Original Article

Taiwan J Ophthalmol 2017;7:149-154

Access this article online

Quick Response Code:

Website: www.e-tjo.org

DOI: 10.4103/tjo.tjo_45_17

Intraocular pressure monitoring by rebound tonometry in children with myopia

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Abstract:

BACKGROUND/PURPOSE: Topical atropine treatment is generally accepted to retard the progression of myopia, but it is associated with side effects such as photophobia and elevation of intraocular pressure (IOP). IOP measurements in children are challenging. The traditional applanation tonometry by direct contact with the cornea will require patient's cooperation. The rebound tonometer, using a dynamic electromechanical method for measuring IOP, shows good correlation with traditional tonometry. The purpose of this study is to evaluate the IOP of myopic children under atropine treatment using rebound tonometer and to compare the characteristics between rebound tonometry and applanation tonometry.

METHODS: This study is a prospective study measuring IOP by rebound tonometer in myopic children under regular low-dose atropine treatment. We recruited children with refraction error showing myopia over −0.5 D with 0.15%, 0.3%, or 0.5% atropine eye drops use every night or every other night for myopia control. Children with treatment duration of atropine <1 month were excluded from the study. IOP measurements were performed by applanation tonometer (Tono-Pen XL, Reichert) and rebound tonometer (ICARE). The reliability of rebound tonometer was analyzed with percentage. Comparison of IOP between rebound tonometer and applanation tonometry was presented.

RESULTS: The rebound tonometry was well tolerated by all participants and caused no complaints, discomfort, or adverse events. Totally 42 myopic eyes of 42 subjects were included in the study. The average age of these participants was 10 years old, range from 5 to 16. Median = 10 years old. The average IOP of the right eye by rebound tonometer was 17.4 ± 3 mmHg, and 17.1 ± 3 mmHg by applanation tonometry. Nearly 19%, 33%, and 24% of difference of IOP readings between rebound tonometer and Tono-Pen applanation are within 0 mmHg, 1 mmHg, and 1–2 mmHg, respectively.

CONCLUSIONS: Rebound tonometry has good correlation with applanation tonometry and 76.1% of differences between two tonometers are <2 mmHg. The advantage of drop-free rebound tonometry has made it easier to obtain IOP readings in myopia children under atropine treatment.

Keywords:

Atropine, intraocular pressure in children, myopia, rebound tonometry

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Submission: 08-11-2016
Accepted: 18-04-2017

Introduction

In pediatric ophthalmology, for all practitioners, intraocular pressure (IOP) measurements in children are challenging. A variety of tonometers are used in clinic, but no ideal technology of pressure measurement is concluded in pediatric patients.

The traditional measurement of IOP is the Goldmann applanation tonometry (GAT) mounted on a slit lamp. IOP is determined by measuring the force necessary to flatten the cornea underneath the tip of the Goldmann tonometer. GAT requires the instillation of topical anesthetics before measurement and a very high degree of cooperation from the child. Other applanation handheld tonometers (e.g., the

How to cite this article: Weng J, Tsai IL, Kuo LL, Tsai CY, Woung LC, Hsiao YC. Intraocular pressure monitoring by rebound tonometry in children with myopia. Taiwan J Ophthalmol 2017;7:149-54.

Perkins [Haag-Streit, Koeniz, Switzerland] and Kowa [Kowa Optimed, Inc., Torrance, CA, USA]) are also available for patients in a supine position. A new technology, the rebound tonometer (ICARE, Helsinki, Finland), using a dynamic electromechanical method for measuring IOP, became available in human in 2003. The instrument uses a minimal force to propel a very lightweight probe, whose impact on the cornea is almost imperceptible by human subjects, such that local corneal anesthesia is not necessary.[1] In animal study, the rebound tonometer was easy to use and accurately measured IOP in rats and mice.[2] In general, it does not require topical anesthetics instillation hence avoids the anxiety that caused by eye drops before measurement in children.[3-6]

