

Comparison of Perkins, Tono-Pen and Schiøtz tonometers in paediatric patients under general anaesthesia

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مقارنة بين أجهزة قياس توتر العين من طراز بيركنز وتونوبن وشيوتز في مرضى الأطفال تحت التخدير العام

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الخلاصة: هدفت هذه الدراسة المستعرضة إلى استقصاء إمكانية استخدام أي من أجهزة قياس ضغط العين من طراز تونوبن، وشيوتز، وبيركنز في الممارسة العامة، لقياس ضغط العين المرتفع. وتم خلال الدراسة فحص 74 عينا في 37 مريضاً من الأطفال تحت التخدير العام، بواسطة كل من أجهزة قياس التوتر الثلاثة. وقد سُجِّلت اختلافات يُعْتَدُّ بها إحصائياً في قراءات الأجهزة الثلاثة. على أن أكبر قدر من التوافق قد شوهد بين طراز بيركنز وتونوبن بفارق وسطي قدره 1.4 مم زئبق مع حدود توافق (من -5.7 إلى +8.6) في مستوى 95%. أما طراز بيركنز فهو نمط يحمل باليد من أتماط جهاز قياس توتر العين من طراز غولدمان (الذي يمثّل المعيار الذهبي لقياس ضغط العين من الداخلي). وعلى ذلك، فإن الجهاز طراز تونوبن الذي يتميز بسهولة استخدامه ومأمونيته، يُعدُّ جهازاً يمكن التعويل عليه للاستخدام في الممارسة العامة.

ABSTRACT This cross-sectional study aimed to investigate if the Tono-Pen, Schiøtz and Perkins tonometers could be used interchangeably in general practice for measuring elevated intraocular pressure. A total of 74 eyes of 37 paediatric patients under general anaesthesia were checked with all 3 tonometers. All of the tonometers gave significantly different measurements from each other. However, with a mean difference of 1.4 mmHg and 95% limits of agreement of -5.7 to +8.6, the greatest agreement was between the Perkins and Tono-Pen tonometers. The Perkins tonometer is a hand-held variant of the Goldmann tonometer (the gold standard for intraocular pressure measures). Therefore the Tono-Pen with its ease of use and safety could be a reliable device for use in general practice.

Comparaison entre les tonomètres de Perkins, Tono-Pen et de Schiøtz chez les patients pédiatriques sous anesthésie générale

RÉSUMÉ Cette étude transversale visait à déterminer si les tonomètres Tono-Pen, de Schiøtz et de Perkins pouvaient être utilisés de façon interchangeable en médecine générale pour mesurer l'hypertension intraoculaire. Au total, 74 yeux de 37 patients pédiatriques sous anesthésie générale ont été contrôlés avec les trois tonomètres. Des mesures significativement différentes ont été obtenues avec chacun d'entre eux. Toutefois, avec une différence moyenne de 1,4 mmHg et des limites d'agrément à 95 % comprises entre -5,7 et +8,6, le meilleur agrément a été observé entre les tonomètres de Perkins et Tono-Pen. Le tonomètre de Perkins est une variante portable du tonomètre de Goldmann (la référence en matière de mesure de la pression intraoculaire). Le tonomètre Tono-Pen, d'un maniement pratique et sûr, est donc un appareil fiable qui peut être utilisé en médecine générale.

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Introduction

Glaucoma, as the third leading cause of blindness, accounts for 15% of the burden of blindness worldwide. Glaucoma affects more than 67 million people in the world, and the prevalence is about 1% in the population aged over 50 years. It is estimated that more than £300 million was spent in the United Kingdom in 2002 on glaucoma [1]. In glaucoma, irreversible injury to the optic nerve fibres at the optic disc causes characteristic visual field defects. The disease is usually progressive and is asymptomatic in its early stages. Elevated intraocular pressure (IOP) is the most important risk factor for glaucoma [2] and tonometry remains the cornerstone of both diagnosis and management [3]. General practitioners are in a favourable position to detect glaucoma because they see many patients, many of whom are elderly with risk factors other than elevated IOP [4]. There is a real need for a safe, easy to use and cost-effective device to measure IOP in general practice.

