A CRYOTHERMIC CATARACT EXTRACTION TECHNIQUE*

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Cryogenic cataract extraction was first described by Krwawicz in 1961,[1] who performed the operation using a plastic insulated metal applicator, cooled by immersion in dry ice and alcohol. Kellman and Cooper[2] described a series of cataract extractions using a liquid nitrogen system with a vacuum-insulated cannula and freezing tip. These cases were done with a broad iridectomy. Bellows[3] described a small instrument of his own design, containing solid carbon dioxide and also described its use in 6 cases of cataract extraction with broad iridectomy. In one of his cases, the iris was torn.

These instruments and techniques, although applicable to cataract extraction with broad iridectomy, were not considered suitable as a routine safe method for round pupil extraction, because of certain inherent dangers.

Problem of Instrument Design

The major problem associated with round pupil cryogenic cataract extraction was insulation of the iris from the frozen applicator and prevention of accidental iris adhesion to the instrument. In the first few cases, the iris was retracted superiorly with two pairs of iris forceps, one held by the operator and the other by a skilled assistant, and the cryoextractor applied to the lens, taking care not to touch the iris. A large incision was essential for this manoeuvre, but progressive freezing of the lens as the operation proceeded, caused adherence of the lens capsule to the undersurface of the iris, which could not be visualized and resulted in iris laceration in 2 cases. A small retractor made from a bent iris repositor was tried, but this was found to be too narrow to protect the iris from the cryoextractor, even when this was positioned near the centre of the lens. Applying the cryoextractor near the centre of the lens made extraction of the lens more difficult as the lens froze solid, became less malleable and the instrument negotiated the round pupil with difficulty.

When the lens was pulled forward with the cryoextractor applied near its centre, almost all the zonular fibres became stretched simultaneously. These pulled on the ciliary body in a forward direction (which might tear or cause severe oedema of the ciliary body) and on the ora serrata via the posterior orbiculociliary fibres, possibly predisposing to retinal detachment. Another factor thought to be of importance when using this method was that the vacuum present in the hyaloid fossa between lens and vitreous could suck vitreous and the ciliary body, anteriorly. This occurred in the first 10 cases done by this technique, causing vitreous loss in 2 cases and a prolapse of the vitreous through the pupil in another 3, in 2 of which the vitreous touched the endothelial surface of the cornea.

To overcome these drawbacks in the previously documented techniques of cryoextraction, a new technique and appropriate instruments were designed.[4] The iris was retracted from the superior pole of the lens and protected from the cryoextractor by a specially designed retractor. The cryoextractor was applied to the lens at its superior pole and the lens extracted by a sliding technique. In contrast to previously documented techniques,[1,3] no counterpressure was exerted on the limbus, before or during application of the cryoextractor.

The original cryoextractor was constructed of a hollow perspex barrel, 6 in. long and $1\frac{1}{2}$ in. in diameter, open at one end and tapped at the other. This was fitted to a $2\frac{1}{2}$ G hollow, brass point with a large, slanted opening to allow escape of CO_2 gas and to prevent an accumulation of gas, pushing the solid CO_2 snow up the barrel and away from the tip. It had an oval contact surface 2 × $1\frac{1}{4}$ mm. and a small platform which allowed it to be used with the iris retractor *in situ*, and was so designed that the ice that formed on the anterior lens capsule was insulated during the extraction and accidental contact with the iris could thus be prevented. The temperature of this instrument when ready for use was −45°C.

The second instrument was invented by myself and built in collaboration with the Department of Mechanical Engineering of the University of the Witwatersrand.[5] The basic physical principal used is the Joule-Thomson effect, due to the expansion in atmospheric pressure of compressed carbon dioxide gas. A central gas passage constructed from an 18-gauge aspiration needle, silver-soldered to a 25-gauge hypodermic needle, narrowed at the end to three-thousandths of an inch, is used. This is contained in an outer casing constructed from an 18 or 16-gauge needle closed at the end with a plate of silver, two-thousandths of an inch thick and silver-soldered to a hollow copper ballpoint refill. The inner gas passage is connected to the flexible nylon tube, having an outer diameter of one-eighth of an inch and an inner diameter of one-sixteenth of an inch. A thinner tube would have been desirable but was not obtainable in South Africa. The outer gas passage is connected to an exhaust port. The gas passages are housed in a standard 'Bic' ballpoint pen, as shown in Figs. A and B. The nylon tube is connected to a standard

