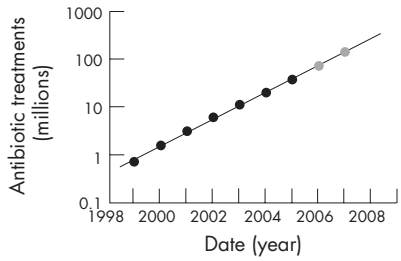

Figure 1 Doses of oral azithromycin donated by the International Trachoma Initiative for trachoma control over time (black points), including projections for the future (grey points).[31] The log linear graph suggests an exponential increase in the distributions, unaffected by the Cochrane Collaboration Report released in 2002.

trials designed to assess biannual and annual repeat distributions, intensive treatment of children and construction of latrines are currently under way. If they are conducted well, we expect that Cochrane Collaboration reports will only be too happy to include them.

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REFERENCES

1 **Wright HR**, Keeffe JE, Taylor HR. Elimination of trachoma: are we in danger of being blinded by the RCT? *Br J Ophthalmol* 2006;**90**:1339–42.
2 **Schachter J**, West SK, Mabey D, *et al.* Azithromycin in control of trachoma. *Lancet* 1999;**354**:630–5.
3 **Melese M**, Chidambaram JD, Alemayehu W, *et al.* Feasibility of eliminating ocular Chlamydia trachomatis with repeat mass antibiotic treatments. *JAMA* 2004;**292**:721–5.
4 **Solomon AW**, Holland MJ, Alexander ND, *et al.* Mass treatment with single-dose azithromycin for trachoma. *N Engl J Med* 2004;**351**:1962–71.
5 **West SK**, Munoz B, Mkocha H, *et al.* Infection with Chlamydia trachomatis after mass treatment of a trachoma hyperendemic community in Tanzania: a longitudinal study. *Lancet* 2005;**366**:1296–300.
6 **Steingrímsson O**, Olafsson JH, Thórarinsson H, *et al.* Single dose azithromycin treatment of gonorrhea and infections caused by C. trachomatis and U. urealyticum in men. *Sex Transm Dis* 1994;**21**:43–6.
7 **Bailey RL**, Arullendran P, Whittle HC, *et al.* Randomised controlled trial of single-dose azithromycin in treatment of trachoma. *Lancet* 1993;**342**:453–6.
8 **Dawson CR**, Schachter J, Sallam S, *et al.* A comparison of oral azithromycin with topical oxytetracycline/polymyxin for the treatment of trachoma in children. *Clin Infect Dis* 1997;**24**:363–8.
9 **Mabey D**, Fraser-Hurt N. Antibiotics for trachoma. *Cochrane Database Syst Rev* 2002;(1):CD001860.
10 **Mabey D**, Fraser-Hurt N, Powell C. Antibiotics for trachoma. *Cochrane Database Syst Rev* 2005;(2):CD001860.
11 **Baral K**, Osaki S, Shreshta B, *et al.* Reliability of clinical diagnosis in identifying infectious trachoma in a low-prevalence area of Nepal. *Bull World Health Organ* 1999;**77**:461–6.
12 **Bird M**, Dawson CR, Schachter JS, *et al.* Does the diagnosis of trachoma adequately identify ocular chlamydial infection in trachoma-endemic areas? *J Infect Dis* 2003;**187**:1669–73.
13 **Solomon AW**, Peeling RW, Foster A, *et al.* Diagnosis and assessment of trachoma (table of contents). *Clin Microbiol Rev* 2004;**17**:982–1011.
