Goldmann applanation tonometry pdf

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add Contributing Editors: add Intraocular pressure and tonometry Introduction The intraocular pressure (IOP) of the eye is determined by the balance between the amount of aqueous humor that the eye makes and the ease with which it leaves the eye. The Goldmann equation states: Po = (F/C) + PvPo is the IOP in millimeters of mercury (mmHg), F is the rate of aqueous formation, C is the facility of outflow, and Pv is the episcleral venous pressure. [1] An association between increased IOP and the loss of sight in glaucoma has been noted for many centuries. In the 17th century, Richard Bannister (English physician) noticed the hardness of eyes in cases where cataract operations did not improve vision. In the 19th century, William Bowman (English ophthalmologist) developed a method of estimating the tension, or hardness, of the eye by palpating it with his fingers through the closed eyelid. Bowman and others noticed that there was a definite relationship between the level of IOP and the likelihood that the eye would lose sight; the higher the IOP, the greater the chance that the eye would become blind. Therefore, IOP remained the primary focus in the diagnosis and treatment of glaucoma for many years.[2] As instruments were being developed for more objective measurement of IOP, population surveys at that time found that only approximately 2 percent of the population had IOP levels above 21 mm Hg.[3] This observation led to the belief that IOP measurement above 21 mm Hg is abnormal, and that the goal of glaucoma treatment was to lower the IOP to below 21 mmHg. Later studies challenged this belief. In the 1960's, Armaly organized a collaborative investigation of "ocular hypertensives" with intraocular pressure greater than 21 mmHg, but without optic nerve damage or visual loss. These patients were followed carefully, without treatment. He found that the majority of patients in his study did not develop visual field loss over a 7-year period.[4] The Ocular Hypertension Treatment Study also investigated ocular hypertensive patients and addressed whether treatment of elevated IOP prevented or delayed the onset of glaucomatous damage. Half of the participants were randomized to treatment to lower their IOP by 20%, and half were randomized to observation. All subjects were followed closely with visual field exams and optic nerve photos. After 5 years of follow up, 9.5% of the observation group developed glaucoma while 4.4% of the medication group developed glaucoma, defined as optic disc or visual field deterioration. Decreasing the IOP reduced the risk of progression to glaucoma;- however, the majority of ocular hypertensive patients did not develop damage within 5 years.[5] As the risk factors for glaucoma continued to be explored further, IOP remains at present the only significantly modifiable risk factor in the treatment of glaucoma. Treatment is initiated in eyes that have developed glaucomatous optic nerve damage and/or visual field loss, or in eyes at significant risk for developing glaucoma. IOP is then lowered to a 'target level' determined by many factors including baseline level of IOP, extent of damage, rate of prior change, other relatively static risk factors, life expectancy, medical history, and family history. Target IOP should be constantly re-evaluated to ensure stability of the optic nerve and visual field and to ultimately preserve patient's visual function. Types of tonometry Applanation tonometry is based on the Imbert-Fick principle, which states that the pressure inside an ideal, dry, thin-walled sphere equals the force necessary to flatten its surface divided by the area of flattening (P = F/A, where P = pressure, F = force and A = area). In applanation tonometry, the cornea is flattened, and the IOP is determined by varying the applanating force or the area flattened. [1] Goldmann and Perkins applanation tonometry The Goldmann applanation tonometer measures the force necessary to flatten a corneal area of 3.06mm diameter. At this diameter, the resistance of the cornea to flattening is counterbalanced by the capillary attraction of the tear film meniscus for the tonometer head. The IOP (in mm Hg) equals the flattening force (in grams) multiplied by 10. Fluorescein dye is placed on the patient's eye to highlight the tear film. A split-image prism is used to divide the image of the tear meniscus into a superior and an inferior arc. The intraocular pressure is taken when these arcs are aligned such that their inner margins just touch. Applanation tonometry measurements are affected by the central corneal thickness (CCT). When Goldmann designed his tonometer, he estimated an average corneal thickness of 520 microns to cancel the opposing forces of surface tension and corneal rigidity to allow indentation. It is now known that a wide variation exists in corneal thickness among individuals. Thicker CCT may give an artificially high IOP measurement, whereas thinner CCT can give an artificially low reading. Other errors that may affect the accuracy of readings from a Goldmann tonometer include excessive or insufficient fluorescein in the tear film affecting the thickness of the overlapping arcs, high astigmatism, irregular or scarred cornea, pressure from a finger on the eyelid while taking the measurement, and breath holding or Valsalva maneuver by the patient during measurement. The Perkins tonometer is a portable Goldmann applanation tonometer that can be used with the patient in either the upright or supine positions.