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Research Article

OCULAR HYPERTONIA AND THE ACCOMMODATIVE EFFORT: WHICH RELATION?

Said Iferkhass*., Nihad Elhalouat and Abdelkader Laktaoui

Ophthalmology Service. Military Hospital my Ismail. Meknes. Morocco

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A B S T R A C T

Introduction: Our work consists in studying the ocular tension and its evolution before and after relaxation of the accommodation by a full optical correction (FOC).
Materials and methods: we have a prospective study from January 2014 to December 2016; out of 60 patients including 36 (60%) followed somewhere else for open-angle glaucoma (based on visual field alteration without structural damage) and 24 (40%) isolate ocular hypertonia, followed in ophthalmology department Military Hospital Moulay Ismail in Meknes.
The following data were analyzed: age of patients, antecedents, average value of three ocular tones taken by applanation tonometer before and after three and six months of initial full optical correction port.
Results: The average age is 45 years [7-60 years] with sex ratio H / F: 1. 66.5% of our patients had symptomatic farsightedness and 88.2% of cases an accommodative spasm. Comparing the refraction of spherical equivalent before and after cycloplegic on the 120 eyes of our cases, shows an average difference of 1 diopter. The ocular tone decreased by a mean of 6.24mmHg in the right eye (OD) and 6.52mmHg in the left eye (OS), after three months of FOC. And after six months it decreased: 7.74mmHg OD and 7.82 mmHg OG. The difference was statistically significant ($p = 10^{-3}$). **Conclusion**: Based on our study data, relaxation of accommodation by FOC, particularly in symptomatic hypermetropic patients or those with accommodative spasm, improves ocular tone and functional signs. This leaves us to evoke the hypothesis of an "accommodative hypertonia".
This study paves the way for other prospective and multicenter studies to confirm or annihilate it.

INTRODUCTION

Ocular hypertonia is defined as an intraocular pressure more than 21 mmHg, and itis a major factor in glaucoma. Accommodation is an active and reflex phenomenon that is essentially involves the ciliary muscles. Clinical findings of decreased ocular tension in some patients after relaxation of accommodation led us to study the relationship between accommodation and ocular hypertonia. Our work consists in studying the ocular tension and the visual field as well as they evolves before and after relaxation of accommodation by a full optical correction.

MATERIALS AND METHODS

In this work, we realized a prospective study of 60 patients, including 36 (60%) followed somewhere else for open-angle glaucoma (based on visual field alteration without structural damage) and 24 (40%) isolate ocular hypertonia in the Ophtalmology department of the Moulay Ismail Military Hospital in Meknes, over a period of 2 years from January 2014 until December 2016.

Corresponding author:* **Said Iferkhass
Ophthalmology Service. Military Hospital my Ismail.
Meknes. Morocco

Intraocular tension was confronted to pachymetry, which was at our patients between: 520 and 555 µm.
We excluded from this study, open-angle glaucoma with structural alteration, angle-closure glaucoma or secondary glaucoma. The patients over 60 years of age and those already having optical correction were already excluded.

The data analyzed were ; the age of the patients, their reasons of consultation, the medical history, the average value of three ocular tone measurements per aplanation tonometer; before the full optical correction and after three and six months , para-clinical assessment

RESULTS

The average age of our patients was 45 years (range 7-60)(table1) with a sex ratio of 1. Among the 60 patients, 20 patients present headache (33% of cases), 15 patients blurred vision (25% of cases), 6 cases of conjunctivitis (10% of cases),5 patients dry eyes (8% of cases), 3 cases of eye pain (5% of cases), and 11 patients have other functional signs (Table 2).

Table 1 Breakdown of patients by age group

Tranche d'âge	7au 20ans	21ans au 40	40 au 66ans
Nombre de cas	5	13	42
Valeur en %	8 ,33%	21,66%	70%

Table 2 the distribution of patients according to functional signs in relation to accommodative effort:

	Headache	visual blur	dry eye	conjunctivitis	eye pain	blépharitis	vertigo	other
Number of cases	20	15	5	6	3	1	1	9
Value (%)	33	25	8	10	5	1,6	1,6	15

31 patients (51.66% of cases) had risk factors for glaucoma with predominant vascular factors. in fact, 11 patients with a history of diabetes, 8 cases of high blood pressure (25.8% of cases), 3 cases of cardiopathy (8.8%), and 9 cases of family history of glaucoma (29.1%), (table 3).

