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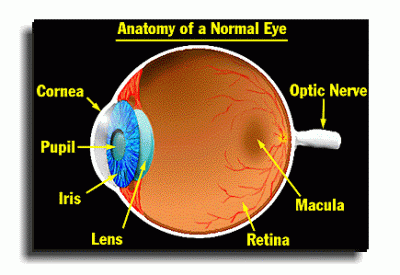
**A Review on Common Ophthalmic Tests**

**Abstract**

This is a review on ophthalmic tests that can be performed on patients. Many of these tests are associated with different diseases, such as glaucoma, macular degeneration, and diabetic retinopathy. The tests that are reviewed are tonometry, visual fields, thickness tests, and fundus photography. What is also discussed is the importance of eye exams and how often that patients should see either an optometrist or ophthalmologist.

**Introduction**

Have you ever noticed how much you use your eyes on a day to day basis? Of course you have, because if you are reading this, then you are using them right now. Eyes are important, obviously, but like any organ in our human body, diseases, and other issues, can occur, which inhibits our way of being able to see. Many of these diseases, that can occur, are irreversible because there aren’t many cures that have been created at this point in time. Some examples of the more common diseases that happen within the eyes are glaucoma, macular degeneration, and diabetic retinopathy. According to the CDC, these are three of the most common eye dieseases1.

 Before we get into the details of the paper, I just want to go over the basic anatomy of the eye, as you can see if **Figure 1.** Starting at the front of the eye there is the cornea, which is a clear, dome-shaped portion of the eye. Directly behind that is the iris, which is the color part of the eye, and is also a muscle because it opens and closes with the different amount of light that is exposed to it. The pupil is the opening, or dark hole that you see when looking at someone’s eyes. Directly behind the pupil is a lens, this portion helps to focus light into the back of the eye by changing it’s shape. In the space between the lens and the retina, there is a jelly like substance, called the vitreous humor, which helps to nourish the eye, as well as hold it’s shape. The retina is the light sensitive tissue within the eye and contains the macula and the optic nerve. The macular is a certain area that helps with giving us our central vision, while the rest of the retina gives us our peripheral vision. The optic nerve connects the eye to the brain, containing millions of nerve fibers, that transmit signals to the specific part of the brain that is responsible for our sight2.

**Figure 1. Anatomy of a Normal Eye.** This figure shows the different areas of a normal eye and where they are located5.

Glaucoma is a disease that generally occurs in people over the age of 40 and can either affect both eyes or a singular one. What the disease consists of is elevated intraocular pressure, or the pressure within the eye. This causes functions to be lost, and/or damaged, like drainage of fluid in the eye. A gradual decrease in the function of the retina and the optic nerve causes vision loss, turning the vision of the person to look like they are looking through a tunnel. The patient will start to lose their peripheral vision first, gradually losing more and more towards the center until there is no more vision at all3.

There are different types of glaucoma, but the main two types are primary open-angle glaucoma (POAG) and narrow-angle glaucoma. POAG is a silent type of Glaucoma when at the early stages of the disease6. There is a gradual increase in intraocular pressure, with no pain, that causes a gradual decrease in vision, sometimes not even alarming the patient until much of their vision is lost. Narrow-angle glaucoma is also called acute glaucoma, which is when there is severe pain and cloudy vision. This is caused by the eye pressure being so high that it causes other functions within the eye that drain fluid to be blocked, which is why it is called narrow angle, because the angle within the eye that drains the fluid is narrowed3.

