TONOMETRY

BY

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HJALMAR SCHIÖTZ described his tonometer in 1905. His first publication was followed by quite a number of essays—of both practical and theoretical interest—from various countries. Most of them are built on very few examinations though. The only one of any importance is B. Cridland's in 1917, founded on 1001 examinations. But even this number is much too small to decide such an important question as this: "Are the limits for normal intra-ocular pressure given by Schiötz really the right ones?" There have, for years, been those who would have especially the upper limit higher than that given by the inventor of the instrument.

In order to try and solve this problem I have tonometrically measured 1,095 persons with 2,186 eyes between them. Every one of them was examined with Gullstrand's slit-lamp and the binocular microscope of Czapski-Zeiss in maximal homotropin-cocain mydriasis as well as being also examined with the ophthalmoscope in the ordinary way.

I have published my results in the *Festschrift für Ernst Fuchs*, pages 221-242 (*Arch. f. Ophthalm.*, Tome 105, June, 1921). In this I have mentioned the most important publications about tonometry issued after 1905. The following is a recapitulation of the essentials from my results:—

All examinations are made with the lower weight of the instrument = 5.5. In 1915 I published a paper in the *Norsk Magazin for Laegevidenskapen* recording the influence of different weights upon accurate results in tonometry. I soon found, like others, for instance Schiötz, that the index gave a greater oscillation with heavier weights than with that of 5.5, probably caused by an act of massage. The examined were all lying on a couch. Care was always taken in the accurate application of the footplate of the instrument on the cornea, as Schiötz and Priestley Smith have advised it should be. Two measurements were always taken in succession. Were they not alike the average was taken. *In that way we can read with an accuracy of one decimal.* Even with such a precise instrument as the Schiötz tonometer we cannot read the oscillation of the index with greater accuracy than 0.5 mm., viz., 1 decimal. *When I have used 3 decimals in my tables it is only to be able to compare the tables of the different authors.* In my above-mentioned German work on this subject the lowest action of the index is always notified, viz., the highest intra-ocular pressure. With action 3, I mean both 3 and 3+, with 3.5, 3.5 and 4 —.

The persons examined can be divided into two groups: the first group counts 1,128 eyes, which, in every respect were completely normal in 567 individuals between 10 and 87½ years. The second one counts 1,052 eyes in 526 persons 15 to 80 years old. In these I have found cataract of some kind or other. In most cases the opacity was of the kind which Vogt has described as "kronar-cataract." These opacities I have described in my book *Kliniske Linsestudier*, which was kindly abstracted in this journal by Dr. Sym, 1921, pages 177-181. This form of cataract is, in my opinion, not to be regarded as a malady, but only as a physiological peculiarity—just as wrinkles, baldness and grizzling of the hair in old age. This cataract must not be mistaken for another kind which is known to develop after the forty-fifth year of age in an increasing frequency. This is derived from the so-called "water-slits" ("*wasserspalt*," after Becker and v. Hess, who first described them). This cataract is the ordinary senile form. The kronar-cataract and the "water-slit" cataract often melt together in old age. This kronar-cataract is not to be mistaken for the so-called "cataracta coerulea punctata," which we find in about 5 per cent. of all normal lenses examined with the slit-lamp. These small spots, scattered in all layers of the cortex, are congenital and probably not inclined to increase.

The kronar-cataract is of a very typical appearance. To begin with, it is located in an intermediate zone between the outer and the middle third part of the lens radius. It is always separated from the lens capsule by clear cortex. In its initial state, it has radially placed club palisade or lancet-shaped opacities, which at first are isolated, but which later on are inclined to coalesce. They are always lying parallel to the lens fibres and the surface of the "nucleus lentis." They may be so thin that they may be overlooked with the magnifying mirror. As shown in Table II, there is practically no difference, to speak of, between the tension of the group of eyes with opacities and that without. In my opinion, both the onset and period of cessation of sexual life must be regarded as having a slight but distinct influence on the development of cataract, not only the senile, but also the kronar. That the cessation of sexual life must have at least something to do with the development of cataract, I based on the fact that out of 387 women with cataract (examined by me), 48 per cent. had passed through 1 to 15 pregnancies and 13 per cent. had had one or more miscarriages, while out of all women with clear lenses (examined by me), only 15 per cent. had borne 1 to 13 children, and only 3 per cent. had had miscarriages. We know from other observations (Chvostek and Kehr) that when the ovarian function is in abeyance a rise of the calcium and cholesterol content of the blood will follow. And we also know that the

above-mentioned two substances may possibly have something to do with the aetiology of the cataract (Laqueur). The percentage of cataract found in my women patients under 50 years of age has also been considerably higher than among men examined by me. After this age the curves lie completely parallel. I also have observed how the elements of the koronar-cataract seem to take a rapid growth just about the time of the climacteric. I therefore feel inclined to believe that a frequent suspension of the ovarian function such as in pregnancy and lactation may have some influence on the development of the cataract. Dr. Gallus, in Bonn, has recently published a paper—independent of my results on this subject—in which he comes to almost the same conclusion.

