INVESTIGATION CONCERNING THE LENS CAPSULE

Its importance in the technique of intra-capsular cataract extraction

BY

M. KLEIN

LONDON

IN a previous paper, p. 93, I reviewed the cataract operation, and especially the complications, their frequency and consequences, and arrived at the conclusion that the intra-capsular method is superior to the extra-capsular. I now propose to examine the anatomical and physiological aspects of intra-capsular extraction.

The two delicate phases of an intra-capsular extraction are the dislocation of the lens, and its removal from the eye. Many authorities think that the success of the operation depends entirely upon the strength of the lens capsule in relation to that of the zonule. If the strength of the capsule be greater than that of the zonule, the latter gives way first and the cataract can be removed in the capsule. But when the zonule is stronger than the lens capsule, the capsule opens and only extra-capsular extraction is possible.

This problem is, however, not so simple, and if it is to be completely understood we have to know the finer anatomy of the capsule and zonule, their relation to the vitreous, their physical properties, especially their strength, and finally the changes which occur in these structures in cataractous eyes. Knowledge of the anatomy and physiology of the lens capsule and zonule will help us to appreciate the technique necessary for the operation, as well as the precise rôle played by each instrument.

The lens capsule proper, like Descemet's or Bowman's membrane, is structureless and elastic. Some specimens show striations, which run parallel to the surface and are regarded by some authorities as signs of a lamellar structure. Sometimes, indeed, it is possible to break up the capsule into lamellae by treatment with a solution of pot. permanganate, or 10 per cent. sodium chloride. O. Schulze and O. Becker regard the lamellar structure as a senile change. Normally the lamellae are so firmly cemented together that the lens capsule may be regarded as a homogeneous membrane, and lamellarization takes place only in pathological conditions (E. E. Blaauw).

The lamellae must not be confused with the zonular lamella, which is a very thin and elastic membrane covering the peripheral

parts of the anterior lens capsule, which can easily be separated from it. The zonular fibres are attached to the zonular lamella, and not to the lens capsule proper.

The thickness of the lens capsule is not uniform. The posterior capsule is thinner than the anterior, and in both the central area

FIG. 1.

(From Duke-Elder Textbook, Vol. I. After Fincham.)

(anterior and posterior pole) is thinner than the rest. The maximum thickness of the capsule lies between the equator and the centre concentrically.

The thickness of normal capsules varies with age (Table I, after Salzmann).

The zonular fibres form a meshwork between lens and ciliary body and they arise from the whole area of the ciliary body. The

TABLE I

Thickness of the normal lens capsule in μ after Salzmann

No.	Age	Anterior pole	Maximum of anterior capsule	Equator	Maximum of posterior capsule	Posterior pole
1	14 days	6	8	3	18	2.5
2	2½ years	8	12	7	18	2
3	7 years	8	13	9	17	2
4	9 years	8	15	8	22	2
5	15 years	9	14	14	23	3
6	19 years	12	23	17	26	3
7	23 years	11	18	14	21	3
8	26 years	10	18	10	17	3
9	32 years	12	16	16	21	2.3
10	35 years	14	21	17	23	4
11	36 years	9	21	16	22	3.4
12	40 years	16	22	16	18	3
13	41 years	11	18	18	23	3
14	48 years	11	22	15	28	3.4
15	53 years	14	25	16	23	3
16	56 years	18	23	14	16	3
17	71 years	14	21	9	9	2.3

shorter fibrils coming from its anterior parts pass straight to the lens through the posterior chamber. The longer ones which come from the back of the ciliary body are applied firmly to the vitreous or are embedded in it. On the lens they are attached to the zonular lamella which, as already mentioned, occupies a ring-like area concentric with the equator. The length of the fibres varies, the longest, in adults, may reach a length of 7 mm., the thickness is between 9 and 30 μ , very rarely 40 μ . The thick fibres split up at their two ends into thinner branches. The fibres are not elastic and when relaxed they show no tendency to curl but bend at sharp angles. When stretched they will lengthen considerably before breaking. With advancing age the zonular fibres show certain changes. In young subjects they are very tough, and experiments on young animals have shown that stretching of the zonular fibres may damage the vitreous and ciliary body. In old people the zonular fibres become fragile to such a degree that in cases of senile retraction of the vitreous body the zonular fibres may sometimes be severed spontaneously.

