• Clinical Research •

Measurement of shallow anterior chamber depth using Lenstar and ultrasound biomicroscopy

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Abstract

● **AIM:** To study the relationship between ultrasound biomicroscopy (UBM) and Lenstar when measuring anterior chamber depth (ACD) in eyes with shallow anterior chamber, and the necessity of conducting both examinations.

● **METHODS:** This is a retrospective observational study including 56 acute primary angle closure (APAC) eyes and 47 primary angle closure suspect (PACS) eyes with shallow ACD. ACD value measured by Lenstar and UBM were documented. The Bland-Altman plots were examined separately in all included eyes, APAC eyes and PACS eyes, for the assessment of agreement between two measurements. The agreement was compared across different population by evaluating mean difference, width of 95% limit of agreement (LoA) and the presence of proportional bias or outliers in Bland-Altman plots.

● **RESULTS:** The average ACD in APAC eyes (1.71±0.23 mm) was significantly smaller than that in PACS eyes (1.79±0.25 mm, *P*=0.038). Bland-Altman plots of both APAC eyes and PACS eyes showed small mean difference without the presence of proportional bias. However, compared with PACS eyes, the Bland-Altman plot of APAC eyes had wider 95% LoA and more outliers outside the 95% LoA.

● **CONCLUSION:** Despite the small ACD values, the two methods in measuring ACD, Lenstar and UBM, demonstrate substantial consistency when measuring PACS eyes. However, for the APAC population, the agreement might be limited, and thus the measured values should be interpreted with caution.

● **KEYWORDS:** ultrasound biomicroscopy; Lenstar; acute primary angle closure; primary angle closure suspect; anterior chamber depth

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INTRODUCTION

Angle closure glaucoma is a vision-threatening disease and was predicted to be responsible for almost half of the world's glaucoma blindness[1]. People with shorter anterior chamber are prone to angle closure, ocular hypertension and subsequent glaucomatous optic neuropathy[2]. Therefore, monitoring and intervention are of great importance. Accurate measurement of anterior chamber depth (ACD) is necessary, especially in patients with anomalous ACD.

For primary angle closure suspect (PACS) patients, their response to topical medications, as well as many structural factors, influence the decision between active intervention (laser peripheral iridotomy or surgery) and expectant treatment for PACS patients, especially the results of gonioscopy (angle status, synechiae, iris bombe and *etc*). However, the extent of shallow anterior chamber is also a determinant factor in the choice of therapy. As shown in previous studies, PACS patients with slightly shorter ACD had limited potential for developing into acute angle closure or angle closure glaucoma[3-5]. Therefore, accurate measurement of ACD is important for PACS patients. For acute primary angle closure (APAC) patients who require surgical intervention, a precise ACD value is also important. Latest study suggested that modification for

intraocular lens power calculation may be necessary for eyes with shallow anterior chamber[6]. Besides, a precise value can also enable surgeons to comprehend the condition for surgeries.

Nowadays, various biometric measurements are available for ACD evaluation. Each of these methods may provide results with slight difference, especially in some specific patient population[7-11]. Lenstar is a non-contact device using partially coherent light to provide information about axial length, aqueous depth, corneal thickness, lens thickness and *etc*[12]. Ultrasound biomicroscopy (UBM), on the other hand, requires applanation and indentation to analyze ACD and anatomical structures of anterior chamber[13]. Despite its convenience, UBM only allows static observation with reports of limited interfaces, and its agreement with gonioscopy can be limited[14]. Therefore, gonioscopy, which offers a comprehensive dynamic perception of the anterior chamber angle should not be omitted. In a previous study of preoperative cataract patients, Lenstar yielded longer mean ACD compared with UBM, with a relatively high correlation between the two tests[15]. Similarly, a study of high myopia eyes showed larger ACD using Lenstar than applanation biometry despite the absence of statistically significant difference[16]. Such numerical difference can partly be explained by the artifact of indentation during contact measurements and misdirection of scan probe.