Table 3 Distribution by medical history showing: dominance of diabetes, glaucoma in the family and arterial hypertension (HTA).

Patients Antecedents	Patients followed for glaucoma	Patients followed for ocular hypertension	Value%/ cases having medical history
HTA	7	1	22 ,9
Cardiopathy	2	1	8.6
Diabetes	8	3	31.5
Glaucoma in the family	5	4	25.7

Studying the refractive status of our patients showed that 30 cases have association of astigmatism-hyperopia (50% of cases), 28 cases of hyperopia (47% of cases), 1 case of astigmatism (1.6% of cases) and 1 case of myopia (1.6 of the cases). Reversed Astigmatism or oblique astigmatism is the most frequent type of astigmatism since it is found in 24 cases or 77.4% of cases of astigmatism (fig.1).

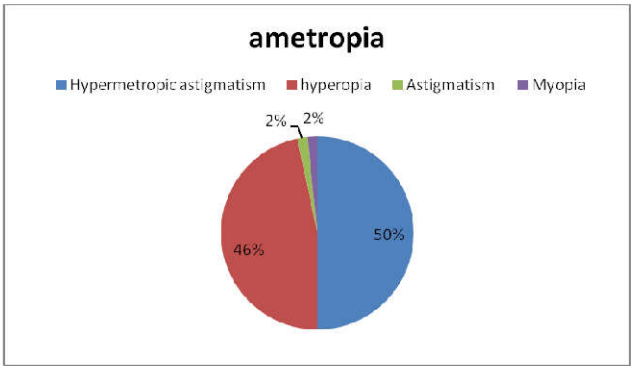

Figure 1 Distribution by type of ametropia showing dominance of hypermetropic-astigmatism and hyperopia.

The comparison of the spherical equivalent refraction before and after inducing cycloplegia of our cases (120 eyes) shows a difference of 1 diopter (fig2)

The mean of corrected intraocular pressure before full optical correction, in our ocular hypertensive patients or glaucomatous under treatment is: 22.49 mmhg in the right eye and 22.5mmhg in the fellow eye. After three months of full optical correction we noticed the improvement of intraocular pressure with a mean of: 16.25 mmHg and 15.98mmHg respectively. These numbers decreased more after six months of full optical correction with a mean of: 14.75mmhg (OD) and 14.68(OS) (fig.3) .The difference was statistically significant ($p = 10^{-3}$).)

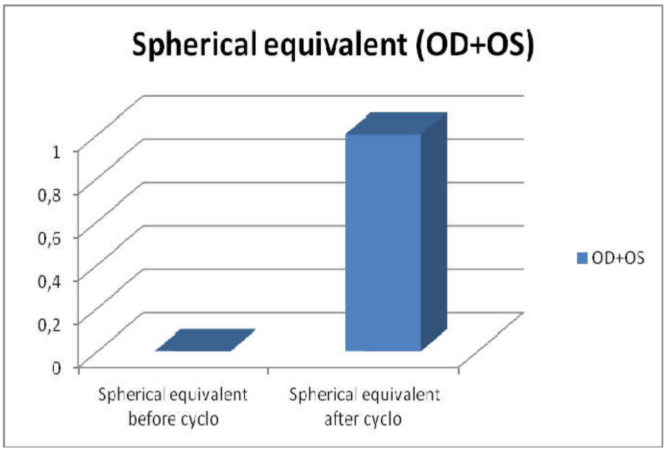

Figure 2 Comparison of spherical equivalence before and after cycloplegia

The humphrey's visual field (SITA standard 24.2) showed a gain in the mean deviation, in three months, at an average of -2.5 in both eyes (Before RE -6,0760db LE -4,7393; after three months of FOC : OD -2,3913, OS -2,4554) (fig.4).

Fluctuations of ocular tone are significantly decreased compared to the beginning of the study.

According to the majority of patients, we noticed, a symptomatic improvement with disappearance of headache, lacrimation and ocular pain.

