RESEARCH PAPER | Medical Science | Volume : 5 | Issue : 3 | March 2015 | ISSN - 2249-555X

Can Ultrasound Biomicroscopy Match the Gold Standard Ultrasound Pachymetry for the Measurement of Central Corneal Thickness?

KEYWORDS: Ultrasound Biomicroscopy, Ultrasound Pachymetry, Central Corneal Thickness.

Neeharika P. Shah

M & J Western Regional Institute of Ophthalmology B. J. Medical College & Civil Hospital Ahmedabad Gujarat, India

ABSTRACT *Aim: Ultrasound Biomicroscopy (UBM) has emerged as a valuable tool in the diagnosis of various Ophthalmological conditions. Some applications in Glaucoma include measurement of Central Corneal Thickness (CCT), lens thickness, anterior chamber depth and angle, trabecular iris angle, angle recess area, etc. CCT acts as a confounding factor for the diagnosis of primary open angle glaucoma because while measuring intraocular pressure (IOP) by Applanation tonometry, a thicker cornea leads to overestimation of IOP and a thinner cornea leads to underestimation of IOP. Our study aims to assess the accuracy with which UBM measures the CCT vs. the gold standard Ultrasound Pachymetry (USP). Method: Our study was a prospective study undertaken during the period from June 2009 to June 2011. We studied 120 eyes of 60 patients diagnosed with Primary open angle Glaucoma. Imaging using UBM with a 50 MHz probe was done to measure CCT. Pachymetry using Ultrasonic Pachymeter was done till 3 consistent reliable readings were obtained and the average of these readings were taken as the final CCT reading.*

Result: After analyzing by means of statistical principles, the coefficient of correlation between UBM and USP values was 0.76. UBM overestimates CCT in the range of 25 -30 microns. Applying paired 't' test, the p value came out to be 3.48387 x e -21 (p< 0.05), implying that there is a statistically significant difference between the values of CCT as measured via UBM and USP.

Conclusion: UBM has various utilities in the field of Glaucoma – it provides us with high resolution images of structures such as a trabeculectomy site, a peripheral iridectomy, etc and allows us to measure various anterior segment parameters. UBM is not as accurate as USP in the measurement of CCT. Hence, more research is needed to standardize the techniques in order to make UBM accurate and reliable for CCT measurement.

Introduction

Ultrasound Biomicroscopy

Ultrasound is an indispensible tool in medical imaging and has an important role in ophthalmic diagnoses. Routinely used B scan ultrasound imaging has a Frequency of 5-10 MHz. The use of high frequencies in the 20-100 MHz range for ocular imaging has greatly improved the resolution of ocular ultrasound, so much that the inventors named this process as biomicroscopy, that is imaging of living structures at microscopic resolution. The resolution of Ultrasound Biomicroscopy (UBM) is much higher than that of B scan, but the penalty paid is loss of depth of penetration. For a 50 MHz probe it is 5mm. [1]

Glaucoma is defined as a chronic progressive multifactorial anterior optic neuropathy characterized by typical optic nerve head changes and irreversible visual field defects for which raised intraocular pressure (IOP) is the most important risk factor. Primary Open Angle Glaucoma (POAG) is a chronic progressive anterior optic neuropathy characterized by typical optic nerve head changes, irreversible visual field defects, open angles and no obvious causative ocular or systemic conditions.[2] POAG is a diagnosis of exclusion. There are several confounding factors for the diagnosis of POAG. The factor of

interest amongst them in our study is Central Corneal Thickness (CCT). CCT acts as a confounding factor for the diagnosis of primary open angle glaucoma because while measuring IOP by Applanation tonometry, a thicker cornea leads to overestimation of IOP and a thinner cornea leads to underestimation of IOP. Our study attempts to answer the question "How accurately and reliably can we measure CCT by Ultrasound Biomicroscopy in POAG patients?"

The applications of UBM in Glaucoma include the measurement of various parameters. Some of these are Corneal thickness, Anterior chamber (AC) angle, AC depth, Lens thickness, Angle opening distance, Trabecular Iris angle, Trabecular – Ciliary process distance, Iris – Ciliary process distance, Angle recess area, etc.[1], [3]

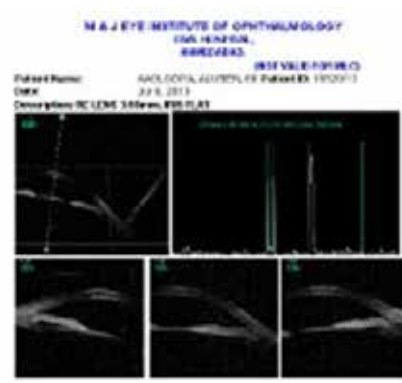

Figure 1: Ultrasound Biomicroscopy probe

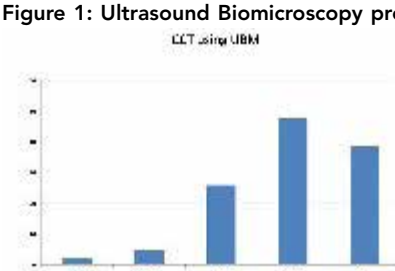

Figure 2: Performing Ultrasound Biomicroscopy

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Figure 3: Ultrasound Biomicroscopy scan