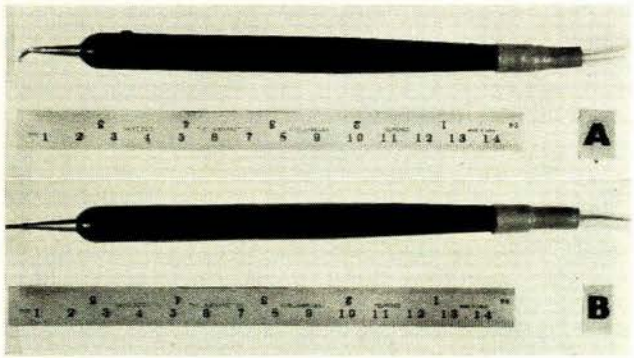

Fig. A. Retinal detachment probe. *Fig. B.* Cataract probe.

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carbon dioxide cylinder via an electric 3-way solenoid valve operated by means of a foot switch.

Immediately the solenoid valve is opened, expansion of the gas commences at the tip and there is an almost instantaneous temperature drop. The temperature at the tip can be varied by allowing incomplete expansion and the present cataract model is constructed to give a temperature of −70°C when in contact with the lens. Immediately the solenoid valve is closed, the gas in the supply line is bled to atmosphere and, as the expansion ceases in the probe tip, the temperature rises. The rise is extremely rapid due to the low thermal capacity of the probe tip and immediate cooling occurs once the gas flow is restarted.

Approximately 100 cataract extractions can be performed, using a 3 lb. cylinder of carbon dioxide, costing 60 cents (85 US cents).

Technique used for a Routine Cataract Extraction

The cases were either performed under local anaesthetic (Van Lint method) with a premedication of Pethidine, Largactil and Phenergan, 3 - 4 hours pre-operatively, or under a general anaesthetic. Oral Diamox was used as a routine, 250 mg. *t.i.d.*, one day pre-operatively and 500 mg. on the morning of the operation. The pupils were dilated with phenyl epherine 10% and guttae homatropine and cocaine in all cases. A fornix base flap was used with a cornea-sclera incision of 180° made with a graefe knife or keratome and scissors. These double atraumatic edge-to-edge blue 6/0 catgut sutures were used with a small peripheral iridectomy in all cases. The cornea-scleral sutures were retracted and the ice guard was inserted, retracting the iris against the scleral tip. Care was taken to ensure that the iris was picked up by the tip of the retractor and did not slip off. The cornea was retracted forward by an assistant as well as a large area of the upper half of the lens in contact with the ice guard and well clear of the iris margin.

The applicator is placed in contact with the lens when it is at *normal room temperature*. The foot switch is depressed and immediately the gas flow commences, freezing occurs. A preliminary small drop of water on the tip of the probe may be used which, by means of surface tension, runs onto the lens capsule and forms a larger contact area that is most useful in cases of hypermature cataracts. After 4 - 6 seconds, adherence to the lens was felt and traction commenced on the superior pole in a vertical direction until the superior pole was dislocated and the iris fell back from the equator of the lens which could be seen as it was delivered. At this stage a rotary movement was commenced with traction parallel to the limbus. The zonule broke easily at the sides and as soon as this occurred, the lens could be slid over the vitreous face with little resistance on the inferior zonular fibres, probably because they were torn by the shrinkage of the capsule. No counterpressure is used at any stage during the extraction in most cataracts, but it has been found of late that in a hypermature lens a little counterpressure helps to ease the lens out more easily.

The retractor was removed after delivery of the lens by carefully lifting it forward and avoiding traction of the iris. The iris was reposited, taking care to free the angle and 5% pilocarpine was instilled into the anterior chamber, air was used to restore the anterior chamber and the conjunctival flap was pulled over the suture line and anchored in position.

The Management of the Dislocated Lens

The very high incidence of severe complications associated with the extraction of dislocated lenses has made most surgeons hesitate to operate in such cases; however, with the introduction of cryosurgery using a controllable probe, operation on such cases can now be undertaken with little risk.

