid Lipiodol does not produce a bitter taste in the throat, or form a powdery deposit on the lids with subsequent burning (Milder and Demorest, 1954), as may occur when using water soluble contrast medium.

Although water-soluble substances have been used for dacryocystography (Aakhus and Bergaust, 1969; Sargent and Ebersole, 1968), for the above reasons we have used ultra-fluid Lipiodol.

Dacryocinematography has been used to determine

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the function of the system (Street and Howell, 1967; Trokel and Potter, 1972) but requires elaborate equipment and our experience with it has not been rewarding.

Some workers have instilled radio-opaque substances into the conjunctival sac (Epstein, 1961; Koszczynski and Nowicka, 1968) and performed serial radiography (Raynaud, Perdriel, Sais, and Martin, 1964). We have devised a system whereby ultra-fluid Lipiodol is instilled into the conjunctival sac, macro-radiographs are taken to determine physiology, and then intubation distension macro-dacryocystography, with or without subtraction, is used to determine the anatomy.

Material and methods

One hundred lacrimal systems were studied in 51 patients with lacrimal problems. History and physical findings were documented for every patient to determine which were 'normal systems' (history and physical examination negative).

An upright postero-anterior control film in the Waters' position is first taken. Then two drops of ultra-fluid Lipiodol are simultaneously placed in each palpebral aperture. No local anaesthetic is necessary. The patient is in the upright position. We found that films taken 3, 15, and 30 min after instilling the contrast gave the most useful information. The macro-radiographic technique is used. With a co-operative patient and a head-fixation device, subtraction studies may be done if desired. After the 30 min film, the patient is placed on the x-ray table and macro-dacryocystography performed.

Results

Of the 100 lacrimal systems examined in 51 patients, we classed 16 of these as normal by virtue of negative history and physical examination. The others consisted of 18 common canalicular occlusions, 14 common canalicular stenoses, 6 incomplete sac obstructions, 18 complete sac obstructions, 4 naso-lacrimal duct stenoses, and 2 complete naso-lacrimal duct obstructions. Fourteen had upper 'functional blocks' and 7 had lower 'functional blocks' (Table I). One

Table I *Results of testing*

Normal systems	16
Common canaliculus blocks	18
Common canaliculus stenosis	14
Sac stenoses	6
Complete sac blocks	18
Duct stenoses	4
Complete duct blocks	2
Upper functional abnormalities	14
Lower functional abnormalities	7
Functioning DCR	1

patient had a functioning dacryocystorhinostomy. There were no adverse reactions to the medium used.

Normal

The results are shown in Table II. In all cases except

Table II *Normal systems*

Case	Age	Other eye	3 min	15 min	30 min
1	60	Stenosis cc	O	AB	ABC
2	10	Sac stenosis	AB	ABC	ABCX
3	37	Sac stenosis	O	A	AB
4	52	Block cc	A	AB	ABC
5	37	Sac block	AB	ABC	ABCX
6	38	Duct stenosis	A	ABC	ABCX
7	64	Block cc	O	A	ABC
8	52	Physiological dysfunction	AB	AB	ABCD
9	62	Sac block	A	ABC	ABCX
10	37	Sac block	AB	ABC	ABCX
11	33	Fracture-mucocele	A	AB	ABC
12	64	Block cc	O	A	ABC
13	55	Physiological dysfunction	AB	AB	ABCD
14	22	? Diverticulum sac	Not done	AB	ABC
15	42	Normal	B	AB	ABC
16	42	Physiological dysfunction	O	AB	ABC

A - contrast in sac

B - into duct

C - removed from sac

CX - moved down system

D - removed from duct

cc - common canaliculus

five, contrast enters the sac and/or duct by 3 min. In the remaining five cases, contrast entered the sac between 3 and 15 min. It is probably relevant that one of these patients had a microphthalmic eye, and the other four were aged 60 years or more.

Complete anatomical occlusions

Complete occlusions within the lacrimal drainage apparatus are diagnosed by clinical methods such as probing or syringing, or more satisfactorily by dacryocystography.

Of the 38 patients in this group, there were 18 blocks located at the level of the common canaliculus, 18 sac obstructions, and 2 whose obstruction was situated in the naso-lacrimal duct.

In none of the patients whose obstructions lay above the naso-lacrimal duct, did contrast enter any part of the system.

