• Brief Report •

Intraocular pressure before and after capsulorhexis using two viscoelastic substances and two surgical approaches in enucleated porcine eyes

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Abstract

• **AIM:** To investigate the influence of ophthalmic viscoelastic devices (OVDs) and different surgical approaches on the intraocular pressure (IOP) before and after creation of the curvilinear circular capsulorhexis (CCC) as a measure for anterior chamber stability during this maneuver.

• **METHODS:** Prospective experimental WetLab study carried out on enucleated porcine eyes. IOP was measured before and after CCC with the iCare Rebound tonometer (iCare ic200; iCare Finland Oy, Vantaa, Finland). The OVDs used were a cohesive one [Z-Hyalin, Carl Zeiss Meditec AG, Germany; hyaluronic acid (HA)] and a dispersive [Z-Celcoat, Carl Zeiss Meditec AG, Germany; hydroxy propylmethylcellulosis (HPMC)]. The CCC was created using Utrata forceps or 23 g microforceps in different combinations with the OVDs.

• **RESULTS:** Using the Utrata forceps the IOP dropped from 63.65±6.44 to 11.25±3.63 mm Hg during the CCC. The use of different OVDs made no difference. Using the 23 g microforceps the IOP dropped from 65.35±8.15 to 36.55±6.09 mm Hg. The difference between IOP drop using either Utrata forceps or 23 g microforceps was highly significant regardless of the OVD used.

• **CONCLUSION:** Using the sideport for the creation of the capsulorhexis leads to a lesser drop in IOP during this maneuver compared to the main incision in enucleated porcine eyes. The use of different OVD has no significant influence on IOP drop.

• **KEYWORDS:** cataract surgery; ophthalmosurgical viscoelastic device; intraocular pressure; capsulorhexis; enucleated porcine eye
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INTRODUCTION

The introduction of ophthalmosurgical viscoelastic devices (OVDs) has improved the safety of cataract surgery significantly[1-2]. As cataract surgery is one of the most frequent surgical procedures[3] any improvement of the surgery unfolds a huge impact globally. An OVD is injected into the anterior chamber to create and maintain space between the lens and the corneal endothelium[4-5] during surgery. Two different substances have evolved as the most important OVDs: hyaluronic acid (HA) and hydroxy propylmethylcellulosis (HPMC)[4]. Rheologic properties of OVDs, such as viscosity, elasticity, pseudoplasticity, and cohesion, affect the products' function and performance. Based on rheologic properties, OVDs can be generally classified as cohesive or dispersive. Given each products' unique characteristics, OVDs are not interchangeable[1-2]. Prolonged adhesion to the corneal endothelium enhances endothelial protection[2,6]. A stable anterior chamber situation and high pressure on the anterior lens capsule significantly facilitates the creation of a curvilinear circular capsulorhexis (CCC)[7-8]. High pressure in the anterior chamber flattens the anterior lens capsule thus making a rhexis tear more unlikely[7-8]. This postulate of the capability of a high molecular weight OVD seems believable and gets mentioned constantly in the literature, however proof of a significant relation between capsule flattening and certain features of the OVD used have not been published.

HA is a highly viscous substance which is appreciated for its (claimed) ability to maintain space in the anterior chamber. This should facilitate the critical steps of the operation like

the capsulorhexis and the emulsification of the lens. On the other hand, cohesive properties should show to a faster drain out of the anterior chamber and achieve an inferior endothelial protection compared to HPMC[4,9]. HPMC is a dispersive OVD with a lower viscosity. It shows good adherence to intraocular structures including the corneal endothelium protecting this sensitive tissue during surgery[5-6,10]. It is postulated, that it stays longer in the anterior chamber during surgery, but its ability to keep the anterior chamber deep is said to be not as good as with HA[1-2].

This study investigates the intraocular pressure (IOP) at different steps of cataract surgery using OVDs with different properties in a porcine *ex vivo* model. Previous studies have shown that IOP measurement in *ex vivo* porcine eyes is feasible using different techniques like indentation tonometry and rebound tonometry[11]. Studies on porcine eyes have shown a marked underestimation of IOP, which is most probably due to differing elastic properties of the cornea and differences in the thickness of the central cornea[11]. However, although an underestimation was found, it was also a constant one showing a linear function[12].

Better understanding and an adjusted use of appropriate OVDs will enhance a safe cataract surgery procedure.

MATERIALS AND METHODS

Ethical Approval The Ethical Committee of the State's Chambers of Physicians agreed with the execution of this study in writing without a formal hearing as the porcine eyes were byproducts and no animal was killed for the study. The study was conducted in accordance with the ARVO Statement for the Use of Animals in Ophthalmic and Vision Research.

This is a prospective experimental *ex vivo* study to evaluate intraoperative IOP during cataract surgery immediately before the creation of the capsulorhexis and immediately after that.

