Glaucoma Screening in Primary Care: The Role of Noncontact Tonometry

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Background. Guidelines for glaucoma screening by the primary care physician have not been firmly established. Despite its limitations as a screening test, intraocular pressure measurement by tonometry remains the mainstay of glaucoma monitoring but is not widely used in the primary care setting. The purpose of this study was to compare the effectiveness of noncontact tonometry using the Pulsair instrument with that of conventional tonometry using the Goldmann applanation tonometer as a screening tool for glaucoma.

Methods. Intraocular pressure was measured by noncontact and Goldmann applanation tonometry in both eyes of 50 volunteers who enrolled in a glaucoma screening program at a primary care clinic.

Results. Noncontact tonometry correctly identified over 90% of the patients with intraocular pressures greater than 22 mm Hg.

Conclusions. Noncontact tonometry is an easy, practical, and well-tolerated method of intraocular pressure measurement. When combined with direct ophthalmoscopy, noncontact tonometry can easily be used in routine primary care health examinations to detect glaucoma.

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The handheld, air-puff, noncontact tonometer has been used for the measurement of intraocular pressure (IOP) since 1972. Results obtained with noncontact tonometry have a high statistical correlation to those obtained using conventional Goldmann applanation tonometry[1–8] (Table 1). All methods of applanation tonometry, both noncontact and contact, obey the Imbert-Fick law,[9–10] which states that the force required to applanate the cornea is proportional to the IOP. A noncontact tonometer directs a jet of air at the eye at sufficient pressure to exceed the IOP and applanate the cornea to a "planomirror," which is detected by the optical system of the instrument.[11] The time from air ejection to corneal applanation is converted into a measurement of IOP in millimeters of mercury (mm Hg) and digitally displayed on the instrument.[11]

Noncontact tonometry has gained general acceptance, mostly among nonmedical eye care practitioners, as a screening tool for glaucoma. It is not widely used by primary medical care physicians who may have within their practices many patients with undiagnosed glaucoma.

To date, the Schiotz applanation tonometer has been the most widely used device for IOP measurement in the primary care setting. After administration of topical anesthesia to the eye, the Schiotz footplate is placed directly on the cornea, causing an indentation inversely proportional to the IOP.[12]

At the present time, guidelines for glaucoma screening by the primary care practitioner have not been firmly established. Improvement in the diagnostic skills for the early detection of glaucoma in the primary care setting, coupled with clear guidelines for referral to an ophthalmologist, could have significant economic and health implications.

The measurement of IOP by any form of tonometry has been shown to be an imperfect, insensitive screening tool for glaucoma.[13] Limitations notwithstanding, tonometry remains the mainstay of glaucoma monitoring. If glaucoma screening is to become a routine part of the periodic health examination in the primary care setting, however, there is debate as to whether tonometry should be the screening tool used. Examination of the

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Table 1. Comparison of Readings Obtained Using a Noncontact Tonometer and Goldmann Applanation Tonometer

Study	No. of Eyes	Correlation Coefficient (r)	Standard Deviation
Fisher et al[1]*	773	0.88–0.95	1.56–2.66
Forbes et al[2]	570	0.90	2.86
Halberg et al[3]	267	0.86	3.17
Decker and Keuther[4]	94	0.96	2.38
Draeger et al[5]	80	0.87	2.16
Dittmar et al[6]	64	0.72	6.56
Kitazawa et al[7]	229		3.99
Shields[8]†	911	0.84–0.95	0.70–1.16

**Summary of seven clinical trials during 1985–1987. Only study to use Pulsair NCT.*
†Summary of three clinical trials.

optic disc for the changes indicative of glaucoma by direct ophthalmoscopy is a valuable clinical skill but requires training and patience. Direct ophthalmoscopy has been characterized as a promising surveillance method, superior to tonometry in availability, in the hands of a skilled primary care clinician.[12]

The purpose of this investigation was to demonstrate the practicality of noncontact tonometry (NCT) as an adjunct screening tool for glaucoma in the primary care setting. Guidelines for glaucoma screening, including criteria for referral to an ophthalmologist, are discussed.

Methods

The study sample consisted of 50 patients who voluntarily participated in a glaucoma screening program at the Naval Medical Clinic in Seattle.

