Intraocular pressure rebound

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Hyperosmolar solutions and digital massage are frequent adjuncts employed to minimize vitreous loss at cataract extraction (Scott, 1962; Virno, Cantore, Bietti, and Bucci, 1963; Murray and Tipler, 1966; Guyton, 1954; Kirsch and Steinman, 1955). The former is effective in reducing vitreous mass during the time interval usually necessary to complete a lens extraction, but the latter may not have great value in this regard. In rabbit experiments in the closed eye, within 5 minutes of the completion of massage, vitreous weight has reached its baseline (Obstbaum, Robbins, Best, and Galin, 1971). In patients, intraocular pressure has usually reached its lowest level within 15 minutes of the completion of 5 minutes of digital massage. In the open eye also, previous massage does not increase the vitreal water loss that occurs after simply opening the rabbit eye (Galin, Robbins, and Obstbaum, 1971).

Since the application of digital massage and the administration of hyperosmolar therapy are often carried out together, a study was initiated to determine if hyperosmolar vitreous dehydration could offset the phenomenon of compression vitreous rebound in rabbits.

Materials and methods

New Zealand albino rabbits of approximately 3 kg. were the experimental animals. Anaesthesia was effected with intravenous sodium pentobarbitol, 30 mg./kg. Vitreous weights were determined by a freezing technique which has been described elsewhere (Robbins and Galin, 1969). Essentially the method consists of enucleating the globes, freezing them with dry ice, dissecting the outer coats, and isolating the frozen vitreous spheroid. The vitreous masses are then weighed to within milligram accuracy.

Ten control animals were anaesthetized and both globes were enucleated and treated as above. In various groups of experimental animals digital massage was applied to one eye for 30 seconds and released for 2 seconds, the total massage periods varying from 1 to 10 minutes. Intraocular pressures were measured with a Schiötz tonometer calibrated for the rabbit eye at the end of each massage period and the eyes were then enucleated and appropriately handled (Robbins and Galin, 1969).

An aqueous solution of 20 per cent. mannitol, 2 g./kg., was rapidly infused into an ear vein after one eye of a group of rabbits was enucleated. The second eye was enucleated 60 minutes after the infusion terminated, and both eyes were frozen and ultimately dissected. Additionally, a group of rabbits underwent bilateral enucleation and processing 60 minutes after a mannitol infusion. Baseline and post-treatment intraocular pressures were also obtained. An additional group of animals underwent mannitol infusion as above, followed by 5½ minutes of digital massage before enucleation. The control eyes were enucleated either before the infusion or 60 minutes after the termination of the infusion, just before uniocular digital massage.

In another group of rabbits, compression of the eye for 5½ minutes was accomplished with 50 g. applied to the cornea with a Bailliart ophthalmodynamometer. The experimental eyes were enucleated at progressive time intervals after the termination of compression. Similar experiments were conducted in which ophthalmodynamometric compression was initiated 60 minutes after the termination of a mannitol infusion.

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Results

Table I lists the control vitreous weights in ten rabbits. The vitreous masses differ in weight by an average of only 0.22 per cent., indicating that one eye may readily be used as a control for the treated fellow eye.

Table I *Vitreous weights in control animals measured by a freezing technique*

Rabbit No.	Vitreous weight (g.)		Per cent. difference
	Left	Right	
1	2.040	2.032	0.39
2	1.778	1.780	0.11
3	1.850	1.846	0.22
4	1.586	1.582	0.25
5	1.340	1.345	0.37
6	1.893	1.896	0.16
7	1.374	1.379	0.36
8	2.009	2.007	0.10
9	1.540	1.540	0.00
10	2.072	2.068	0.19

Average weight variation = 0.22 per cent.
SD = 0.12 per cent.

Fig. 1 records the intraocular pressure change and the vitreous weight change resulting from ocular digital massage. It should be noted that the vitreous initially gains weight and then progressively decreases in weight with continued massage. All measurements were taken immediately after the massage so that no vitreous "rebound" was noted.

