

From Looking to Seeing and understanding Accommodation

This talk on "accommodation" was presented by Dr. G. D. Hoonka, at Hotel Krishna, 5 PM on July 25th 2004. This talk was presented with OHP support, hand drawn diagrams and working models explaining the process of accommodation in great details. The program was sponsored by Himalaya Drugs.

In our school days our teachers often used to say - "Look at the board and see what is written". But inspite of doing the same habitually, difference between looking and seeing was not clear. Now we realize that between the process of looking 'to seeing, some interaction does occur between the eyes and brain. What is that and how it is accomplished? is the theme of today's talk.

In context of senile cataract operation even with PC IOL, we know that due to loss of accommodation the pleasure of reading or Computer work is hampered. Therefore to explore the possibility to restore the accommodation is the aim behind this talk, so as to share our experiences in this regard and also to stimulate further research for creating physiologically true replica of human lens with dynamic accommodation & also the accommodating spectacles & medicine for presbyopes.

Working of the eye is comparable to a focussing camera which can be set from infinity to a close up shot However far and near objects can't be focussed simultaneously -It is always "One at a time".

For clear focussing of near objects eye has to increase its refractivity. This process of changing focus is called accommodation. Theoretically in animal Kingdom it can be achieved by any of the four ways:

1. As seen in some snail's eyes - by elongating the eye to 'H'. In camera it amounts to shifting the photographic plate backwards.
2. As seen in some fishes - by advancing the lens forward. But Tscherning's calculation showed that in man 10 mm advance will be necessary whereas anterior chamber is only 3mm deep. It is similar to shifting spectacles towards tip of nose.
3. As seen in some birds like eagle - by increasing curvature of cornea.
4. By increasing curvature of lens in man raises its power from +18 to 23 D.

Before elaborating accommodation - mechanics, which is solely based on elastic forces of lens and ciliary body against the action of ciliary muscles, recalling their brief anatomy will be better for the proper understanding of the subject :-

Anatomy of the structures responsible for the process of accommodation

The crystalline lens

Derived from embryonic ectoderm it is a bi-convex mass of pliable (soft & elastic) tissue which is enclosed in a highly elastic capsule and held in situ by the suspensory ligament - zonule of Zinn Its anterior surface lies behind the iris and posterior surface resting in the retrolental patellar fossa, is separated from the face of vitreous by a capillary film of aqueous. Its equator lies only 0.5 mm from ciliary process (Sorsby vol. 1 P-126). Its dimensions are shown in fig. 2.

As per B. Patnaik (Adler's Physiol) during accommodation in human lens it is not the cortex but the nucleus which undergoes the deformation. Thus as long as nucleus remains soft and elastic it can be moulded easily by the thin but extremely elastic capsule, whereas hard & inelastic presbyopic nucleus fails to mould.

The lens capsule

Thickness of capsule is not uniform. As per Fig. 3 it is thickest towards equator and thinnest at posterior pole. Capsule is so elastic that:-

1. On capsulotomy, particularly in children, its cut edges gap and roll out.
2. After absorption of traumatic cataract undulating folds are seen on the floating capsule.
3. Long standing dislocated lens, owing to freedom of zonular pull becomes almost spherical.
4. When capsule of water swollen lens is punctured by a fine needle water jets out. Thus it is the elastic recoil of the capsule that moulds the lens for near vision.

The Suspensory Ligaments

Though derived from vitreous but look like fine hair but are strong and visible to naked eyes. Their length is (stallard) between 2-7 mm and resistance to rupture is equivalent to 100 g. in children and 60G in elderly. Due to resemblance to hair it is also called "Zonula Ciliaris". Further pull of the zonules to stretch the capsule is comparable to pull of hair on skin which is easily demonstrable. Strands of suspensory ligaments, passing forward and backwards cross each other, are divided into three groups :-

1. Anterior group (AZ) :- They arise from pars plana of ciliary body almost as far back as ora serrata (which is 8 mm behind limbus). After lying in contact with ciliary body, curve towards equator of lens for insertion into capsule 1.5 mm anterior to equator. They are longest (7 mm).
2. Posterior group (PZ) :- They arise from the summits and sides of ciliary processes and pass backwards for insertion into capsule 1 mm posterior to equator. Their length is 4 mm.
3. Equatorial group (EZ) :- They arise from the summits of ciliary processes and pass directly inwards to be inserted at the equator which is 0.5 mm away. They are shortest (2 mm) and are pulled by radial fibers under sympathetic control.

