apprehension and muscular tension is not only present in highly nervous patients but may also occur in those who know something of the operative details, such as doctors and nurses. In war surgery general anæsthesia has to be induced, for the psychic trauma of recent battle is too much for local anæsthesia to be accepted by the wounded soldier, at least at the field hospital level, and indeed many of the eyes are too severely injured for local anæsthesia to be effective.

So the choice of either a general or a local anæsthetic for intraocular operations must be made after careful consideration of all the relevant facts about each patient's general condition, mentality and behaviour. For intraocular operations it is essential to take any step which will prevent the serious hazard of vitreous loss, a disaster which not only endangers the prospect of visual recovery in the operated eye but may also be a factor associated with the catastrophe of sympathetic ophthalmitis. Also, after operation it is desirable that there should be no nausea, retching, vomiting or restlessness which might reopen the incision and induce prolapse of the intraocular contents. In operations under local anæsthesia measures have therefore to be taken which will promote both mental and physical relaxation of the patient. It is well known that physiological relaxation is incomplete without muscular relaxation.

Good anæsthesia, either local or general, is essential to save sight; bad anæsthesia may be disastrous. It is therefore of immense importance that a competent anæsthetist, trained to appreciate the hazards of intraocular operations, should give the general anæsthetic and supervise basal narcosis when such is indicated; otherwise local anæsthesia is the safer course. It is also important for the eye surgeon to have an adequate knowledge of the action of various anæsthetics and know what to do in an anæsthetic emergency.

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General Anæsthesia in Ophthalmology

Ophthalmic surgery, in particular cataract extraction, has favoured local anæsthesia for reasons based on history, tradition and even prejudice. Developments in operative technique have contrived to make the operation safer and smoother, as indeed has modern anæsthesia which also renders the patient oblivious of the whole procedure. With local anæsthesia the surgeon may be distracted from the operation by the patient's discomfort or restlessness. Snow & Sensel (1966) have even recorded a death under local anæsthesia for cataract extraction; this death, they maintain, could have been avoided if pulse rate, blood pressure and respiration had been monitored.

This paper outlines the technique of general anæsthesia employed in a small personal series of 70 cases of cataract extraction. The effects of suxamethonium on ocular dynamics will also be reported and reference made to straining and intraocular pressure.

Patients were carefully assessed prior to operation, attention being paid to disease and to such drugs as hypotensive agents, diuretics, digitalis, anticholinesterases and tranquillizers. The average age in this series was 70 years and there was a high incidence of poor risk patients: 6 were being treated with digoxin and diuretics, 10 had hypertension, 4 were diabetics on hypoglycæmic agents, 5 had chronic bronchitis, one had gross emphysema and another a thoracoplasty. There was also one patient with myotonic dystrophy. Three patients were persistent smokers.

Premedication consisted of pethidine, promethazine (25 mg of each) with 0·6 mg atropine. Anæsthesia was induced slowly with thiopentone and suxamethonium and the larynx sprayed with 2 ml of 4% lignocaine: intubation was performed with sterile nonlubricated Oxford or flexometallic tubes. Anæsthesia was maintained with nitrous oxide, oxygen and halothane with spontaneous respiration. Blood pressure and pulse rate were monitored at frequent intervals. At the end of operation the pharynx was always inspected for secretions, which were removed by suction; otherwise they would be cleared by coughing. The endotracheal tube was removed under deep anæsthesia.

Recovery from anæsthesia was reasonably rapid and the patients were gradually sat up. Sedation was usually with promethazine and small doses of pethidine for pain. On the day following operation, mild sedation was with promazine 25–75 mg per day.

Complications: There were no complications at operation. Late complications included 2 instances of pulmonary embolism, one pulmonary collapse, one hyphæma and 2 cases of iris prolapse. Pulmonary embolism occurred in one case on the fifth, in the other on the seventh day:

one of them, a man aged 82 with pre-existing hypertension and cardiac arrhythmias, developed cardiac failure after the pulmonary embolus but responded to digoxin and diuretics; three days later his iris prolapsed. Hyphæma occurred in the patient with gross emphysema. Pulmonary collapse occurred in a frail patient of 70 years: response to antibiotics was satisfactory. Vomiting was protracted in only one patient. Explosive-like coughing occurred in one patient with a very irritable tracheobronchial tract as the endotracheal tube was being removed. In neither instance were these effects detrimental.

