CHOROIDAL CIRCULATION IN GLAUCOMA*

I. BIO-HAEMO-PHOTOMETRY IN CHRONIC OPEN-ANGLE GLAUCOMA

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As blood thickness depends on the concentration of blood cells in the vessels, the measurement of the thickness of the choroidal blood (which can now be done accurately by our bio-haemo-photometric method) facilitates the study of the choroidal circulation. The present communication reports the results of applying this method to the study of glaucomatous eyes, especially those with chronic open-angle glaucoma.

This photometric method, introduced by us in 1960, entails the measurement of the colour characteristics of the light illuminating the pupillary field of an eye which is diasclerally transilluminated at the same time by a suitably filtered light. The choroidal blood thickness of the transilluminated sector is calculated in microns, using a scale obtained experimentally by measuring known blood thicknesses. The mean choroidal blood thickness in 100 normal eyes is shown by age group in Fig. 1.

FIG. 1.—Mean choroidal blood thickness in 100 normal eyes, by age group.

This method of studying the choroidal circulation in cases of glaucoma has also enabled us to investigate the correlation between the blood thickness and the level of intra-ocular pressure, and between the choroidal blood thickness and the circulation in ocular nervous tissues.

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Procedure

A group of patients with chronic open-angle glaucoma was selected, partly to ensure that all were suffering from the same type of disorder and partly because pupillary mydriasis is necessary for our method of bio-haemo-photometry. Mydriasis was induced by the instillation of a 10 per cent. epinephrine solution. The technique has been described in our previous papers (Cristini and Fiorenzi, 1960, 1961a, b; Cristini and Forlani, 1961).

The glaucomatous patients (a total of 48 eyes) were divided into three age groups (35 to 49, 50 to 64, and 65 and over) to facilitate the comparison of the choroidal blood thickness with that found in normal subjects of the same age. This subdivision of the 100 normal and the 48 glaucomatous subjects by age group showed that the average ages in each series were comparable (Table I).

TABLE I

AVERAGE AGES OF NORMAL AND GLAUCOMATOUS SUBJECTS

Age Group (yrs)	Average Age (yrs)	
	Normal	Glaucomatous
35-49	42.8	43.2
50-64	59.2	58.7
65 and Over	72.4	71.5

The average was calculated by the equation $\bar{X} = \frac{\sum x}{n}$.

The clinical and bio-haemo-photometric data referring to the 48 glaucomatous patients are summarized in Table II (opposite).

Results

Choroidal Blood Thickness.—This proved to be constantly lower in glaucomatous eyes than in healthy controls (Fig. 2).

FIG. 2.—Mean choroidal blood thickness in normal and glaucomatous eyes, by age group.

The statistical results are shown in Table III (opposite).