The Ciliary Muscles

This is a circum lenticular muscle and its chief mass is composed of involuntary smooth muscle fibers that are divided into three parts with a common origin in the ciliary tendon which blends with scleral spur. Here it is noteworthy that during the muscular contraction it is the inserted part which is pulled towards the fixed origin.

1. Meridional Fibers (MF) :- (Brucke's Muscle) The greater part of ciliary muscle is composed of meridional fibers running antero-posterior on the inner aspect of the sclera to find diffuse insertion into the suprachoroid (about 8 mm behind the limbus) where muscle stars are produced. Under the parasympathetic control through short ciliary nerves its contraction pulls the suprachoroid and ciliary body forwards and inwards by 0.5 mm (Davson). As a result periphery of the vitreous is also compressed so that patellar fossa along with lens move forwards (High lights).

2. Annular or circular fibers (Muller's Muscle) (AF) :- Most of the remaining fibers run so obliquely in interdigitating V shaped bundles that it appears running in a circle around the ciliary body concentrically with the root of iris. Their sphincter like action constricts the ciliary ring around the lens & thereby relaxing the anterior and posterior zonules. These are parasympathetically controlled through short ciliary nerves and are synergistic to meridional fibers.

3. Radial Fibers (RF) :- The third portion of the ciliary muscle which is composed of few thin fibers, arising most anteriorly fans out to find insertion in the root of the iris in close relation to the dilator pupillae. Under sympathetic control through long ciliary nerves, they focus distant objects, by pulling the equator of the lens further.

Enervation

The accommodation is regulated by the autonomic nervous system. Due to antagonistic control by parasympathetic and sympathetic it has come in line with the pupillary activity. Whereas as per Sherrington's principle constrictor or dilator activity can be "one at a time", otherwise if simultaneous, antagonist activity will be nullifying and ineffective. Thus Retardation or acceleration, Bradycardia or Tachycardia, sympathetic or parasympathetic activity can be only one at a time.

Participation of sympathetic elements in human accommodation has been debatable since long. By now sufficient evidence has accumulated that active accommodation for distant vision does exist. It is based on the presence of sympathetically enervated genuine radial fibers, which on stimulation by subconj. inj. adrenaline (Briggs, Alpren and Bennett) leads to hypermetropia due to extra flattening of lens. Whereas sympathetic palsy, seen in Horner's syndrome or in experimental superior cervical ganglionectomy induces myopia and meiosis. This effect cannot be attributed to merely vasoconstriction which decreases the volume of ciliary body.

Stimulus for Accommodation

The reply to question that "What triggers the accommodation ? is contained in the ocular estimation of distance of the object looked at. This is estimated by the combination of the following clues :-

1. Blurring of image: - By itself this clue is not useful since eye cannot determine whether blurring is due to nearness, remoteness or due to fog. Similarly blurring due to chromatic and spherical aberration is also of limited use.

2. Vengeance of light rays: - Rays from near object are oblique or divergent so that closer the object greater the vergence and lesser would be brightness of the image due to Stiles - Crawford's effect which is appreciated easily in night by watching the car lights The oblique light will appear dull and small.

3. Physiological Diplopia :- Whenever object nearer than the object of fixation is looked at it produces blurred images on the temporal sides of both fovea and also the diplopia which is normally suppressed mentally & the degree of suppression varies with the distance. When such blurred images are projected to visiospsychic area (19) the related object is oriented as nearer. After determining the distance it is upto the area 4 & 8 to send signal to Edinger-Westphal Nucleus (EWN) to see it clearly. Thus ground is prepared by the blurred images but it is the desire to see clearly that triggers the accommodation Therefore our presumption that accommodation is initiated as a voluntary reaction but completed by the reflex mechanism is also supported clinically.

Whenever corticonuclear tract (CNT) between motor area 4 & 8 and EWN is disturbed by brainstem tumour inverse Argyl Robertson Pupil is produced i.e. only accommodation is lost where as light reaction is retained. I wish some MRI study to confirm the exact afferent of this psycho-optical reflex.

Nervous Pathways for Accommodation

Book diagrams based on clinical findings showing accommodation pathways are not anatomical but just schematic only. That is how Gray's Anatomy writes it as presumptive and Parson - Diseases of the Eye also mention it as conjectural.