(*i*) *Luxation into the anterior chamber.* Removal of the lens is imperative. In my opinion, strong miotics such as DFP and Humorsol are of little value. The lens requires some form of support and the double-needle operation described by Barraquer[6] and by Calhoun and Hagler[7] is the method of choice especially when combined with cryoextraction of the lens. This needle has the advantage that excellent scleral support is provided during the operation, which greatly helps alleviate vitreous loss.

(*ii*) *Subluxations.* A subluxated lens should be removed if it is a mature or hypermature cataract, if there is evidence of lens-induced uveitis, for optical reasons such as high lenticular myopia or astigmatism or troublesome monocular diplopia or if complete luxation seems imminent.[7] In children with subluxation conservatism is indicated because of the high incidence of vitreous loss, and needling is the method of choice.

(*iii*) *Luxation into the vitreous.* Removal of the lens is indicated if a mature or hypermature cataract is present or where there is lens-induced uveitis. Hypermature cataracts in the vitreous, tend to fragment with a resultant severe uveitis and become fixed to the retina. A large percentage of cases develop glaucoma, the mechanism of which is not fully understood. Chandler[8] believes that such glaucoma is due to pupillary block and advocates iridectomy. However, in the experience of Calhoun[7] as well as myself, removal of the lens from the lower vitreous will benefit the glaucoma. The method of choice in the removal of a lens in the vitreous, is by the use of a double needle and cryoextraction. The lens is trapped by placing the patient in a prone position, floating the lens into the pupillary space and passing the double needle through the pars plana on both sides. Once the needle is in place the patient can be turned into the supine position and the lens removed by cryothermy.

It is essential in all these cases that the probe be applied to the lens at normal temperature and only when contact has been made is freezing commenced. Rapid heating is essential as the probe has often to be applied a number of times before good contact is obtained. This is due to the refraction by the vitreous in front of the lens, disturbing the operator's judgement. Also the iris is often adhered to in such cases and rapid release is imperative. A thin straight probe is desirable as all the operative steps can be easily seen and vitreous loss and iris laceration prevented and accidental adherence of the probe to the sutures released. These features are illustrated in Figs. 1 - 10.

