ORIGINAL RESEARCH

Quantitative Anterior Chamber Drainage and its Relationship with Initial Intraocular Pressure in Ocular Hypertension: A Comparative Study

Yajie Zheng, MD; Yuan Wu, MD

ABSTRACT

Background • Glaucoma encompasses a spectrum of ophthalmic diseases characterized by optic disc atrophy, depression, visual field defects, and decreased vision. The use of quantitative anterior chamber (AC) paracentesis for fluid drainage in patients remains a topic of debate.

Objective • This study aims to determine the utility of quantitative AC paracentesis needles, investigate the relationship between quantitative AC drainage and initial intraocular pressure (IOP) in individuals with ocular hypertension (OHT), and identify appropriate drainage volumes for OHT patients with varying initial IOPs.

Methods • Sixty Bama miniature piglets were obtained and underwent one week of routine adaptive feeding. An OHT animal model was established by injecting Carbomer into the AC. Quantitative AC drainage (0.025 mL) was performed using a BD needle, and postoperative IOP levels were measured.

Results • (1) A total of 120 eyes with initial high IOP ranging from 21 mmHg to 96 mmHg underwent quantitative (0.025 mL) AC drainage using a BD needle, resulting in an average IOP reduction of 17.227 mmHg. (2) A significant correlation was observed between initial IOP and the magnitude of post-drainage IOP reduction ($P < .01$), indicating that higher initial IOP values corresponded to greater IOP decreases following quantitative drainage. (3) For initial IOP values below 40 mmHg, post-drainage IOP exhibited significant variability, with an average decrease of 13.986 mmHg. (4) Conversely, for IOP values above 40 mmHg, the decrease in IOP following drainage showed minimal variation with the initial IOP, resulting in an average IOP decrease of 19.225 mmHg.

Conclusions • The decrease in IOP resulting from 0.025 mL of fluid drainage from the AC is directly proportional to the initial IOP. Quantitative (0.025 mL) AC drainage effectively reduces IOP levels when the initial IOP exceeds 40 mmHg, with minimal dependence on the initial IOP. Conversely, for piglets with an IOP below 40 mmHg, higher initial IOP values correspond to greater IOP reductions following quantitative drainage. Quantitative (0.025 mL) AC drainage normalizes IOP levels for intermediate IOP values. Additionally, a volume of 0.05 mL quantitative AC drainage can restore IOP levels in piglets with an IOP of 40-60 mmHg. (*Altern Ther Health Med.* 2023;29(7):322-327).

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INTRODUCTION

Glaucoma is a collective term for a group of ophthalmic diseases characterized by optic disc atrophy, depression, visual field defects, and decreased visual acuity. Pathologically, it is associated with increased intraocular pressure (IOP) and insufficient blood supply to the optic nerve, which are independent risk factors.[1] The development and progression of glaucoma are also influenced by the optic nerve's tolerance to pressure-induced damage.[2] Glaucoma is attributed to elevated IOP resulting from impaired aqueous humor (AH) circulation, leading to symptoms such as eye swelling, tearing, and a rapid decline in vision. These manifestations significantly impact patients' overall quality of life.[3] Glaucoma is the second most common cause of irreversible blindness in Western Europe, affecting approximately 3% of individuals aged 40 and above. Projections indicate a staggering increase, with an estimated 111 million cases anticipated by 2040.[4,5]

Quantitative drainage is a widely employed intervention technique during acute glaucoma attacks, offering the advantage of minimizing systemic side effects associated with the high-dose systemic administration of ocular hypotensive drugs. This approach particularly benefits elderly and frail individuals, serving as a preparatory measure for subsequent