Healthy children demonstrate some diurnal fluctuation in IOP.[5] General speaking, noncontact air-puff tonometer, as well as standard applanation tonometer, requires good cooperation to obtain reliable IOP data. In pediatric patients, not every child can tolerate this kind of procedure.[4,5]

Myopia is a prevalent ocular disease in Taiwan among school children, and high myopia (myopia at least −6.0 D) is associated with potentially blinding complications. Saw and Wong found some interventions such as low-dose atropine eye drops, bifocal lenses, or contact lenses have been used in retarding the progression of myopia in children.[6] Low dose atropine treatment is generally accepted to retard the progression of myopia. However, topical atropine is associated with side effects such as photophobia, elevation of IOP, and possible long-term adverse events including UV light-induced retinal damage and cataract formation.[6,7] Adverse effects are often related to dosage or other factors.[7] Papers focusing on the safety of atropine treatment in childhood myopia are published. More common adverse effects such as dermatitis, allergic conjunctivitis, and pupil size-related photophobia were compared between different concentrations of atropine, but fewer paper discussed the changes in IOP before and after treatment. Topical atropine therapy for up to 3 years seemed to be safe in myopic children in one study from Taiwan; neither the cumulative dose nor the duration of atropine therapy was statistically associated with the risk of having elevated IOP.[7] Regarding above issues, we tried to evaluate the IOP of myopic children under atropine treatment by rebound tonometry.

Methods

This is a prospective study measuring IOP using rebound tonometer (ICARE, Helsinki, Finland) in 44 myopic children under 0.15%, 0.3%, or 0.5% atropine treatment from the Department of Ophthalmology at Zhongxing Branch, Taipei City Hospital in 2011. This protocol was approved by the Institutional Review Board of Taipei City Hospital, and the informed consent was obtained from the parents for all enrolled participants. We recruited children who were well tolerated with IOP measurements by two types of different tonometers and refraction error showed myopia over −0.5 D. Children with treatment duration of atropine <1 month were excluded. IOP was first measured by ICARE rebound tonometry by a single ophthalmologist; IOPs were recorded as well as reliability designations as outlined by the instruction manual. Second, after instilling topical anesthetic, applanation tonometer with Tono-Pen XL was performed on each eye by another technician. IOP measurements by Tono-Pen instead of by standard GAT were selected for comparison. The advantage of Tono-Pen measurement includes presenting IOP readings and reliability index (5%–20%) at the same screen. Repeat measurements can be performed once low-reliability index reported. Detailed ocular examinations were performed including best-corrected visual acuity, refractive error, and optic nerve head appearance. The concentration of atropine treatment was recorded. We excluded eyes with pediatric glaucoma or glaucoma suspect according to fundus photography and eyes with central corneal scar. Eyes with infectious diseases, uveitis, or with documented ocular trauma history were excluded.

IOP measurements were performed by applanation tonometer (Tono-Pen-XL, Reichert) and rebound tonometer (ICARE Finland Oy, Vantaa, Finland) by one technician and one ophthalmologist. All values are reported as mean ± standard deviation unless otherwise noted. All statistical tests were two-sided, and the threshold for significance was set at $\alpha = 0.05$. Bland–Altman analysis was performed for comparison between two tonometers. IOP readings by two tonometers were compared using linear regression and Student's *t*-test (Statistical Analysis and Reporting System).

This portable rebound tonometer ICARE has a stainless steel probe with a length of 50 mm and diameter of 1.4 mm that is repelled horizontally by a coaxial two magnet systems, touches the cornea very gently at a distance of 4–8 mm, and the bounced probe induces a voltage in the solenoid, which is converted to a digital signal.[1-4] Disposable probes are used in different patients to prevent the risk of cross-infection.