Suxamethonium

The effects of suxamethonium on the extraocular muscles have been studied at operations for the correction of strabismus. The muscle to be resected or recessed was detached near the insertion and connected with full sterile precautions by means of a wire weighing 0·2 g to a microforce transducer (Sanborn FTA–100–1). The signal was amplified by means of a Sanborn carrier amplifier (350–1100 CM) and the output displayed on a meter. Also a continuous recording was obtained by connecting the output to a Mingograph 24 B with appropriate resistors in circuit.

Frequent measurements of intraocular pressure (IOP) from the opposite eye were made with a Schiøtz tonometer using 5·5 g and 7·5 g weights. The average of these was taken.

Premedication of these patients consisted of varying doses of pethidine, promethazine and atropine. Induction was with cyclopropane for children and thiopentone for adults. Anæsthesia was maintained with nitrous oxide, oxygen and halothane. Suxamethonium was omitted for intubation. The effects of premedication and anæsthesia on the results have not been excluded.

The head was fixed to the operating table, as slight movements and respiration distorted the records. The test drug was usually injected into a vein on the back of the hand and during the period of apnœa artificial ventilation was given. This investigation placed no additional hazard on the patient save for an increase in operating time.

Results: Tension of the extraocular muscles after suxamethonium has been studied on 15 occasions. A pilot study of the first 3 patients showed an increase in tension after the drug and these are not reported here.

Case 1 D B

The lateral rectus was detached and pre-loaded with 20 g of tension. Within 25 seconds of the injection of 25 mg suxamethonium the tension had risen by a further 20 g. This fell to +14 at 40 seconds, to +10 at one minute and at three minutes was +8. At five minutes it was only +2 g. Respiration ceased at 40 seconds and returned at three minutes (Fig 1). A further injection of 20 mg produced a similar though less pronounced effect.

Case 2 H K

The lateral rectus was not pre-loaded; 25 mg suxamethonium produced a rise of tension within 20 seconds to 14 g. There was still some residual pressure at ten minutes. Apnœa started at 50 seconds and lasted for three minutes. The IOP rose from the resting value of 14·6 to 17·2 mmHg and had reached a value below resting (13·8) at four minutes.

Case 3 M W, man aged 36

The lateral rectus was pre-loaded with different weights. With 40 g there was a further rise in tension of the muscle of 24 g but with a pre-load of 20 g the

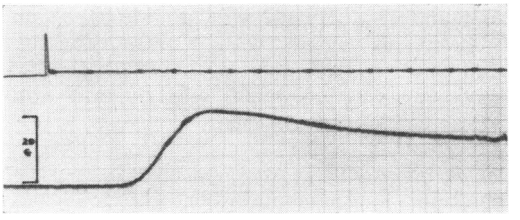

Fig 1 **Case 1** *Effect of suxamethonium on extraocular muscle tension. Upper trace indicates time of injection of suxamethonium. Lower trace tension of extraocular muscle. Calibration = 20 g. Paper speed 0·25 cm/sec*

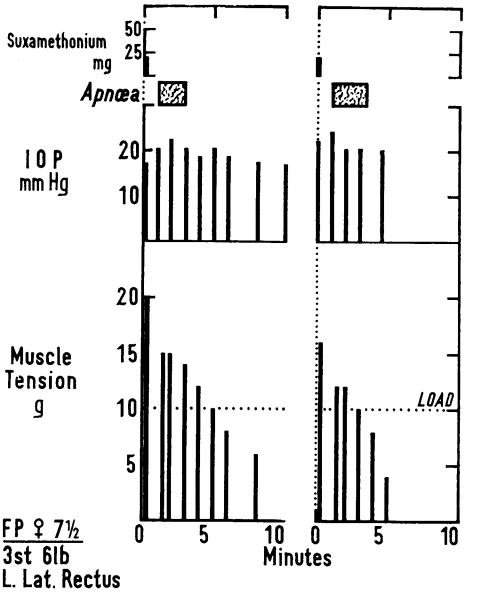

Fig 2 **Case 4** *Effect of suxamethonium on muscle tension and IOP*

rise was only 16 g. The dose of suxamethonium on both occasions was 20 mg. The reduced effect may be related to the fact that it occurred after the second injection. IOP rose by 5 mmHg on both occasions but had returned to control value by eight minutes.

