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Clinical features of the Anterior Chamber Depth

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Abstract

Purpose: To determine whether anterior chamber depth (ACD) has any clinical importance as well as the significance in various physiologic and pathologic processes.

Methods: Recollection of the most relevant data from the relationships of ACD in eye care were extracted from PubMed, SCOPUS, Google Scholar and ARVO. Forty-two total articles were used in the construct of this review.

Results: Anterior chamber depth has a direct proportional relation with axial length, corneal power and anterior chamber angle. It has an inverse proportional relation with age. Shallow anterior chamber depth was associated with and increased risk of endothelial cell density loss after phacoemulsification surgery, less ascorbic acid concentrations that translates to endothelial damage independently of surgery, angle closure glaucoma and angle closure secondary to retinal vein occlusions, trabeculectomy and tube placement complications and IOL formulae selection and refractive outcome inaccuracies. Population studies found this parameter to be different depending on the observed race and high rates of heritability, men were found to have deeper anterior chambers than women across all ethnic groups.

Conclusion: ACD plays an influential role in many physiologic and pathologic conditions. These include, IOL lens formula usage, expected refractive outcomes after phacoemulsification surgery, corneal endothelial cell loss, closed angle glaucoma, trabeculectomy and anterior chamber tube endothelial cell loss, closed angle glaucoma, trabeculectomy and anterior chamber tube processes.

Keywords

Anterior chamber geometry, Axial length, IOL formula

ACD Characteristics and Modifying Factors

Anterior Chamber Depth (ACD) plays an important role in several eye conditions, including inflammatory eye processes, keratoconus, endothelial cell density loss (ECDL), oxidative stress in endothelial cells, glaucoma surgical interventions, phacoemulsification surgery, anterior chamber dimensions, intraocular lens (IOL) formula calculations and surgical post refractive errors.

ACD corresponds to the distance between the corneal endothelium to the anterior lens capsule. Some authors may include the corneal thickness (CT) in this term, increasing approximately 0.5mm, corresponding to the average CT in mm. Although this is not a consensus, it is usually specified as ACD-CT [1].

ACD varies with age and gender. It has an inverse proportional relation with age, and directly proportional relation with the anterior chamber angle (ACA), and axial length (AL) [2,3]. Moreover, for every millimeter increase in AL the ACD distance increases by 0.07 mm, and by every year increment in a patient's life the ACD decreases by 0.005mm. This led to the following formulas; estimated ACD [3.339 - 0.005(age in years)] and ACD [0.07(axial length in mm)+1.4892] [4]. Other reported rates of ACD shallowing per year have been described, by Xu in the Beijing Eye Study at 9 µm/year [5] Fernandez-Vigo by 10.4 µm/year [6], Rufer 11.5 µm/year [7], Sun by 11.9 µm/year [8] Sng by 15 µm/year [9] and Yan by 17 µm/year [10]. The relevancy of this issue, albeit the immense variations just described, lies in the young individual that receives an IOL. Given their theoretically

long-life expectancy, ACD decrements affect the tolerability of the lens [6].

In addition to these observations, wide ACA is associated 80 with a deeper anterior chamber (AC), longer AL and higher corneal power, as proven in the Gutenberg Health Study [11]. In a cohort study comparing the AC in children (mean age 7.1 ± 3.3 years) and adults (73.7 ± 7.8 years), children had significantly deeper ACD, longer inter scleral-spur distance and larger corneal curvatures [12].

Due to modern technology, there are several approaches in anterior chamber measurement. Naturally, some techniques are far more accurate than others. Hoffer and Savini studied which were the most accurate methods. By comparing the older of them, manual optical pachymeter, versus mode A ultrasound. And pachymetry versus partial coherence inferenciometry (PCI, such as IOL Master). They determined that mode A ultrasound gave shorter ACD readings, related to the ultrasound velocity, across the different density between the cornea and aqueous humor. Optical pachymetry proved to be just as unequivocal as PCI, existing only a minor and not statistically significant difference among them. Thus, concluding that for accurate ACD measurement, optical means such as PCI and standard pachymetry shall be the prefered methods in acquiring this measurement [13].