In all our ocular hypertonic patients there was no retinal structural damage since peri-papillary RNFL is strictly greater than 85um in both eyes with normal ganglion cell layer.

Among our patients considered as glaucomatous by their doctors, we had stopped the treatment for 20 patients, 15 of them were on monotherapy and 5 with biotherapy. We switched to montherapy in a single patient who had a tritherapy.

The repeated follow-up of these patients shows that there is no increase in ocular tone (confronted to pachymetry) after stopping treatment. This fact proved that it was just isolated hypertonia and not primary open angle glaucoma.

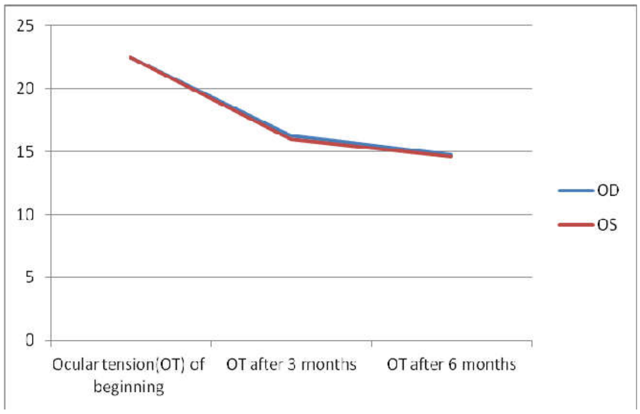

Figure 3 evolution of average of the ocular tone (OT): initial, after three and 6 months of full optical correction port: showing improvement of intraocular pressure.

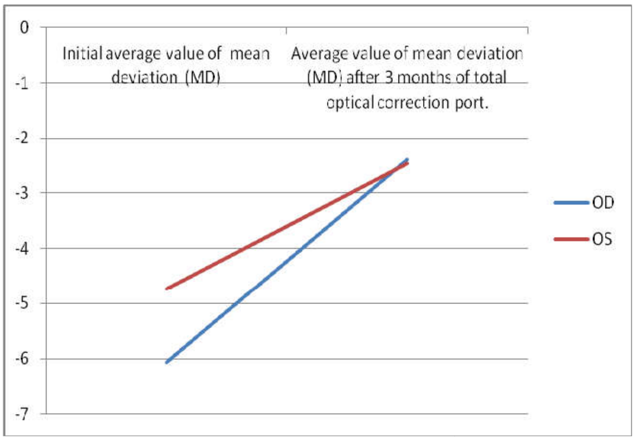

Figure 4 Evolution of the average value of MD: initial MD and after 3 months of total optical correction port

DISCUSSION

Among the physiological mechanisms still poorly known and controversial issue, accommodation remains a model of complexity. Ocular tone results from the balance between the production of aqueous humor by the ciliary bodies and its elimination through the iridocorneal angle. Its regulation is influenced by the anatomy of the anterior segment of the eye but also by various endogenous molecules [4-5].

The relationship between accommodation and ocular tone remains to be studied and, according to some authors, the accommodative phenomenon underestimates the value of ocular pressure [6]

Through this study we want to show the influence of accommodative effort on the ocular tone.

To obtain a total relaxation of the accommodation, it is necessary to apply of repeated cycloplegic and several months of total optical correction port [7]; that is why we checked our patients after three and six months of the first correction under cycloplegic conditions.

The accommodative effort may be responsible for frequent disorders that vary from one individual to another. Accommodative spasm (AS) [8-9] is an involuntary condition when there is an accommodative response greater than normal compared to the accommodative stimulus [8-9]. It can start suddenly, with great susceptibility to being bilateral. It can be constant or intermittent. This phenomenon occurs remotely and / or closely, is frequently associated with pupillary myosis and convergence spasm, disappears with cycloplegia and can resolve itself spontaneously [9]. During accommodative spasm, hypermetropes may appear less hypermetropic, or may appear myopic and myopic may appear more myopic

53 of our patients (88.2% of cases) had an accommodative spasm, of which 22 cases (36.6%) were myopic before the application of cycloplegics and 31 patients (or 51.6%) had less hypermetropia, and a decrease of two refractive diopters in the only strong myopic after cycloplegic.