Case 4 F P, girl aged 7½
The lateral rectus was pre-loaded with 10 g; 20 mg suxamethonium on two occasions produced rises in muscle tension of 20 g and 16 g respectively and lasting for ten minutes. The IOP rose from 17·3 to 20·6 mmHg within one minute of injection and had returned to control level at eight minutes. On the second occasion the IOP only rose by 2 mmHg and fell below base line at two minutes (Fig 2).

These experiments demonstrated the rapid increase in muscle tension after the injection of suxamethonium and the increase in IOP. The tension rise began before the onset of apnœa and was still present when respiration returned. Intraocular pressure returned to control levels before muscle tension. Suxamethonium did not reduce muscle tension in extraocular muscle as might well be expected from a drug which produces paralysis.

An attempt was made to see if decamethonium, another depolarizing relaxant, would have less effect on the parameters measured.

Case 5 E E, woman aged 48
Decamethonium, 5 mg, raised the tension of the inferior rectus which was pre-loaded with 20 g by 14 g. The effect came on within 25 seconds and lasted for 24 minutes. The IOP was elevated for only a short time. Apnœa lasted for 20 minutes which was within the normal range for this drug which is longer acting than suxamethonium (Fig 3).

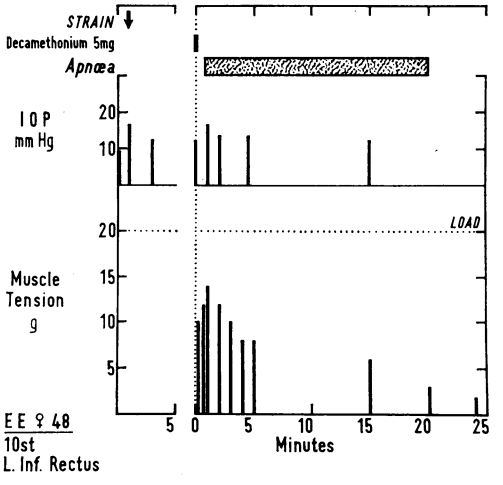

Fig 3 **Case 5** *Effect of decamethonium on muscle tension and IOP*

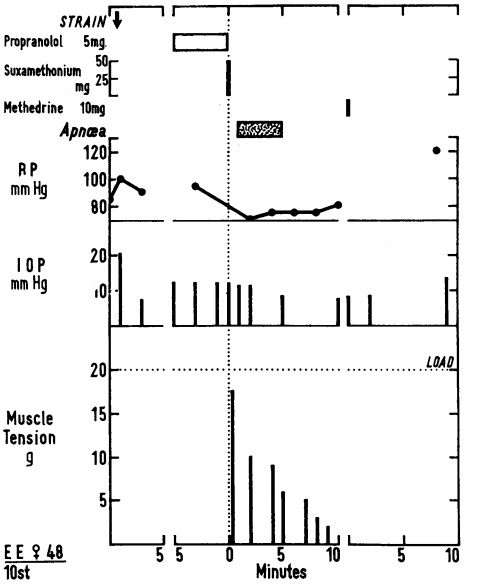

Fig 4 **Case 5** *Effect of propranolol and suxamethonium on muscle tension and IOP*

This patient presented on a later occasion for further treatment to the inferior rectus muscle which was pre-loaded with 20 g. A beta-adrenergic blocking agent, propranolol, was administered in a dose of 2 mg over a period of five minutes. This reduced the blood pressure and the IOP. Suxamethonium in a dose of 50 mg produced a rise in muscle tension of 17 g, returning to base line at nine minutes. The IOP did not rise and in fact even fell below control level. At the end of the operation, the blood pressure and IOP were still low. Methylamphetamine 10 mg given over a period of ten minutes raised the blood pressure from 80 to 120 mmHg and the IOP from 8·8 to 13·8 mmHg (Fig 4).