The next common disease found within eyes is macular degeneration, which is caused by the deterioration, or degrading, of the macula, which is the part of the retina that gives you your most central vision. This disease is incurable, as of now, and is the leading cause of blindness, overcoming glaucoma for this statistic. The macula is a very important part of the eye, as it helps us to be able to see color, read, see fine details, etc.3

There are different types of macular degeneration: dry and wet. Dry Macular Degeneration is the most common type and consists of protein build up on the macula that is constricting those specific cells to not have oxygen, causing them to die and not work. Wet has a similar process, but it causes the blood vessels to start leaking within the back of the eye, which means that the macula then starts to bulge, or be lifted from its normal position. This causes a distortion of vision to occur, since this process is also causing those cells to not get enough oxygen as well. This is obviously a big issue because much of our day to day sight comes from this tiny portion of the eye, as you see in **Figure 15.**

As well as different types, there are different stages: early age-related macular degeneration (AMD), intermediate AMD, and late AMD. Early AMD consists of no vision loss, but a visual on drusen, the buildup of fatty proteins. The drusen are located on the macula itself, showing as yellow spots. Intermediate AMD is when there is some vision loss, and larger drusen and/or pigment changes to the retina may occur. In Late AMD, there has been a significant vision loss and a large amount of drusen and/or pigment changes to the retina. All of these signs can be detected by an eye doctor, which is why eye visits are so crucial when diagnosed with this disease5,6.

The last common disease that I will be talking about is diabetic retinopathy. This disease is caused by diabetes, hence why it is in the name, and is the most common cause of blindness in working people7. What this causes is damage to the blood vessels when high blood sugar is present, which can happen to a diabetic patient if they aren’t taking care of their body. These blood vessels can leak blood, swell, create new blood vessels, or even close all together, causing a stroke like effect in the back of the eye. All these problems can cause vision to be lost, which is never a good thing8.

There are two main stages of diabetic retinopathy, or diabetic eye disease: Non-proliferative diabetic retinopathy (NPDR) and Proliferative diabetic retinopathy (PDR). With NPDR, many diabetics have this, and it’s caused by the blood vessels leaking in the retina, which could cause the macula to swell, having vision loss like macular degeneration. Most times, patients with NPDR will notice their eyesight to be blurry, since the leaking and issues are happening within the middle of the retina. PDR can take away both the peripheral and central vision. This stage is more advanced than NPDR and is caused when new blood vessels are being noticed or growing. They often tend to bleed within the eye, possibly causing floaters, or small blocks in your vision, with little leakage, but if leakage is occurring more frequently and in higher volumes, they can cause huge chunks of vision to be lost. With the new blood vessels, they can also form scar tissue. This causes the retina, in that specific area, to be very fragile and cause the chances of having a retinal detachment to be higher than normal8.

Throughout this paper, I will be explaining different types of tests that doctors can do in order to determine whether a patient has any one of these diseases, or even more than just those three. It is important that these tests be done, especially with a family history of any of these diseases, so that the doctors can treat early, or even help to prevent, the diseases.

**Tonometry**

Tonometry is a test that is done in order to determine intraocular pressure (IOP), which is a symptom with glaucoma, as stated previously. The first device to determine IOP, by indentation, was created in 1863 by von Graefe, to which it measured IOP by a plunger-like device that would be placed on the sclera, or the white part of the eye, and the indentation the plunger left was to determine the eye pressure. The first applanation tonometer, or the measurement of the flattening of the cornea, was created in 1867, but not accepted into the society of eye doctors until 1872. Today, there are different types of tonometry, such as Goldmann, Non-Contact (Airpuff), Pneumotonometry, and Indentation9.

A person holding a camera

Description automatically generated with low confidence Goldmann tonometry consists of a weight, called the tonometer, that is already fixed. How the eye pressure is determined is by the flattening of the cornea, using the tonometer to put slight pressure on the cornea. Based on how much pressure is applied to the eye, that is the number of the intraocular pressure. What a patient will see is the tonometer, that’s about 3.06mm in size, with a cobalt blue light that activates a fluorescent dye **(Figure 2)**. This dye is inside a numbing reagent so that patients don’t feel the device on one of the most sensitive areas of the body. This device is mounted on a slit lamp, which is similar to a microscope, that patients put their heads into so that the doctor has easier access to the eye itself, as seen in **Figure 2.** Some of the positive things about this device is that the patient doesn’t feel anything when it touches their eye, it just looks scary. Some of the downsides is that the eye pressure is taken and observed by a person, which all humans can make mistakes, and the pressure could be different for every person. Another downside is that the corneal thickness of the patient can also alter what the pressure reading is, and so doctors assume that there could be a 3mm Hg (the measurement and its units) difference, whether higher or lower, than what the observer took themselves. The last drawback is that when a patient holds their breath, it causes the eye pressure to go up as well, and because this device looks scary, some people instinctively hold their breath, causing the intraocular pressure to be invalid. Overall this is a technique that patients seem to be willing to do, especially since they can’t feel anything9.

