Optimization of the ultrasonic eye axial length meter gain

O. Parusnikova, A. Katashev[1]

Institute of Biomedical Engineering and Nanotechnologies, Riga Technical University, Latvia

[1]E-mail: katashev@latnet.lv

Introduction. One of the most popular methods of eye cataract treatment is extraction of the damaged natural lens and insertion of the artificial intraocular implant [1]. Treatment success in a great extent depends on appropriate selection of the size and optical power of the implant lens. Although number of methods (e.g. Binkhorst, Holladay, SRK-T etc. [2]) was proposed to calculate lens optical power from the patient eye data (Fig. 1a), all they may be transformed to the equation:

$$P = \frac{n}{L - ACD} - \frac{n \cdot K}{n - K \cdot ACD}, \qquad (1)$$

where P – implant power for emmetropia (normal vision), n – relative water to vitreous body refractive index, ACD – estimated postoperative anterior chamber depth (mm), L – axial length (mm), and K – corneal curvature (dioptres) [3]. From the equation (1) one could see that accuracy of optical power calculation depends, among other parameters, on the accuracy of measurement of the eye optical length.

Measurements of the eye optical length routinely are performed by means of ultrasonic A-mode biometric scanners [4]. Typical A-echogram (Fig. 1b) visualise eye structures, thus distance among them may be measured. Improper gain selection affects amplitudes of the peaks and makes identification of the eye structures difficult, hereby generating errors in optical length values. Besides, still there are no clearly defined criteria for gain selection, except of quite a subjective concept of “good” image.

The goal of the present study was to explore the influence of ultrasonic biometer gain on the accuracy of axial length measurement and develop recommendations for gain selection.

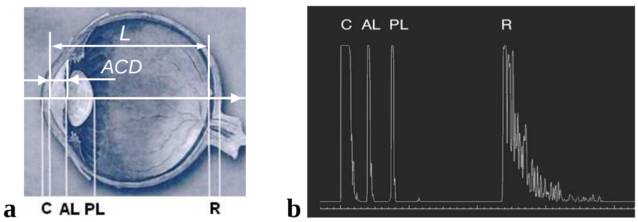

Fig. 1. a – Eye anatomical structure, b – A-echogram of the normal eye. Peaks correspond to cornea (C), anterior (AL) and posterior (PL) capsule of lens and retina (R)

Materials and methods. Measurements have been made using Alcon Ocuscan® ophthalmology ultrasonic biometer [5]. Biometer allows measurements both in dry mode, when US probe is in direct contact with sclera, and immersion mode, when contact gel – filled ring is placed over the sclera (Fig. 2). Gain of the biometer may be selected in the range from 0 to 100% of the maximum.

Fig. 2. Immersion measurement. Probe is placed 5 – 10 mm over the cornea [5]

Alcon® artificial eye phantom (Fig. 3) was used as an measurement object. The phantom is made of acrylic polymer; its internal structure of the phantom resembles one of an eye. The distance between cornea and retina was equal to 24.2±0.15 mm. Alcon Ocuscan®: 10MHz probe was inserted into the phantom aperture, filled with the contact gel. Diameter of the aperture tightly matches this of the probe, providing secure probe fixation and alignment of the ultrasound beam normally to phantom reflecting structures with angular deviation less then 10".

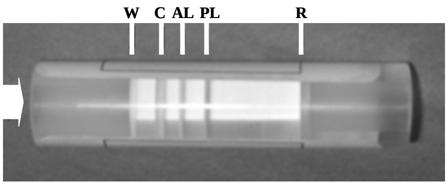

Fig. 3. The eye phantom is divided into following areas: water layer (W), cornea (C), arterior (AL) and posterior (PL) capsule of lens and retina (R). The arrow indicates an aperture for insertion of a biometer probe [5]

There are two modes of eye axial length measurement in biometer Alcon Ocuscan®: manual and automatic. In manual mode operator has to identify echogram peaks and mark those corresponding to cornea and retina. In automatic mode, selection of the peaks is made by biometer software.

For the measurement in automatic mode, 10 gain levels in the range from 52% to 100% were selected (at lower gains device was not able to measure axial length in automatic mode due to low peaks amplitude). Using randomized sequence to prevent possible time bias, 5 measurements for each gain level were obtained. Absolute difference between measured axial length and actual phantom distance was used for estimation of measurement accuracy.

For the manual mode, the same gain levels were used. For each gain level, five echograms have been recorded. Axial length was measured by manual selection of C and R peak by trained expert. Afterwards, acquired images have been printed out and passed to 3 independent experts. Experts has two tasks: 1) evaluate quality of every image by assigning score 1 ("bad"), 2 ("average") or 3 ("good"), and 2) with a pen mark "correct" peaks, i.e. those peaks, that correspond to eye anatomical structures (C, AL, PL and R, Fig. 1). Experts were acknowledged that images were obtained with different gains, but gain itself was not communicated; besides experts may see on the image value of the measured axial length. Difference between measured axial length and nominal phantom value, expert scores for each image and number of correctly identified peaks were used for further analysis.