Tubocurarine has been used prior to suxamethonium in the belief that it would prevent the rises in IOP produced by the latter drug. This was assessed in three patients.

Case 6 F D, aged 3. Weight 33 lb (15 kg)
Tubocurarine, 4 mg given slowly, produced a slight fall in IOP and muscle tension of the medial rectus which was pre-loaded with 20 g. Suxamethonium, 15 mg, caused a marked rise in IOP from 19·5 to 27·4 mmHg returning to normal at five minutes. Muscle tension rose to 16 g and fell to base line at seven minutes. The onset of apnœa was not delayed and respiration returned at four minutes.

Case 7 J T, man aged 31. Weight 178 lb (81 kg)
The administration of 10 mg Tubarine caused a small fall in IOP. The injection of 50 mg suxamethonium caused a rise in IOP which lasted for three minutes, while the tension in the medial rectus, which was preloaded with 20 g, rose to 15 g and returned to base line at ten minutes (Fig 5).

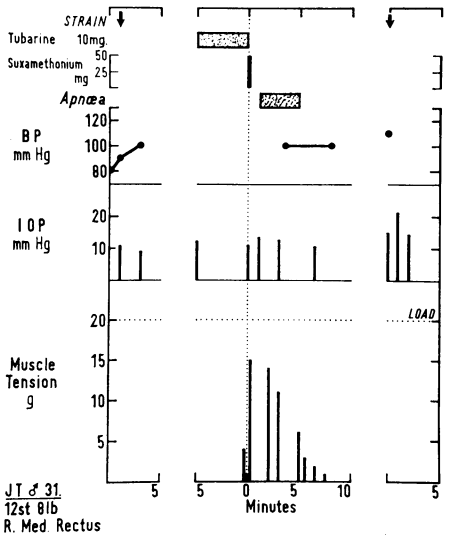

Fig 5 Case 7 *Effect of Tubarine and suxamethonium on muscle tension and IOP*

Case 8 L R, aged 22. Weight 168 lb (76 kg)
The administration of 10 mg tubocurarine caused a reduction in IOP from 21·2 to 17·9 mmHg. With the injection of 50 mg suxamethonium, this returned to resting level without further increase. The tension of the lateral rectus, which was pre-loaded with 20 g, rose 7 g returning to base level at five minutes. The blood pressure during the injection of the muscle relaxants varied from 80 to 90 mmHg.

The Effect of Strain on Intraocular Pressure
The effect of straining on IOP was measured at convenient times during these operations, and though the IOP did rise markedly, it was of short duration.

In Case 5 straining raised the IOP from 9·5 to 16·5 mmHg but this had returned to 12·6 mmHg after 2 minutes (Fig 3). At her second operation, intubation under light anæsthesia produced straining. The blood pressure rose from 85 mmHg to 100 mmHg and settled at 90 mmHg. The IOP rose from 5 to 21 mmHg but within 2 minutes had reverted to 10·5 mmHg (Fig 4).

In Case 7 a rise of IOP was noted during intubation from 9 to 10·8 mmHg but lasting only one minute. During extubation, when the tube was deliberately removed under light general anæsthesia, the IOP rose from 15·1 to 21·2 mmHg but fell to 14·5 mmHg after one minute (Fig 5).

Changes in intra-abdominal pressure may be measured by means of a tube inserted into the lower bowel. Straining, coughing and sighing were demonstrated by this means from normal patients at rest. The effect on IOP must have been equally marked.

A summary of the effects of the various drugs on IOP and muscle tension is shown in Tables 1 and 2.

Discussion
70 consecutive cases of cataract extraction have been presented. Many of the patients were poor risks but with careful pre-operative assessment, meticulous anæsthetic management and attentive post-operative care complications were minimal. There were no complications at operation and the late complications could reasonably be ascribed to pre-existing disease. Pulmonary embolism in a patient aged 84 years with cardiac arrhythmias would not be unexpected even without operation. Hyphæma occurred in the patient with gross emphysema while pulmonary collapse was the result of sedation in a frail old lady of 70 years of age. No ophthalmic complication developed in the patient who had violent coughing at extubation or in the patient who vomited. Three patients who could not resist the temptation to return to smoking by the third post-operative day had excellent operative results.