Each patient was given an information sheet on NCT followed by an explanation of the procedure and a demonstration of the air puff on a finger. A single member of the nursing staff (B.J.A.) conducted all IOP measurements with the Pulsair (Keeler, Ltd, Windsor, UK) instrument. Three valid readings were taken of the cornea of each eye, and a mean reading was calculated for each eye. An elevated IOP was defined as a measurement of 22 mm Hg or greater.[14]

A single member of the physician staff (M.E.R.) then conducted IOP measurements for each patient using a properly calibrated Goldmann applanation tonometer (Haig-Streit, Bern, Switzerland) mounted on a slit lamp (Marco-V, Jacksonville, Fla). One drop of a combination of sodium fluorescein 0.25% with benoxinate HCl 0.4% was instilled in the lower fornix of each eye. Three readings were taken in each eye, and a mean IOP reading was calculated. After recording the IOP, the tonometer was reset to 10 mm Hg for the next reading. Both patient and physician were blinded to all results.

All six IOP measurements for each patient were made within approximately 2 minutes. The time interval between the measurements made using the Pulsair tonometer and those made using the Goldmann tonometer was approximately 15 minutes.

Results obtained by NCT using the Pulsair instrument were then compared with those obtained using the Goldmann tonometer in each of the 50 patients tested to determine the sensitivity, specificity, and positive and negative predictive value of NCT as a screening tool for glaucoma. Linear regression was performed to determine correlation coefficients for intraocular pressure as measured by the two techniques.

Results

Of the 50 patients in the study, there were 33 men and 17 women with a mean age of 52 years and an age range from 23 to 73 years.

The nurse who operated the Pulsair tonometer quickly became competent in its use. The handheld instrument was easily maneuvered to the eyes of each patient. Patient acceptance of the air impulse delivered by the Pulsair instrument was excellent. The most frequent patient complaints during Goldmann applanation tonometry were transient burning from the fluorescein/benoxinate hydrochloride drops and temporary eye discomfort produced when the tonometer drum touched the lashes.

Noncontact tonometry correctly identified 12 of the 13 patients with an IOP of 22 mm Hg or greater in one or both eyes for a sensitivity of 92.3%. Specificity and positive predictive value for NCT were 73% and 54.5%, respectively. Noncontact tonometry correctly identified 27 of 28 patients with an IOP of less than 22 mm Hg for a negative predictive value of 96.4%.

The two methods of IOP measurement yielded similar pressure readings. The correlation coefficients were .77 for the left eye and .62 for the right eye.

Discussion

Glaucoma is a chronic, progressive, degenerative disease of the optic nerve, and is usually bilateral, although not always symmetrical.[14] It is characterized by loss of tissue from the optic nerve, and manifested by a progressive increase in the size of the cup, thinning or notching of the disc rim, disc hemorrhage, and nerve-fiber-layer defects (Figure 1). Functionally, glaucoma manifests itself as visual field loss, either locally (arcuate defect, nasal step, or paracentral scotoma) or diffusely (a generalized loss of sensitivity).

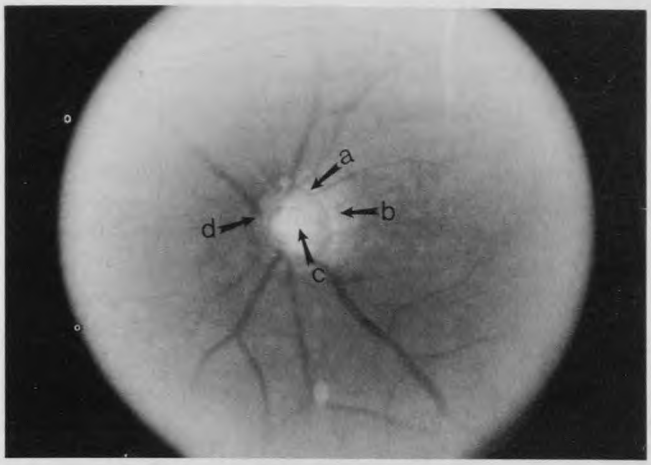

Figure 1. The glaucomatous optic disc is characterized by increased pallor and cupping, with nasal shift of the major vessels and thinning of the disc rim. Arrows designate: (*a*) absent temporal rim; (*b*) peripapillary atrophy; (*c*) enlarged cup with thin nasal rim (cup/disc ratio 0.8); (*d*) nasal displacement of vessels.

Glaucoma is the second most common cause of blindness in the United States (almost 80,000 individuals) and the leading cause of blindness among black Americans. Approximately 2 million people have this disease in the United States, although half remain undiagnosed. Five to ten million Americans have elevated IOP.[14] Glaucoma-related optic nerve damage in whites is uncommon before the age of 50 years; however, the disease often affects blacks as much as a decade earlier.