Results and discussion. For both automatic and manual modes, the absolute difference between phantom nominal axial length and measured value depends strongly on biometer gain (Fig. 4). This difference does not exceed 1 mm or 4% from the nominal value for gains ranged from 59% to 72% and boosts up for auto mode at higher gains. Form manual mode, error grows not so fast and does not exceeded 2 mm. For the lower gain (52%), error of auto mode measurement increase, while for the manual mode axial length have not been calculated because of difficulties in identification of echo from retina. Although direction of the deviation from the nominal length is not shown on the Fig. 4, initial data demonstrated, that in auto mode axial length is always underestimated, but in the manual mode overestimated at lower gains.

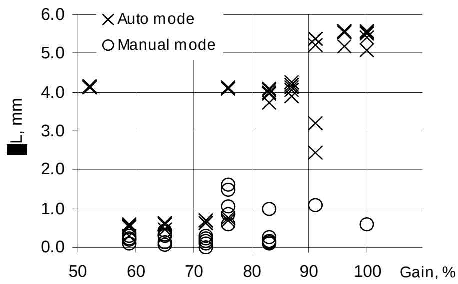

Fig. 4. Deviation form nominal axial length as function of biometer gain. For the manual mode, only data from echogram with all four peaks identified are shown

To estimate agreement between experts, Kendall's coefficient of concordance W [6] has been calculated for the scores of the echogram quality. Value of W appears to be equal to 0.64 that imply reasonably good agreement between experts. Fig. 5 demonstrates average score, assigned by experts, and average number of identified peaks as function of the biometer gain. The data from all three experts are nearly similar. Besides, the scores assigned by the expert II are generally higher, that may be explained by lowest qualification of the expert 2 (doctor assistant) comparing with expert I and III (medical doctors). Data on Fig. 5 demonstrates that better results corresponds to the gain 59% -72%, that coincides with those estimated using axial length measurements.

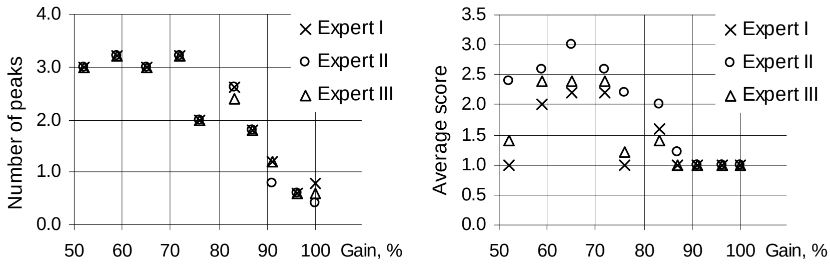

Fig. 5. Average image score (a) and number of identified peaks (b)

Conclusion and recommendations. For the Alcon Ocuscan® ophthalmology ultrasonic biometer, the optimal range of the gain, minimizing axial length measurement error, maximizing image quality and number of correctly identified eye structures, lies between 59% and 73%. This result has been obtained both by auto mode measurements and by expert evaluations, so in a routine practice one may select the most convenient method.

Error due to inappropriate gain selection is considerably reduced in manual mode when measurements are made by the trained experienced professional. Therefore one would recommend performing such optimization measurements if the instrument is mainly operated in automatic mode.

Two questions still should be answered: 1) do these phantom-based methods provide optimal gain value for the human eye measurements as well, and 2) do these methods are adaptable for other models of US of biometers.

References

1. http://www.acrysofrestor.com/
2. http://doctor-hill.com/iol-main/iol_main.htm/
3. John A. Retzlaff, Donald R. Sanders „Lens Implant power calculation", SLACK Incorporated, New Jersey 08086, 1990, 58lpp.
4. KarolinneMaia Rocha, MD, PhD, Ronald R. Krueger, Ophthalmic Biometry, MSE Cole Eye Institute, Cleveland Clinic Foundation, 9500 Euclid Avenue, Mail code i-32, Cleveland, OH 44195, USA © 2008 Published by Elsevier Inc.
5. Ocuscan® Operator's Manual, ©Alcon Laboratories, Inc., 1999, 102.lpp.
6. Legendre, P (2005) Species Associations: The Kendall Coefficient of Concordance Revisited. Journal of Agricultural, Biological and Environmental Statistics, 10(2), 226–245.

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Appropriate choice of the eye lens implant is crucial for cataract treatment success. Nowadays, implant is selected by measuring anatomical length of the eye ball and its structures by mean of ultrasonic imaging. The accuracy of the measurement is influenced by the image quality affecting parameters, gain being the most important among them. The paper presents the results of gain optimization for the commercial eye axial length meter.