Surgery was carried out on 40 enucleated porcine eyes. Slaughtering and preparation had taken place 2d before the surgeries. The globes were stored at 8°C before being used for the study.

After fixation IOP was measured using rebound tonometry[13-16] with a handheld device (iCare ic200; iCare Finland Oy, Vantaa, Finland). This device can provide IOP measurement in an upright as well as in a supine position which is the case intraoperatively[17-18].

As there is a post-mortem decrease in IOP[19-20], balanced saline solution (BSS) was injected into the vitreous cavity until an IOP between 8 and 20 mm Hg could be measured. This was sufficient to create the corneal incisions immediately afterwards.

The individual steps of the surgery were carried out resembling exactly the surgery on a human eye according to national and international guidelines[21-22] with the addition of IOP measurements.

Surgical steps: 1) The enucleated porcine eyes were fixated in a pre-formed mould with needles pierced through the tenon enabling the following surgical steps without significant movement. 2) IOP measurement[17]. 3) Injection of BSS into the vitreous cavity if needed, followed by another IOP measurement, this step was repeated until an IOP between 8 and 25 could be measured. 4) Configuration of the microscope. 5) Creation of the main incision with a 2.5 mm keratome facing the surgeon (6 o'clock), tunnel length was targeted to be 2–2.5 mm. 6) Instillation of an OVD according to the study group until a reflux of the OVD is noticed indicating a complete aqueous/OVD exchange. 7) Creation of two 0.9 mm paracenteses at 3 and 9 o'clock. 8) Instillation of an OVD according to the study group. 9) IOP measurement[17]: a recordable result for IOP included 6 measurements that were arithmetically averaged by the device. 10) Creation of the capsulorhexis[7,23] with Utrata forceps or 23 g-microforceps according to the study group. 11) IOP measurement[17].

All surgical steps were carried out by the same surgeon with an experience of >10 000 cataract surgeries. The incisions were self-sealing, no leakage was observed between the surgical steps.

Different configurations were investigated in the following groups: group 1, use of a cohesive OVD, creation of the capsulorhexis with Utrata forceps through the main incision; group 2, use of a dispersive OVD, creation of the capsulorhexis with Utrata forceps through the main incision; group 3, use of a cohesive OVD, creation of the capsulorhexis with 23 g-microforceps through the sideport; group 4, use of a dispersive OVD, creation of the capsulorhexis with 23 g-microforceps through the sideport.

The features of the dispersive OVD (Z-Celcoat, Carl Zeiss Meditec AG, Germany; "OVD A") and the cohesive OVD (Z-Hyalin, Carl Zeiss Meditec AG, Germany; "OVD B") are displayed in Table 1. All information according to the manufacturer.

Each group consisted of 10 eyes. The measured values for IOP were noted during surgery as well as the necessity of renewed instillation of an OVD in the anterior chamber.

RESULTS

For each of the group, 10 porcine eyes were prepared, surgical steps and measurements were taken and the data were collected. There was no significant difference in IOP prior incision in the four groups [P>0.05; F(3,39)=2.195, P=0.105, n=40].

Group 1 (HA, Utrata forceps): IOP was 11.0±2.86 mm Hg prior the first incision, 65.5±5.87 mm Hg prior capsulorhexis and 12.5±2.54 mm Hg after completed capsulorhexis.

Group 2 (HPMC, Utrata forceps): IOP was 11.9±3.28 mm Hg prior the first incision, 61.8±6.74 mm Hg prior capsulorhexis and 10.0±4.32 mm Hg after completed capsulorhexis.

Table 1 Comparison of OVD used in this study

Parameters	OVD A	OVD B
Substance	Hydroxypropyl-methylcellulose	Sodium hyaluronate
Origin	Botanical	Bacterial fermentation
Concentration (mg/mL)	20	10
Osmolality (mOsmol/kg)	265–300	300–350
Molecular weight (megadalton)	0.08	2.9
Pseudoplasticity	-	75
Zero-shear viscosity ($Pa \cdot s^2$)	7	72

OVD: Ophthalmic viscoelastic devices.

Table 2 IOP dropped significantly during the creation of the capsulorhexis in all groups

Parameters	IOP prior first incision	IOP prior rhexis	IOP after rhexis	IOP difference prior/after
HA/Utrata (*n*=10)				
Median	11.0	65.5	12.5	-53.0
SD	2.86	5.87	2.54	5.6
HPMC/Utrata (*n*=10)				
Median	11.9	61.8	10.0	-51.8
SD	3.28	6.74	4.32	8.9
HA/23 g (*n*=10)				
Median	14.8	64.3	35.8	-28.5
SD	3.76	6.78	4.84	9.7
HPMC/23 g (*n*=10)				
Median	13.6	66.4	37.3	-29.1
SD	4.42	9.59	7.33	7.9

The use of different OVDs did not alter the drop significantly whereas different surgical approaches had significant influence. IOP: Intraocular pressure; OVD: Ophthalmic viscoelastic devices; HA: Hyaluronic acid; HPMC: Hydroxy propylmethylcellulosis; SD: Standard deviation.