Incomplete anatomical occlusions (stenoses)

These symptomatic patients have lacrimal systems which are patent to syringing, but dacryocystography shows stenosis in some part of the system. Of the 24 systems in this series, 14 had common canalicular stenosis, 6 had sac stenosis, and 4 had stenosis of the naso-lacrimal duct. The functional tests need to be interpreted in association with the dacryocystogram so as not to confuse these cases with purely functional abnormalities.

Results are shown in Table III. In only 11 of the 24 cases did any contrast enter the system. In these cases, there was no progress of the contrast beyond the sac, and in no patient did it reach the duct.

Table III Cases of anatomical stenosis

Site	Case	3 min	15 min	30 min
cc	1	O	A	A
	2	O	O	A
	3	A	A	A
	4	A	AC	AC
	5-14	O	O	O
Sac	1	A	A	A
	2	O	A	A
	3	O	A	AC
	4-6	O	O	O
Duct	1	O	A	A
	2	A	A	A
	3	A	A	Not done
	4	A	A	Not done

FIG. 1 Right-sided lower sac stenosis in 10-year-old boy with a recurrent regurgitating mucocoele. Left side was asymptomatic

Functional abnormalities

There were 21 systems patent to syringing in patients with watering eyes who also had anatomically normal dacryocystograms. These patients can be said to have functional abnormalities, and can be divided into two types. In the first type, there is a functional abnormality located in the upper part of the system (orbicularis-puncta-canalculi). In the second type, the dysfunction is located in the lower part of the system (sac-duct-inferior meatus). The results are shown in Table IV. There were 7 lower and 14 upper functional abnormalities. Upper dysfunction occurs more often in older patients (average age 57), than in those with lower dysfunctions (average age 49). Upper dysfunction has a high incidence of bilaterality (12 of 14), and none had an anatomical abnormality on the opposite side. In lower dysfunction 5 of the 7 cases had an anatomical abnormality on the opposite side. These findings of bilaterality and increasing incidence with age support the theory of decreasing

FIG. 2 At 3 min contrast may be seen in both sacs. (Ultra fluid Lipiodol) **FIG. 3** In 30 min film, contrast persists in right sac. Left system is empty, indicating normal function

efficiency of the lacrimal pump because of weakening of the orbicularis with age (Jones 1957; Worst 1971).

Table IV Functional abnormalities

Functional abnormality	Case	Age	Other eye	3 min	15 min	30 min
Upper	1	74	LFA	O	O	A
	2	55	Normal	O	A	A
	3	22	Normal	O	O	A
	4	70	UFA	O	A	A
	5-14	22-74	UFA	O	O	O
Lower	1	45	Duct stenosis	B	B	B
	2	64	Stenosis cc	A	A	A
	3	40	Sac stenosis	A	A	A
	4	74	UFA	A	AB	AB
	5	55	Normal	AB	AB	AB
	6	21	Sac block	A	A	Not done
	7	67	Block cc	A	A	A

Discussion

Various methods have been used to determine the transit time from conjunctival sac to nose. Microscintigraphic methods (Carlton and others, 1973)

FIG. 4 3 min film of youth with medial canthal abnormalities bilaterally, with right lower punctum partially in lacus. Contrast is present in sac and duct on left side but not on right. Intubation dacryocystography was normal. (Ultra fluid Lipiodol)

FIG. 5 15 min film shows absence of contrast on right side. On left, upper arrow depicts emptying of sac of contrast, and lower arrow shows the progression down duct. Surgical lid procedure is indicated on right side only

showed that Technetium pertechnetate reached the sac in 4 to 43 s, and the nose in 4 to 323 s (median 43 s). With fluorescein staining of various solutions, it was found (Linn and Jones, 1968) that aqueous solutions pass through in 60 s, 0.25 per cent hydroxymethylcellulose in 90 s, and 2.5 per cent methylcellulose in 255 s. Saccharin can be tasted 5 to 17 min after conjunctival instillation (Lipsius, 1956), while in another paper 40 per cent of the patients could taste it in 3 min, and 90 per cent in 15 min (Hornblass, 1973). Water-soluble contrast medium has a transit time of 3 to 5 min. Iodized oil injected into the sac (Pantopaque) normally leaves it in 15 min (Milder, 1971), and in normal eyes the 30 min film should show the complete system from injection to emptying (Milder and Demorest, 1954).