Accommodative spasm puts patients in a permanent accommodative effort; it leads these subjects to a feeling of permanent fatigue, with eye pain, itching, lacrimation, dry eyes, early presbyopia, an over-valued near addition, myopic over-correction, and mixed astigmatism [10]. Work on screen, video games, and telephones, amplified by the conditions of work or daily life, are often at the origin of these artificial myopisations more frequent than formerly [3]. These accommodative, motor or symptomatic disorders are only rarely expressed by the patients and attest to an accommodative visual physiology of which many elements still elude us [11].

Regarding the refractive status after cycloplegic of our patients, hypermetropic astigmatism and spherical hypermetropia are the most frequently found (95% of cases) while myopia and isolated astigmatism or myopic, are found only in 5% of cases.
The comparison of the spherical equivalent refraction before and after inducing cycloplegia of our cases (120 eyes) shows a difference of 1 diopter.

Since Helmholtz's theory, the measurement of the refractive state at distance is a reference data which makes it possible to determine the refraction induced by accommodation during near vision according to the distance.

The measure of accommodation is only one of the elements of visual evaluation, and its amplitude varies with age, [12].

Ametropia and ciliary muscle

Morphological changes of the ciliary muscle are observed in case of ametropia. Circular fibers of the ciliary muscle (Rouget Muller muscle) are hypertrophied in hyperopic patients [13-14]. This is related to the fact that farsighted use their accommodation for far vision. For nearsighted people, the opposite phenomenon occurs. The eye must relocate the image, there is a hypertrophy of the longitudinal fibers (Brücke muscle) [14].

In a more detailed examination of ciliary muscle thickness and refractive error, Pucker *et al* [13], determined that the apical region (mainly circular and radial fibers) of the ciliary muscle was significantly thicker in farsighted patients, while the posterior region (mainly longitudinal fibers) of the ciliary muscle was significantly thicker in nearsighted patients. This result is remarkable because it at least partially explains why the hyperopic patients paradoxically have the posterior parts of the ciliary muscles thinner than myopic patients. The additional accommodative effort observed in hyperopic patients would be directed towards their largest circular and radial muscle fibers. Pucker *et al.* [13] have also curiously found that the thickness of the ciliary muscle has a quadratic relationship with refractive error.

Ametropia induces a modification of the basal state of ciliary muscle tone and thus a modification of accommodative physiology [15-16].

Ametropia and accommodation

If hyperopic patients use their accommodation permanently for distance vision, the myopic ones have powerful accommodative microfluctuations which are more variable than in the emmetropic ones [17]. The power of these accommodative micro-fluctuations increases significantly with the reading requirements and higher levels of myopia [17]. Charman and Heron [18] found that the fixation on a near-stationary object causes rapid fluctuations in the mean level of accommodation.

Richdale *et al*. [19], Jeon *et al*. [20] and Perdue and Sivak [21] suggest that there is a redistribution and reorientation of the ciliary muscle during accommodation. This idea is supported by Lossing *et al*. [16], which revealed that OCT images of the anterior region of the ciliary muscle become darker with accommodation compared to the non accommodated eye. Walker and Mutti [22] determined that accommodation may result in transient ocular shape changes.

During accommodation, lenticular changes affect the focusing power of the eye [23] and spherical aberration [24] and therefore can reasonably affect the astigmatism whose power and axis are small [25].

Brzezinski, 1982 *et al* [26] defined astigmatic accommodation as a phenomenon of lenticular compensation to the total astigmatism of an eye, by sectoral contraction of the ciliary muscle. They think that the eye has ability to reduce its total astigmatism by a sectoral contraction of the ciliary muscle. This sectoral contraction produces a lenticular astigmatism that totally or partially corrects the total astigmatism of an eye.

Bayakuno *et al* [27] reported that the type of target graph and the severity of astigmatism influence accommodative response.

Accommodation and ocular hypertonia

The mean of corrected intraocular pressure before full optical correction, in our ocular hypertensive patients or supposed glaucomatous (with treatment) is: 22.49 mmhg in the right eye and 22.5mmhg in the fellow eye. After three months of full optical correction we noticed the improvement of intraocular pressure with a mean of: 16.25 mmHg and 15.98mmHg respectively. These numbers are more decreased after six months of FOC with a mean of: 14.75mmhg (OD) and 14.68(OS)

The difference was statistically significant ($p = 10^{-3}$), with improved ocular tone after optical correction.