FIG. 1 *Influence of various periods of digital massage on intraocular pressure and vitreous weight*

Table II lists the effects of mannitol therapy in reducing intraocular pressure and, concomitantly, vitreous mass. In all cases, comparison between the treated eye and the untreated fellow eye shows mannitol inducing a distinct reduction of vitreous mass accompanying the fall in pressure.

Table III lists the intraocular pressures and vitreous weights 60 minutes after the completion of a 20 per cent. mannitol infusion. It is clear that hyperosmolar therapy reduces vitreous weight and does so in essentially equal degree to both eyes. Table IV records the effect of 5½ minutes of digital massage initiated 60 minutes after a 20 per cent. mannitol

infusion on intraocular pressure and vitreous weight. It should be noted that in the unopened eye the vitreous weight reduction induced by hyperosmolar therapy is augmented by digital massage if measured immediately after massage.

Table II *Vitreous weight and intraocular pressure reduction induced by hyperosmolar mannitol*

Rabbit No.	Vitreous weight (g.)		IOP decline with mannitol (Schiotz units 5.5 wt)	Per cent. weight loss with mannitol
	Untreated eye	After mannitol		
11	1.638	1.572	3.0→12.5	4.03
12	1.720	1.653	3.0→11.5	3.90
13	1.683	1.620	3.5→12.0	3.74
14	1.506	1.452	3.0→12.0	3.58
15	1.908	1.834	4.0→14.0	3.88

Average weight loss = 3.83 per cent. SD = 0.15 per cent.

Table III *Comparison of vitreous weight and intraocular pressure change induced by hyperosmolar mannitol in both eyes of the same animal*

Rabbit No.	Right		Left		Per cent. weight change Right v. Left
	Vitreous weight after mannitol (g.)	IOP change with mannitol (Schiotz units 5.5 wt)	Vitreous weight after mannitol (g.)	IOP change with mannitol (Schiotz units 5.5 wt)	
16	1.600	3.0→11.0	1.598	3.0→10.5	0.13
17	1.540	3.5→10.0	1.530	3.5→10.0	0.65
18	1.810	4.0→11.5	1.812	4.0→11.0	0.11
19	1.747	3.0→10.0	1.743	3.0→10.0	0.23
20	1.928	3.5→12.5	1.934	3.0→13.0	0.31

Average weight variation = 0.29 per cent. SD = 0.14 per cent.

Table IV *Influence of digital massage on vitreous changes induced by hyperosmolar mannitol*

Rabbit No.	Mannitol alone			Mannitol and massage				Per cent. weight loss from massage
	Vitreous weight(g.)	IOP changes (Schiotz units, 5.5 wt)		Vitreous weight(g.)	IOP changes (Schiotz units, 5.5 wt)			
	After mannitol	Before mannitol	After mannitol	After mannitol and massage	Before mannitol	After mannitol	After mannitol and massage	
21	1.839	4.0	10.0	1.777	4.0	10.0	14.0	3.36
22	1.954	3.5	9.5	1.912	3.5	10.0	16.0	2.15
23	1.640	4.0	11.0	1.593	4.0	10.5	17.0	2.86
24	1.556	3.0	10.0	1.519	3.5	9.5	15.5	2.38
25	1.677	3.0	10.5	1.636	3.0	10.0	17.0	2.44
26	2.065	3.5	9.0	1.998	3.5	9.0	16.0	3.24
27	1.470	3.5	11.0	1.410	3.5	10.5	18.0	4.08
28	1.870	4.5	9.5	1.830	4.5	10.0	16.0	2.14
29	1.592	3.5	8.5	1.551	3.0	8.5	14.5	2.58
30	1.610	4.0	9.0	1.582	4.0	9.0	15.0	1.74

Average weight loss attributable to massage = 2.70 per cent. SD = 0.63 per cent.