- 1) Thus information of blurred images via area (19) reaches to EWN.
- 2) Normal Suppression of blurred image continues unless signal from area 4,8 reaches EWN to clear the image.
- 3) I therefore can presume that When desire from 4,8 to "See" clearly stops the suppression & opens the window of EWN, the calculated information is released from here to accomplish the accommodation

Theories of Accommodation

Existing theories of accommodation as they stand cannot explain all the phenomenon of the accommodation However while awaiting the precise mechanism of accommodation, now every one has agreed that the essential feature of accommodation is lenticonus formation

(1) Helmholtz' Theory :- In the act of accommodation all fibers of Ciliary muscle contract to relax all zonules so that elastic lens becomes spherical in shape by reducing its radius of curvature of anterior surface from 10 mm to 6 mm i.e. equal to posterior surface. Against this theory it is argued that in aged people due to increased diameter of the lens relaxation of zonules and lenticonus shall be persistent. But even if it is so the hard and inelastic lens cannot bulge any more.

(2) Tscherning's Theory :- By this theory it was rightly contested that during the act of accommodation anterior surface of lens assumed not a spherical but a hyperbolic lenticonus. But to explain this it was suggested that all fibers of ciliary muscle contract

to tighten all zonules and thereby to flatten the equator by which anterior surface of lens bulged as nipple. But the so called tightening of the zonules is contradicted by the trembling of the lens seen during full accommodation. However formation of lenticonus is confirmed by the work of Finchem but, later on Nordenson found that periphery of un-accommodated lens is also relatively flat (fig.6) and therefore peripheral flattening cannot be part of accommodation of as suggested by Tscherning.

3. Schachar's Theory :- In 1992 Schachar proposed a new theory. As per this in the act of accommodation while meridional & annular fibers of ciliary muscle contract to relax anterior and posterior group of zonules, at the same time contractions of radial fibers tightens the equatorial zonules for flattening the lens periphery and thereby to produce the lenticonus. Since parasympathetically (MF & AF) induced lenticonus and sympathetically (RF) induced flattening cannot be simultaneous as proposed, this theory which is mixture of Helmholtz's and Tscherning becomes improbable and unacceptable. This is against the Sherington's principle of reciprocal enervation.

4. Mv Unified Theory :- In line with reciprocal pupillary activity I have to propose this theory that can explain all phenomenon of accommodation

(a) For Near Vision--Contraction of MF & AF --Relaxing AZ & PZ--Lenticonus In other words C. Ring Shrinks -- Cap. Shrinks -- Nucleus squeezed out.

During the accommodation sympathetically controlled equatorial zonules do not participate. It is supported by the fact that length of EZ is not altered on account of equal shrinkage in the ciliary ring and lens diameter by 1 mm.

(b) For Active Distant Vision - Sympathetic contraction of RF-- stretching of EZ pull & flatten the equator so that lens diameter approximately increases to 9.2 mm & radius of curvature of anterior surface increases to 9.9 mm.

In other words Zonule stretches -- Cap stretches -- Nucleus Sucked in.

This theory can explain all the lenticular changes enumerated below:-

1. Lens moves forward by 0.5 mm due to vitreous compression by MF.
2. Diameter of Lens reduced by 1.3 mm
3. Thickness of the lens increases by 1.25 mm
4. Anterior pole bulges forward by 1.75 mm (total of 1+3)
5. Forward shift of iris making AC shallow by 1.5 mm (AC = 2.5-3.6 mm)
6. Wrinkles from equator disappear due to loose zonules.
7. During the maximum accommodation smaller & lose lens of young ones trembles.

Mechanism of Accommodation

Now the details of Near Vision accommodation can be elaborated, stepwise as following:-

1. *Parasympethitically initiated contraction of MF of CM compresses the vitreous from ora serrata onward. So that retrolental patellar fossa vaults anteriorly (demonstrate) pushing the the lens by 0.5 mm in the directions of least resistance towards pupil.* At the same time by the contractions of AF ciliary ring is not only constricted but it is also pulled forward and inward so that zonular tension of AZ. and PZ is removed. Synergetic Contraction of MF & AF maximize zonular relaxation. Forward shift of lens by 0.5 mm accounts for about 1.50 accommodation which is utilized by the dynamically accommodating IOL(Highlights).

2. Due to relief from zonular stretching in attempt to reduce the surface area lens changes its shape. If lens capsule was uniformly thick, then it must have assumed spherical shape (Demonstrate). But on account of thinner anterior capsule nucleus is moulded as a lenticonus. As soon as thinnest post. polar capsule, which is under maximum stretch, gets relieved from zonular stretch, then similar to elastic recoil of catapult (Demonstrate) the thinner opposite anterior pole is made to herniate towards the least resistance i.e. pupillary area inform of lenticonus. By lenticonus, depending upon the age, full amplitude of accommodation upto 15D can be achieved upto the age of 10 years.