At present the Schiøtz indentation tonometer is the standard method of tonometry in general practice. Its use requires that the patient lies down. The instrument must be put together before use and dismantled and properly cleaned afterwards. Leydhecker called it a "monster" [5], but said that its clinical usefulness is much better than its construction would lead us to expect. However, although 2 consecutive measurements in 1 eye have satisfactory repeatability [6], and there is little mean difference in IOP obtained by Schiøtz and applanation tonometry in population studies, the agreement between readings obtained by the 2 methods in individual eyes is far from satisfactory [6,7].

The Tono-Pen is a hand-held, easy to use tonometer that uses the same physical principle as the Goldmann applanation

tonometer [8,9]. The patient can be seated in an ordinary chair and the examiner only needs to change a disposable latex tip and press one button on the Tono-Pen before use.

The Goldmann applanation tonometer (Haag Streit AG, Bern, Switzerland) is currently the most widely used tonometer by ophthalmologists in their consulting rooms, and is considered to be the gold standard for measuring IOP [10,11]. The Goldmann tonometer, however, cannot be used for bedridden patients, for younger children, in the operating room and in other situations outside the consulting room. The Perkins tonometer (Clement-Clarke Inc., Columbus, Ohio, USA) is a portable Goldmann applanation tonometer. However, it is not easy to use and not always suitable.

The aim of this study was to discover if the Tono-Pen and Schiøtz tonometers can be used interchangeably with the Perkins/Goldmann tonometers, particularly for IOP measurements in the setting of examination under general anaesthesia.

Methods

Sample

The cross-sectional study took place in Khatam Al-Anbia Eye Hospital in the north-east of the Islamic Republic of Iran. It included 74 eyes from 37 subjects. All children were selected from among patients undergoing examination under general anaesthesia from February to August 2005 in our hospital. The reasons for examination were: suspected congenital glaucoma (18 cases), congenital cataract (8), persistent hyperplastic primary vitreous (5), retinopathy of prematurity (2) or eye deviation (4). Patients with corneal scar, history of ophthalmic surgery and systemic conditions associated with increased risk in general

anaesthesia were excluded. Informed consent was obtained from the parents of all patients.

Data collection

The examinations were performed for all patients under general anaesthesia. All of the procedures were the first operations of the day and performed between 08:00 and 09:00 hours. The tonometry was the first step in all cases and was performed in the first 3 minutes of anaesthesia by one of the authors (F.R.). The examinations were performed in the following order: Perkins applanation tonometry (Clement-Clarke Inc., Columbus, OH, USA), Tono-Pen XL tonometry (Mentor, Santa Barbara, CA, USA), and finally Schiøtz indentation tonometry. For each subject the Tono-Pen was calibrated and a new OcuFilm™ was used. The TonoPen makes repetitive measurements for each patient and, based on an internal statistical algorithm, provides a *P*-value for its measurement which denotes the consistency of measurement (*P*-values < 5% are highly reliable and those 5%–10% are acceptable). Tono-Pen measurements were repeated at least 4 times for each eye and the average at *P* < 0.05 was recorded. The Schiøtz reading was repeated using 5.5, 7.5 and 10.0 plungers for each subject. The Schiøtz measurements were converted to mmHg according to the 1955 Friedenwald scale and, after

omitting the outlying data, the mean of 3 readings was recorded.

Statistical analysis

The portable tonometers were compared with each other using 2-way analysis of variance [12]. For comparison of the portable tonometers with the gold standard, Goldmann applanation tonometry, Bland–Altman plots were used, which display the difference against the mean, and 95% limits of agreement were calculated as ± 1.96 standard deviations (SD) of the differences [13]. To determine whether the new tonometers differed significantly from the gold standard, we used Friedmann's 2-way analysis of variance by ranks [14]. All statistical analyses were done using SPSS, version 11.0.5.

Results

The study included 37 patients (22 males and 15 females), with a mean age of 22.9 (18.6) months (median = 12, range: 3–72 months).

The IOP values of the portable tonometers differed significantly from each other (*P* < 0.05) (Table 1). The mean IOP values were 13.7, 15.1 and 16.6 mmHg for the Perkins, the Tono-Pen and the Schiøtz tonometers respectively. Measurements

Table 1 Mean difference and 95% confidence interval (CI) along with 95% limits of agreement of the 3 portable tonometers (Perkins, Tono-Pen and Schiøtz)

Tonometer	Mean (95% CI) difference (mmHg)	95% limits of agreement (mmHg)	<i>P</i> -value ^a
Tono-Pen versus Perkins	+1.4 (+0.6 to +2.3)	–5.7 to +8.6	0.005
Schiøtz versus Perkins	+2.9 (+1.6 to +4.1)	–7.7 to +13.5	0.001
Schiøtz versus Tono-Pen	+1.5 (+0.2 to +2.7)	–9.2 to +12.1	0.017

^aFriedmann's 2-way ANOVA by ranks.

performed with the Tono-Pen XL tonometer were similar to those of the Perkins tonometer, whereas IOP values measured with the Schiøtz were higher and more variable. The 95% limits of agreement were narrowest between the Perkins and Tono-Pen tonometers.