Tables V to VIII list the effects of 5½ minutes of 50 g. of ophthalmodynamometric compression on intraocular pressure and vitreous weight at the end of compression and for varying periods thereafter. It should be noted that vitreous weight and intraocular pressure rebound become manifest approximately 5 minutes after compression ceases. Fig. 2 indicates that hyperosmolar therapy does not reduce compression rebound in the closed eye.

FIG. 2 Influence of 50/g. ophthalmodynamometric compression on intraocular pressure and vitreous weight in the undisturbed eye and 60 min. after hyperosmolar mannitol

Vitreous mass change
 after mannitol and compression
 ----- after compression alone
 IOP recovery
 ——— after compression

Table V Effect of 50 g. ophthalmodynamometric compression on vitreous weight and intraocular pressure after 5½ min. of compression

Rabbit No.	Control eye	Experimental eye			Per cent. weight change
	Vitreous weight (g.)	Before compression	After 5.5 min. of 50 g. compressive force		
		IOP (Schiotz units, 5.5 wt)	IOP (Schiotz units, 5.5 wt)	Vitreous weight (g.)	
31	1.349	2.0	8.5	1.332	-1.26
32	1.361	3.0	9.0	1.325	-2.64
33	1.656	3.5	9.0	1.618	-2.29
34	1.393	2.5	8.0	1.347	-3.30
35	1.778	3.5	8.0	1.730	-2.69

Average vitreous weight change = 2.44 per cent. SD = 0.74 per cent.

Table VI Effect of 50 g. ophthalmodynamometric compression on vitreous weight and intraocular pressure 5 min. after termination of 5½ min. of compression

Rabbit No.	Control eye	Experimental eye				Per cent. weight change
	Vitreous weight (g.)	Before compression	After 5.5 min. of 50 g. compressive force	5 min. after termination of compressive force		
		IOP (Schiotz units, 5.5 wt)	IOP (Schiotz units, 5.5 wt)	IOP (Schiotz units, 5.5 wt)	Vitreous weight (g.)	
36	1.442	3.5	8.5	1.5	1.434	-0.55
37	1.520	4.0	7.0	2.5	1.506	-0.92
38	1.518	2.5	8.0	2.0	1.510	-0.53
39	1.574	3.5	8.0	1.5	1.562	-0.76
40	1.536	5.5	10.0	3.0	1.525	-0.71

Average weight change = -0.69 per cent. SD = 0.16 per cent.

Table VII *Effect of 50 g. ophthalmodynamometric compression on vitreous weight and intraocular pressure 7 min. after termination of 5.5 min. of compression*

Rabbit No.	Control eye		Experimental eye			Per cent. weight change
	Vitreous weight (g.)		Before compression	After 5.5 min of 50 g. compressive force	7 min. after termination of compressive force	
			IOP (Schiotz units, 5.5 wt)	IOP (Schiotz units, 5.5 wt)	IOP (Schiotz units, 5.5 wt) Vitreous weight (g.)	
41	1.458		4.0	9.0	1.0 1.481	+1.58
42	1.633		4.0	9.0	1.0 1.648	+0.92
43	1.552		3.0	8.0	1.0 1.572	+1.28
44	1.464		2.0	8.0	1.5 1.482	+1.22
45	1.618		3.5	8.5	1.5 1.639	+1.30

Average vitreous weight change = + 1.26 per cent. SD = 0.23 per cent.

Table VIII *Effect of 50 g. ophthalmodynamometric compression on vitreous weight and intraocular pressure 10 min. after termination of 5.5 min. of compression*

Rabbit No.	Control eye		Experimental eye			Per cent. weight change
	Vitreous weight (g.)		Before compression	After 5.5 min. of 50 g. compressive force	10 min after termination of compressive force	
			IOP (Schiotz units, 5.5 wt)	IOP (Schiotz units, 5.5 wt)	IOP (Schiotz units, 5.5 wt) Vitreous weight (g.)	
46	1.384		4.0	9.5	2.0 1.416	+2.31
47	1.422		3.5	8.5	1.5 1.462	+2.81
48	1.493		2.5	8.5	1.0 1.523	+2.07
49	1.426		3.5	8.5	1.5 1.470	+3.09
50	1.430		2.5	8.0	2.0 1.470	+2.79

Average vitreous weight change = + 2.61 per cent. SD = 0.41 per cent.