Table 1. Instruments and Equipment

Instruments and equipment	Manufacturer
Pig breeding cage	Animal Experimental Center of Xi 'an Jiaotong University
Phenobarbital Sodium for Injection	Shanghai SPH New Asia Pharmaceutical Co., Ltd.
TKR-200C small-animal ventilator	Jiangxi Teli Anesthesia & Respiratory Equipment Co., Ltd.
ECG monitor	Jiangxi Teli Anesthesia & Respiratory Equipment Co., Ltd.
Magnetic stirrer	Daihan Scientific, Korea
Levofloxacin Ophthalmic Ointment	Shentian Pharmaceutical (China) Co., Ltd.
Levofloxacin Eye Drops	Shentian Pharmaceutical China Co., Ltd.
Rebound tonometry	Tianjin Suowei Electronic Technology Co., Ltd.
Carbomer 940	Shanghai Solarbio Bioscience & Technology Co., Ltd.

Abbreviations: ECG: electrocardiogram.

surgical interventions following IOP reduction.[6,7] In the case of glaucoma secondary to traumatic hyphema, quantitative drainage effectively reduces intraocular pressure and facilitates the release and dissipation of hematocele, thereby preventing corneal blood staining.[8]

However, significant controversies persist regarding the optimal volume of fluid drainage when applying quantitative anterior chamber (AC) paracentesis in glaucoma patients. Insufficient drainage volume may impede attaining desired therapeutic outcomes, while excessive drainage can increase the risk of complications and negatively impact patient prognosis.[9,10] Porcine eyes closely resemble human eyes in various aspects, including retinal vasculature, the presence of conical photoreceptors in the outer retina, comparable scleral thickness, corneal collagen fiber arrangement, and the absence of a tapetum layer. Therefore, porcine models are considered highly suitable for ocular research.[11-13]

Consequently, this study focused on Bama miniature pigs as research subjects to investigate the relationship between quantitative drainage and initial IOP in ocular hypertension (OHT). Additionally, the study aimed to analyze the appropriate drainage volume for OHT patients with varying initial IOP values. The findings of this study hold significant clinical implications, as they can contribute to achieving more favorable treatment outcomes and enhancing patient well-being. The details of the study are presented below.

MATERIALS AND METHODS

Animal Data

A total of 40 Bama miniature pigs (animal certificate number: SCXX-2005-0001) were procured between January 2019 and June 2020. The pigs were subjected to routine adaptive feeding for one week. The selection of the 40 Bama miniature piglets was randomized regarding sex. The pigs had a body weight range of 30-35 kg (mean: 32.00 ± 3.00 kg) and an age range of 180-200 days (mean: 190.97 ± 6.36 days). All selected Bama miniature pigs were housed in the experimental animal room, receiving standard feeding and illumination protocols. The Animal Care and Use Committee of our hospital approved this study, and all experimental procedures strictly adhered to animal care guidelines.