In cataractous eyes both zonule and capsule undergo certain changes. The lens capsule gets thicker. Rötth and Klein have found that capsules of intra-capsularly extracted lenses are considerably thicker than normal ones of corresponding age.

As Table II shows, the *minimum* values of cataractous lens capsules were about the same as the average normal in Salzmann's figures. Cataractous lens capsules are much thicker than normal. The low figures obtained after celloidin paraffin embedding are probably due to shrinkage during preparation.

TABLE II

Thickness of cataractous lens capsules in μ after Rötth and Klein

	Anterior pole	Maximum of anterior capsule	Equator	Maximum of posterior capsule	Posterior pole
<i>Gelatine method—</i>					
Average	24	30	12	10	6
Maximum	32	35	20	22	15
Minimum	12	23	5	6	2
<i>Celloidine-Paraffine method—</i>					
Average	10	15	7	5	2
Maximum	17	21	10	9	4
Minimum	4	6	3	2	1

The changes in the zonular fibres in cataractous eyes consist of diminution of their resistance, with relative increase in their fragility.

The anatomical aspect, however, is not sufficient for the complete understanding of the problem, as it does not give information as to the tensile strength of the capsule and zonule, whether, that is, the thickening of the capsule in cataractous eyes is accompanied by an increase of its strength. In intra-capsular operation success depends on the strength of the capsule, it should not give way during operation. Examination of the tensile strength of the capsule, *i.e.* how great a force is necessary to break it, is a delicate problem.

The only data to be found in the literature about the strength of the capsule are those by Pflugk, who found that in normal human lenses a strip of one millimetre width, cut from the middle parts of the posterior capsule, broke under a pulling force of 1 gram. If a 1 mm. wide strip of the anterior and posterior capsule were tested together the breaking weight was 6-8 grams. Similar values were obtained in lens capsules of pigs' eyes. This correspondence between human and pigs' lens capsules is not surprising, as other tissues of the eye are also similar. In comparative tonometric experiments by Leimke, and distensibility experiments by Ridley, human and pigs' sclerae showed great parallelism. According to Pflugk the breaking point of cataractous lens capsules was below normal, and two grams weight was sufficient to break them when anterior and posterior capsules were tested together.

The method used in Pflugk's experiments was as follows: he cut strips from the middle part of the lens capsule one and two millimetres wide, the tensile strength of which was tested with an apparatus designed for testing the elasticity and tensile strength of threads in the textile industry. This apparatus is very elaborate and gives reliable figures as far as threads are concerned, but for lens capsules (either in whole or part) the method of examination is open to criticism. We have to bear in mind that the lens capsule, the anterior as well as the posterior, is a segment of a sphere, and even the narrowest strip cut from a spherical surface can never be flattened into a plane. If we put into the apparatus a strip of the lens capsule and expose it to a pulling force acting at the two ends of the strip, the distribution of the pulling force will be uneven and thus the figures obtained do not give the true strength of the capsule. Since, however, all these experiments of Pflugk were made in a similar way the error is the same all round and we can accept his conclusion that the tensile strength of the cataractous lens capsule is diminished.

The author's investigation of the strength of the capsule.—It is an important condition in these experiments that the testing