The fluctuations of ocular tension measurements have significantly decreased compared to the beginning of the study Concerning the visual field, we observed a marked improvement in the perimetric indices with a mean deviation gain (MD), in three months; of -2.5 on average in both eyes (-3.7 in the right eye and -2.3 in the left eye)

This improvement of the visual field can be explained by an improvement of the visual function and the resolution of the clinical signs in particular the dry eye after optical correction. Through these results, the role of accommodation in the onset of some ocular hypertension or the overestimate of ocular tone in glaucoma can be discussed.

To explain this accommodative phenomenon, and in the absence of certain physicophysiological scientific data, we have made hypotheses to discuss the phenomenon.

Can we talk about an "accommodative hypertonia"? Or this hypertonia is an indirect consequence related to ocular surface irritation such as dry eye or blepharospasm?

This observational and prospective study shows a decrease in the ocular tone of a means of 6.24mmHg OD and 6.52 mmHg OS and 7.74mmHg OD and 7.82 mmHg OS after respectively three and six months of full optical correction. The resolution of clinical symptoms in the majority of our patients and the survey of accommodative spasm after six months of optical correction, are all arguments in favor of this hypothesis.

If really it is an accommodative ocular hypertonia, why it occurs mostly at the prepresbyopic and presbyopic age and why not at an early age as accommodative strabismus?

Indeed The average age of our patients was 45 years (range 7-60). 70% of our patients are over 40 years old and only 21.66% are between the ages of 21 and 39 years, that is, the majority of our patients are pre-presbyopic or presbyopic or even adults.

Accommodation and presbyopia

Ageing leads to progressive and global alteration of visual function. Therefore it also degrades near vision independently of the loss of the accommodative function even if the degradation of this latter function remains predominant [18]. Concerning accommodation, this results in an increase in reading distance in near vision. This natural phenomenon, known as presbyopia, is one of the first signs of ageing. From adulthood, visual adaptive capacity decreases progressively making near vision difficult at the age of 43.7 years on average in the emmetropic subject. The increase in the demand for near vision, particularly on screen work, sometimes results in visual fatigue that varies according to the subject [28] - The exact origin of presbyopia has long remained a matter of debate.

In the oldest Helmoltz theory, [29], the crystalline lens is considered to be the main cause of visual disturbance. Among the structures involved in accommodation, the ageing of the ciliary body [30] and the zonule [31] has only a very limited impact on their physiological function. The capsule is not involved [32]. There remains only the crystalline content that has changed significantly since the age of onset of presbyopia [33-34-35].

Ciliary muscle and presbyopia

If the works of Stieve and Rohen cited by Weale (1962) [36] show a decrease of the ciliary muscle in its posterior part, they highlight a widening of the circular fibers bundle which becomes more triangular because of the age. It would reach its maximum thickness after 40 years when presbyopia is established.

Mechelle Perdue *et al*. [21] in their study confirm previous reports that the human ciliary muscle retains its ability to contract throughout life. However, the ciliary muscle has also shown age-related changes, which can be partly explained by the forces exerted by lens ageing and zonules.

Tamm and al [37] found that longitudinal fibers (35 years: 0.565 mm2 vs. 85 years: 0.215 mm2) and radial fibers (35 years: 0.462 mm2 vs. 85 years: 0.322 mm2) decreased with age while the circular fibers (35 years: 0.0096 mm2 against 85 years: 0.0256 mm 2) increased with age.

The ageing also results in increased amounts of connective tissue in the ciliary muscle [21-37-38].

Moreover, Fisher (1985) [39] showed that the ciliary muscle contraction force is approximately 50% greater in a young presbyopic than in a young subject whereas atrophy does not appear before 70 years age. Thus, the increase in muscle volume is related to an increase in its contractile power.

These observations support the thesis of a constancy of muscular contraction as described in Helmholtz's theory, regardless of age, or even an increase in this muscular action.

By which mechanism accommodation could give hypertonia?

The pathophysiology of accommodation and its disorders remains unknown and leaves many questions:

The accommodation is a simple active and reflex phenomenon with an ocular anatomo-optical support or is it a cerebral phenomenon involving several brain centers? Or are there other physicochemical mechanisms associated with this complex phenomenon?