Discussion

A series of studies from this laboratory has attempted to clarify the status of pre-incision manoeuvres used in lens extraction (Obstbaum and others, 1971; Galin and others, 1971; Robbins and Galin (1969); Robbins, Blumenthal, and Galin, 1970a; Robbins, Obstbaum, Best, and Galin, 1970b). Certain steps appear to be of benefit. Excellent akinesia is essential to prevent global and scleral retraction which might "shrink" the vitreous container. Retrobulbar anaesthesia, however, has no direct effect on vitreous weight (Robbins and others, 1970b). The use of hyperosmolar solutions also appears worthwhile since vitreous mass in the closed and open eye is reduced. Furthermore, this form of therapy appears to maintain effectiveness during the time usually needed to perform a lens extraction. Other drugs and manipulative measures appear to have little direct or indirect effect on the vitreous.

Digital massage may hasten motor and sensory akinesia and reverse their usual sequence, so that it augments the effects of retrobulbar anaesthesia (Gasser and Erlanger, 1929). It also reduces vitreous weight during the period of compression and for a short period thereafter. This manoeuvre in the rabbit, however, leads to an increase in intraocular pressure in the closed eye which starts approximately 5 minutes after massage is ended. Intraocular pressure and vitreous mass rebound is not reduced, and not eliminated, if

massage is preceded by hyperosmolar therapy in the closed rabbit eye. Intraocular pressure rebound is uncommon in patients, but the weight and volume of the vitreous are unknown during the recovery phase of intraocular pressure, and need neither parallel nor reflect the state of the intraocular pressure.

If the eye is opened after digital massage has been completed and the vitreous is weighed sequentially, no increase in the normal vitreous weight loss that occurs on opening the eye is apparent. Furthermore, the beneficial effects of previous hyperosmolar therapy is not augmented by previous digital massage in the open eye model.

The most significant reductions in vitreous weight occur after simply opening the eye. There is progressively leaks from the vitreous so that its mass is progressively reduced. There is continued vitreal water loss without classic vitreous loss. Whether choroidal or subchoroidal volume changes immediately negate this effect is not known. This water loss can be augmented by hyperosmolar therapy, but is not changed by previous digital massage or by drugs such as acetazolamide. This latter agent also has no direct or indirect beneficial effect on vitreous weight (Robbins and others, 1970b).

It is always pleasant to watch air suck in as a lens is delivered indicating the creation of negative intraocular pressure. This phenomenon infers that nothing internal or external is decreasing the volume of the scleral shell. One is never certain, however, when this event will occur. When the eye is initially opened, bulging of the iris, furrowing of the cornea, and a host of other clinical hints alert the surgeon to rule out the presence of external pressure and he can act accordingly. Even these signs, however, may not be immediately apparent, as in a delayed retrobulbar haemorrhage. Unfortunately, save for the catastrophe of expulsive choroidal haemorrhage, no available laboratory or clinical data indicate whether the uvea or subchoroidal space is primarily involved in vitreous prolapse. Studies to evaluate these potentials as major causes of vitreous loss during operations for lens extraction are now being undertaken.

It appears from these studies that only a few of the present preoperative steps designed to minimize vitreous loss are truly effective, and that attempts to shrink the vitreous mass, though worthwhile, are probably not the best. The most useful measures appear to be the elimination of vitreous compression from within the globe or from outside.

Summary

Hyperosmolar mannitol reduces vitreous weight in the closed rabbit eye during the time usually required for a lens extraction, but digital massage has no such effect. The latter induces a vitreous rebound associated with an increase in intraocular pressure in the closed rabbit eye. Though mannitol reduces this rebound effect, it does not eliminate it.

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