Although an elevated IOP is commonly associated with glaucoma, specific reference to IOP is omitted in its description because a definite level of IOP has never been reliably correlated with the clinical and pathological changes of glaucoma.[13] The vast majority of patients with an IOP greater than 22 mm Hg do not have glaucoma ("ocular hypertensives"). Most patients with glaucoma repeatedly have an IOP greater than 22 mm Hg (as measured by a Goldmann tonometer or its equivalent) at some point in the course of the disease prior to treatment.[14] However, approximately one sixth or more patients with otherwise characteristic glaucoma have an IOP consistently below 22 mm Hg. These patients comprise a subgroup with "normal tension glaucoma."[14] Although this raises the question of an IOP-independent pathophysiological mechanism for glaucoma, it does not negate the benefit of identifying those at risk for glaucoma through measurement of IOP.

Since IOP has at least a strong contributory relationship to optic nerve damage in most patients with glaucoma, the reduction of IOP is thought to retard such damage in most instances, and remains the focus of therapeutic intervention.[14] Several studies have shown such correlation between IOP control and progression of glaucomatous damage. In 79 patients with advanced glaucoma, Odberg[15] found progression in 33% who had IOPs consistently less than 16 mm Hg compared with 86% who had IOPs consistently greater than 20 mm Hg. Kolker[16] found that central vision was lost after a minimum of 4 years in 4% of patients with average IOPs of less than 18 mm Hg, in 19% of patients with IOPs of 18 to 22 mm Hg, and in 29% of patients with IOPs greater than 22 mm Hg. Quigley and Maumenee[17] determined that visual field progression occurred in only 12% of patients (followed for 8 to 40 years), with IOPs averaging 16 mm Hg.

The failure of therapy to completely eliminate progressive glaucomatous damage from elevated IOP is the basis for controversy regarding the appropriateness of current treatment guidelines for glaucoma. Five randomized, controlled clinical trials of glaucoma therapy are currently being conducted in the United States and the United Kingdom to better define the efficacy and risks of both medical and surgical management of glaucoma. Complicating factors in assessing the efficacy of medical therapy for glaucoma include poor compliance (documented in one third or more of patients for whom treatment is initiated), and variability (by race) in resistance to topical therapy (blacks being more resistant than whites to reduction of IOP).[14]

Paradoxically, tonometry, which measures IOP, is the most widely used method for diagnosis and monitoring of glaucoma, despite its poor sensitivity, specificity, and positive predictive value.[13] The sensitivity of IOP evaluation in the detection of glaucoma is approximately 50%. Data from four large epidemiological studies demonstrated that more than half of individuals exhibiting glaucomatous visual damage had normotensive eyes at the time of screening.[18–22] The lack of a definitive IOP cut-off level for glaucoma further complicates the matter. Limitations aside, tonometry remains the mainstay of glaucoma monitoring until a more sensitive method is adopted.

The primary care physician should become routinely involved in screening for glaucoma. Certainly within the patient population presenting to primary care clinics there is a large number of patients with undetected ocular disease.

What screening tool or methods should be used by the primary care physician for glaucoma detection? Direct ophthalmoscopy has been suggested as a practical screening test for the primary care setting, with the presence of one or more of four signs constituting a positive test: (1) a horizontal cup-to-disc ratio greater than or equal to 0.6; (2) extension of the cup to the disc

Table 2. Risk Factors for Glaucoma

- Elevated IOP (≥ 22 mm Hg)[14]
- Age > 50 years[15]
- Black race[30]
- Family history[29,31,32]
- Associated conditions[29]
  - Diabetes mellitus—strongest association with glaucoma
  - Thyroid disease
  - Nearsightedness
  - Hypertension
  - Cardiovascular disease

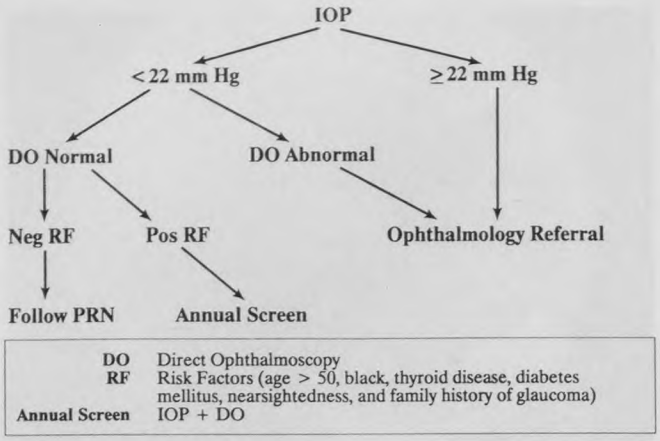

Figure 2. Algorithm for glaucoma screening by primary care physicians.