After the injection of contrast medium (Demorest and Milder, 1955), follow-up radiographs have helped to show up 'functional blocks'. These were cases patent to syringing, with normal cannulation-type dacryocystographs, where there was a delay in transit into the nose as seen on a 30 min follow-up film. 25 to 30 per cent of patients were stated to have 'functional blocks'. We feel that with improved methods of dacryocystography, many of these patients would be shown to have had anatomical abnormalities, and would not be true cases of physiological dysfunction. In addition the determination of function

after injection appraises only the lower part of the system. The method described separates upper from lower functional abnormalities.

It is important to distinguish these cases. Cases of lower functional abnormality ought to do well with dacryocystorhinostomy, whereas this operation would not be expected to help an upper dysfunction. In the latter the treatment would consist of bypassing the system by means of an artificial tear passageway.

In a patient with stenosis, where the progress of contrast is delayed, the development of epiphora depends on other factors, such as tear secretion and the efficiency of the lacrimal pump.

The use of an oily medium, although more viscous, is useful in differentiating normal from abnormal systems.

In all normal patients, the contrast medium entered the system and only in pathological cases with epiphora did it fail to enter. Macrography aids markedly in visualization of the contrast. Postero-anterior views decrease the radiation dose to the lens.

Summary

Functional dacryocystography and intubation macrodacryocystography used together are valuable in assessing the anatomy and function of the lacrimal drainage apparatus.

II. Angiography

In Part I we described the procedure for following by means of serial macro-radiography the progress through the lacrimal passages of a non-viscous oily medium instilled into the conjunctival sac. Although

this test separated 'normals' from 'abnormals' and helped to define and categorize 'functional abnormalities' of the lacrimal system, the medium used had a higher viscosity than tears (25 centipoises). There-

fore, we decided to use a water-soluble medium of low viscosity in this second procedure.

Water-soluble contrast media have been used before for classical cannulation dacryocystography—isopaque (Aarhus and Bergaust, 1969), renographin (Sargent and Ebersole, 1968), urographin (Bartolomé 1972), and other agents (Priegnitz, 1966). Others have used urographin instilled into the conjunctival sac in conjunction with cine-dacryocystography (Epstein, 1961), and also with cannulation dacryocystography (Koszczyński and Nowicka, 1968).

Part II relates a method for assessing the function and anatomy of the lacrimal excretory system using a water-soluble contrast medium. Angiographin (Schering) is used in functional dacryocystography, followed by dacryocystography using ultra-fluid Lipiodol (May and Baker) as described by Lloyd (1973).

Material and methods

Several patients with epiphora attending for dacryocystography had functional studies performed. Various water-soluble contrast media were instilled into the conjunctival sacs and their progress followed through the lacrimal system by serial radiography. Angiographin was found to be the most suitable, as it combined a low viscosity, high iodine concentration, and low incidence of ocular irritation. The patient is placed in an upright position and a control film is taken. A postero-anterior position is used to decrease the radiation dosage to the lens. Two drops of contrast are instilled into each conjunctival sac, and a series of films taken. It was found that films taken at 30 and 90 s provided the most useful clinical information. With a co-operative patient and a head-fixation device, subtraction films may also be obtained. Immediately following this functional DCG, the patient is placed on the table and has an intubation macro-dacryocystography using ultra-fluid Lipiodol (Lloyd, 1973). Twenty-five patients (50 lacrimal systems) were studied in this way.

Results

Of the fifty lacrimal systems studied, thirteen were classed as 'normals', by virtue of their being completely asymptomatic (Table V). The results may be

Table V *Normal systems*

Case	30 s	90 s
1	AB	ABCD
2	A	AC
3	AB	ABCD
4	—	—
5	A	AC
6	A	ABC
7	AB	ABCD
8	A	ABC
9	A	AC
10	A	AC
11	AB	ABX
12	A	AC
13	A	AC

A — contrast in canaliculus and/or sac
B — contrast in duct
C — contrast gone from 'A'
D — contrast gone from 'B'
X — contrast moved down system

Table VI *Abnormal systems*

Case	Diagnosis	30 s	90 s
1-8	Complete sac block	—	—
9	Incomplete sac block	—	—
10-13	Stenosis, cc	—	—
14-22	Obstruction, cc	—	—
23	Calculus of sac	—	—
24-29	Punctal-canalicular obstruction	—	—
30	Trauma to lower canaliculus	A	AX
31	Post-inflammatory lower canaliculus obstruction	A	ABC
32-36	'Upper phys. dys.'	—	—
37	'Lower phys. dys.'	A	A

A — contrast in canaliculus and/or sac
B — contrast in duct
C — contrast gone from 'A'
X — contrast moved down system

seen in Table VI. In every case except one, some contrast could be seen in the area of the sac in the 30 s film. The exception was a 70-year-old patient in whom no contrast was seen in the 30 or 90 s films. She was the oldest patient in the series. Therefore, in all normal cases except one, contrast enters the system and moves partially or totally through it.