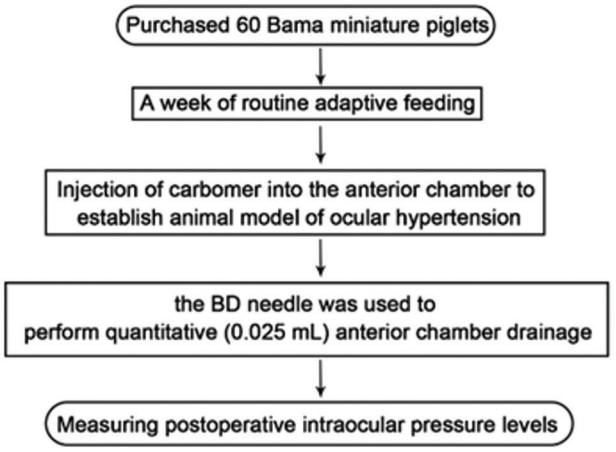
Instruments and Equipment

The study utilized a range of instruments and equipment including: (1) Pig breeding cage: The pig breeding cages were sourced from the Animal Experimental Center of Xi'an Jiaotong University; (2) Phenobarbital Sodium for Injection: The phenobarbital sodium used in the study was obtained from Shanghai SPH New Asia Pharmaceutical Co., Ltd; (3) TKR-200C small-animal ventilator: The small-animal ventilator used during the study was manufactured by Jiangxi Teli Anesthesia & Respiratory Equipment Co., Ltd; (4) ECG monitor: The ECG monitor used for monitoring cardiac activity in the experimental pigs was also provided by Jiangxi Teli Anesthesia & Respiratory Equipment Co., Ltd; (5) Magnetic stirrer: The magnetic stirrer employed for mixing purposes was sourced from Daihan Scientific, Korea; (6) Levofloxacin Ophthalmic Ointment: The levofloxacin ophthalmic ointment used in the study was obtained from Shentian Pharmaceutical (China) Co., Ltd; (7) Levofloxacin Eye Drops: The levofloxacin eye drops utilized in the study were provided by Shentian Pharmaceutical China Co., Ltd; (8) Rebound tonometry: The rebound tonometry device, used for measuring intraocular pressure, was sourced from Tianjin Suowei Electronic Technology Co., Ltd; (9) Carbomer 940: The carbomer 940 used in the study was obtained from Shanghai Solarbio Bioscience & Technology Co., Ltd. See Table 1 for the instruments and equipment used in this study.

Clinical Procedures

Modeling Method. An animal OHT model in piglets was established by injecting Carbomer into the AC.[14] The procedures were as follows: (1) Carbomer suspension preparation: 0.15 g of Carbomer 940 was accurately weighed and placed in a beaker. Then, 30 mL of distilled water was added, and the mixture was continuously stirred for 20 minutes using a magnetic stirrer until a semi-transparent suspension was obtained. Subsequently, a 100 g/L sodium hydroxide titration solution was added to adjust the pH of the suspension to a controlled range of 7.3-7.5 for later use[15]; (2) Pre-injection preparation: The IOP of the piglets was measured continuously for three days before modeling. The animals were gently stroked to reduce their nervousness during the measurement. Three consecutive measurements

Figure 1. Flow chart.



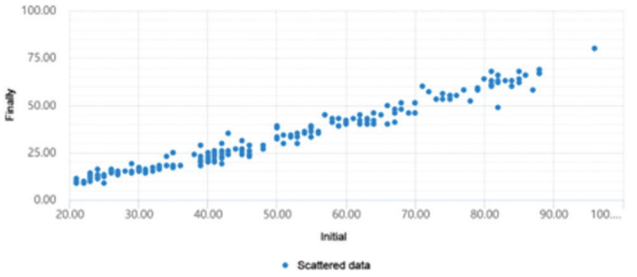
Note: The figure illustrates the flowchart depicting the sequential steps involved in the surgical procedures for modeling ocular hypertension (OHT) and performing quantitative anterior chamber (AC) drainage with intraocular pressure (IOP) measurement. The process includes establishing the OHT animal model, injection of Carbomer into the AC, intervention using BD needles for quantitative AC drainage, and subsequent IOP measurement using rebound tonometry.

were performed each time to minimise errors, and the average value was recorded.

The piglets were then anesthetized by intraperitoneal injection of sodium pentobarbital (150 mg/kg) according to the body weight of 3.5-4.0 mL/kg. The right eye of each piglet was designated as the experimental eye, and 1 mL of Carbomer suspension was injected into the AC; (3) Injection method: Following anesthesia, the piglets' eyeballs were secured by clamping the conjunctiva with micro-tweezers. A 30G needle was connected to a syringe, and 1 mL of Carbomer suspension was drawn into the syringe. Under microscopic guidance, the needle was punctured 1 mm outside the limbus, carefully avoiding contact with the anterior lens capsule, iris, and corneal endothelium. After the injection, the needle was withdrawn.