General anæsthesia can provide conditions for the surgeon to work unhurriedly in a relaxed atmosphere while at the same time safety and comfort are offered to the patient. With endotracheal anæsthesia control of ventilation is assured and the anæsthetist is freed to monitor pulse rate, blood pressure, respiration and if necessary the electrocardiogram.

Techniques involving deep sedation may be dangerous in patients with muscle disease. One patient with myotonic dystrophy in this series was anæsthetized with only atropine as premedication followed by 150 mg thiopentone, nitrous oxide, oxygen and halothane via an endotracheal tube. No relaxant was necessary and sedation was limited to codeine. These patients are very prone to the respiratory depressant effects of sedation and mortality at operation is high (Kaufman 1960).

Snow & Sensel (1966), who advocate local anæsthesia, reviewed 1,000 cases of cataract extraction. There were 36 cases of hyphæma, 34 of coughing and vomiting, 6 of vitreous loss, one of iris prolapse and 4 of retrobulbar hæmorrhage. Pöntinen *et al.* (1966) have reported the use of neuroleptanalgesia with fentanyl and dehydrobenzperidol supplemented in some instances with general anæsthesia and in some with local anæsthesia. The intraocular pressure was

Table 1

Intraocular pressure (mmHg) after administration of suxamethonium

Case No.	*Subject*	*Control*	*Tubarine*	*Time after administration (min)* 1	2	3	4	5	6	7	8
2	H K	14·6		17·2	17·2		13·8		11	11	
6	F D	20·2	19·5	27·4	23·7			18·5			18·5
3	M W	15·1			20·6	20·6	20·3			18·7	13
3	M W (2)	13		18·1	16·4	15·8		13·8		11	
4	F P	17·3		20·6	22·5	22·5	20·6	19			17·3
4	F P (2)	22·5		24·4	20·6						
5	E E Decamethonium	12·6		16·4	13·8						12·7
5	E E Pronethalol	12·6		11·5	11·6			8·6	8·6		8
7	J T	12·1	11	13·8		12·7				10·5	
	P H										
	B E	15·8		12·6	13·2						11·5
	B E (2)	11·5		13·6			12				
1	D B										
	A L	12·2		20·6	24	20·8	14·6				
8	L R	21·2	17·9	20·4		21·2	19·6				

Table 2

Extraocular muscle tension (g) after administration of suxamethonium

Case No.	*Subject*	*Tubarine*	*Time after administration (min)* <1	1	2	3	4	5	6	7	8	9	10	20
2	H K		12	14			10	8	6	5			4	
6	F D	−2	16	11	8		4	4		2			0	
3	M W		24				10	8		4			0	
3	M W (2)		16			8		5		2			0	
4	F P		20	15	15	14	12			8			2	
4	F P (2)		16	12	12	10	8	4					0	
5	E E Decamethonium		12	14	12	10	8	8		6				2
5	E E Pronethalol		17		10			9	5	2			0	
7	J T	4	15	14		11		6	3				1	
	P H		10	0										
	B E		20	10				6	4	2			0	
	B E (2)		12		6		6			0				
1	D B		20	12	10	10	8	6	4	2			0	
1	D B (2)		16	14	10		8			6			2	
	A L		10	10	0									
8	L R	0	7	8	6	4	1	0						

reduced but the pupil tended to be small. Of 137 cases reported, 7 developed prolapse of the iris or vitreous, and this occurred even when local anæsthesia was used. With spontaneous respiration there was a high incidence of cardiac arrhythmias while slight overdose of the drugs resulted in profound respiratory depression with elevated carbon dioxide tensions. Even when combined with general anæsthesia, the neurolept drugs gave minimal warning signs of lightening of the level of anæsthesia. A drawback of local anæsthetic techniques is the failure to guarantee success on every occasion while monitoring of vital signs is often absent, patient care being delegated to the nursing staff.