Of the systems with anatomical abnormalities (Table VI) eight had sac obstructions, one had an incomplete sac obstruction, four had common canaliculus stenosis, nine had common canaliculus obstruction, and one had a calculus of the sac. In none of these cases did contrast enter the system. In six systems there was gross punctal and/or canaliculus obstruction present. Functional tests were done but again no contrast entered the system. Two systems with lower canaliculus disease (one post-traumatic and one post-inflammatory) showed contrast entry. The post-traumatic case had contrast in the sac at 30 s, which progressed down the sac in 90 s. The post-inflammatory case had contrast in the sac at 30 s and in the duct at 90 s. These two cases presumably had some flow through the patent upper canaliculus.

Six systems of patients with epiphora had normal intubation dacryocystograms, but of these five had negative functional tests indicating a functional disturbance at the 'upper end' (lids-punctum-canalicular) of the system. In the remaining case contrast was present in the sac at 30 s but this showed no progression in the 90 s film, indicating a 'lower end dysfunction' (sac-duct). Examples of angiographin dacryocystograms may be seen in Figs 6 to 9.

Discussion

Angiographin was found to be the most suitable water-soluble medium. It is composed solely of meglumine diatrizoate, in a 65 per cent solution. It does not contain a sodium salt which can escape into the tissues to cause toxic and irritant reactions (Sargent and Ebersole, 1968). It has a relatively high iodine content of 306 mg/ml. The diatrizoate salt was preferred to the other two salts used as contrast agents, namely those of iothalamate and metrizoic acid,

FIG. 6 Intubation dacryocystograms of 14-year-old boy with bilateral ectropion following repair of epicanthic folds. Epiphora is present on right side only. Clinically there is more ectropion on the left side. A duct diverticulum (a normal variation) is present on right, otherwise dacryocystograms are normal

FIG. 7 30 s film shows filling of both canaliculi on left side. No contrast has entered right naso-lacrimal system. (Angiographin)

FIG. 8 90s film shows absence of contrast in right system, and progression of contrast to naso-lacrimal duct on left. A surgical procedure on right lid only is therefore indicated

FIG. 9 This 50-year-old woman with right-sided epiphora had normal dacryocystograms. On 30 s film, no contrast is present on the right side, but there is some contrast in sac on left. The 90s film showed absence of contrast in both systems thereby indicating an 'upper functional abnormality' on the right, and a normal system on left. (Angiographin)

as it is considerably less soluble (Grainger, 1969). Its viscosity is 5.1 centipoises at 37°C which is within the normal range for tears. The viscosity of tears is between 1.312 to 5.875 centipoises, (mean 2.916) Schuller, Young, and Hill, 1972. Conray 280 (4 centipoises) at 37°C with a lower viscosity was also tried but because of a lower iodine content (280 mg/ml), it was not as easy to see.

The first film has to be taken speedily, as there is a movement of tears toward the sac with a blink (Maurice, 1973). Using this material, which is diluted by tears, it was not possible to demonstrate radiologically the contrast in the pharynx. The flow time of water-soluble contrast injected into the sac was 15 to 30 s for Sinografin (Sargent and Ebersole, 1968). Interpretation of the angiographin functional test is greatly assisted by macrography.

Although functional testing with angiographin is a simple test and less time-consuming than using ultra-fluid Lipiodol, it is harder to see the contrast in the

system. The test does help to distinguish normal from abnormal cases in most instances. An irritant conjunctivitis was seen in some of the patients tested.

For the above reasons we prefer to use ultra-fluid Lipiodol in functional testing.