On activation of the measurement button, the rebound tonometer automatically takes six readings of IOP and discards the highest and lowest readings. The device averages the four readings and then gives a reliability indicator that reflects the standard deviation of individual IOP measurements [Figure 1].[1,8-11]

Results

The rebound tonometry was well tolerated by all participants without any complaints of pain or corneal damage under slit lamp examination. Nineteen boys and 26 girls were recruited in this study. One boy failed to pass applanation examination was excluded. Totally 44 myopic eyes of 44 children were included. Two children were excluded because failed to obtain reliable IOP readings after repeat measurements. Demographic data and clinical characteristics are given in Table 1. The mean age of these participants was 10 years (range 5–16). Median age was 10 years old.

This device provides a reference of its reliability by showing a short line beside IOP readings (P solid-reliable, P bottom-acceptance but less reliable, P middle-less reliable, P top-suggest repeat measurement). Regarding the reliability of rebound tonometry measurement in children at the first try, 21% were Psolid readings, 31%, 25%, and 23% were Pbottom, Pmiddle, and Ptop, respectively [Figure 2] IOP by rebound tonometry were taken from each eye until a Psolid reading obtained. Only reliable readings were used for analysis. IOP readings of the right eyes were collected for analysis.

The comparison of IOP between rebound tonometer and applanation tonometry is listed in Table 2. The

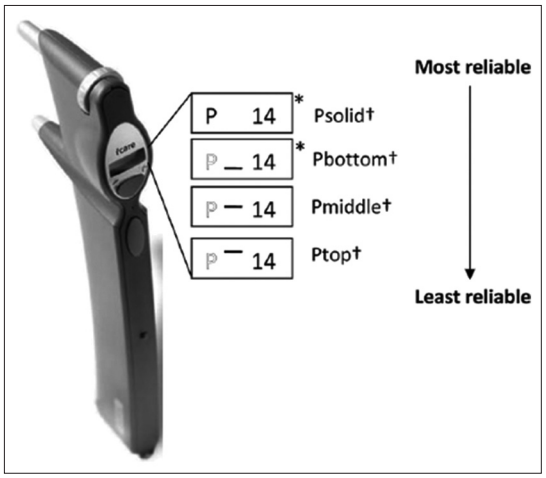

Figure 1: Schematic of ICARE tonometer display window for intraocular pressure and reliability. The most reliability reading is accompanied by a solid letter P. The next three levels of reliability are accompanied by the letter *P* and a horizontal line either at the bottom, the middle, or the top, displayed as solid, bottom, middle, and top, respectively