force should be exerted uniformly over the whole area of the capsule. The technique was as follows: The lens capsule (ox eye, pig's eye and human cataractous lens) was very carefully removed from the lens. First a circular incision was made at the equator with a sharp Graefe's knife, after which the anterior capsule was easily removed with the finger tip or a blunt capsule forceps. The lens capsule was then fastened to the end of a piece of glass tubing, the edges of which were rounded. The thread (thick sewing silk) used for tying the capsule to the tubing had to be carefully applied, the capsule being delicate and easily damaged. The glass tubing used with ox lenses had a diameter of 8 mm. (inner diameter 5 mm.), in tests on human and pig's lenses the tubing had an external diameter of about 4.5-5 mm., inner diam. approximately 3 mm. The free end of the tubing was then connected with a system in which the pressure could be increased or diminished (blowing or suction) and the pressure + or - read on a manometer. The manometric reading at the moment when the capsule burst was taken as a measure of the strength of the capsule. For breaking the anterior capsule of ox lenses the figures varied between 1.2-5 atm. pressure. Normal pigs' lenses could withstand a pressure or suction of 500 mm. Hg without breaking. I had no opportunity of examining normal human lenses, but we may assume that the strength is near to that of pigs' lenses. I have tested cataractous human lens capsules, obtained by intra-capsular extraction. Their breaking point was about 150-200 mm. Hg pressure. In these experiments the stress on the capsule was more uniformly distributed than in Pflugk's experiments as in both experiments, pressure and suction the lens capsules took up a spherical shape.

These experiments give some idea how strong this thin and delicate membrane is, and indicate how great a strain it can withstand before giving way. The strength of the cataractous lens capsules is less than that of a normal, but it can resist a considerable strain.

As regards the strength of the zonule, Pflugk had found; in the case of a 1-2 mm. wide strip cut from the zonular network, that the breaking point was at one gram weight. This method of testing the zonule is, however, even more open to objection than his experiments on lens capsules, as the conditions under which the experiments took place were entirely different from those in the living eye.

The conditions in Barraquer's experiments are much closer to those in the eye. He found that at the age of 40 years a 30 gram weight was necessary to break the zonule. The resistance of the zonule diminishes with age, and this is also the case in cataractous eyes. According to Barraquer the zonules of myopic eyes are more fragile than those of hypermetropic eyes.

The relation between lens and vitreous is also very important. If it were true, as suggested by some authorities, that adhesions between lens and vitreous are frequent, intra-capsular extraction would lead inevitably to vitreous loss. In slit-lamp examinations, however, De Saint Martin found that a narrow retro-lental space was present between vitreous and lens in 84 per cent. of adults. The absence of adhesions between lens and vitreous in the great majority of cases makes it possible to perform intra-capsular cataract extractions without damage to the vitreous, and this is confirmed by experience.

The preceding considerations show that the conditions in the cataractous eye are generally favourable for intra-capsular extraction: the capsule is comparatively tough, the zonule fragile, and the lens can be removed without damage to the vitreous.

From a practical point of view the intra-capsular operation has two phases, (1) dislocation of the lens, *i.e.* severing the connection between lens and zonule, and (2) the removal of the loose lens from the eye. In the forceps intra-capsular operation, the first phase, *i.e.* the dislocation of the lens, is done by forceps and squint hook. A small fold on the capsule is gripped with forceps and by careful traction and rotation movements the zonule is *gradually* broken. It is, perhaps not correct to speak of breaking or tearing of zonular fibres, as in most cases of intra-capsular operation the zonule is separated with the zonular lamella. This may be the reason why adherent zonule fibres are rarely found on lenses after intra-capsular extraction.

The separation of the lens from the zonule requires delicate manipulation. By means of a capsule forceps a fold is grasped at the lower part of the anterior capsule (tumbling method), and by pulling the lens in a certain direction the zonule fibres become stretched in the corresponding section. The sclera at the limbus is now impressed over the stretched zonule by means of a squint hook, thus the stress on the zonule fibres is increased. This additional stress together with the traction exerted with the forceps is usually sufficient to break the zonule. If the direction of the traction is for example 7 o'clock, the impression of the limbus is to be made at the same place.

The same procedure is then repeated in different directions so as to separate section by section the zonule from the lens.

Sometimes it may be necessary to combine the traction with a gentle rotation movement.

If the lens is so loose as to move quite freely with minute and cautious manipulation of the capsule forceps, then the second phase of the operation begins, namely the removal of the lens from the eye.

FIG. 2.

The arrow indicates the direction of the traction with forceps. Stretched zonule at VII o'clock. Impression with squint hook at VII o'clock.