Various other studies managed to compare different optic biometry in ACD measurement, but mostly in normal and long axial eyes[17-18]. At the time of this writing, there was a lack of information regarding the interchangeability and agreement of Lenstar and UBM in eyes with short ACD. Will shallow anterior chamber amplify the relative disparity between the two methods thus exceed the allowable range of measuring error and make the results no longer interchangeable. Besides, we noticed numerous patients were asked to test both UBM and Lenstar even after their anterior chamber angle structures were confirmed using gonioscope. If agreement of these two measurements can be proved, considerable medical expenditure will be saved from the patients themselves and from the medical resources.

Therefore, the aim of this study is to probe in the correlation of Lenstar and UBM in eyes with shallow ACD and evaluate under what circumstances can these two tests be interchangeable. The results of this study will rationalize the necessity of conducting seemingly accordant examinations and explore the possibility of avoiding excessive examinations.

PARTICIPANTS AND METHODS

Ethical Approval The study followed the ethical standards of the Declaration of Helsinki and was approved by the ethics committee of the Eye, Ear, Nose, and Throat Hospital, Fudan University (2021065). Informed consent was obtained from all partiapants.

Study Design and Subjects This is a retrospective observational study based on the outpatient medical history of patients who visited the Eye, Ear, Nose, and Throat Hospital of Fudan University, Shanghai, China due to APAC from December 2022 to January 2023. Eyes with APAC and unilateral APAC patients' PACS eyes were both studied. All included eyes should meet the following criteria: 1) age of the patients should be from 18 to 80; 2) the patient should test both Lenstar and UBM within 2d before performing any laser or surgical treatment; 3) the included eyes should manifest shallow anterior chamber under slit-lamp examination; 4) ACD value of both measurements should be under 2.4 mm. The exclusion criteria included: 1) any history of intraocular surgery; 2) patients of acute secondary angle closure, patients with past history or patients with possibility of lens dislocation at this visit. Totally 103 eyes of 70 patients were included in this study, including 56 APAC eyes and 47 contralateral PACS eyes.

Statistical Analysis Statistical analysis and graph plotting were conducted using STATA 16.0 (College Station, TX, USA). Normally-distributed quantitative data was presented as mean±standard deviation. Non-normally distributed quantitative data was presented as median (P25, P75). Shapiro-Wilk test was used for assessing the normality of data distribution. Student's *t* test was used in comparing normally distributed quantitative data (age and UBM measured ACD) between groups. Wilcoxon signed-rank test was used in comparing non-normally distributed quantitative data [intraocular pressure (IOP) at visit and ACD measured by Lenstar]. To assess the agreement of UBM and Lenstar when measuring ACD, Bland-Altman graphs were plotted. Parameters including mean difference, width of 95% limits of agreement (LoA), and existence of outliers or proportional bias in Bland-Altman plot were used to evaluate agreement. Proportional bias exists if the bias increases or decreases in proportion to the magnitude of measured value. Correlation analysis was used to detect whether proportional bias existed. Multivariate normality test was used prior to conducting linear regression. Spearman's rank correlation was used for testing linear relation of data without bivariate normality. *P* values under 0.05 were considered statistically significant.

RESULTS

APAC Eyes Had Shorter ACD than PACS Eyes Age and sex of the APAC group and PACS group were comparable, as shown in Table 1. The IOP on the time of visit was significantly higher in APAC group than PACS group ($P<0.001$). Lenstar measured ACD did not follow normal distribution. Non-parametric rank-sum test showed no significant difference between APAC eyes and PACS eyes. UBM measured ACD was normally distributed. Significant shallower anterior