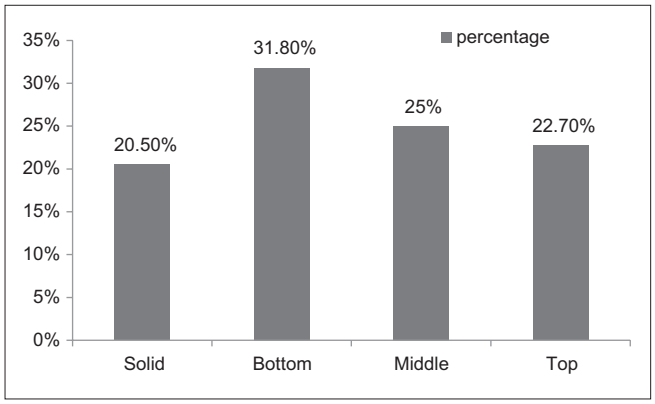

Figure 2: Reliability at first try of intraocular pressure measurement

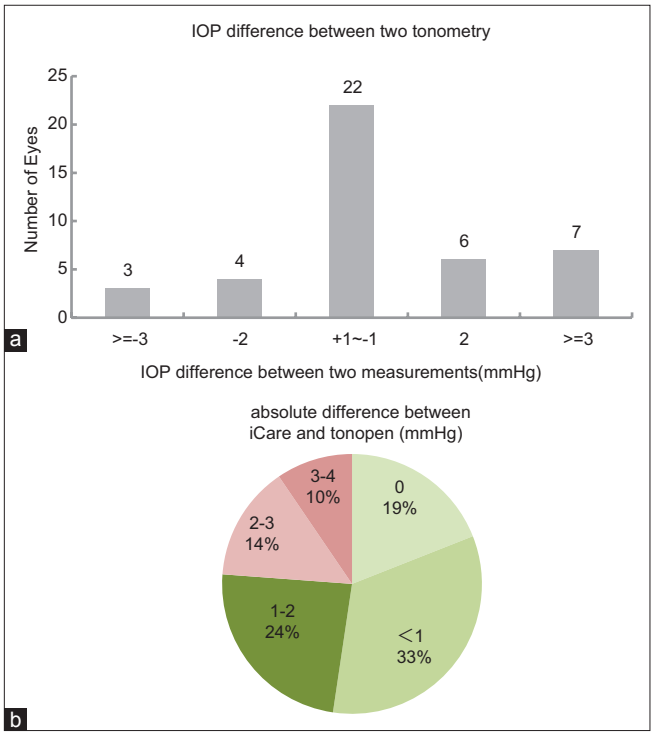

Figure 1 (a and b): (a) Differences of intraocular pressure between two measurements by rebound tonometry and applanation tonometry (n = 42, two with unreliable applanation readings were excluded). (b) Percentage of difference of intraocular pressure between ICARE and tonopen

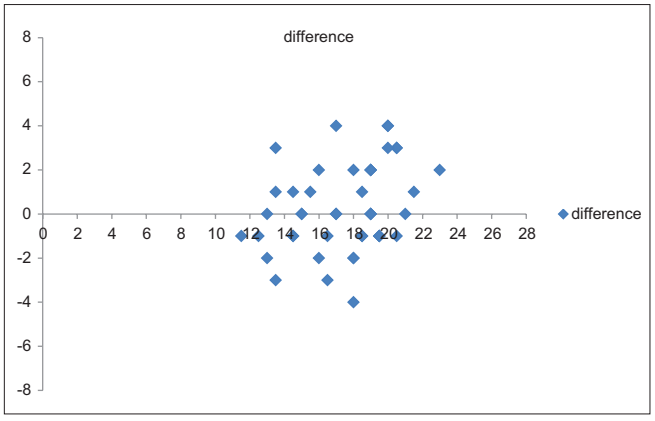

Figure 3: The Bland–Altman plot of the average versus the difference of intraocular pressure measurements between rebound tonometry and applnation tonometry (in mmHg). **Some points with same values (same average and same difference of intraocular pressure). Three cases had intraocular pressure average of 19 mmHg and 0 mmHg differences, two cases of average 19 mmHg and 2 mmHg differences, 2 cases of average of 17 mmHg and 0 difference, two of average 20 mmHg and 4 mmHg difference, etc.

average IOP of the right eye by rebound tonometer was 17.4 ± 3 mmHg (range: 11–24 mmHg), and 17.1 ± 3 mmHg (range: 12–22 mmHg) by applanation tonometry.

Regarding the differences between two measurements, 8 (19%) has the same readings, 14 (33.3%) has <1 mmHg difference between two measurements, 10 (23.8%) has difference between 1 and 2 mmHg, 6 (14.3%) has difference of 2–3 mmHg, and 4 (9.5%) has difference between 3 and 4 mmHg [Figure 1b].

In conclusion, almost 20% of the IOP readings were the same by two tonometers, 76.1% has IOP difference <2 mm Hg (clinical significant difference) between two tonometers, and over 90% of the differences were <3 mmHg [Figure 1a].

Second, 52% of measurements were with acceptable reliability (PSolid and PBottom) at first try by rebound tonometry in the right eye [Figure 2]. In this study, for improving the reliability, repeat IOP measurements of myopic children were taken until Psoild readings were obtained. Only PSolid readings are used for further analysis.

Third, compared these two tonometers in IOP measurement in myopic children, the Bland–Altman plot of the average versus the difference of IOP measurements between rebound tonometry and applanation tonometry indicated good correlation between tonometers, and further suggesting similar agreement in low (~10 mmHg) and high (~24 mmHg) IOP ranges [Figure 3].