3. Proportionate to parasympathetic discharge amount of accommodation is regulated. When stimulation for near vision stops, ciliary ring relaxes and recoils back to distant vision state, the tightened anterior zonules & posterior zonules restore the site, size and shape of the lens to the un-accommodated state. However equatorial zonules remains unaltered.

4. Since concentrically positioned ciliary muscle contract equally all around the lens in both the eyes, any amount of astigmatism or anisometropia cannot be corrected by the efforts of accommodation. Whereas in presbyopia although hardened lens fails to bulge despite the contraction of ciliary muscle, even then anterior shift of lens or PC IOL will provide atleast 10 accommodation so that people beyond 60 yrs. also can focus objects upto one meter but not within a meter. Working of accommodating IOL is based on the anterior shifting of Capsular bag.

Active accommodation for distance vision

Our daily life is dominated by the effortless distant vision because rays from objects 6 meter (20') away are regarded parallel and being parallel they come to focus on fovea of emetropic eye i.e. without any accommodation. Whereas fact remains that although our eyes are not telescopic eagle's eyes still on account of distant vision accommodation fruits and birds on tree top of +20' height are clearly seen & successfully hit if desired. At a distance of one meter 10 accommodation is necessary and at 6 M & 10M it will be +0.170 & 0.100 respectively. Even this small amount of accommodation is of paramount importance for shooting fruits, birds and playing outdoor games like badminton and Cricket with the pitch of 20M long, so as to accurately hit and catch the ball. This infact can be achieved by fine adjustment within the amplitude of 10 and indeed it is perfectible with the practice. However change in size of retinal image of moving ball or shuttle cork also helps in estimation of correct distance and correct focussing.

Mechanism of active distance vision accommodation

During sports when active DV is required Sympathetic stimulation by contracting the Radial fibers pull the equatorial zonules thereby lens is further flattened. It is noteworthy that degree of contraction of Radial fibers and flattening of lens is finely adjusted by the sympathetic discharge from the hypothalamic center which is also influenced by psycho-sensory stimuli.

In short :- NV = Ciliary Ring Shrinks --+ Cap Shrinks --+ Squeezed Nucleus
DV = Ciliary Ring stretches --+ Cap. Stretches --+ Sucked in Nucleus

(Demonstrate sucked in drop by a dropper)

Recent Trends

Can we restore the accommodation lost by lens extraction or presbyopia ? At least that seemed improbable until now. But accumulating evidence strongly suggest that it is indeed possible with the ultramodern techniques some of which are worth mentioning.

For Presbyopia

Though multifocal glasses are of great value still with the modern trend to discard spectacles, in USA conductive keratoplasty using radiowaves is approved by FDA. Apart from this at New Mexico University an artificial Bionic Muscle is being developed and its transplantation around the ora Serrata will either elongate or shorten the AP length of the eye similar to snail's eye is under trial.

For senile cataract

PC Bifocal/ multifocal and dynamically accommodating plate or two pieces IOI are already implanted in metrocities Similar to normal near vision contracting forces of ciliary muscles are transformed into ante nor shift of accommodating IOL Optic by 0.50 to 0.63 mm. Due to the increased distance between the lens and retina, pseudophakic accommodation between +13 to 1.70 enables the eye to enjoy the boon of near vision without spectacles in majority of the cases.

For infantile cataract

IOL with increasing power is under trial. This acrylic lens has 3-4 water tight vacuum chambers stacked on top of one another. Power of lens can be increased stepwise by pricking a hole by LASER in one of the chamber in which rush of aqueous raises its refractive index & refractivity. So repeated change of IOL is not required.

Conclusion

In conclusion I would like to recall the story of Panda vas brothers Four of them were simply looking about the bird but only Arjun who was seeing the bird's eye attentively could shoot it down. The most significant lesson derived from this story is that looking is different from seeing because seeing is the intentional mental process which triggers the accommodation making the looked at things visible. Ultimately vision remains the power and art of seeing things because eyes see what brain shows in the range of looking, seeing, watching, observing, gazing or staring Thus our vision is not only clearly focussed by the mind but also modified by emotions and sometime even deranged to produce illusions, delusions & hallucinations. How perfectly it has been described in the literature as- "Jaki rahi bhavana jaisi, prabhu moorat dekhi tin taisi "

Therefore while ending the talk I would like to reiterate that eyes look and mind sees.