**Figure 2. Goldmann tonometry.** “Goldmann applanation tonometer on the eye9.”

Another technique that is done to find the IOP is the Non-Contact, or Airpuff, tonometry. It was originally created, and used, when there was no topical anesthetic around or available at the time. This technique is very similar to the Goldmann technique, but instead of it being a device that is pushed onto the eye, it is air that is pushing the cornea. Once the cornea is flattened, a weak laser shoots out of the device and hits the corneas surface at an angle, bouncing back at the machine and giving it the intraocular pressure that is then recorded. Some advantages of this device is that there is no anesthetic required, which can put some patients at ease, and there is not sterilization required in between patients since it is just a puff of air and there is not contact with the patient’s eye. Some downsides are that they require electricity, are fragile to carry, they require lots of maintenance, and also have issues with being accurate with the difference in corneal thickness9.

Pneumotonometry is another type of way to get IOPs, and it’s very similar to indentation tonometry. What this device has is a plunger that is about 5mm in diameter that is made of silicon. The device is placed onto the cornea, causing a slight indent, and when both the tip of the device and the cornea are flat, that is the IOP that is then recorded and reported to the doctor. The tip is generally held onto the cornea for 5-10 seconds, to allow the device to get the most accurate pressure. In general, it does compare well to the Goldmann technique, though it is typically 2-4mm Hg higher and may underestimate really high pressures in patients. Some of its advantages are that it is easily portable and free of needing a slit lamp, unlike the other two previously mentioned. It also takes less skill than Goldmann, so it’s easy for technicians to learn. Some disadvantages are that the tip is difficult to sanitize between uses, is in need of repair more frequently because it damages easily, and to replace the necessary materials to make this device is expensive9.

Lastly, Indentation tonometry, which is when a force, and/or weight, indent or sink into a soft part of the eye, which can go further than if it were a harder position. There are many newer forms of indentation tonometry today, including McKay-Marg, Rebound Tonometry, Dynamic Contour Tonometry, and Transpalpebral Tonometry. The one that I A picture containing person, indoor, holding, small

Description automatically generatedwill focus on is rebound tonometry, which was actually created for animals that have small eyes, like mice, so that veterinarians can get their eye pressures. The newest device on the market is the ICare tonometer, as shown in **Figure 3.** What this device contains a 1.8mm, in diameter, plastic ball on a wire that is held in place in the device by a magnetic field. When the button on the device is pushed, the wire then springs the ball onto the cornea, which causes a deacceleration, and the momentum of the rebound is then seen within the device and recorded for the doctors’ use. No anesthetic is needed for this device because it touches the cornea of the patient very briefly, and it mainly feels like an eyelash is poking the eye. The advantages of this technology is that it is very portable, there is no slit lamp needed, it is battery powered, which means no cords, and can be used by anyone with little training. The pins are also able to be disposed between patients, which clears the air about needing to disinfect the device. Some disadvantages is that it can only be used on a patient that is sitting upright, or else the pins will fall out, the disposable pins cause an increase in spending, and accuracy isn’t the best when being used for long-term use, like when trying to watch the IOP of a patient with glaucoma9.