When using PCI devices (IOL Master 500 or IOL Master 700) versus Scheimpflug camera methods (Pentacam AXL), the doubt remained if these had good agreement. In fact, the precision for these methods in acquiring ACD was just as exact. Although they may vary in the collection of other parameters such as AL (where IOL Master devices excell) or corneal curvatures (where Pentacam AXL was proven more accurate) [14].

Many other ophthalmological exploration estimations may be obtained from the anterior chamber, such as the Van Herick method for iridocorneal angle estimation. Recently, a newer `Van Herick Plus´ method was described by Sihota for peripherally measured ACD and angle [15]. Since the inferior part of the anterior chamber is more oftenly closed than the temporal or nasal section [16], a short vertical light beam straddling the inferior limbus and not reaching the pupil (to prevent miosis that may open the angle) was far more sensitive than standard Van Herick technique and it had a good correlation with anterior segment optical coherence tomography (AS-OCT): This method could be used for more accurate screening 110 methods for eyes requiring full gonioscopy for iridocorneal angle evaluation [15].

Physiological conditions may change the ACD measurement. Mete et al. found that the valsalva maneuvers reduce it by anterior displacement of iridolenticular diaphragm during this exercise [17]. Pregnancy was found to vary ACD in the third trimester versus postpartum period; these changes were not statistically significant, but the changes were attributed to CT change as a response to stromal water retention by hormonal effect [18]. For many years, the question remained if low birth weight was related to adulthood modifications in anterior chamber geometry. It was not until the Gutenberg Health Study provided with the database power to analyse whether this factor negatively impacted the AL and ACD. Contrary to the expectation, low birth weight was no associated with short ACD after adjustment with age and sex [19].

Interestingly, certain supra-physiologic activities such as space flight, leads to variations in ocular structures that are clinically important. Spaceflight-associated Neuro-ocular Syndrome (SANS) was described by the National Aeronautics Space Administration (NASA) after many observations in astronauts that spent more than 1 month in spaceflight and had developed hyperopic shifts, optic disc oedema, choroidal folds and globe flattening. After 1 year of follow up, the astronauts in this cohort presented many ocular changes. Amongst them was a significant change in AL and ACD that explained the hyperopic shift, optic nerve oedema and choroidal thickness was present as well. More research on zero gravity conditions and their effect on ocular physiology are needed to answer why the hyperopic shift remained for more than 1 year after the spaceflight return and if the other ocular signs and symptoms are preventable [20].

Less obvious physiologic changes and their relationships with ACD are related to ascorbic acid (AA) concentrations. These vary greatly among sex and ACD. Despite AA being twenty times higher in concentration in aqueous humor than that of plasma, differences in this vitamin either defends or exposes the endothelial cells to detrimental reactive oxygen species (ROS). Higher AA concentration in the AC, reduces the possibility of ROS interacting and damaging many other structures such as the trabecular 140 meshwork, lens, and the rest of the corneal layers. Since the phacoemulsification surgery readily replenishes the anterior chamber volume, along with this relevant molecule, there is an incremental risk of ECDL. Albeit, it wasn't fully understood if ACD or AL played any independent role in AA concentration. Just recently, we can observe that female gender, and shallow ACD are associated with lower AA concentrations. Hence, venturing patients with these characteristics to phaco surgery may have an even greater effect in ECDL [21]. It has been theorized that a few sets of genes; SVCT1, SVCT2, and GLUT1, and their polymorphisms [22] may be responsible for this difference in aqueous humor AA concentrations in women. As well as with ACD dimensions [21,22].

ACD Variations

There are several studies that determine the normal

parameters of ACD. Ethnic variations are an important consideration when discussing ACD. It has been extensively proven that age, sex, spherical equivalent and ethnicity have a significant effect on this parameter [23]. The heritability of ACD distance was conclusively proven by Klein et al. who conducted familial correlation and heritability in 750 subjects using the data from the Beaver Dam Eye Study cohort. Alongside ACD that was highly heritable (estimates ranging from 51 - 94%), so did other variables such as SE, corneal curvature and AL [24].