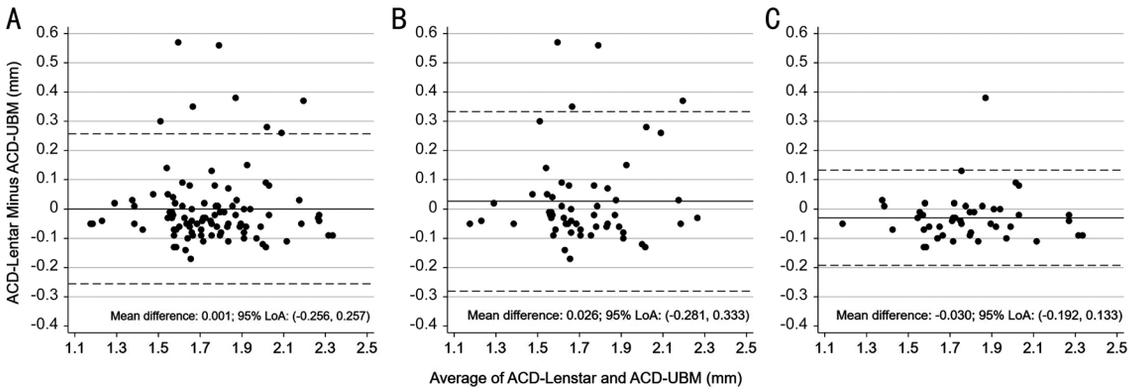

Figure 1 Bland-Altman plots analyzing the agreement of ACD measured by Lenstar and UBM A: Bland-Altman plot of all eyes with shallow anterior chamber (*n*=103); B: Bland-Altman plot of APAC eyes (*n*=56); C: Bland-Altman plot of PACS eyes (*n*=47). For each individual scattering point, the Y value represents the difference in ACD measured by Lenstar and UBM, while the X value represents the average of two measurement methods. The solid line parallel to the X-axis represents the overall mean difference of ACD measured by Lenstar and UBM across all samples. The two dash lines parallel to the X-axis indicate the 95% limits of agreement (mean±1.96SD). The exact value of mean difference and 95% LoA are displayed in the bottom of each plot. UBM: Ultrasound biomicroscopy; ACD: Anterior chamber depth; APAC: Acute primary angle closure; PACS: Primary angle closure suspect; LoA: Limit of agreement.

Table 1 Results of ACD measured by Lenstar and UBM

Parameters	All (*n*=103)	APAC eyes (*n*=56)	PACS eyes (*n*=47)	*P*
Age (y)	63.21±6.75	62.71±6.13	63.81±7.45	0.415
Sex (M/F)	32/71	19/37	13/34	0.493
IOP (mm Hg)	16.9 (12.6, 34.6)	28.5 (14.1, 39.6)	14.0 (11.8, 17.0)	<0.001
ACD-Lenstar (mm)	1.71 (1.57, 1.88)	1.66 (1.57, 1.87)	1.73 (1.57, 1.92)	0.567
ACD-UBM (mm)	1.74±0.24	1.71±0.23	1.79±0.25	0.038

UBM: Ultrasound biomicroscopy; ACD: Anterior chamber depth; IOP: Intraocular pressure; ACD-Lenstar: Anterior chamber depth measured by Lenstar; ACD-UBM: Anterior chamber depth measured by ultrasound biometry; APAC: Acute primary angle closure; PACS: Primary angle closure suspect. *P* value represents the intergroup comparison between APAC group and PACS group. Age and ACD-UBM are normal-distributed and presented as mean±standard deviation. IOP and ACD-Lenstar is non-normally distributed and presented using median (P25, P75).

chamber was found in APAC eyes (1.71±0.23 mm) than PACS (1.79±0.25 mm) eyes (*P*=0.038).

Agreement in ACD Value Examined by Lenstar and UBM Figure 1 was the Bland-Altman plot illustrating the agreement of two methods. The mean difference is small in both APAC eyes and PACS eyes. In APAC eyes, Lenstar had a consistent bias towards higher value compared to UBM, while in PACS eyes, Lenstar measured ACD was smaller than UBM measured ACD. The range of 95% LoA was much larger in APAC group than PACS group. The exact values of mean difference and both ends of 95% LoA were displayed in Figure 1. Most of the scattering dots located within 95% LoA in PACS group, while several scattering dots from APAC group fell outside of 95% LoA.