14 **Chidambaram JD**, Lee DC, Porco TC, *et al.* Mass antibiotics for trachoma and the Allee effect. *Lancet Infect Dis* 2005;**5**:194–6.
15 **Lee DC**, Chidambaram JD, Porco TC, *et al.* Seasonal effects in the elimination of trachoma. *Am J Trop Med Hyg* 2005;**72**:468–70.
16 **Lietman TM**, Neuwelt MD, Gandhi NG, *et al.* Trachoma research: it takes more than a village. *Lancet* 2006;**367**:395.
17 **Jha H**, Chaudary J, Bhatta R, *et al.* Disappearance of trachoma in western Nepal. *Clin Infect Dis* 2002;**35**:765–8.
18 **Dolin PJ**, Faal H, Johnson GJ, *et al.* Reduction of trachoma in a sub-Saharan village in absence of a disease control programme. *Lancet* 1997;**349**:1511–12.
19 **Hoechsmann A**, Metcalfe N, Kanjaloti S, *et al.* Reduction of trachoma in the absence of antibiotic treatment: evidence from a population-based survey in Malawi. *Ophthalmic Epidemiol* 2001;**8**:145–53.
20 **Chidambaram JD**, Bird M, Schiedler V, *et al.* Trachoma decline and widespread use of antimicrobial drugs. *Emerg Infect Dis* 2004;**10**:1895–9.
21 **Taylor H**. Towards the global elimination of trachoma. *Nat Med* 1999;**5**:492–3.
22 **Chidambaram JD**, Alemayehu W, Melese M, *et al.* Effect of a single mass antibiotic distribution on the prevalence of infectious trachoma. *JAMA* 2006;**295**:1142–6.
23 **Lostumbo L**, Carbine N, Wallace J, *et al.* Prophylactic mastectomy for the prevention of breast cancer. *Cochrane Database Syst Rev* 2004;(4):CD002748.
24 **Reacher MH**, Huber MJ, Canagaratnam R, *et al.* A trial of surgery for trichiasis of the upper lid from trachoma. *Br J Ophthalmol* 1990;**74**:109–13.
25 **Reacher MH**, Muñoz B, Alghassany A, *et al.* A controlled trial of surgery for trachomatous trichiasis of the upper lid. *Arch Ophthalmol* 1992;**110**:667–74.
26 **West S**, Munoz B, Lynch M, *et al.* Impact of face-washing on trachoma in Kongwa, Tanzania. *Lancet* 1995;**345**:155–8.
27 **Emerson PM**, Lindsay SW, Alexander N, *et al.* Role of flies and provision of latrines in trachoma control: cluster-randomised controlled trial. *Lancet* 2004;**363**:1093–8.
28 **West SK**, West ES, Alemayehu W, *et al.* Single-dose azithromycin prevents trichiasis recurrence following surgery: randomized trial in Ethiopia. *Arch Ophthalmol* 2006;**124**:309–14.
29 **Burton MJ**, Kinteh F, Jallow O, *et al.* A randomised control trial of azithromycin following surgery for trachomatous trichiasis in The Gambia. *Br J Ophthalmol* 2005;**10**:1282–8.
30 **Lietman T**, Porco T, Dawson C, *et al.* Global elimination of trachoma: how frequently should we administer mass chemotherapy? *Nat Med* 1999;**5**:572–6.
31 **International Trachoma Initiative**. *Program statistics 1999–2006*. New York: International Trachoma Initiative.