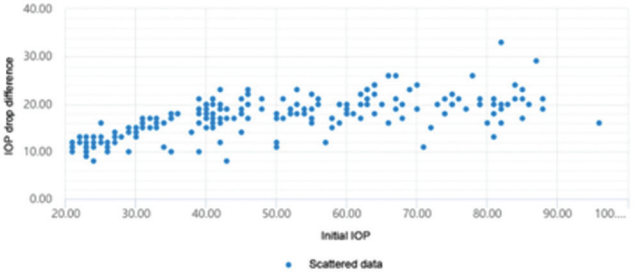
The AC became shallower as the AH flowed out, and the eyeball softened. Subsequently, the needle was reinserted through the same puncture site and gently rotated to position the syringe needle's inclined plane toward the AC angle. It allowed for the rapid injection of 30 μL of 5 g/L Carbomer suspension. During the injection, the color of the iris vessels lightened, and the AC deepened, with some Carbomer suspension flowing out as the IOP increased. The needle was then removed, and the conjunctival wound was gently clamped with smooth forceps for 1 minute to complete the OHT model in the piglets. Following modeling, Levofloxacin Ophthalmic Ointment was routinely applied to the corneal surface, and the piglets were administered Levofloxacin Eye Drops twice daily for 7 consecutive days.[16,17]

Figure 2. Scatter diagram of intraocular pressure changes before and after quantitative drainage



Note: The figure presents a scatter diagram illustrating the changes in intraocular pressure (IOP) before and after applying quantitative drainage. Each data point represents an individual eye, with the x-axis indicating the initial IOP and the y-axis representing the post-drainage IOP. The plot visually demonstrates the reduction in IOP following the quantitative drainage procedure.

Figure 3. Relationship between the decrease of intraocular pressure after quantitative drainage and the initial intraocular pressure. IOP, intraocular pressure.



Note: The figure depicts the relationship between the decrease in intraocular pressure (IOP) following quantitative drainage and the initial IOP. The x-axis represents the initial IOP values, while the y-axis represents the decrease in IOP after the drainage procedure. The plot provides an overview of the correlation between the initial IOP and the extent of IOP reduction achieved through quantitative drainage. The abbreviation "IOP" stands for intraocular pressure.

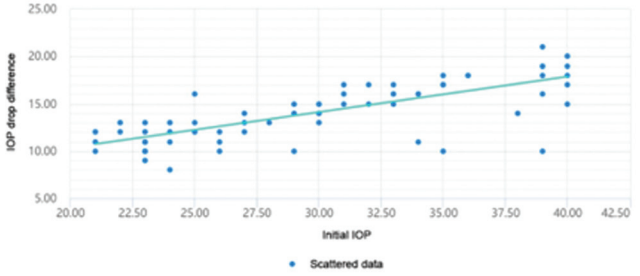
Intervention Method

After modeling, quantitative AC drainage using a BD needle (0.025 mL) was performed, and the IOP level was measured using rebound tonometry. The primary outcome measure was the IOP level. Refer to Figure 1 for a visual representation of the study flowchart.

Statistical Analysis

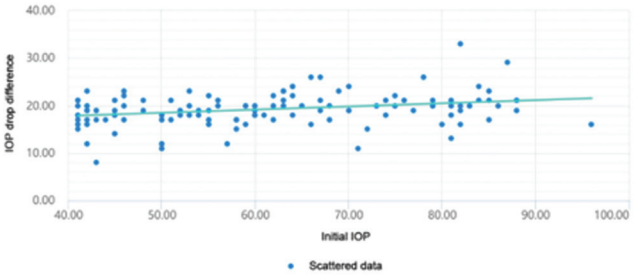
Data processing was conducted using Statistical Product and Service Solutions (SPSS) 18.0 software (SPSS Inc., Chicago, IL, USA). The *t* test was utilized to analyze the measurement data, which were presented as mean ± standard deviation ($\bar{x} \pm s$). Statistical significance was defined as a *P* value less than .05 ($P < .05$).

Figure 4. Relationship between the decrease of intraocular pressure after quantitative drainage and the initial intraocular pressure (initial intraocular pressure < 40). IOP, intraocular pressure.