The ciliary muscle is the largest intraocular muscle it is the common anatomical element between accommodation and the balance of the ocular tone. It is characterized by a complex structure, a rich blood supply and a high activity, especially during the day, and even during the night [40]. It has contractile behavior thanks to atypical and characteristic smooth and striated muscle fibers [41] and its activity involves adjacent structures [40]. In fact, it continually connects the anterior and medial segments of the eye.

Ciliary Tone and Uveoscleral Resorption

Effect of atropine, pilocarpine and epinephrine

According to pharmacological studies, uveoscleral resorption is mainly dependent on ciliary tone, mainly under parasympathetic influence. Indeed, the ciliary tone depends on the importance of the extracellular spaces of the ciliary body and therefore the importance of resistance to the flow of the aqueous humor. The resorption therefore decreases when the tone increases and conversely. Thus this resorption doubles after instillation of atropine while it decreases up to 10 times after instillation of pilocarpine [42].

From the experiences of Anders Bill *et al*. [43] on the "cynomolgus" species of monkeys, pilocarpine stops uveoscleral flow almost completely. This decrease in uveoscleral drainage is probably due to contraction of the ciliary muscle [44]. In contrast, atropine acts by preventing pilocarpine from closing these uveoscleral pathways [45] Epinephrine appears to increase uveoscleral drainage of the aqueous humor in humans [46-47], presumably by relaxing the ciliary muscle by stimulating its $^{\beta}$-adrenergic receptors.

Effect of Circadian Rhythm

According to a study performed during the evaluation of latanoprost, the control group showed a greater uveoscleral resorption at night than during the day, a significant difference that could be explained by nocturnal relaxation of the ciliary body [5]

Accommodation, induced by pilocarpine, and intraocular pressure

Kathryn Crawford, Paul L. Kaufman [48] by applying topical prostaglandin F2α tromethamine twice a day to the eyes of monkeys, found after the seventh dose, significant ocular hypotension for at least six hours. Intraocular pressure (IOP) drops to between 35% and 50% (approximately 8 to 10 mm Hg). They found that topical pilocarpine administered before the seventh application dose of PGF2α twice a day blocked the lowering effect of PGF2α induced IOP and increased accommodation to a maximum.

Atropine sulphate pretreatment of the eyes receiving pilocarpine and prostaglandin F2α completely prevented pilocarpine-induced accommodation without affecting the prostaglandin F2α-induced ocular hypotensive effect the authors [45] assumed that prostaglandin α reduced IOP by increasing uveoscleral drainage of the aqueous humor, and pretreatment of pilocarpine contracted the ciliary muscle, obliterating the intramuscular spaces and closing the uveoscleral drainage pathway and thus blocking its physiological effect.

Findings

ciliary muscle contraction unaffected by age (or even increase in muscle action) [21-39] and hypertrophy of circular fibers of the ciliary muscle (Rouget Muller muscle) with age [36-37] and in hyperopic patients [13-14], are in favor of an increase in ciliary muscle tone with age and this may be a source of resistance to resorption of aqueous humor via uveosclerous pathway.

Assumed mechanism

In spite of the complexity of the physiological and pathological processes occurring in this common anatomical element between accommodation and the regulation of the intraocular tension which is the ciliary body, we would think that ciliary muscle contraction during accommodation decreases the uveoscleral resorption by increased ciliary tone, which is mainly under the influence of the parasympathetic. The increase in ciliary muscle tone results in a decrease in the extracellular spaces of the ciliary body and increases the importance of resistance to the flow of the aqueous humor. However, this hypothesis remains to be reconsidered.

CONCLUSION

According to the data in our study, accommodative effort is a factor of elevation and overestimation of ocular tone, particularly in symptomatic hyperopic patients or those with accommodative spasm.

Relaxation of accommodation by full optical correction allows improvement of ocular tone and functional gains This lets us evoke the hypothesis of an "accommodative hypertonia"

This study opens the way to other prospective and multicenter studies to confirm or reverse it

Conflict of Interest: The authors declare that there is no conflict of interest regarding the publication of this paper.

Consent: all the patients are consenting

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