The normal position of the lens is in the patellar fossa of the vitreous, and between lens and vitreous there is only a very narrow space, filled with liquid. The extraction of the lens must be done very slowly and gently. If the lens were removed abruptly, by a sudden movement, vitreous prolapse would almost certainly follow, on account of physical adhesion between lens and vitreous. The lens is, so to speak, slid out from the patellar fossa by adroit manipulation of traction and impression movements with capsule forceps and squint hook. When the lower edge of the lens has

been lifted up to the height of the middle of the cornea, there is no need to use any more force. We may abandon the capsule forceps and rely entirely on gentle pressure with a hook, or—as practised by some authorities—the capsule forceps alone may be used without the help of the hook.

There are some technical points which are of importance. The most uniform pull is achieved by the sucking cup methods (Barraquer etc.). It is perhaps this which accounts for the higher percentage of successful intra-capsular operations as compared with the forceps method.

In the forceps method it is important that the forceps should be opened only to 3-4 mm. as otherwise the fold, made by the grip of the forceps, would be large and the capsule becomes over-stretched in certain directions. This may lead to bursting of the capsule. When the fold is relatively small the risk of over-stretching is eliminated.

Much depends also upon the instruments used. If for example the edges of the capsule forceps are sharp it will cut the capsule instead of gripping it; on the other hand if it is too blunt it may slip off and difficulty may be experienced in getting a grip on the capsule.

The skill and practice of the surgeon is obviously an all important factor. With growing experience, the proportion of successful intra-capsular extractions will increase. In Halász' paper the rôle of experience is well demonstrated. At the I. Univ. Eye Clinic, Budapest, in the years 1930-32, when intra-capsular operation was introduced, only 42 per cent. of the attempted intra-capsular operations were successful. In the next two years the figure rose to 51 per cent., and with increasing experience the successful intra-capsular operations in the following year reached the figure 69 per cent.

This figure corresponds with the good average, varying from 60-75 per cent., experienced by different authorities. It appears that about 75 per cent. is the limit which can be expected at present by forceps intra-capsular extraction. Improvement can only be hoped for from new methods of operation. De Saint Martin and others employ the suction cup-forceps combined method. The experiments concerning the strength of the lens capsule, described in this paper, support this combined method, as the suction cup gives a more uniform traction on the capsule than the forceps. But apart from this consideration there are other reasons for the higher percentage of success with the suction cup method. There are some types of cataracts for which the suction cup method is suitable, which are unsuitable for the forceps method. For instance in cases of tumescent cataracts or certain hypermature cataracts, where the forceps slip off, the suction cup can easily get a grip.

In some instances the capsule may be fragile and the forceps, even with the gentlest handling, are liable to tear the capsule, whereas with the suction cup method a firm hold can be obtained without risk of rupture.

In the suction cup-forceps combined method the separation of the lens from the zonule is done by the suction cup. When the lens is loose, the suction cup is removed, and the extraction is completed by forceps and squint hook.

Whether this combined method is the cataract operation of the future, only clinical experience will decide.

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A CASE OF CONJUNCTIVAL IMPLANTATION CYST FOLLOWING OPERATION FOR DETACHMENT OF RETINA

BY

J. R. ASCOTT, M.B., B.S.

M.O., QUEEN MARY'S HOSPITAL, ROEHAMPTON

History.—Male. Age 33 years. November 12, 1940, knocked down by a lorry, unconscious for a few minutes, no immediate ocular symptoms.

About four days later noticed a grey haze over the right eye; this gradually became worse until at times the eye was practically blind.

About four weeks after the accident he reported sick, and detachment of the retina was diagnosed.

December 23, 1940, operation for detachment of retina. No improvement of vision followed. About three months later his wife noticed a swelling under the R. lower lid, and this slowly increased in size during the next few months, not producing any symptoms.

Condition on examination.—August 29, 1941. R.V.: P.L. with —7.0 D. sph. H.M. at 3 metres in lower field. L.V.: 6/18 with —1.25 D. sph. 6/6.