The upper row of Figure 1 presents scatter plots showing the IOP results obtained with the tonometers as a function of each other and the lower row depicts the 95% limits of agreement. It is clear from the plots that the greatest variability was between the Schiøtz and Perkins readings, followed by the Schiøtz and Tono-Pen readings. The greatest agreement was between the Tono-Pen and Perkins measurements.

Discussion

In the current study, we compared IOP measurements obtained using 3 portable tonometers, the Schiøtz tonometer, the Tono-Pen XL and the Perkins applanation tonometer. The Goldmann tonometer is considered to be the gold standard of IOP measurement and the Perkins tonometer is a hand-held variant of the Goldmann tonometer. Measurements performed with the Tono-Pen XL tonometer were in good agreement with that of the Perkins tonometer. IOP values measured with the Schiøtz were higher and showed more variability.

Limits of agreement is considered the appropriate method for comparing different methods of clinical measurement [13]. In this case it tells us how much 2 methods of tonometry are likely to differ and takes into account both systematic differences as well as other reasons for variation. There is a short time pulsation in the IOP of an eye [5] and the way 2 different measurements are carried out may vary for the same method. As the systematic difference is small and

the limits of agreement clinically acceptable, the new method may replace the old one. Although correlation coefficients have been widely used in comparing methods of tonometry, this is in principle an incorrect method [13].

We completed the measurements within the first hours of the day, in order to avoid IOP variability due to diurnal variations. As the examinations were done under general anaesthesia and we wished to avoid any further effect of lowering IOP by indentation tonometry, we did not randomize the sequence of the tests. Theoretically, this might have induced some bias as IOP tends to decrease with repeated testing. The decrease in IOP with repeated testing, however, is only about 1 mmHg or less [15,16]. This is negligible when compared with the limits of agreement, typically more than ± 6 mmHg, as in the current study. Moreover, contrary to this theory, the IOP measured with the Schiøtz tonometer was the highest and that with the Perkins tonometer was the lowest, even though the Perkins was the first tonometer used each time and the Schiøtz was the last.

Initially, the 95% limits of agreement of at least ± 7 mmHg that we found between different tonometers seem to be rather large. It should be remembered, however, that a repeat test with a Goldmann tonometer also has non-negligible inter-observer limits of agreement of typically ± 4 mmHg, not only for a single reading but also for the average of 2 readings or the median of 3 readings [15–17].

There is a previous study comparing the Tono-Pen, Perkins and Schiøtz tonometers in paediatric patients [18]. This found a good correlation between the Tono-Pen and Perkins tonometers ($r = 0.867$) and found no statistically significant difference between the mean difference of IOP values