ACD Discrepancy was not Proportional to the Extent of Shallow Anterior Chamber As mentioned above, for each eye included in this study, Lenstar measured ACD and UBM measured ACD had certain discrepancy. Figure 2 showed that the difference between measurements had no significant linear correlation with the average value of two measurements, either in APAC eyes (*P*=0.567) or in PACS eyes (*P*=0.901).

DISCUSSION

In this retrospective study, a shorter ACD was found in APAC eyes than PACS eyes. This study also showed the agreement between Lenstar and applanation UBM in measuring ACD of eyes with shallow anterior chamber, including both APAC eyes and PACS eyes. Despite the low mean difference and no presence of proportional bias, the agreement of two measuring methods in APAC population was relatively inferior to the agreement in PACS population.

Previous study regarding ACD measurement using A-scan and UBM found an inferior consistency in eyes with ACD less than 3.0 mm[19]. However, in our study, where the measurement values were notably smaller, the mean difference remained minimal. When the magnitude of ACD increased or decreased, the difference in ACD remained relatively constant. Therefore, ACD value itself was not the proportional bias when measuring the difference of ACD using Lenstar and UBM. We also conducted linear correlation analysis and the correlation results (*R* square=0.739) of shallow anterior chamber eyes were close to previously published results in cataract eyes (*R*=0.704) with

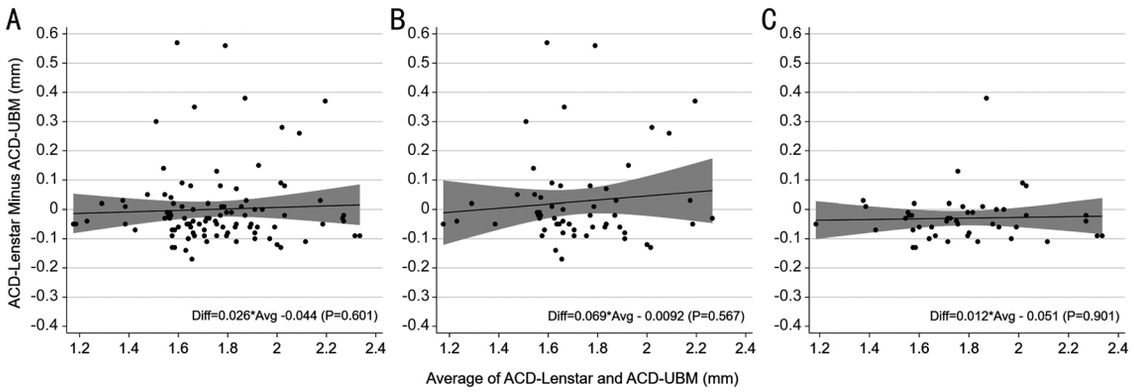

Figure 2 Assessment of proportional bias between Lenstar and UBM for ACD measurement A: Analysis of proportional bias in all included eyes (*n*=103); B: Analysis of proportional bias in APAC eyes (*n*=56); C: Analysis of proportional bias in PACS eyes (*n*=47). For each individual scattering point, the Y value represents the difference in ACD measured by Lenstar and UBM, while the X value represents the average of two measurement methods. The solid line represents the regression line, which indicates the existence of trend, or proportional bias. The shaded region around the regression line represents the 95% confidence interval. The regression equation and *P*-value are displayed in the bottom-right corner of each plot. UBM: Ultrasound biomicroscopy; ACD: Anterior chamber depth; Diff: Difference; Avg: Average; APAC: Acute primary angle closure; PACS: Primary angle closure suspect.

normal ACD[15]. A strong positive correlation between Lenstar measured ACD and UBM measured ACD still existed in eyes with shallow anterior chamber, especially in PACS eyes (*R* square=0.894).