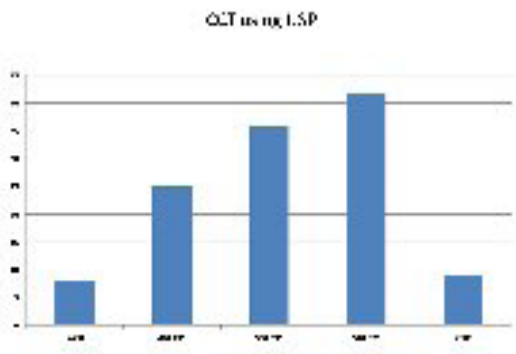

Figure 4: Ultrasonic Pachymeter

Pachymetry

Pachymetry is the term used for measurement of corneal thickness. It also measures corneal rigidity and consequently has an impact on the accuracy of IOP measurement by Applanation tonometry. Applanation tonometry is based on Imbert Fick's law, which assumes that cornea is a perfect flexible, dry sphere which is infinitely thin. Therefore a thicker cornea is less compliant leading to overestimation of IOP and a thinner cornea leads to underestimation of IOP.

Effect of CCT on various tonometers: Goldmann applanation tonometry is the gold standard for IOP measurement in glaucoma. Ocular blood flow pneumotonometer and non-contact tonometer show a higher influence of CCT on the IOP measurement than Goldmann tonometry.[4] Dynamic contour tonometry is a newer promising modality, affected to a lesser degree by CCT, but has been found to overestimate IOP.[5]

There are various techniques for pachymetric measurements. The Ultrasound techniques are Conventional Ultrasound Pachymetry and Ultrasound Biomicroscopy.

The optical techniques are Manual Optical Pachymetry, Specular microscopy, Scanning Slit technology, Optical Coherence Tomography, Confocal microscopy, Laser Doppler Interferometry.[6]

The alternative methods for measurement are Pentacam and Pachycam.

Ultrasound Pachymetry (USP)

This is one of the most commonly used methods nowadays and is regarded as the gold standard.[7],[8],[9] Some of the advantages over other methods are that it is fast, that is very less time is consumed for taking measurements. The machine is portable, hence it can be carried to remote areas; it is simple to operate hence easier for paramedical staff to use. It does not require any coupling medium. Since the probe can be sterilized, it can be used intraoperatively. The method requires minimal observer judgement and is therefore consistent and repeatable. Thus, inter-observer variation is eliminated. However, there are a few disadvantages too. These are that it is a contact method, hence there are chances of transmission of infections. Measurements are not accurate in edematous corneas. It has low resolution. Its accuracy depends on the perpendicularity of the probe's placement over the cornea. Thus the examiner's experience can influence the reliability of the measurement.

Pachymetry using Ultrasound Biomicroscopy

Corneal thickness can be measured by the caliper incorporated in the machine or through the UBM software after acquisition of images.

The advantages of using UBM for pachymetry are that anterior segment examination can be carried out along with measurement of corneal thickness. It is especially useful in cases where the cornea is opaque. Various layers of the cornea can be identified via UBM.

The disadvantages of UBM are the bothersome requirement of immersing the eye in a coupling fluid; the requirement for the patient to be supine during the examination, which may be inconvenient for individuals with disorders such as Kyphosis, Scoliosis, Spondylosis, etc. It is a contact method, hence transmission of infections may occur. The device cannot be used intra-operatively.

Method

Our study was a prospective study conducted at M & J Western Regional Institute of Ophthalmology undertaken during the period of June 2009 to June 2011. We studied 120 eyes of 60 patients who were diagnosed with POAG. A written and informed consent for the procedures performed was taken from all patients.

A detailed history taking and anterior segment examination with slit lamp biomicroscopy was done for all patients.

The other procedures performed were - IOP measurement using Perkin's hand held tonometer was done. Gonioscopy was done using Goldmann's two mirror lens and graded as per Shaffer's classification. Fundus examination using slit lamp biomicroscopy with a + 78 D lens or indirect ophthalmoscopy was done in all patients. Visual field examination was done with Octopus perimeter (Haag Streit Octopus Perimeter, Cal Coast Ophthalmic Instruments, Inc., California, USA) in all patients. UBM using a 50 MHz probe was done to analyze anterior segment parameters including CCT. Pachymetry using Ultrasonic pachymeter (Sonomed Pacscan 300P Pachymeter, Cal Coast Ophthalmic Instruments, Inc., California, USA) was done till 3 consistent reliable readings were obtained. The average of these readings was taken as the final reading.

Results

CCT using UBM:

The mean CCT was found out to be 553 microns.