margin in any meridian; (3) disc hemorrhage; (4) or a difference in the cup-to-disc ratio of 0.2 or more between both eyes.[12] The diagnostic skills of primary care physicians in the detection of these optic disc changes indicative of open-angle glaucoma have been shown to markedly improve with a simple educational program.[23]

Handheld NCT for IOP measurement may also help the primary care practitioner in the identification of patients at risk for glaucoma. One advantage of NCT is easy maneuverability of the device to the eye in any position. This is particularly convenient when examining nonambulatory and very young patients.[1] The noncontact feature obviates the need of corneal anesthesia and disinfection of applanation devices against infectious agents, including the human immunodeficiency virus.[24] The risk of corneal abrasion occasionally sustained during Schiotz tonometry[25] is nonexistent with NCT.

The risks of air-impulse, noncontact tonometers are related to specific conditions, including inadvertent instillation of air into eyes with corneal disease[26,27] or a recent history of surgery or global perforation, as well as aerosolization of highly contagious and infectious diseases such as epidemic keratoconjunctivitis. Air-impulse tonometry should be avoided in these situations.

Glaucoma screening is most effective when IOP measurement is combined with direct ophthalmoscopy and targeted to populations at increased risk of disease (ie, blacks and the elderly). Age is the single most important predictor of glaucoma; its prevalence increases from less than 0.5% at 40 years to 7% at 80 years.[28,29] The frequency of glaucoma in blacks is eightfold greater than that in whites.[30] The risk of glaucoma occurring in a child or sibling of an individual with glaucoma is approximately 40%.[12] A summary of risk factors for glaucoma is listed in Table 2.

A suggested algorithm for glaucoma screening by primary care physicians is provided in Figure 2. All patients with an IOP of 22 mm Hg or greater should be referred to an ophthalmologist for further evaluation. This evaluation may include IOP measurement with a Goldmann tonometer, magnified stereoscopic visualization (as with the slit-lamp biomicroscope) of the optic disc and nerve fiber layer through a dilated pupil, visual field testing, and gonioscopy (ie, inspection of the angle).

Noncontact tonometry with the Pulsair instrument is a valid screening tool for elevated IOP because it is highly sensitive (92.3%), as demonstrated by this study, when compared with Goldmann applanation tonometry. All but one patient with an IOP of 22 mm Hg or greater in one or both eyes as determined by Goldmann tonometry was correctly identified by NCT. Of the 50 patients tested with both NCT and Goldmann tonometry, 22 patients had IOPs of 22 mm Hg or greater as identified by NCT and would have been referred to an ophthalmologist according to the algorithm outlined in Figure 2. Of those, 12 patients would have had elevated IOP confirmed by Goldmann applanation tonometry and 10 would have been identified as false positives. Because the Pulsair NCT is a useful negative predictor of potential disease, the use of this instrument might result in a large number of false positives (45.5% in this study) being referred to ophthalmologists as glaucoma suspects. However, the benefit of identifying the true positives who potentially would remain unidentified without the screening process, coupled with the noninvasive nature of NCT, far outweigh the negative aspects of identifying a large number of individuals without disease.

Direct ophthalmoscopy in the patient with an IOP of less than 22 mm Hg will determine whether the patient should be referred to the ophthalmologist (ie, in the case of an evaluation denoting abnormal optic disc cupping and nerve fiber layer dropout) as opposed to being followed by the primary care physician (Figure 2). Patients with an IOP of less than 22 mm Hg and normal direct ophthalmoscopy should undergo repeat glaucoma screening annually if they possess any other risk factor for the disease (Table 2).

Conclusions

Noncontact tonometry with the Pulsair instrument is a practical, reliable, and well-tolerated method of IOP assessment, which can be performed by well-trained, nonphysician personnel. When combined with direct ophthalmoscopy, IOP measurement by tonometry can easily be used as a routine part of the periodic health examination performed by the primary care physician for the purpose of detecting glaucoma.

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