Be that as it may, considering the width of 95% LoA and the presence of outliers, the interchangeability and agreement of Lenstar and UBM in measuring ACD should still be interpreted with caution. The Bland-Altman plots showed a quite wide 95% LoA, especially in APAC eyes (0.614 mm for APAC eyes and 0.325 mm for PACS eyes). In our study, the average ACD was 1.71±0.23 mm for APAC eyes. Since APAC patients already had rather small ACD value, such relatively large difference between methods might influence medical decisions. As demonstrated in the Bland-Altman plot of APAC population, several scattering points resided outside the range of 95% LoA, which may suggest discrepancy between two measurements. Therefore, for APAC population, we suggest the clinical consistency of ACD measured by the two tests require prudent pondering.

On the other hand, the average ACD of PACS eyes was 1.79±0.25 mm in this study. ACD of PACS eyes were relatively shorter than the impression from clinical practice because the included PACS eyes were from the contralateral eyes of APAC patients. Although the width of 95% LoA was only 0.325 mm for PACS eyes, fluctuation in ACD measurement should still raise the clinicians' attention.

The discrepancy in measuring ACD may partly be due to the operator bias since this was a retrospective study. Besides, even if Lenstar and UBM were done within 2d, APAC patients may experience substantial changes in their clinical conditions. Furthermore, the value reported by UBM depends on manual operation rather than automatic output. Excessive indentation of the cornea and misdirection of ultrasonic wave might influence the measurement.

An inferior consistency in APAC eyes to PACS eyes may be explained by the following reasons. First, while the PACS eyes had substantially normal IOP, APAC eyes had a wide IOP range (surging because of acute angle closure, or dwindled due to mannitol use). Therefore, the resistance against indentation also varied from each other, making ACD difference statistically insignificant and the consistency relatively poor. Second, although neither of the two methods took the cornea thickness into account when measuring ACD, the oedema of cornea during APAC attack may still lead to measuring error. Similarly, APAC may cause other abrupt changes to the anterior segment which can contribute as confounding factors. Lastly, even if this study excluded eyes with lens dislocation secondary angle closure, there was possibility of patients with sparse lens zonulae, zonular laxity and subsequent change in lens position, simply not sufficient enough for diagnosing secondary angle closure. Anteriorly positioned lens is one of the structural pathogenesis of angle closure glaucoma. Besides, considering that the majority of our study population were elderly, these subjects were not excluded. Hence the possibility of measuring errors caused by body position (supine position during UBM but sitting position during Lenstar) might still exist.

This study aimed to explore the necessity of conducting both UBM and Lenstar in eyes with shallow anterior chamber. In this study regarding eyes with shallow anterior chamber, we noticed that agreement of UBM and Lenstar in examining ACD was relatively poor in APAC eyes. Meanwhile, even

if the anterior angle has been observed and documented by using gonioscope, UBM should be adopted since it provides other anterior chamber configurations, such as pupil diameter and the existence of plateau iris without constricting pupils. Such findings are important for APAC eyes since they help scheme therapeutic plans. As reported recently, difference in ACD measured by UBM and IOLMaster may help clinicians recognize acute secondary angle closure due to lens subluxation[20], which is commonly misdiagnosed as APAC[21-22]. Due to the fact that the occurrence rate of APAC is low[23-24], conducting both UBM and Lenstar will not necessarily impose heavy burden on medical resources. On the other hand, for PACS eyes with shallow anterior chamber, excessive examinations may be avoided considering the agreement between Lenstar and UBM and relatively deeper anterior chamber.

This study has several limitations. To start with, other appliances such as IOLMaster was not analyzed in this study, yet IOLMaster was a necessary examination for APAC eyes before surgical interventions. The interchangeability of IOLMaster and other apparatus still requires further studies. Moreover, as a retrospective study based on the outpatient medical records, the examinations were conducted by different operators. The existence of excessive indentation and probe misdirection might have affected the results of this study.

In conclusion, this study provided insight into the agreement of Lenstar and UBM when analyzing ACD in eyes with shallow anterior chamber. For PACS eyes, the two measurements might be interchangeable despite the shallow anterior chamber. However, for APAC eyes, the two test results may differ notably, thus comprehensive and thorough examinations can be necessary.

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