Fourth, total IOP readings obtained by two tonometers in the right eyes are presented in Figure 4. A very good correlation was noticed with most of the differences within 2 mm Hg, which might be considered not clinically significant in pediatric group. No significant difference was noted between the two groups of IOP readings by applanation tonometer and rebound tonometer by *t*-test (P = 0.536). In Figure 5, good agreement between IOP by rebound tonometer versus Tono-Pen applanation was shown. Tono-Pen applanation IOP (Y-axis) is plotted against rebound tonometer (X-axis). Linear regression r^2 = 0.635, the slpoing suggesting that ICARE and Tono-Pen difference are not likely to be related to high or low IOPs. Repeat measurements by standard applanation tonometer could be used for confirmation in children with abnormal IOP readings. In these myopic eyes, regular clinical follow-up is necessary.

Table 1: Demographics of study population

	n (%)
Gender (male/female)	18/24 (43/57)
Refraction status (SE)	
Myopia <1.0 D	8 (19.0)
1.0 D≤ myopia<2.0 D	12 (28.6)
2.0 D≤ myopia<3.0 D	12 (28.6)
3.0 D≤ myopia<4.0 D	4 (9.5)
4.0 D≤ myopia	6 (14.3)
Strabismus	
Yes	3 (7.1)
No	39 (92.9)
Best-corrected visual acuity (Snellen)	
20/20	38 (90.5)
20/25~<20/20	4 (9.5)

SE = Spherical equivalent

Table 2: ICARE tonometer intraocular pressure compared with applanation tonometry

Tonometry	*n*	Mean±SD	Minimum	Maximum
Applanation	42	17.07±2.66	12	22
Rebound tonometry	42	17.48±3.27	11	24
ΔICARE-Tono-Pen*	42	1.62±1.23	0	4

*Significant value of two groups is P=0.536. SD = Standard deviation

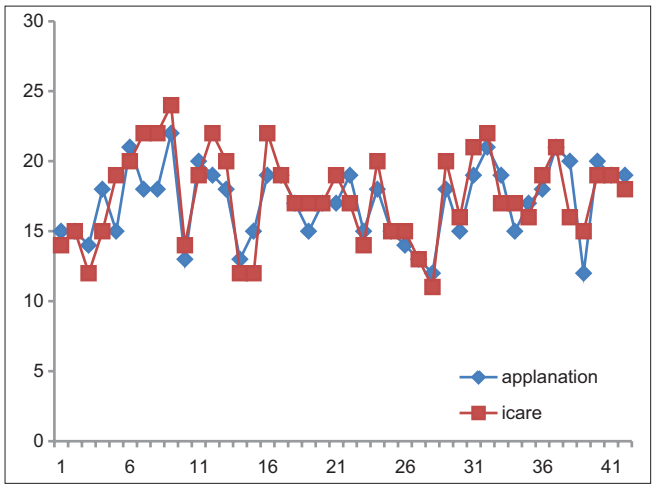

Figure 4: Distribution of intraocular pressure by two tonometry

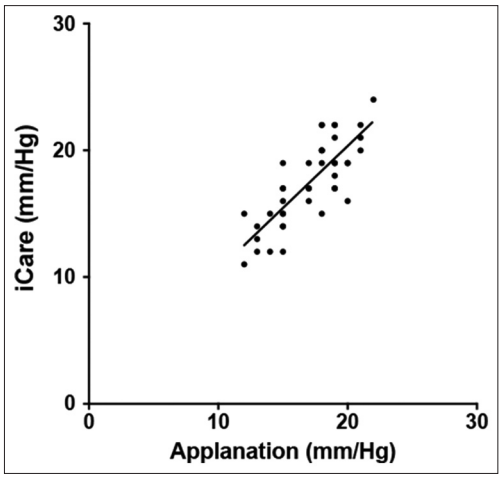

Figure 5: Agreement between intraocular pressure by rebound tonometer versus tonopen applanation (recording in mmHg)