Table 3 The use of different OVD had no significant influence on IOP drop, different surgical approaches even more so

Factors	Dependency	*P*	Statistical significancy
Factor 1 (OVD)	HA/HPMC	0.909	No influence; *P*>0.05
Factor 2 (instrument)	Utrata/23 g	<0.001	Significant influence for factor “instrument”, *P*<0.05
Interaction	HA/HPMC * Utrata/23 g	0.731	No interaction; *P*>0.05

Two-factor variance-analysis ruled out any interdependency between a certain OVD/instrument combination. OVD: Ophthalmic viscoelastic devices; IOP: Intraocular pressure; OVD: Ophthalmic viscoelastic devices; HA: Hyaluronic acid; HPMC: Hydroxy propylmethylcellulosis.

Group 3 (HA, 23 g microforceps): IOP was 14.8±3.76 mm Hg prior the first incision, 64.3±6.78 mm Hg prior capsulorhexis and 35.8±4.84 mm Hg after completed capsulorhexis.

Group 4 (HA, 23 g microforceps): IOP was 13.6±4.42 mm Hg prior the first incision, 66.4±9.59 mm Hg prior capsulorhexis and 37.3±7.33 mm Hg after completed capsulorhexis.

Using Utrata forceps, IOP was 11.45±3.03 mm Hg prior the first incision, 63.65±6.44 mm Hg prior capsulorhexis and 11.25±3.63 mm Hg after completed capsulorhexis.

Using 23 g microforceps, IOP was 14.2±4.04 mm Hg prior the first incision, 65.35±8.15 mm Hg prior capsulorhexis and 36.55±6.09 mm Hg after completed capsulorhexis.

The IOP after completed capsulorhexis was not significantly different regardless of which OVD was used. However, there was a significant difference when different instruments and approaches where used (Table 2).

As different surgical instruments showed significant influence on IOP drop in contrast to different OVDs, an interdependency between the two variables could be a reason for bias. A two-factor variance-analysis was carried out to eliminate such an error. The analysis could rule out any interdependency, the result of this analysis was highly significant. Therefore, it can be concluded that the reduction in IOP during the creation of the capsulorhexis is only related to the surgical approach and not the use of a certain OVD or any OVD/instrument combination (Table 3).

DISCUSSION

The use of different surgical instruments and the use of a different entrance (2.5 mm main incision *vs* 0.9 mm sideport) showed significant differences. After the creation of the CCC using the 23 g microforceps a markedly higher IOP was measured indicating more stable circumstances during

this procedure compared to the use of Utrata forceps without any interdependency between the two variables. This can be attributed to an increased outflow of OVD through a larger incision.

The use of different OVDs to stabilize the anterior chamber during the creation of CCC showed no significant difference in enucleated porcine eyes when using the same surgical approach. These results may be surprising considering the literature[2,4,7-8,23-24]. The postulate of high molecular weight OVDs being superior in respect of flattening the anterior capsule and thus facilitating the creation of the CCC can be found throughout the scientific literature on cataract surgery, but studies to prove a direct and significant correlation have not been published.

The proven similarity or even parity in IOP at different stages of the operation regardless of the OVD used stands in marked contrast not only to the feeling most surgeons notice when using different OVDs but the same surgical approach but to numerous references in the literature without reliable evidence apart from the surgeons' sensations. If the maintenance of a high IOP is clearly not the reason for this sensation, other properties of the OVD like viscosity, concentration or crosslinking may attribute to this effect[2,4]. These properties must be investigated in further studies. An explanation for the results cannot be given at this time of investigation. All other properties of OVDs have to be investigated in the same way to identify the factor that explains the different feelings encountered by surgeons during cataract surgery. An explanation may then be found taking biochemical and biophysical features into account[1,2,4].

Central corneal thickness was not evaluated in this study. However, variations in central corneal thickness[25] may have led to slight differences in the measured IOP which are improbable to have an impact on the results.

Results obtained by surgery on porcine cadaver eyes are not directly transferrable to surgery on human eyes. Apart from obvious anatomical and functional differences[26-27] and post mortem changes[19-20] there are technical aspects to be considered like retro- or parabulbar anaesthesia[28] which can elevate posterior vitreous pressure and thereby IOP.

The results of this study prove their repeatability in an *in vivo*-study in human eyes. Should these results support the findings of our study, the prolonged stability of IOP in the anterior chamber using a 23 g instruments could be favourable especially in demanding or complicated situations like posterior vitreous pressure or elevated intracapsular pressure.

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