TABLE I.—COMPLETELY CLEAR LENSES.

Year	Number	O. S.	Number	O. D.	Average Tension
10 ...	17	4.588	17	4.588	4.588
11—20 ...	117	4.509	117	4.468	4.489
21—30 ...	111	4.354	111	4.342	4.348
31—40 ...	106	4.566	106	4.955	4.761
41—50 ...	96	4.065	88	4.138	4.102
51—60 ...	82	4.091	82	4.134	4.112
61—70 ...	37	4.122	37	4.216	4.169
71—80 ...	4	5.250	4	5.125	5.188
	570	4.443	572	4.483	4.470

TABLE II.—MORE OR LESS DEVELOPED CATARACT.

Year	Number	O. S.	Number	O. D.	Average Tension
15—20 ...	24	4.625	24	4.633	4.629
21—30 ...	58	4.327	57	4.438	4.388
31—40 ...	37	4.433	38	4.538	4.486
41—50 ...	106	4.495	105	4.519	4.507
51—60 ...	150	4.380	150	4.420	4.400
61—70 ...	88	4.261	88	4.386	4.324
71—80 ...	56	4.848	57	4.746	4.797
81—87½ ...	8	5.312	8	5.437	5.375
	527	4.585	527	4.638	4.863

We see from the tables that the lower limit which Schiötz has fixed = 6 with 5.5, cannot be kept. This he has said himself in one of his later publications. We may find an oscillation of 7 to 8, and even more, both in individuals with clear lenses and in those with cataract more or less developed, although we cannot find any pathological alteration of the eye. Therefore, before claiming any fixed lower limit, we ought to make at least 10,000

tonometrical measures on normal eyes, and by the same examiner.

An action of 7 to 8, or more, with a weight of 5.5, does not, in young and healthy people at least, indicate a pathological hypotony. We must confess that at the present moment we do not know the lower limit, yet I am bound to say that when I have found such a low pressure in elderly persons I very often have seen more or less developed "chorio-retinitis." Of 24 individuals with this hypotony, and more than 50 years of age, I have found "chorioiditis or chorio-retinitis" in 23 of them.

Still more difficult is it to determine if an oscillation of < 3 with weight 5.5 is pathological or not if we otherwise cannot detect any sign of pathological alteration which may indicate glaucoma, such as, for instance, the sign of Bjerrum or that of Seidel. The latter, the wing-shaped enlargement of the blind spot, may be a very important symptom of "glaucoma chronicum incipiens," when far developed. But one must always be suspicious, even if the "wings" are small. Holth made in 1895 a very exact study of the so-called "vessel scotoma." He used the method of Bjerrum. Both in looking for glaucoma and in seeking those peculiar concentric ring-scotomata, which Wettendorfer has mentioned in describing some cases of high myopia, and which I never could find, although I, both in my private practice and especially in England and Germany, have examined a great number of eyes with a high degree of myopia and always have been on the look-out for this symptom. But what both Holth and I often have seen is this: that by moving the small Bjerrum object very slowly, small wing-shaped enlargements on the upper and lower border of Mariotte's blind-spot appear, where no other sign of glaucoma is to be seen. The reason is, in the opinion of Holth, that the retina is tired out by gazing at this small object. He has proposed the name "staring-blindness."

When we read the literature about tonometry, we notice that very few have reported cases with the tension < 3 , with weight 5.5 in normal eyes. Cridland personally has told me that he has seen a few with pressure 2, with 5.5, for years not presenting any sign of glaucoma, but who by and by turned out to be glaucomatous. *In all persons examined by me I have only found 6 normal eyes, where the intra-ocular tension was less than 3, with the before-mentioned weight.* In only one of these cases have I found the pressure 2; the rest show 2.5. They were all people between 21 and 28 years of age. Though I could not find any glaucomatous symptom, I think they all must be regarded as suspicious, and ought to be kept under observation for years. This opinion of mine is based on the fact that I have found only 68 persons out of all those which I had the opportunity to use the

tonometer who had an intra-ocular tension of 3 with the lower weight. *But I certainly do not mean that the oscillation 3 or less, with 5.5 indicates operation when no other sign of glaucoma is present.*

It seems that the upper limit 3 with 5.5, which Schiötz has proposed for intra-ocular tension threshold must be kept up. We also ought to make notes of results found with the tonometer in the manner in which the inventor of the instrument has proposed:—In a fraction to write down the weight used as numerator and the found oscillation as denominator. This way to state the result ought to be international. We ought not to change it into mm. Hg., because Schiötz and Priestley Smith, by numerous experiments, have shown that the fraction gives us the average of a series of different Hg. measures.