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TABLE II

Age Group (yrs)	Case No.	Age (yrs)	General Arterial Blood Pressure	Visual Acuity	Glaucomatous Haloes	Papillary Pallor	Optic Disc Excavation	Seidel's Scotoma	Bundle Defect	Peripheral Depression	Intra-ocular Pressure		* Choroidal Blood Thickness (μ)
											Eye	mm. Hg	
35-49	1	40	140/95	6/10	+	+	+	+	+	+	L.	47	20
	2	49	135/90	10/10	-	+	+	+	+	+	R.	40	26
	3	40	120/70	10/10	-	-	-	+	-	-	R.	38	16
	4	40	120/70	10/10	-	-	-	+	-	-	L.	38	16
	5	45	175/95	10/10	+	-	-	-	-	-	L.	32	22
	6	40	140/95	10/10	+	+	+	+	+	+	R.	30	31
	7	45	175/95	10/10	+	-	+	-	+	-	R.	24	24
50-64	8	59	130/80	3/10	-	+	+	+	-	-	R.	47	13
	9	59	130/80	10/10	-	-	+	+	-	-	L.	45	13
	10	59	175/95	8/10	-	+	+	+	-	+	L.	38	20
	11	62	160/85	10/10	-	-	-	+	-	-	R.	32	28
	12	62	160/85	10/10	-	-	-	+	-	-	L.	32	28
	13	58	140/85	9/10	-	+	+	+	-	+	R.	32	25
	14	55	165/90	10/10	-	+	+	+	-	-	R.	30	27
	15	59	175/95	8/10	-	+	+	+	-	-	R.	27	30
	16	56	185/90	10/10	-	+	+	+	-	-	R.	26	24
	17	56	185/90	10/10	-	+	+	+	-	-	L.	26	27
	18	58	140/85	9/10	-	+	+	+	-	+	L.	24	29
	19	59	135/85	4/10	+	-	-	+	-	-	L.	24	32
	20	57	150/70	6/10	-	-	-	-	-	-	L.	20	30
	21	64	130/85	10/10	+	+	+	+	-	-	R.	20	22
	22	56	205/110	1/10	+	+	+	+	-	-	R.	18	28
	23	56	205/110	1/10	+	+	+	+	-	-	L.	18	28
	24	64	130/85	10/10	+	+	+	+	-	-	L.	18	29
	25	59	165/90	7/10	-	+	+	+	-	-	L.	31	25
65 and over	26	71	150/75	1/100	+	+	+	+	+	+	L.	44	27
	27	68	200/100	10/10	+	+	+	+	+	+	R.	40	28
	28	72	150/98	5/10	+	+	+	+	+	+	R.	38	22
	29	68	200/100	10/10	+	+	+	+	+	+	L.	35	32
	30	72	150/98	10/10	+	+	+	+	-	-	L.	33	26
	31	75	215/100	8/10	-	+	+	+	-	+	L.	32	15
	32	76	170/110	3/10	-	+	+	+	-	+	L.	30	20
	33	71	140/80	1/100	-	+	+	+	+	+	L.	27	28
	34	71	140/80	10/10	-	+	+	+	-	+	R.	24	34
	35	72	170/75	4/10	+	+	+	+	-	+	L.	24	18
	36	77	155/80	7/10	-	+	+	+	-	+	R.	24	30
	37	67	130/85	4/10	+	+	+	+	+	+	R.	22	35
	38	67	130/85	2/10	+	+	-	+	-	-	L.	22	20
	39	69	165/90	10/10	+	+	+	-	-	-	R.	20	30
	40	72	170/75	2/10	+	+	+	+	-	+	R.	20	31
	41	66	145/70	3/10	+	+	+	-	-	-	R.	20	28
	42	72	200/115	4/10	+	+	+	+	-	+	L.	36	24
	43	77	155/80	4/10	-	+	+	+	-	+	R.	85	15
	44	71	150/75	10/10	+	+	+	+	-	+	L.	55	20
	45	66	145/70	1/100	+	+	+	+	+	+	R.	72	20
	46	72	175/100	8/10	-	+	+	+	+	+	L.	55	18
	47	72	200/115	1/100	+	+	+	+	+	+	L.	36	25
	48	70	215/100	1/100	-	+	+	+	+	+	R.	37	24

* Average of three measurements

TABLE III

CHOROIDAL BLOOD THICKNESS IN NORMAL AND GLAUCOMATOUS EYES, BY AGE GROUP

Age Group (yrs)	Mean Thickness (μ)		Standard Deviation (μ)	
	Normal	Glaucomatous	Normal	Glaucomatous
35-49	52.16	23.571	± 6.47	± 5.22
50-64	47.11	25.166	± 6.83	± 5.38
65 and Over	41.07	24.391	± 5.13	± 5.90

In the glaucomatous eyes the choroidal blood thickness decreased less with age than in the normal controls. The standard deviation in each age group shows no significant difference between the glaucomatous eyes and the healthy controls. This fact increases the significance of a comparison of the averages.

The standard deviation was calculated by the equation $\sigma = \sqrt{\frac{\epsilon(x - \bar{x})}{n - 1}}$.

These results differ from the photographic measurements made by Niedermeier (1958) in a series of cases of glaucoma, but agree with the findings of Broadfoot, Gloster, and Greaves (1961), who observed a decrease in the amount of blood by their photo-electric method of inducing an experimental rise in intra-ocular pressure in animals and man.

Ocular Hypertension and Choroidal Blood Thickness.—As this correlation had to be determined between two different units of measurement, we calculated the “coefficient” of correlation to find out whether any relationship existed between intra-ocular pressure and blood thickness. Bravais’s coefficient of correlation was used:

$$r = \frac{\bar{\epsilon}(x - \bar{x})(y - \bar{y})}{n\sigma(x)\sigma(y)},$$

where x is the thickness and $\bar{x}$ its average, y the intra-ocular pressure and $\bar{y}$ its average, and $\sigma(x)$ and $\sigma(y)$ are the two standard deviations. Table IV shows that there is no significant correlation between the blood thickness and the intra-ocular pressure, as the values of “ r ” are lower than 0.002 in each age group.