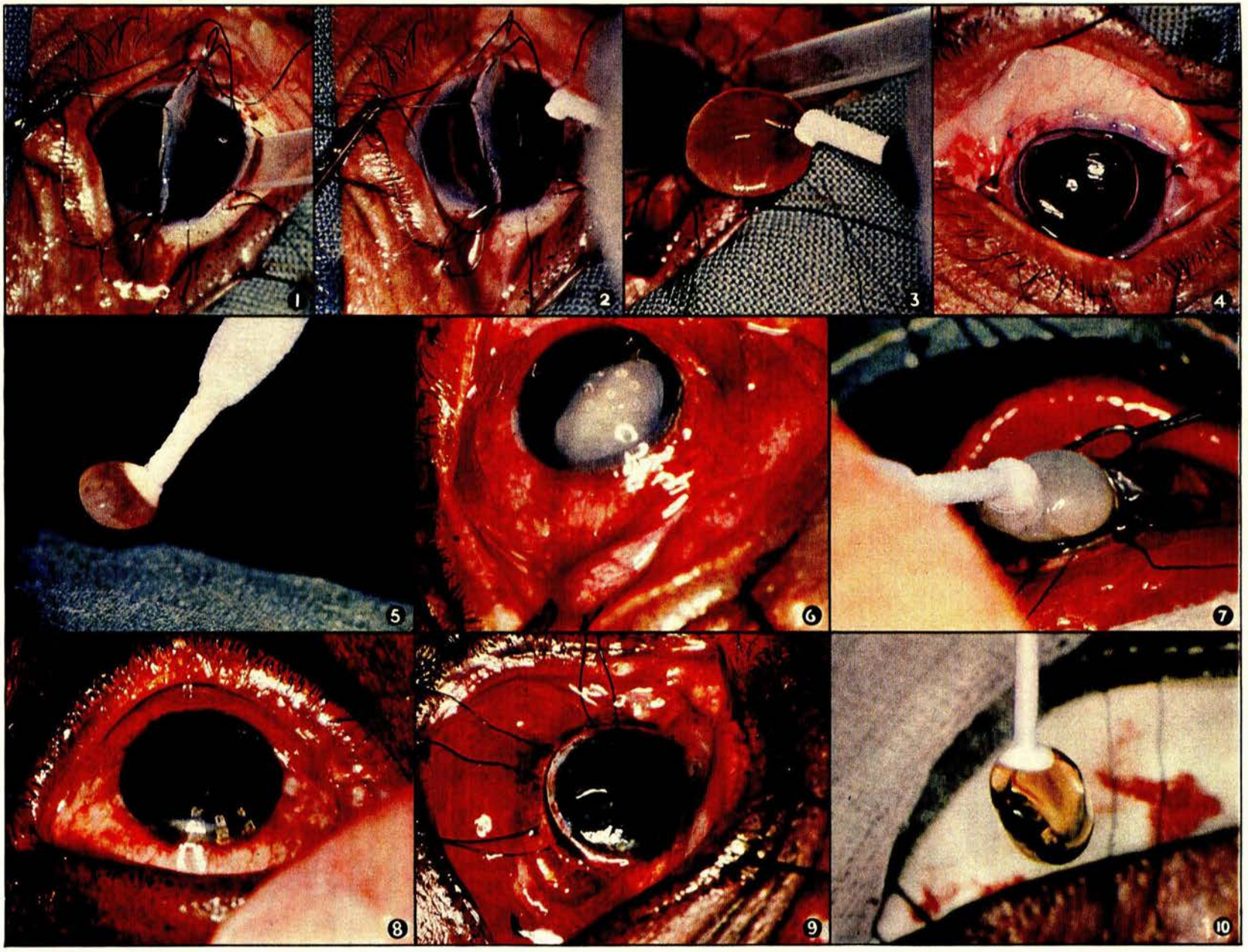

Fig. 1. Retraction of iris with plastic retractor to expose superior pole of lens. *Fig. 2.* Superior polar grip and delivery of upper pole of lens. *Fig. 3.* Delivery of lens showing cryoadhesion. *Fig. 4.* Lens removed. Air in anterior chamber and conjunctival flap pulled over suture line. *Fig. 5.* Cryoextraction of mature cataract showing excellent adhesion. *Fig. 6.* Dislocated lens supported on double-pronged needle. *Fig. 7.* Delivery of above lens. No vitreous loss. *Fig. 8.* Posterior dislocation of lens into vitreous. *Fig. 9.* Lens supported on double-pronged needle. This also prevents ocular collapse and vitreous loss. *Fig. 10.* Delivery of above lens. No vitreous loss. Note strong adhesion to cryoprobe.

Technique used for Dislocated Lenses

These cases were performed under general anaesthesia. Oral diamox was used as a routine, 250 mg. one day preoperatively and 500 mg. on the morning of the operation. A mannitol drip (20%) was used as a routine and the operation only commenced once a diuresis had occurred and the intraocular tension reduced. A Barraquer double-pronged needle was inserted into the pars plana behind the subluxated or anterior dislocated lens and out the opposite pars plana and sclera with the patient in a prone position. Only when the needle was anchored in the sclera over the pars plana was the patient turned into the normal operating position.[9]

A routine fornix-based flap was made and the sclera well thermocoagulated in order to prevent bleeding at a later stage of the operation. A groove situated ½ mm. outside the limbus was made halfway through the sclera. The anterior chamber was cautiously opened with a BP knife and a double-armed 6/0 catgut suture inserted. The wound was carefully enlarged with a Westcott tenotomy scissors and another 2 double-armed catgut sutures inserted. The loops of the sutures were delicately retracted and the cornea lifted to expose the lens.

The probe was slowly introduced into the anterior chamber and placed in contact with the lens. It was a little difficult at times to judge when this had occurred as the vitreous, which was often in front of the lens, caused refraction of the light and interference with gauging of the lens position. When the probe was in contact with the lens the foot switch was depressed, and immediately adherence was seen and the lens extracted. In some cases a small bead of vitreous interposed itself between the probe and the cataract, but this gave rise to no trouble.

Once the lens was being delivered, gentle pressure was applied to the cornea to close the wound behind the lens and prevent vitreous loss. The three 6/0 catgut bridle sutures were pulled up and sealed the wound when the cataract had been delivered. A broad iridectomy was performed as this prevented an undrawn pupil and made easier the visualization and management of retinal detachment should it develop later.