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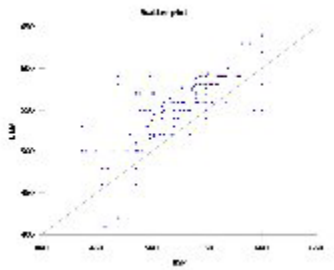
Figure 5: Central corneal thickness (CCT) using Ultrasound Biomicroscopy (UBM)



CCT using USP:
The mean CCT was found out to be 525 microns.

Figure 6: Central corneal thickness (CCT) using Ultrasound Pachymetry (USP) CCT, UBM Vs USP:

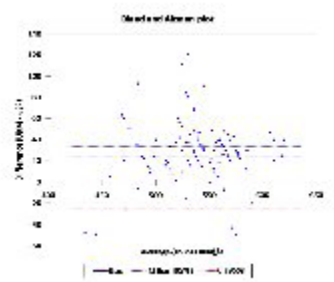


Figure 7: Central corneal thickness (CCT), Ultrasound Biomicroscopy (UBM) Vs Ultrasound Pachymetry (USP)

	USP<540	USP>540	Total
UBM<540	33	0	33
UBM>540	36	51	87
Total	69	51	120

Table 1: Comparison between Ultrasound Biomicroscopy and Ultrasound Pachymetry for detection of thin corneas
Thus the sensitivity of UBM in our study for the detection of thin corneas was 48% and the specificity was 100%. The coefficient of correlation between UBM and USP values was 0.76 (r=0.76), which implies that there is a good correlation between the values of CCT as measured by the two devices. Applying the F test, the p value came out to be 0.87, which implies that there is no significant difference in the variance of the CCT values measured by USP and UBM. UBM overestimates CCT in the range of 25-30 microns. Applying paired 't' test, the p value came out to be $3.48387 \times e^{-21}$ ($p < 0.05$), implying that there is a statistically significant difference between the values of CCT as measured via UBM and USP. Thus we conclude that UBM is not reliable for accurate measurement of CCT.

Discussion
Our study has discovered that UBM has a low sensitivity of only 48%. This implies that using UBM for pachymetry might miss out on the detection of thin corneas. As explained previously, a thin cornea results in underestimation of IOP reading. As a consequence, we may miss out the diagnosis of POAG. Also if IOP is used as a tool to judge adequacy of treatment, an underestimated IOP will lead to misinterpretation of good control and lead to progression of the disease.

The reasons for the inaccuracy of UBM measurement can be multiple. Various studies have tried to address this issue. Urbak S.F. et al reviewed the interobserver and intraobserver reliability for the measurement of CCT, AC Depth and angle structure parameters by UBM.[10] Intraobserver reproducibility was assessed by the coefficient of variation and the interobserver reproducibility by a two-ways ANOVA test. They discovered high intraobserver reproducibility for CCT measurement. However the interobserver reliability for all the measurements was poor. The authors concluded that comparison of measurements should be done by one observer only.[10] Another analysis of the interobserver and intraobserver reliability of UBM images was conducted by Tello C. et al.[11] The intraobserver reproducibility of the measurements was assessed by calculating the coefficient of variation for each individual observer and the F test was used to evaluate interobserver reproducibility. A similar result of high intraobserver and variable interobserver reproducibility was achieved. They concluded that the optimal parameters for quantitative UBM require refinement. Measurements are best taken by a single

observer. UBM has the potential to elucidate anatomic relationships underlying anterior segment disease but caution in interpreting quantitative differences is warranted.[11] In our study, multiple observers performed UBM. The interobserver variability could be one of the reasons for the inaccuracy of the UBM readings in our study.

A review by Pierro L. et al aiming to correlate CCT by Optical Pachymetry, USP and UBM found a strong correlation between the values of CCT by UBM and USP.[12] The authors concluded that UBM can be used as an accurate and reproducible method for pachymetry.[12] A report by Tam E.S. et al compared the reproducibility and mean values of CCT obtained by specular microscopy, UBM and USP.[13] They discovered that there was no statistically significant difference between the mean Standard Deviations by USP and UBM. According to their study, USP & UBM produced similar CCT measurements.[13] Another study by Haya M. Al-Farhan et al compared the CCT measurements using UBM, USP and Very High Frequency Ultrasound Scanner and concluded that UBM may not be used interchangeably with USP and Very High Frequency Ultrasound Scanner.[14]

Conclusion:
UBM has various utilities in the field of Glaucoma – it provides us with high resolution images of structures such as a trabeculectomy site, a peripheral iridectomy, etc and allows us to measure a whole lot of parameters such as CCT, AC angle, AC depth, Lens thickness, Angle opening distance, Trabecular Iris angle, Trabecular – Ciliary process distance, Iris – Ciliary process distance, Angle recess area, etc.[1],

Even though it is specific as regards to detecting thick corneas, UBM is not a sensitive instrument to measure CCT as compared to USP. There is a statistically significant difference in the values of CCT as measured by UBM and USP.

Still more research and advancements are required to standardize the methods and techniques in order to make UBM reliable, accurate and reproducible.

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