TABLE IV
CORRELATION OF INTRA-OCULAR PRESSURE AND CHOROIDAL BLOOD THICKNESS IN GLAUCOMATOUS EYES, BY AGE GROUP

Age Group (yrs)	Means		Standard Deviations		Coefficient of Correlation
	Intra-ocular Pressure (mm. Hg)	Choroidal Blood Thickness (μ)	Intra-ocular Pressure (mm. Hg)	Choroidal Blood Thickness (μ)	
35-49	35.571	23.571	± 6.52	± 5.22	0.002
50-64	30.944	25.166	± 14.56	± 5.38	0.0019
65 and Over	36.478	24.391	± 16.96	± 5.90	0.0017

Choroidal Circulation and Circulation in the Ocular Nervous Tissues.—The ophthalmoscopic and perimetric changes reported in Table II were regarded as the pathological expression of an altered circulation in the ocular nervous

tissues. The relationship between this and the circulation in the choroid could not be studied statistically, but a comparison in single cases has shown no clinical correlation between the rates of the circulation changes in the nervous tissues and in the choroid.

Conclusions

(1) Choroidal blood thickness in chronic open-angle glaucoma is much less than that in normal eyes.

(2) There is no statistical correlation between the rate of reduction of the choroidal blood thickness and the degree of intra-ocular pressure in glaucomatous eyes.

(3) In single cases, no relationship could be traced between the reduction in the choroidal blood thickness and the ophthalmoscopic and perimetric changes in glaucomatous eyes.

These findings tend to confirm the clinical reports of numerous authors (including Elschnig, 1928; Duke-Elder, 1940, 1957; and Cristini, 1951a, b) that, in glaucomatous eyes, the choroid is ischaemic. This appears to exclude any causal relationship with ocular hypertension.

Choroidal ischaemia in chronic glaucoma might be caused by a vasosclerosis characterized by a reduction in the number of small vessels which are filled with blood (Cristini, 1951a). This agrees with the findings already demonstrated in the parenchyma of the optic nerve (Wolff, 1947; Duke-Elder, 1940, 1957; Cristini, 1951a, b, 1959).

The absence of a precise clinical relationship between the reduced choroidal circulation and the circulation in the optic nerve may be explained by the fact that these two vascular networks are not interdependent.

Summary

The thickness of the choroidal blood was measured by our "bio-haemophotometric" method in 48 eyes with chronic open-angle glaucoma, and was found to be considerably lower than that in a control series of 100 normal eyes.

A statistical comparison of the results shows no relationship between the degree of intra-ocular pressure and the rate of reduction of choroidal blood thickness. A clinical analysis of single cases showed no relationship between the reduction in choroidal blood thickness and the ophthalmoscopic and perimetric changes of glaucoma.

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OBITUARY

A. E. ILES, O.B.E., M.B., B.S., F.R.C.S. (1881-1962)

Arthur Ernest Iles, a well-known West Country ophthalmic surgeon, died at Clifton, Bristol, on March 19, at the age of 81. Born in Bristol, and educated at Clifton College, he was Lady Habersfield Scholar at Bristol Medical School, and graduated M.B., B.S., London, in 1910. He became F.R.C.S. in 1913, and was house surgeon at Bristol Eye Hospital from 1913 to 1915. For distinguished work as Ophthalmic Specialist to the Grand Fleet in 1915 to 1919, and for research on gunlayers' eyesight, he was awarded the O.B.E. (Military) in 1918. On resuming his civilian career, he was appointed Honorary Surgeon to Bristol Eye Hospital, and to the Eye Department of the General Hospital, and became Lecturer in Ophthalmology at the University from 1930 until he retired in 1948, when he became Honorary Consulting Surgeon to the two hospitals. His association with the Eye Hospital lasted for 28 years, during more than half of which he was Senior Surgeon. He was a Past-President of the South Western Ophthalmological Society and of the Bristol Medico-Chirurgical Society. A consultant of very wide experience, he was a friendly good-natured man with whom it was always a pleasure to be associated.

Mr. Iles' first wife died in the period between the Wars, leaving two daughters and a son. The son and one daughter are medical graduates of Bristol University, as is his widow, while the daughter of this marriage is at present a medical student there. To all the members of the family we extend our sincere sympathy.

CORRIGENDA

Professor Cristini has confessed to us that, owing to a temporary aberration on the part of his (temperamental) electronic computer, the following errata in the paper "Choroidal Circulation in Glaucoma" by G. Cristini, D. Forlani, and C. Scardovi (*Brit. J. Ophthalm.*, 1962, 46, 99) should be noted:

Page 102, l. 20, for "no" read "a".

l. 21, for "0-002" read " - 0-4388".

Table IV, second column, for "30-944" read "28-222".

last column, for "0-002" read " - 0-4388".

for "0-0019" read " - 0-7831".

for "0-0017" read " - 0-5624".

Page 103, l. 7, for "no" read "a".

l. 29, for "no" read "a".