Rebound tonometry

Rebound tonometry: new opportunities and limitations of non-invasive determination of intraocular pressure

A Cervino

Age differences in central and peripheral intraocular pressure using ICare, a rebound tonometer

Goldmann applanation tonometry (GAT) has been the gold standard for intraocular pressure (IOP) measurement since its appearance in clinical practice almost 50 years ago.[1] Despite being relatively unchallenged, the last few years have become a continuous search for a new standard method for IOP measurement, mainly for the following three reasons.

1. The demonstrated dependence of GAT accuracy on corneal biomechanics, curvature and thickness.[2–4]
2. The advent of refractive surgery procedures has exponentially increased the number of postsurgical eyes on which GAT has been widely proved to be inaccurate.[3 5]
3. The need for topical anaesthesia to take measurements, mainly in those practices where non-medical personnel are involved in IOP measurement.

Non-contact tonometry seemed to overcome the need for corneal anaesthesia, as well as facilitating the IOP measurement procedure. A series of devices have been marketed and are

currently being used in several practices as the default screening test for IOP. Studies comparing the values obtained with pneumotonometry against GAT have shown that the results are comparable when measuring normal eyes[6] versus those with glaucoma.[7] New pneumotonometers even account for the cardiac pulse, detecting it and firing at the same point of the cycle, minimising the variability of the measurements[8 9] However, pneumotonometry readings are still affected by corneal morphometric changes and are underestimated after refractive surgery procedures, although statistical models have been proposed to predict the amount of underestimation.[10]

Dynamic contour tonometry,[11] ocular response analyser,[12] proview phosphene tonometer,[13] TDGc-01 ''PRA'' transpalpebral tonometer[14 15] and rebound tonometry are some of the most recent approaches to the ultimate tonometer. Some of them provide accurate IOP values without topical anaesthesia, are not affected by corneal characteristics (at least not as conventional GAT is affected) or allow the patient to self-evaluate their IOP.

Rebound tonometry has recently appeared in clinical practice after being used for some time in animal research. Its relatively low cost, portability, no need for anaesthesia and ease of use make it ideal for routine clinical practice.

The method includes the processing of the rebound movement of a rod probe resulting from its interaction with the eye. Each disposable probe consists of a magnetised steel wire shaft covered with a round plastic tip at the end that minimises the risk of corneal injury from the probe impact during the acquisition. After pressing the measurement button, the probe hits the eye and bounces back. This movement is detected by a solenoid inside the instrument. Then, the moving magnet induces voltage into the solenoid and the motion parameters of the probe are monitored. The probe bounces faster as the IOP increases and, consequently, the higher the IOP, the shorter the duration of the impact.

The software is preprogrammed for six measurements, discarding the highest and lowest IOP readings and calculating the average IOP value from the rest.[16] Further details on the clinical instrument for use on human eyes are described elsewhere.[17 18]

Experimental studies were carried out to calibrate the early versions of the instrument and evaluate its accuracy in rats[19–21] and mice,[19 22–24] showing good agreement, although a slight overestimation of IOP readings compared with values obtained by GAT or invasive cannulation.

In human eyes, rebound tonometry showed a slight overestimation of IOP when compared with GAT in its conventional and portable versions,[17 18 25–27] with limits of agreement typically lower than 4 mm Hg, although differences could be as high as 7.7 mm Hg for eyes with high IOP.[25] It has also been reported to be similarly affected by intrasession and intersession variations as other commercial non-GAT tonometers.[25 26]

Portability and no need for anaesthesia are some of the advantages of rebound tonometry, making it suitable for patients with disability and for screening at home, as well as saving space and time in the consulting room. Comparison of rebound tonometry with other portable devices on animal eyes has shown that there is good agreement with optical interferometry tonometry in mice,[24] more accurate and repeatable than electronic tonometry (TonoPen XL) on rat eyes[21] and slightly lower on canine eyes.[28] On human eyes, van der Jagt and Jansonius[15] showed good agreement between ICare and TonoPen XL with GAT, and less discomfort with ICare. Garcia-Resua *et al*[18] reached the same conclusions comparing ICare and TonoPen XL with Perkins tonometry. Good agreement was also found against portable pneumotonometry (Pulsair 3000), and less discomfort with rebound tonometry was also highlighted as an important advantage.[16]

Rebound tonometry is yet another way of obtaining repeatable, reliable IOP readings. However, portability, ease of use and good results are what make rebound tonometry different from other commercial tonometers currently in use on the small corneal area used to obtain the measurements. As one of the premises of inventors, rebound tonometry was primarily designed to fit the low scale of eyes of rats and mice.[29] Consequently, the additional benefit of rebound tonometry is the possibility of taking measurements at different corneal locations easily using only a small part of the cornea.