The Beijing Eye study evaluated a total of 2985 individuals using AS-OCT. The mean ACD was 2.42 ± 0.34 mm, and shallower in women than in men. The study found that shallow ACD was significantly (p < 0.001) related to age, hyperopic refractive error, female versus male gender, shorter body height and optic disc area [5].

The Singapore Chinese Eye Study evaluated 1060 subjects using AS-OCT and found a mean ACD of 3.24 ± 0.35 mm, greater in men (3.29 ± 0.36 mm) than in women (3.19 ± 0.33 mm). Women had a greater lens vault (LV), iris curvature and IOP than men. Most importantly, shallow ACD was directly influenced by age, large LV, angle opening distance at 750 µm from the scleral spur (AOD750), large ACW, short AL, grand iris area and posterior corneal arc length (PCAL). In this study, the cardinal factors determining the ACD measurement are PCAL and LV. Other variables like height (in direct disagreement to 170 the results found in the Beijing Eye Study), diabetes mellitus, iris curvature, IOP, cup-to-disc ratios were not significantly associated with ACD [9]. Despite this fact, diabetes is still an important risk factor to consider for its lens thickness (LT) enlargement mechanisms [25].

Chinese population has a shallower AC, smaller anterior chamber width (ACW), anterior chamber angle/volume (ACA, ACV), independently of age and AL, compared with Caucasians. Thus, it is wise to consider the AC characteristics in regard to ethnicity [23]. In fact, when comparing AC parameters between Chinese and Vietnamese populations, the former had an even greater ACD, rendering the latter with important clinical consequences, mainly related to primary angle closure [26].

Lozano et al. found in a retrospective study involving 124 subjects that the mean ACD in a Hispanic population in the northern mexican region was 2.92 ± 0.44 mm and that ACD had a positive correlation with pupil diameter in a statistically significant manner [27].

Surgical Considerations Regarding ACD

Surgical interventions such as phacoemulsification techniques have an important modification effect in ACD. The relative change in ACD was more pronounced and statistically significant, in shorter AL eyes than in normal AL or high AL [28].

ACD proved to be a key predictor for refractive outcomes in age related cataract surgery (ARCS). This measurement increases in the first two weeks after phacoemulsification cataract surgery, in a statistically significant matter. This expansion halted after the two week period. Depending on whether this change in ACD is relatively small, and hyperopic overcorrection is seen postoperatively, the contrary leading to a more myopic result. Accordingly, Ning et al. proved that there is a positive relationship between preoperative ACD and postoperative refractive error. Additionally, to a significant correlation between the incidence of refractive errors depending on whether the AL is < 22 mm or > 26 mm. The author also proposed two regression formulas for correctly estimating this ACD change. Although further validation is still required. These formulas are, for postoperative 200 ACD (3.524 + 0.294 × preoperative ACD) and postoperative ACD (3.361 + 0.228× [preoperative ACD + 1/2 LT]) [29].

Furthermore, shallow ACD along with short AL is an important risk factor for ECDL. Khalid et al. demonstrated that AL between 22-23.5 mm and ACD in the 2-3 mm range had greater mean change in corneal endothelial density after phacoemulsification surgery with IOL implantation [30]. Along with these findings, anterior chamber volume (ACV) and lens density (LD) may also be crucial factors regarding ECDL [31].

Likewise, in Descemet Stripping Automated Endothelial Keratoplasty (DSAEK) and in Descemet Membrane Endothelial Keratoplasty (DMEK), a shallow ACD creates a greater loss of endothelial cells and a deleterious effect on their long-term survival [32].

It is known that the pseudoexfoliation syndrome (PEX) gives rise to many surgical challenges, including floppy iris syndrome, glaucoma, zonular dialysis, phacodonesis, lens subluxation and less intracameral response to mydriatic agents. It was recently proposed by Gungar et al. another clinical correlation involving PEX and its effect on ACD. They compared normal AL eyes versus normal AL PEX eyes after phacoemulsification surgery, concluding there was a substantial change in ACD compared to non PEX individuals. This is paramount to consider in IOL formula selection and postoperative refractive results [33,34].