Note: The figure demonstrates the relationship between the decrease in intraocular pressure (IOP) after quantitative drainage and the initial intraocular pressure when the initial IOP is below 40. The x-axis represents the initial IOP values, while the y-axis represents the decrease in IOP following the drainage procedure. The plot provides insights into how the initial IOP level influences the extent of IOP reduction achieved through quantitative drainage in cases where the initial IOP is below 40. The abbreviation "IOP" stands for intraocular pressure.

Figure 5. Relationship between the decrease of intraocular pressure after quantitative drainage and the initial intraocular pressure (initial intraocular pressure > 40). IOP, intraocular pressure.



Note: Figure 5 illustrates the relationship between the decrease in intraocular pressure (IOP) following quantitative drainage and the initial intraocular pressure when the initial IOP is above 40. The x-axis represents the initial IOP values, while the y-axis represents the decrease in IOP after the drainage procedure. The plot highlights the association between the initial IOP level and the magnitude of IOP reduction achieved through quantitative drainage in cases where the initial IOP exceeds 40. The abbreviation "IOP" stands for intraocular pressure.

RESULTS

Analysis of IOP Changes Before and After Quantitative Drainage

All 60 piglets successfully underwent modeling and intervention, resulting in a total of 120 eyes with initial high IOP levels ranging from 21 mmHg to 96 mmHg. Quantitative anterior chamber (AC) drainage using BD needles (0.025 mL) was performed, leading to a mean reduction in IOP of 17.227 mmHg (Figure 2).

Relationship between the Decrease in IOP after Quantitative Drainage and the Initial IOP

The decrease in IOP following quantitative drainage was significantly correlated with the initial IOP ($P<.01$). As illustrated in Figure 3, higher initial IOP values corresponded to a greater reduction in IOP after undergoing quantitative drainage.

Relationship between the Decrease in IOP after Quantitative Drainage and the Initial IOP (Initial IOP < 40 mmHg)

For piglets with an initial IOP below 40 mmHg, the extent of post-drainage IOP reduction exhibited significant variability in relation to the initial IOP. The average decrease in IOP was measured to be 13.986 mmHg, as depicted in Figure 4.

Relationship between the Decrease in IOP after Quantitative Drainage and the Initial IOP (Initial IOP > 40 mmHg)

In cases where the initial IOP exceeded 40 mmHg, the decrease in IOP after drainage showed minimal variation from the initial IOP. On average, the IOP decreased by 19.225 mmHg, as demonstrated in Figure 5.

DISCUSSION

Pathological elevation of IOP, which leads to optic nerve damage through mechanical compression and optic nerve ischemia, is a major contributing factor in the development of glaucoma.[2,18] The severity of visual function impairment is directly related to both the level and duration of elevated IOP.[19,20] Previous studies[21,22] have indicated that the increase in IOP in glaucoma is primarily attributed to the disruption of the dynamic balance of AH circulation, although excessive AH secretion may also contribute in some cases. Regardless of the underlying cause, such elevations in IOP can result in angle narrowing or closure, trabecular sclerosis, and other complications. Therefore, it is of utmost importance to actively implement effective measures for reducing IOP in patients with acute glaucoma, as this can significantly impact their prognosis and clinical outcomes.[23,24]

AC paracentesis is a direct, efficient, and rapid method that can be performed repeatedly to lower IOP[25] effectively. Under topical anesthesia, the conjunctival sac is flushed with antibiotic saline, and the AH is drained by gently pressing the puncture opening with the tip of a sterile 1 mL syringe.[26] Previous research[27] has demonstrated that AC drainage can alleviate elevated IOP, circumvent systemic side effects associated with high-dose systemic administration of IOP-lowering drugs, and serve as a foundation for subsequent surgical interventions.

This study established an OHT animal model in piglets, and intervention was carried out using BD needles. A total of 120 pig eyes with high IOP levels ranging from 21 mmHg to 96 mmHg underwent quantitative AC drainage using BD needles (0.025 mL). The average reduction in IOP was

measured to be 17.227 mmHg, indicating that AC drainage effectively reduces IOP levels in piglets and brings them back within the reference range. These findings validate the effectiveness and rationale of this approach.