Rebound tonometry seems to be useful to obtain reliable IOP readings even when other tonometry techniques cannot be applied owing to central and paracentral scarring, active inflammatory and infectious processes, as well as other conditions that do not allow the acquisition of IOP measures by applanation techniques over a larger area. However, these potential applications are yet to be explored.

Another potential application of this instrument is the measurement of peripheral IOP readings. Gonzalez-Meijome *et al*[30] (***see page 1495***) have explored this advantage, evaluating the possible influence of ageing in the differences in IOP measurements between the centre and the periphery. The authors document the high correlation between central and peripheral readings, and the lack of increase in IOP values despite a marked increase in peripheral corneal thickness. Using a reasonable sample size, divided into three groups by age, the authors have also shown a trend towards lower IOP readings with the ICare associated with ageing. Different interesting hypotheses are considered in this work to explain such behaviour.

Another field to be explored with this instrument is the post-surgical corneas in which peripheral IOP readings could give a reasonable indication of the actual pre-surgical IOP. However, some studies have shown that ICare measurements are weakly correlated with central corneal thickness.[27] So, the relationships between IOP taken with ICare, the central and peripheral corneal thickness and their effect on IOP accuracy on post-surgical corneas are still to be evaluated in clinical trials.

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REFERENCES

1 **Goldmann H**, Schmidt T. Applanation tonometry. *Ophthalmologica* 1957;**134**:221–42.
2 **Ehlers N**, Bramsen T, Sperling S. Applanation tonometry and central corneal thickness. *Acta Ophthalmol (Copenh)* 1975;**53**:34–43.
3 **Chatterjee A**, Shah S, Bessant DA, *et al*. Reduction in intraocular pressure after excimer laser photorefractive keratectomy. Correlation with pretreatment myopia. *Ophthalmology* 1997;**104**:355–9.
4 **Mark HH**, Mark TL. Corneal astigmatism in applanation tonometry. *Eye* 2003;**17**:617–18.
5 **Montes-Mico R**, Charman WN. Intraocular pressure after excimer laser myopic refractive surgery. *Ophthalmic Physiol Opt* 2001;**21**:228–35.
6 **Jorge J**, Diaz-Rey JA, Gonzalez-Meijome JM, *et al*. Clinical performance of the Reichert AT550: a new non-contact tonometer. *Ophthalmic Physiol Opt* 2002;**22**:560–4.
7 **Jorge J**, Gonzalez-Meijome JM, Diaz-Rey JA, *et al*. Clinical performance of non-contact tonometry by Reichert AT550 in glaucomatous patients. *Ophthalmic Physiol Opt* 2003;**23**:503–6.
8 **Lam AK**, Chan R, Lam CH. The validity of a new noncontact tonometer and its comparison with the Goldmann tonometer. *Optom Vis Sci* 2004;**81**:601–5.
9 **Queiros A**, Gonzalez-Meijome JM, Fernandes P, *et al*. Non-contact tonometry synchronized with cardiac rhythm and its relationship with blood pressure. *Ophthalmic Physiol Opt* 2006;**26**:384–91.
10 **Yang CC**, Wang IJ, Chang YC, *et al*. A predictive model for postoperative intraocular pressure among patients undergoing laser in situ keratomileusis (LASIK). *Am J Ophthalmol* 2006;**141**:530–6.
11 **Kaufmann C**, Bachmann LM, Thiel MA. Comparison of dynamic contour tonometry with