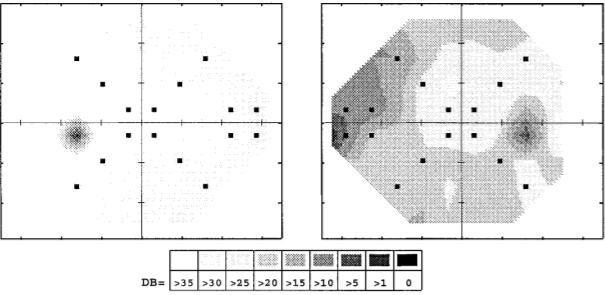
**Figure 3. ICare rebound tonometer.** “The tiny wire with the white ball on the end is driven into the eye very rapidly. The speed of rebound is measured internally and is proportional to the IOP9.”

In a study done by Paolo and his associates, they compared the accuracy of ICare with Goldmann. The study took 178 patients that had POAG, and took their IOPs using both Goldmann and ICare, and they used formulas and methods in order to get the correct IOPs from the patients and calculate the agreement between the two devices. Their final conclusions showed that the ICare tonometer should be used in a clinical setting because of the difference from Goldmann, and it shouldn’t be used on a long-term basis. Goldmann, they claimed, was more recommended in order to be used for long-term patients, like glaucoma patients, so that they can have accurate readings on their IOPs and determine a course of action from there10.

What they used to do, before all this technology came about, they used to tie a specific cuff around someone’s neck and inflate it. They would then measure eye pressure by using the Schiotz Tonometer, which acts very similar to the Goldmann technique. They would also make someone drink 600-1,000 mL of water within four minutes, which is very fast, and then use the same tonometer as the previous technique, to measure eye pressure that way as well11.

As you can see, technology advancement has definitely increased our knowledge in intraocular pressure and made it more bearable for patients. With the more knowledge we have, the better we are at tracking diseases, like glaucoma, that have high eye pressures that cause damage. These devices help doctors to know better, now, when a patient may need to be put on medication to help control the pressure of the eye or just watch for what is going on, because if it goes unmanaged, someone can lose eyesight without even realizing it.

**Visual Field**

A visual field test can be done to determine how much of the vision a patient has lost because of a disease, like glaucoma, or a certain condition. It makes the patient focus on a specific point within their central vison and is usually done one eye at a time to find their individual loss. What it can also determine, besides vision loss, is the blind spots of the eyes as well, since each eye has a natural blind spot, which is the optic nerve12, 13. From my experience working in an Ophthalmic practice, the advantages of a visual field test is that it helps to detect damage, if any, for people that are experiencing different diseases that cause vision loss, or other issues as well. Some disadvantages of this test are that some patients don’t have the patience for this, and so they will start to move their eyes around to follow the flashes, which causes the data to be skewed. Another issue is that patients eyes dry out from not blinking because they believe that if they blink they will miss a key part of the test. Not blinking dries their eyes out, causing spots in their vision to be blurry, which can make the test skewed because they don’t see a flashing light in those areas.

**Figure 4.** “Examples of visual field data for the treated (right panel, left eye) and control (left panel, right eye) eyes of a monkey with experimental glaucoma. Data for the grayscale plates were obtained from the 24-2 full-threshold program of the Humphrey Field Analyzer with a Goldmann III white stimulus. The *filled squares,* which are superimposed on the visual field plots, designate the test-field locations for retinal tissue samples collected to quantify sensitivity-neural relationships for visual field defects cause by glaucoma14.”

In a study done by Ronald Harwerth and his associates, they worked on monkeys, who are really close genetic relatives to humans. They performed tests on monkeys that did have glaucoma, and used the left eye as the control, to which they didn’t treat at all, and the right eye as the one that they would treat. They found that the treated eyes didn’t have as much damage as the untreated ones, as seen in **Figure 414.**

Unfortunately, there isn’t a lot of literature on visual fields, as a whole, besides being used as a diagnostic test. One thing that should be done, regarding visual fields, is a review on the different types of visual fields that can be performed on patients, including the advantages and disadvantages of all the different types. Not just a general description from myself, who is not as reliable as an actual Ophthalmologist.