The use of suxamethonium and the problem of straining are two aspects of general anæsthesia for cataract extraction which the surgeons have viewed with alarm. These have been studied in this investigation.

Suxamethonium, a depolarizing muscle relaxant, usually stimulates the end-plate region of muscle before producing paralysis. However, its effect on eye muscle is rather different. Breinin (1962) has shown in man that it causes contracture of the extraocular muscles. Contracture implies an increase in muscle tension without electrical activity and is believed to be due to stimulation of the slow muscle fibres (Eakins & Katz 1965). We have shown the rise in tension of the extraocular muscles and its rapid onset, which preceded respiratory paralysis and outlasted the period of apnœa. With this rise in muscle tension, suxamethonium caused a rise in intraocular pressure but the effect was short lived, probably due to the expression of fluid from the anterior chamber. Muscle tension had reached control level after ten minutes and it would therefore appear quite safe for suxamethonium to be used during induction of anæsthesia to assist intubation. Its use should perhaps be avoided during operation and for extubation.

Maier & Clark (1965) have advocated decamethonium, also a depolarizing relaxant which has a longer action on respiration than suxa-

methonium. It elevated the IOP in only 3 of their series of 30 patients. In view of the findings that the muscle tension was still elevated at twenty minutes there seems to be little advantage for its use.

Carballo (1965) has used acetazolamide to prevent the rise in IOP after suxamethonium but the rise even in the control series had returned to normal within five minutes and its use seems hardly necessary.

We failed to prevent the rise in tension of the extraocular muscles induced by suxamethonium by the prior administration of tubocurarine; the intensity and duration were unaffected and its use is unnecessary. There was a slight fall in IOP, which may be related to the fall of blood pressure that occurs when tubocurarine is given in the presence of halothane.

Eakins & Katz (1966) have proposed an adrenergic mechanism in the response to suxamethonium of the extraocular muscle in the cat. With a beta adrenergic blocking agent they reduced the response to the relaxant though larger doses sometimes increased the effect; the dose used was 2·5–10 mg/kg which is far in excess of that used in clinical practice. We gave 2 mg to a man weighing 140 lb (64 kg) with a resultant drop in blood pressure to 70–75 mmHg. The effect on muscle tension induced by suxamethonium was unmodified. There was an initial slight fall in IOP which fell more as the relaxant wore off: this fall appears to have been related to the fall in blood pressure and it only rose again when the latter was restored to 120 mmHg with the aid of methylamphetamine. IOP has been shown to depend on the level of blood pressure by Edridge (1963) and Adams & Barnett (1966).

With modern improvements in ophthalmic technique in cataract extraction and the use of sutures, the demands on anæsthesia have probably been overstated. Straining with the open eye is still a tragedy but in the post-operative period it does not appear to influence the outcome unless it is violent and prolonged. We have shown, during studies on squint operations, that when straining was deliberately induced there was a rise in blood pressure and IOP but the duration was short. Furthermore it has been shown that straining, coughing and sighing occur in the normal resting subject and are not the prerogative of the ophthalmic patient subjected to endotracheal anæsthesia.

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General Anæsthesia for Ophthalmic Surgery?

A tranquil field with controlled intraocular pressure is required both during and after ophthalmic surgery. As yet, we are uncertain how to attain these conditions invariably, for only recently has research begun to show interactions between the general physiology and the eye. In addition to our incomplete understanding of this interplay we have inherited dogma and shibboleths from the past and, as a result, we may submit our patients to painful or frightening experiences in the name of ophthalmic anæsthesia. Local anæsthesia, local anæsthesia combined with sedation and general anæsthesia are all employed for eye surgery; since none of these is without objective disadvantage or hazard, it is arguable that the method we select should be that which gives the least subjective discomfort to the patient.

Local anæsthesia: This method can achieve superb results when employed by a meticulous and kindly surgeon. The most cogent objection to its use, retrobulbar hæmorrhage, probably occurs in under 3% of patients (Hill *et al.* 1963) but there is a greater frequency of discomfort associated with the technique. Infiltration anæsthesia is commonly painful, blockade is not always complete and it is difficult for many patients to remain still throughout surgery.