Goldmann applanation tonometry. *Invest Ophthalmol Vis Sci* 2004;**45**:3118–21.
12 **Luce DA**. Determining in vivo biomechanical properties of the cornea with an ocular response analyzer. *J Cataract Refract Surg* 2005;**31**:156–62.
13 **Lam DS**, Leung DY, Chiu TY, *et al*. Pressure phosphene self-tonometry: a comparison with Goldmann tonometry in glaucoma patients. *Invest Ophthalmol Vis Sci* 2004;**45**:3131–6.
14 **Garcia Resua C**, Giraldez Fernandez MJ, Cervino Exposito A, *et al*. Clinical evaluation of the new TGDc-01 ''PRA'' palpebral tonometer: comparison with contact and non-contact tonometry. *Optom Vis Sci* 2005;**82**:143–50.
15 **van der Jagt LH**, Jansonius NM. Three portable tonometers, the TGDc-01, the ICARE and the Tonopen XL, compared with each other and with Goldmann applanation tonometry. *Ophthalmic Physiol Opt* 2005;**25**:429–35.
16 **Kontiola A**, Puska P. Measuring intraocular pressure with the Pulsair 3000 and Rebound tonometers in elderly patients without an anesthetic. *Graefes Arch Clin Exp Ophthalmol* 2004;**242**:3–7.
17 **Fernandes P**, Diaz-Rey JA, Queiros A, *et al*. Comparison of the ICare rebound tonometer with the Goldmann tonometer in a normal population. *Ophthalmic Physiol Opt* 2005;**25**:436–40.
18 **Garcia-Resua C**, Gonzalez-Meijome JM, Gilino J, *et al*. Accuracy of the new ICare rebound tonometer vs. other portable tonometers in healthy eyes. *Optom Vis Sci* 2006;**83**:102–7.
19 **Wang WH**, Millar JC, Pang IH, *et al*. Noninvasive measurement of rodent intraocular pressure with a rebound tonometer. *Invest Ophthalmol Vis Sci* 2005;**46**:4617–21.
20 **Kontiola AI**, Goldblum D, Mittag T, *et al*. The induction/impact tonometer: a new instrument to measure intraocular pressure in the rat. *Exp Eye Res* 2001;**73**:781–5.
21 **Goldblum D**, Kontiola AI, Mittag T, *et al*. Non-invasive determination of intraocular pressure in the rat eye. Comparison of an electronic tonometer (TonoPen), and a rebound (impact probe) tonometer. *Graefes Arch Clin Exp Ophthalmol* 2002;**240**:942–6.
22 **Danias J**, Kontiola AI, Filippopoulos T, *et al*. Method for the noninvasive measurement of intraocular pressure in mice. *Invest Ophthalmol Vis Sci* 2003;**44**:1138–41.
23 **Morris CA**, Crowston JG, Lindsey JD, *et al*. Comparison of invasive and non-invasive tonometry in the mouse. *Exp Eye Res* 2006;**82**:1094–9.
24 **Filippopoulos T**, Matsubara A, Danias J, *et al*. Predictability and limitations of non-invasive murine tonometry: comparison of two devices. *Exp Eye Res* 2006;**83**:194–201.
25 **Martinez-de-la-Casa JM**, Garcia-Feijoo J, Castillo A, *et al*. Reproducibility and clinical evaluation of rebound tonometry. *Invest Ophthalmol Vis Sci* 2005;**46**:4578–80.
26 **Davies LN**, Bartlett H, Mallen EA, *et al*. Clinical evaluation of rebound tonometer. *Acta Ophthalmol Scand* 2006;**84**:206–9.
27 **Iliev ME**, Goldblum D, Katsoulis K, *et al*. Comparison of rebound tonometry with Goldmann applanation tonometry and correlation with central corneal thickness. *Br J Ophthalmol* 2006;**90**:833–5.
28 **Leiva M**, Naranjo C, Pena MT. Comparison of the rebound tonometer (ICare) to the applanation tonometer (Tonopen XL) in normotensive dogs. *Vet Ophthalmol* 2006;**9**:17–21.
29 **Kontiola AI**. A new induction-based impact method for measuring intraocular pressure. *Acta Ophthalmol Scand* 2000;**78**:142–5.
30 **Gonzalez-Meijome JM**, Jorge J, Queiros A, *et al*. Age differences in central and peripheral intra-ocular pressure using a rebound tonometer. *Br J Ophthalmol* 2006;**90**:1495–1500.