Primary open angle glaucoma (POAG) and Primary angle closure glaucoma (PACG) retain an unequivocal relationship with ACD. Even if this either helps or promotes further deterioration. POAG patients have a greater LT and shallower ACD compared to healthy controls, independently of IOP. IOP reduction may also be achieved in lens removal, depicting its great importance in PAOG. ACD being significantly reduced in the female population and with older patients, this represents important risk factors that shall be considered. In PACG, the most well-known risk factors are Asian population, hyperopic eyes, and shallow ACD [35].

In cases where anterior chamber tube placement is imperative, ACD symmetry shall be carefully considered. Since the narrowest part of the AC lies in the superior portion in pseudophakic patients, and the tube-endothelial distance is directly influenced by the ACD, this parameter is essential in order to avoid further endothelial cell loss or injury. Despite this fact, most drainage tubes are placed superotemporally or in a supero-nasal position. Thus, a broader ACD is a protective factor in case of anterior chamber IOL or tube placement [36]. Following trabeculectomy, ACD decreases importantly in the first 4 postoperatives days and reaches 91% of its preoperative value at 14 days. After this 2-week period and so forth, ACD does not in fact significantly change this procedure [37].

The anterior chamber may reduce its length with central retinal vein occlusions (CRVO), mainly by the vascular congestion of the ciliary body and an increase in posterior pole volume, this may be so extreme that the resulting displacement often leads to angle closure in shallow ACD (specially if less than 2 mm) eyes or in the context or reduced AL. This exemplifies the emphasis that we shall all have in performing gonioscopy following CRVO, both for the angle closure that this may cause, and the manifestation of a neovascular glaucoma [38].

Anterior chamber modifications in keratoconus are numerous. Despite the obvious corneal changes that modify its symmetry, ACD cannot only be attributed to corneal curvature, but also limbal alterations are responsible for this parameter increment. Not only does ACD is significantly augmented in keratoconus, but also does the anterior chamber sagittal depth to anterior surface of the lens. The latter being only explained with limbal-scleral changes unrelated to cornea curvature [39].

Even in severe panuveitic syndromes, such as Vogt-Koyanagi-Harada (VKH), does ACD have its usefulness. ACD is decreased in the acute uveitic stage of VKH, consequent of the grand ciliary body oedema. Otsuki et al. measured the ACD in VHK after steroid pulse therapy. Effectively demonstrating that the anterior chamber is the fastest changing parameter, beginning at week 1 pulse therapy. Whereas AL, spherical equivalent, BCVA and flare took at least 4 weeks to have statistically significant change. In addition, they concluded that ACD was the most sensitive parameter in determining anterior chamber inflammation, even more so that the standard cell and flare grading method [40].

IOL Formula Considerations

Gökce et al. assessed the accuracy of several IOL calculation formulas in normal axial length and discovered significant postoperative variations depending on the formula and the ACD. It was found that in ACD ≤ 3 mm, the Barrett Universal formula was most precise and gave the least refractive error [41]. Although Hoffer Q may also be appropriate in this setting [42]. In the 3-3.5 mm ACD range, all the formulas were precise, the small differences between each other hand no statistical significance, thus Holladay 1, Holladay 2, Hoffer Q, SRK/T, Haigis, Hill-RBF, Barret Universal **11** and OLCR may be appropriate for this ACD in normal AL patients. For ACD ≥ 3.5 mm three formulas had the lowest mean refractive error. They were Barret Universal **11,** Haigis, and Holladay 2. Although, Barret Universal **11** and Haigis had better performance than the best [41,42]. For patients with AL ≤ 22 mm plus ACD < 2.4 mm, the most precise IOL formula to date is Barret Universal II**,** Haigis [42], nevertheless, the latter had a wider error range.

Disclosure

The authors report no conflict of interest in this work.

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