**Thickness**

Glaucoma and macular degeneration can both also be tested for the thickness of certain parts of the eye, or more specifically the optic nerve and macula. The thickness of these parts can actually determine whether the disease is progressing. Some tests for glaucoma are an optic coherence tomography (OCT) and retinal nerve fiber layer (RNFL), and for the macula, they are ganglion cell analysis (GCA), ganglion cell-inner plexiform layer (GCIPL) and macular OCT15,16.

What an OCT does is it uses light in order to help determine the thickness of the retina, whether that be the optic nerve or the macula. When this test specifically aims for the optic nerve, and the surrounding retina around it, it shows the thickness of this area, which is the RNFL. There have been multiple studies to show that this test is better at getting measurements than just a simple OCT on the retina. What it tests is the thickness of the optic nerve and the surrounding retina around it. The thickness of the optic nerve tells the doctor how progressive the glaucoma is. The thicker the nerve, the less glaucoma a patient has, but if the nerve is thin, then the patient has more glaucoma. With the macula, this test helps to find if there is any swelling in the macula that might cause distorted vison. These tests are important because they help to determine if there is damage to the optic nerve, caused by glaucoma or trauma, or if there is anything wrong with the macula that might be causing some vision problems with a specific patient14. The advantages of these tests is that it can help the doctor find a problem and it helps to track an issue and how bad the swelling or the thickness is in a patients. One of the disadvantages are that the patients who are older have a harder time with not moving their eyes for a few seconds, whether because they have a short attention span or another issue, and this causes the test to have holes and be unreliable. Another disadvantage is that if the patient isn’t looking right at the target, the test also won’t be accurate, or if there is a cataract, or other foreign body, that may be blocking the view for the machine in order to get a good reading on that area of the retina14,17.

A picture containing white, black, man

Description automatically generatedAnother test is the GCA, which tests the thickness of the ganglion cells surrounding the macula. These are specific cells within the retina layer, and recent studies have shown that if this layer of the retina starts to decrease around the macula, then it can detect glaucoma earlier than the RNFL test12. The advantages and disadvantages for this test are the same as the OCT tests, as mentioned before, because they use the same machine, but it measures a different test.

**Figure 5.** “Cresyl violet-stained sections from control and glaucomatous eyes of monkeys. The ganglion cell layer (GCL) of the central retinal of the glaucomatous eye shows a 97% cell loss. The temporal peripheral retina shows a 75% retinal ganglion cell loss. There was no apparent alterations of the inner nuclear layers (INL) or outer nuclear layers (ONL) of either monkey14.”

On the same note of ganglion cell thickness, another test that focuses on this layer is the GCIPL. It tests the same layer as a GCA and is less variable among individuals that don’t have glaucoma. The advantage of using this test for diagnosing glaucoma are that it can be used as a test for end-stage glaucoma

when the RNFL parameters are at their lowest measurements and the visual field of the patient only has the central vision left16. It is also better than that of the RNFL test when considering moderate to advanced glaucoma because it is better at detecting the progression of the disease18.

A close up of a device

Description automatically generated**Fundus Photography**

Looking into the back of the eye is difficult, especially for patients that are older, or ones that don’t like a light to be shown within their eye for very long. Many patients are too impatient to have a doctor look into their eye, and a great deal others don’t like being dilated, which is when the iris, the color part of the eye that is a muscle, is relaxed and opens up, giving the doctor a better look into the eye. Fundus photography helps with all these issues. Here, a camera takes pictures of the back of the eye, using the pupil as the entrance and exit to give the picture. Typically pictures are taken at 30°, which is considered the normal angle of view for most people. These photographs can be used to find many diseases, and not just diabetic retinopathy, like glaucoma and macular degeneration. With glaucoma, they can be used to be seen side by side and see the damage of the optic nerve from the increased pressure within the eye, and with macular degeneration, they can be used to detect drusen on the macula. The photos can also be used as serial photographs to track the development of the drusen21.