Five cases have been done with a mild vitreous ooze in 1 case. One has only to extract a dislocated lens by this method in order to appreciate the tremendous ease with which this formerly very hazardous procedure can be carried out.

RESULTS

(*i*) *Cataract Extraction*

Thirty-seven extractions were performed with the cryothermic extractor which consisted of a perspex barrel packed with crushed dry ice which cooled a hollow brass tip. Thirty-six extractions have been performed with the new instrument. The total number of cases is 73. Vitreous loss occurred in 3 cases (4·1%). Breakage of the capsule occurred in 2 cases (2·7%). Needlings required were nil, 0%. Flat anterior chamber, 4 cases (5·5%). Hyphaema, 2 cases (2·7%). Torn iris, 2 cases using the old instrument. Keratopathy, 1 case (1·4%).

The most striking feature in these results is the fact that no reoperation was required for capsular remnants and no needlings were performed in the 73 cataract extractions. The incidence of capsular ruptures of 2·7% compares very favourably indeed with the incidence quoted by Lugossy[10] of 11%, using the Arruga forceps or erisophake and of 7% with chymotrypsin added. It must also be noted that in the 36 extractions performed using the new instrument, 13 were of the complicated variety. The incidence of complicated cataracts attempted, utilizing this instrument, was therefore 37% and the results are more significant because of this factor. The 10 complicated cases consisted of 2 with an old iritis and another 2 with an active iritis, 1 phacolytic glaucoma, 2 old trachoma, 1 juvenile cataract in a patient 28 years of age, and 2 cases with pseudo-exfoliation of the lens capsule.

(*ii*) *Dislocated Lens*

In the 5 cases attempted with dislocated lens, there was only a slight vitreous ooze in 1 case, but another case had a severe vitreous haze almost certainly a result of long-standing pre-existing chronic retinitis. It should be noted that 4 of these cases were traumatic in origin and these are the most difficult types to extract as the vitreous face is always ruptured. Only 1 case was a spontaneously dislocated hypermature lens. An intracapsular extraction was possible in all cases.

COMMENT

The advantages of the new cryothermic probe described in this paper are as follows:

1. The instrument is extremely small, light and easily manoeuverable. Its shape being that of a pen is very familiar, as the average surgeon has used such an instrument often.
2. The instrument is connected to a CO_2 cylinder by a very thin flexible tube and this is hardly noticed throughout the operation and does not restrict the surgeon in any way.
3. The dimensions of the probe are extremely small and the present model has a diameter of 1 mm. and if desired, could be made smaller. The probe tip is straight and, therefore, the surgeon can by 'aiming down the barrel' in the same way as a rifle is used, aim the instrument on any specific portion of the lens with great facility.
4. The instrument is placed on the lens in a *warm state* and only when the surgeon is ready, is the foot switch depressed and the gas supply commences. Immediate freezing occurs which ceases instantaneously once the foot switch is closed.
5. Owing to the low thermal capacity of the instrument, there is extremely rapid heating up of the probe without any need for any anciliary electrical device. Iris adhesion and laceration are virtually impossible.
6. Because of the constant enthalpy of the CO_2 gas associated with a fixed nozzle diameter and a fixed position of the nozzle in the hollow probe tip, the tip temperature can be calculated and does not vary.
7. The iceball size can be varied by altering the nozzle diameter. With a smaller diameter the flow of coolant is decreased.

SUMMARY

The technique of cryoextraction using a superior polar grip and iris retraction first described by myself[4] has been improved. A new instrument working on the Joule-Thomson principle, using the expansion of compressed CO_2 gas has been invented. The instrument has numerous inherent advantages and, because of its small size and versatility, should prove of certain value in ocular cryosurgery. It is the first cryoprobe which can be applied to the lens at ambient temperature (room temperature) and has almost instantaneous freezing and rewarming characteristics. Iris adhesion and laceration are virtually impossible. The value of this instrument in the extraction of dislocated lenses has been confirmed by the ease with which these can be extracted and the absence of complications. The extremely low incidence of capsular ruptures of 2·7% is of great significance and the fact that no reoperations were required for visual results in 73 cases, is of even greater significance. It is felt that, with more experience, the capsular rupture figure can be decreased well below the figure of 2·7%.

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