Summary

A functional study of the lacrimal drainage apparatus was made in 25 patients. Angiographin was instilled into the conjunctival sac and serial radiographs were taken. The films were interpreted in conjunction with the intubation macro-dacryocystograms. Although this is a useful procedure, the use of angiographin compares unfavourably with ultra-fluid Lipiodol in a similar procedure.

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References

- AAKHUS, T., and BERGAUST, B. (1969) *Acta radiol Diagn.*, **8**, 369
 BARTOLOMÉ, A. (1972) *Rev. esp. Oto-neuro-oftal.*, **30**, 135
 CALLAHAN, W. P., FORBATH, P. G., and BESSER, W. D. S. (1965) *Amer. J. Ophthalm.*, **60**, 475
 CAMPBELL, H. S., SMITH, J. L., RICHMAN, D. W., and ANDERSON, W. B. (1962) *Ibid.*, **53**, 611
 CAMPBELL, W. (1964) *Brit. J. Radiol.*, **37**, 1
 CARLTON, W. H., TRUEBLOOD, J. H., and ROSSOMONDO, R. M. (1973) *J. nucl. Med.*, **14**, 89
 DEMOREST, B. H., and MILDER, B. (1955) *Arch. Ophthalm. (Chicago)*, **54**, 410
 DOUGHMAN, D. H. (1973) *Int. Ophthalm. Clin.*, **13**, (1), 199
 EPSTEIN, E. (1961) *Trans. ophthalm. Soc. U.K.*, **81**, 284
 GRAINGER, R. G. (1969) *M+B Pharm. Bull.*, **18**, 50
 HENDERSON, P. N. (1973) *Aust. J. Ophthalm.*, **1**, 117
 HORNBLOSS, A. (1973) *Arch. Ophthalm.*, **90**, 435
 HURWITZ, J. J., MAISEY, M., and WELHAM, R. A. N. (1975) *Brit. J. Ophthalm.*, **59**, 313
 IBA, G. B., and HANAFEE, W. N. (1968) *Radiology*, **90**, 1020
 JONES, L. T., (1957) *Amer. J. Ophthalm.*, **43**, 203
 ——— and LINN, M. L. (1969) *Ibid.*, **67**, 751
 KOSZCZYNSKI, Z., and NOWICKA, L. (1968) *Pol. Rev. Radiol.*, **32**, 701
 LAW, F. W. (1967) *Trans. ophthalm. Soc. U.K.*, **87**, 395
 LINN, M. L., and JONES, L. T. (1968) *Amer. J. Ophthalm.*, **65**, 76
 LIPSUS, E. I. (1956) *Ibid.*, **41**, 320
 LLOYD, G. A. S. (1973) *Trans. ophthalm. Soc. U.K.*, **93**, 589
 ——— and WELHAM, R. A. N. (1974) *Brit. J. Radiol.*, **47**, 379
 MALIK, S. R. K., GUPTA, A. K., CHATERJEE, S., BHARDWAJ, O. P., and SAHA, M. (1969) *Brit. J. Ophthalm.*, **53**, 174
 MAURICE, D. M. (1973) *Int. Ophthalm. Clin.*, **13**, 103
 MILDER, B. (1971) In 'The Lacrimal System' by E. R. Viers, p. 81. Mosby, St. Louis
 ——— and DEMOREST, B. H. (1954) *Arch. Ophthalm.*, **51**, 180
 PRIEGNITZ, F. (1966) *Klin. Mbl. Augenheilk.*, **148**, 887
 RAYNAUD, G., PERDRIEL, G., SAIS, J., and MARTIN, H. (1964) *Bull. Soc. Ophthalm. Fr.*, p. 364
 SARGENT, E. N., and EBERSOLE, C. (1968) *Amer. J. Roentgenol.*, **102**, 831
 SCHULLER, W. O., YOUNG, W. H., and HILL, R. M. (1972) *Amer. J. Optom.*, **43**, 1358
 STREET, D. F., and HOWELL, M. H. (1967) *Brit. J. Radiol.*, **40**, 235
 TROKEL, S. L., and POTTER, G. D. (1972) *Amer. J. Ophthalm.*, **70**, 1010
 WORST, J. G. F. (1971) In 'The Lacrimal System', by E. R. Veirs, p. 98. Mosby, St. Louis
 ZAPPIA, R. J., and MILDER, B. (1972a) *Amer. J. Ophthalm.*, **74**, 154
 ——— and ——— (1972b) *Ibid.*, **74**, 160