**Figure 6.** This is a figure that shows how fundus photography works when taking a picture within the eye21.

In a study done by Bruce Beau and his associates, they had 350 patients that had come to the emergency department of a hospital with different kinds of symptoms. They found that most people used the fundus photography rather than ophthalmoscopy, which is an examination of the back of the eye using a magnifier, whether it be a slit lamp, as mentioned before, or a portable one that doctors can put on top of their head. In this study, they found that out of the 350 patients, only 48 of them used ophthalmoscopy, and in many of the patients in the total that they saw, they found the issues that they were dealing with using fundus photography19. If you look at the top right photo of **Figure 6,** you can see that there is a hemorrhage, or blood leaking, which could be due to diabetes, causing diabetic retinopathy.

In another study, done by George Williams and his associates, their objective was to see if **A picture containing indoor, oranges, sitting, orange

Description automatically generated**fundus photography can be used as a tool to screen for diabetic retinopathy. They did find that fundus photography couldn’t be used as a substitute for ophthalmoscopy, but it can be used to screen for diabetic retinopathy, and from there they can be sent somewhere else in order to get the care that they need. They also explain that further research must be conducted to find the cost effectiveness of using this test and placing protocols for screening for diabetic retinopathy20.

**Conclusion**

There are many tests that have not been mentioned in this paper that can also be done in order to find different diseases, but the ones mentioned here are the most common that ophthalmologists use in their practices or hospitals. Overall, all the tests have their advantages and disadvantages, but if the doctor orders them to be taken for you, you have some background knowledge on what these tests do and why they the doctor’s may be ordering the tests as well.

**Figure 6.** “Examples of *non-mydriatic* fundus photographs obtained by nurse practitioners during the FOTO-ED study. Top left: normal posterior pole, showing normal field of view of non-mydriatic fundus photography, which includes the optic nerve, macula, and major retinal vessels. The enlarged inset compares the single field of view of the most commonly used conventional direct ophthalmoscope which only shows part of the optic nerve head, and requires active exploration of the fundus by the examiner. Top right: intraocular hemorrhage. Middle left: Grade IV hypertensive retinopathy with optic nerve edema, arterial attenuation, and retinal hemorrhages. Middle right: Optic nerve edema from intracranial hypertension. Bottom left: Acute retinal ischemia from central retinal artery occlusion. Bottom right: Optic nerve pallor. The black backgrounds of the original images were cropped and the brightness/contrast was adjusted17.”

Annual eye exams are very important, especially since you can’t see inside your eye or determine what is wrong with your vision simply by looking it up online, which is not recommended. Much like you can’t see inside your body and what’s going on there, you go get a physical done, and the same can go for seeing a gynecologist. Every few years, if there was nothing wrong at the last visit, you should go see the doctor so that they can at least follow you, even if you are healthy, so that they can detect anything to be wrong, if something does come up. Another reason people should go frequently is if they have a family history of certain diseases, such as diabetes, glaucoma, macular degeneration, etc. It is recommended that the first visit for anyone should be in kindergarten to start the routine of going in for a couple years, but also for the doctor to see if there are any conditions that the child may have been born with20.

Many of these problems can be caught early and treated, with patient compliance, so that nothing bad happens, like vision loss. Eye exams are very important, and the questions that should be going through everyone’s brain are, “When was the last time I got an eye exam? Did any of my family members have any vision loss issues or diseases that were known?”

 For the future in the field of Ophthalmology, I feel that these tests are more going to be perfected, rather than finding new tests for these diseases. Many of these tests are working really well, and are able to detect all sorts of diseases, not just the three that were mentioned within this paper. These tests could be upgraded to look farther into the eye, or to detect earlier than what they do now, but in order to do that, more research has to be done on these diseases to find how they work and what causes them. I think the future more rests in the hands of research on diseases that are uncurable, or can’t be prevented very well, since there isn’t too much knowledge on what makes these diseases tick.

**Table 1. Summary.** This table is a summary of the tests described in this paper, with it’s advantages and disadvantages, and what kind of diseases that the tests can determine as well.

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