I have made use of both the old and the new means of Schiötz in order to change my results into mm. Hg. to compare them with those of Cridland. Like him, I have arranged my persons in decades (Table III). This shows that my result differs a little from Cridland's. My mean figure is either 17,698 with the old average of Schiötz, or 23,836 with his new one, while Cridland's is 20.06. If we, instead of the figure of Schiötz, take that of Priestley Smith, they are practically alike: 21.16 against 20.06.

Hamburger, in Berlin, who, in the number of *Klinische Monatsblätter für Augenheilkunde* of December, 1921, has published a paper about the intra-ocular pressure, has found exactly the same thing. He specially points out that alterations of the uvea are usually followed by a decrease of the intra-ocular pressure.

TABLE III.

Own Examinations.						Cridland's Examinations.		
Year	Number			Average Oscillation recalculated into mm. Hg.		Year	Number	Average Oscillation recalculated into mm. Hg.
	Indi-viduals	Eyes		By Schiötz old means	By Schiötz new means			
10	17	34	4.588	17.766	23.884	1—10	12	23.75
11—20	141	282	4.559	17.925	24.087	11—20	259	20.69
21—30	169	337	4.368	18.976	25.424	21—30	224	19.30
31—40	144	287	4.624	17.568	23.632	31—40	159	19.13
41—50	198	395	4.294	19.383	25.942	41—50	180	19.26
51—60	232	464	4.256	19.592	26.208	51—60	113	21.47
61—70	125	250	4.493	18.284	24.549	61—88	54	19.59
71—80	61	121	4.993	15.539	21.049		1001	20.06
81—87½	8	16	5.313	14.248	19.748			= 4.17
	1095	2186	4.488	17.698	23.836			

I have made a series of measurements on 8 persons at different times of the day. They were all young people, aged 21 to 28 years, and with normal eyes. *The variations were of very small importance in normal eyes compared to the glaucomatous ones*, in which they often could be very considerable.

There proved to be *no difference in the pressure whether the eyes were blue or brown in colour*. Variation of tension may differ greatly in the 2 eyes of one and the same individual.

I have examined the tension under the power of different drugs on a number of normal persons' eyes. I have made use of holocain, homatropin, eserine, pilocarpin, morphia and cocain. At first I only noted the above-mentioned 8 cases. Later on I have continued these, in my opinion, rather important observations. Not having intended to publish them, I have no exact idea of the number of the readings.

Holocain of 2 per cent. solution seems to have no influence on the intra-ocular tension, but not seldom I could observe, under the corneal microscope and the light focus of the slit-lamp, round or polygonal dry spots, such as Koeppe has described. They were superficially located under the epithelium of the cornea and disappeared completely after a few (maximum 6) hours. These are surely caused by the drying out of the superficial layers of the cornea as in the case with the transient stains and opacities, which we can see after instillations of cocain.

Homatropin 1 per cent. solution had no effect on the tension of the normal eye.

Cocain hydrochloride 2 per cent. solution had no influence, but instilled with 5 per cent. the tension sunk in all the examined persons.

Pilocarpin hydrochloride 2 per cent. solution and salicylate of eserine $\frac{1}{2}$ per cent. solution caused in every case a decrease of tension. In some persons it might happen that the pressure sunk more (3) of the dividing lines of the tonometer.

Three persons who, from other reasons, had got morphia injected subcutaneously were examined with the tonometer. I could not find any alteration of tension even half an hour after an injection of the usual dose: 1 to 2 centigrams. Morphia was otherwise not tried.

Lastly, I must add that I have had the opportunity of measuring the tension of 2 patients attacked by syncope. Their eyes were normal. The intra-ocular pressure was found to be 14 and 10, with 5.5, while they were lying unconscious. Under normal circumstances it was found to be 3.5, and 5 with the same weight.

Dr. McLean's instrument I have never had the opportunity to use. I believe that the higher weight of it will, in small pathological differences, give less exact clinical results than the Schiötz instrument. What I have above mentioned about an act of massage surely will produce its effect.