Research conducted by domestic scholars[28] has indicated that, during AC drainage puncture, selecting the 6 o'clock position on the lower limbus is preferable to facilitate the discharge of hyphema. Additionally, antibiotic prophylaxis should be administered to prevent recurrent accumulation of AH, and all procedures performed on piglets must adhere to strict aseptic techniques.[29] While AC paracentesis effectively reduces IOP in piglets with OHT, no standardised criterion exists regarding the relationship between AC drainage volume and the initial IOP in patients experiencing an acute glaucoma attack.[30]

This study observed a significant correlation between the IOP and the extent of IOP reduction following quantitative drainage ($P < .01$). Specifically, higher initial IOP levels were associated with greater reductions in IOP after undergoing quantitative drainage. When the initial IOP was below 40 mmHg, the post-drainage IOP reduction showed considerable variation, with an average decrease of 13.986 mmHg. Conversely, for initial IOP levels exceeding 40 mmHg, the post-drainage IOP reduction exhibited minimal variation, with an average decrease of 19.225 mmHg. These findings suggest a close relationship between the efficacy of AC paracentesis and the initial IOP level, with higher initial IOP levels corresponding to a lesser response to AC paracentesis intervention.[28]

Moreover, this study utilised an initial IOP threshold of 40 mmHg. The results demonstrated that AC drainage effectively reduced the IOP levels in piglets with high initial IOP, with a smaller decrease in IOP observed for those with higher initial levels (still below normal IOP). Conversely, lower initial IOP levels were associated with greater reductions in IOP following AC drainage. Therefore, it is essential to strengthen the measurement of initial IOP to evaluate and predict the efficacy of AC paracentesis intervention in patients with ocular hypertension. For individuals who exhibit a poor response to AC paracentesis, a combination of drug interventions can be considered a preparatory measure for subsequent surgical treatment.[31]

The novelty of this study resides in its confirmation of the relationship between quantitative AC drainage and the IOP by establishing an animal model of OHT in piglets. Furthermore, the study highlights the potential predictive value of initial IOP measurements in determining the therapeutic efficacy of AC paracentesis. These findings offer valuable guidance for the treatment management of OHT patients undergoing AC paracentesis.

Study Limitations

However, it is important to acknowledge certain limitations in this study that warrant further consideration. Firstly, the specific predictive potential of initial IOP measurement for AC paracentesis in OHT patients can be further supplemented with additional research. Secondly, the comparative analysis of different drug therapies for patients who exhibit poor responses to AC paracentesis could enhance our understanding of their therapeutic effects. Future studies should aim to address these limitations to provide more reliable clinical references for OHT patients undergoing AC paracentesis.

CONCLUSION

In conclusion, the reduction in intraocular pressure achieved through quantitative drainage of 0.025 mL of fluid from the anterior chamber is directly proportional to the initial IOP. Quantitative AC drainage effectively lowers the IOP level in cases where the initial IOP exceeds 40 mmHg, with minimal variation based on the initial IOP value. Conversely, for piglets with an initial IOP below 40 mmHg, a higher initial IOP corresponds to a greater reduction in IOP after quantitative drainage. Quantitative drainage of 0.025 mL can restore the IOP to a normal range for piglets, with IOP values falling between these two ranges. Furthermore, in cases where the IOP falls within the 40-60 mmHg range, a quantitative AC drainage volume of 0.05 mL can also effectively restore the IOP level.

DATA AVAILABILITY STATEMENT

The labeled dataset used to support the findings of this study is available from the corresponding author upon request.

CONFLICT OF INTEREST

The author declares no competing interests.

AUTHORS' CONTRIBUTIONS

YZ and YW designed the study and performed the experiments, YZ collected the data, YW analyzed the data, YZ and YW prepared the manuscript. All authors read and approved the final manuscript.

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This study did not receive any funding in any form.

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