[1] Non-Contact Tonometry Air Puff Tonometer In air puff tonometry, the applanating force is a column of air which is emitted with gradually increasing intensity. At the point of corneal flattening, the air column is shut off and the force at that moment is recorded and converted into mmHg. Readings from these machines may underestimate IOP at high ranges and overestimate IOP at low ranges as compared to the Goldmann applanation tonometer. A minimum of 3 readings should be averaged to estimate the mean IOP as IOP varies during the cardiac cycle. Ocular Response Analyzer The ocular response analyzer is a newer type of non-contact tonometer. This device also uses a column of air of increasing intensity as the applanating force. The ocular response analyzer notes the moment of applanation, but the air column continues to emit with increasing intensity until the cornea is indented. The force of the air column then decreases until the cornea is once again at a point of applanation. The difference in the pressures at the two applanation points is a measure of the corneal elasticity (e.g., hysteresis). Mathematical equations can be used to "correct" the applanation point for high or low elasticity. This "corrected" IOP is thought to be less dependent on corneal thickness than other forms of applanated pressures.[6] Indentation tonometry The principle of indentation tonometry is that a force or a weight will indent or sink into a soft eye further than into a hard eye. Schiotz Tonometer The Schiotz tonometer consists of a curved footplate which is placed on the cornea of a supine subject. A weighted plunger attached to the footplate sinks into the cornea in an amount that is indirectly proportional to the pressure in the eye. The plunger will sink into the cornea of a soft eye further than it will into a harder eye. A scale at the top of the plunger gives a reading depending on how much the plunger sinks into the cornea, and a conversion table converts the scale reading into IOP measured in mm Hg. Pneumotonometer The pneumotonometer is an applanation tonometer with some aspects of indentation tonometry. It consists of a 5mm diameter, slightly convex, silicone tip on the end of a piston that rides on a stream of air. The cornea is indented by the silicone tip. When the cornea and the tip are flat, the pressure pushing forward on the tip is equal to the IOP. The device measures the pressure within the system at this point and the pressure is displayed in mm Hg. The readings correlate well with Goldmann applanation tonometry within normal IOP ranges.[7] Tono-Pen The Tono-Pen involves both applanation and indentation processes. It is a small, handheld, battery-powered portable device. The tonometer has an applanating footplate with a tiny plunger protruding minimally from the center. As the tonometer makes contact with the eye, the plunger receives resistance from the cornea and the IOP producing a record of rising force by a strain gauge. At the moment of applanation, the force is shared by the foot plate and the plunger resulting in a momentary small decrease from the steadily increasing force. This is the point of applanation which is recorded electronically. Multiple readings are averaged. Because the area of applanation is known, the IOP can then be calculated. The readings correlate well with Goldmann tonometry within normal IOP ranges. [6][7][8] Rebound tonometry The newest version of the rebound tonometer is the ICare device (Helsinki, Finland). A 1.8mm diameter plastic ball on a stainless steel wire is held in place by an electromagnetic field in a handheld battery-powered device. When a button is pushed, a spring drives the wire and ball forward rapidly. When the ball hits the cornea, the ball and wire decelerate; the deceleration is more rapid if the IOP is high and slower if the IOP is low. The speed of deceleration is measured and is converted by the device into IOP. No anesthetic is necessary. It shows good agreement with Goldmann and Tono-pen readings.[6] IOP measurements obtained with this tonometer have also shown to be influenced by central corneal thickness, with higher IOP readings with thicker corneas.[9] [10] This tonometer has been shown to be affected by other biomechanical properties of the cornea, including corneal hysteresis and corneal resistance factor.[11] [12] Pascal Dynamic Contour Tonometer The Pascal Dynamic Tonometer (Zeimer Ophthalmic systems AG, Port, Switzerland) utilizes a piezoelectric sensor embedded in the tip of the tonometer to measure the dynamic pulsatile fluctuations in IOP. In contrast to the Goldmann tonometer, measurements with the DCT are reported to be influenced less by corneal thickness, and perhaps corneal curvature and rigidity. These claims are supported by in vitro and in vivo manometric studies. DCT can also be used to measure the ocular pulse amplitude. Disposable covers are used for each measurement and the digital display provides a Q-value which assesses the quality of the measurements. [13] Continuous IOP Monitoring IOP is a dynamic parameter that can fluctuate 4-5 mmHg in healthy individuals and even more variably in glaucoma patients. Advances have been made to develop techniques that can monitor IOP beyond the in-office measurements. Early animal studies have investigated technologies for permanent IOP monitoring, including the surgical implantation of a pressure transducer system, as well as the implantation of an intraocular sensor into the lens capsule.[14] The main drawbacks of these strategies include the surgical risks. The main device developed for temporary IOP monitoring is the soft contact lens sensor (CLS) that measures changes in ocular dimensions over a 24-hour period, which has shown good correlation with true IOP in in vitro manometry studies. This device is currently approved in Europe for clinical use. 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