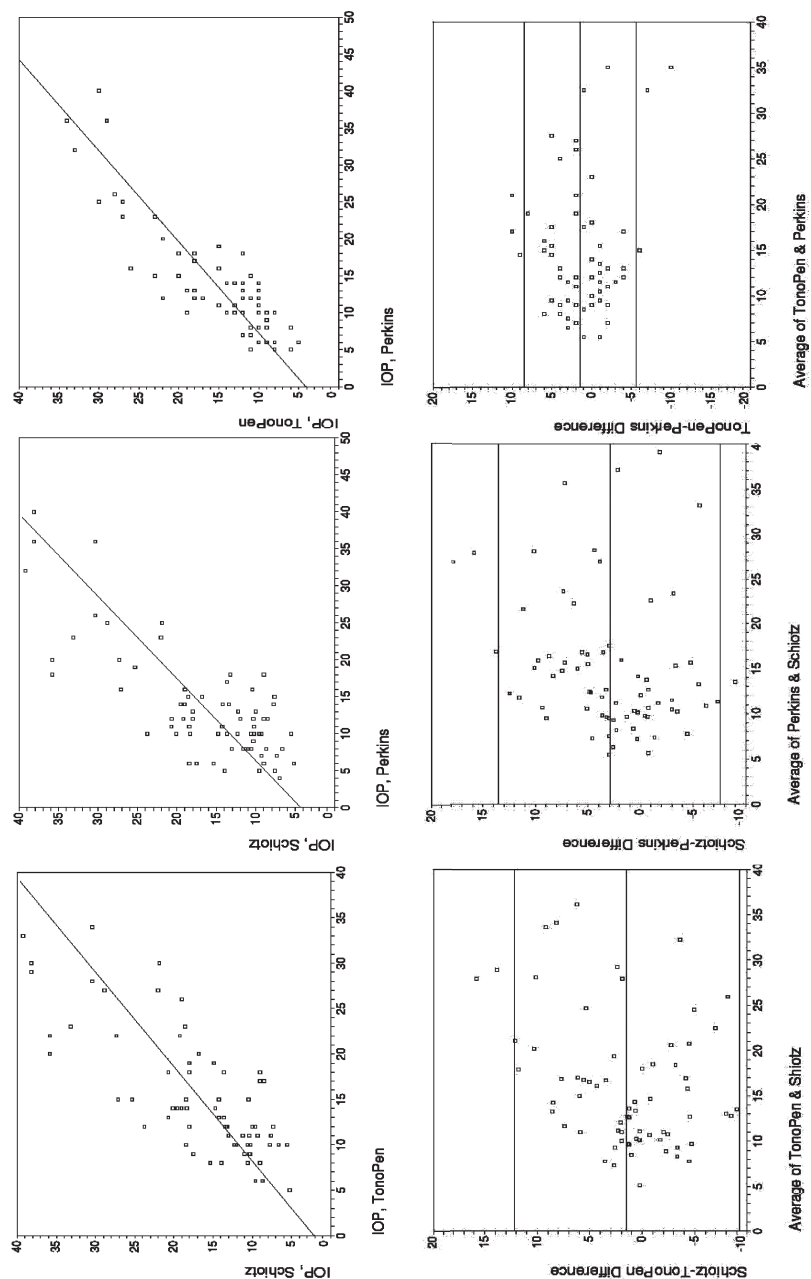


Figure 1 Scatter plots (upper row) showing readings with 3 different tonometers (Perkins, Tono-Pen and Schiøtz) as a function of each other and the corresponding Bland–Altman plots (lower row) showing differences in intraocular pressure as a function of the average [horizontal lines denote mean difference (bias) and 95% limits of agreement]

obtained with the Tono-Pen and Perkins ($P > 0.05$). The Schiøtz measurements were significantly higher than those obtained with the Perkins and the Tono-Pen tonometers ($P < 0.05$). Although the study agrees with our findings, we were doubtful about the results, as the statistical methods for analysis were incorrectly selected [13]. There was no statistically reliable comparison between the Tono-Pen and Perkins tonometers and most previous studies (except that of Van der Jagt and Jonsonius [3]) have revealed a statistically significant mean difference (bias) between the Tono-Pen and the Goldmann tonometer [19–24]. However, in all these studies the authors concluded that the agreement was good enough for the purpose of adequate screening, presumably because in most studies the bias is small when compared with the limits of agreement. In agreement with our study, Bafa et al. did not find any difference between the Tono-Pen XL and the Goldmann applanation tonometer [25]. Previously reported 95% limits of agreement, -8 to $+3$ mmHg [22], -10 to $+5$ mmHg [23], ± 6 mmHg [24], -8 to $+9$ mmHg [25], and -6 to $+8$ mmHg [3] are in good agreement with our findings.

The portable tonometers are advantageous in several situations outside the consulting room, including for bedridden patients, for younger children and in the operating room. In addition, the Tono-Pen XL has a disposable tip (OcuFilm™). This could be an advantage in situations involving a high risk of cross-barrier infection. Moreover, portable tonometers may be suitable for home monitoring in the future. After all, a single IOP reading in the consulting room does not take account of the fluctuating nature of the IOP. Thus, the Tono-Pen seems to be a favourable device in several conditions.

Conclusion

We consider the Tono-Pen to be an alternative to the Perkins tonometer that is easier to use and superior to the Schiøtz tonometer in general practice and particularly for examination under general anaesthesia. The mean difference between Tono-Pen and Perkins measurements (1.4 mmHg) was within clinically acceptable limits.

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