Discussions

To the best of our knowledge, this is the first prospective clinical study comparing rebound tonometry with applanation tonometry (Tono-Pen) on myopic children in Taiwan. Through literature review, many investigators[3,10-18] have evaluated the application of rebound tonometer ICARE and compared with other portable tonometry devices, such as the Tono-Pen XL (Medtronic Solan, FL, USA), or the Perkins tonometer (Haag-Streit), as well as the GAT (Haag-Streit), in both healthy children and those with glaucoma.[15,18-21] With the advantage of elimination extra discomfort and anxiety caused by anesthetic medication before measurement, the rebound tonometer is well tolerated and reproducible in children, especially in younger age, even in infant.[4,5,19-23] The traditional applanation tonometry by direct contact the cornea will require patient's cooperation. Repeat attempts are frequently needed and result in patient's anxiety and prolonged examination time. Regarding the accuracy of IOP readings, many investigators have reported a good correlation between rebound tonometry and other tonometry in healthy adults and those with glaucoma. In pediatric ophthalmology, favorable reproducibility and comfort with rebound tonometer are reported in healthy school children. Kageyama *et al*.[19] compared IOP measurements in 180 healthy children using noncontact air-puff tonometry and rebound tonometry. The rebound tonometry had better preference in age three and younger with a marked higher successful rate: 79% versus 30%, respectively ($P = 0.001$). The success rate was also higher in toddlers 4–6 years of age using rebound tonometry compared with noncontact air-puff tonometry: 86% versus 71%, respectively ($P = 0.025$). For children 7 years of age and older, the success rate was similar between two different tonometers.[19] In this study, all children were well tolerated with IOP measurement by rebound tonometry and the youngest child was 5-year-old. The mean age of these participants was 10 years (range: 5–16).

In this study, the myopia status (spherical equivalent) of more than half children (57.2%) was between one to 3 D, and 24% of children had myopia over 4 D. One-quarter of these myopic children were in risk of progression to high myopia and may have atropine treatment longer than 3 years. The standard treatment to arrest myopia progression is topical atropine. The reported ocular complications include pigmentation of the conjunctiva and cornea, hyperemia, allergy, IOP elevation, and blurred vision.[8] Regular IOP monitor is important in childhood myopia with possible long-term atropine treatment. In clinical practice, the discomfort and inconvenience of IOP test by traditional tonometry decrease the frequency of IOP measurement in myopia. Clinical judgment of abnormal IOP becomes more confusing since there may be fluctuations of IOP measurement and diurnal IOP fluctuations.

The rebound tonometry avoids the distress of children and family from the procedure of traditional tonometry of IOP measurement. It avoids prolonged examination time by increasing successful rate in IOP measurement and omits applying the anesthetic eye drop before the examination. The rebound tonometry may become an alternative choice for regular IOP measurement in myopic children under atropine treatment. IOP monitoring in pediatric patient by rebound tonometry should be corroborated by clinical findings with caution to avoid unnecessary pressure-control treatment.

The limitation of this study included insufficient case number. The results of this study may not represent IOP conditions of all childhood myopia. Studies with larger sample size are needed. Second, regarding to selection bias of participants, children with family history of ocular hypertension or glaucoma are more willing to have IOP examinations. Third, lack of central corneal thickness readings in very young children is also a limitation. Further discussion on this part is needed in the future study.

Conclusions

IOP measurement by rebound tonometry is better tolerated than Tono-Pen applanation tonometry. There are confounders in tonometry measurement (Eye; 2009); however, rebound tonometry has good correlation with applanation tonometry,[24] and 76.1% of differences between two tonometers are <2 mmHg. The advantage of drop-free rebound tonometry has made it easier to obtain IOP readings in myopia children under atropine treatment.

Financial support and sponsorship

Specific acknowledgment of research grant support from Taipei City Government under award number 10001-62-056.

Conflicts of interest

There are no conflicts of interest.

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