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RETINOSCOPY IN ASTIGMATISM

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MEASURING astigmatism by means of retinoscopy is theoretically simple, and consists of ascertaining the point of reversal for each principal meridian separately, and by subtracting the refraction of one from the other the amount of astigmatism is found (Jackson)⁴. Jackson mentions further that descriptions of retinoscopy allude to the characteristic band-like appearance of the light in astigmatism. Such an appearance, however, cannot be perceived, except with certain lenses, or at certain distances in front of the eye, and it is a reliable indication only when the light, the mirror, and the patient's and observer's eye are brought into a certain relation.

In astigmatic eyes it may be observed that the direction of the reflex-movement does not coincide with the direction along which the light is driven by the swinging of the mirror. This apparent change of the principal meridians of the astigmatism may vary during retinoscopy, and it is of practical importance to know the conditions in which this occurs, and how to avoid it.

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The two methods by which the accuracy of retinoscopy can be increased are: (a) the systematic use of trial cylinders, and (b) streak-retinoscopy. To appreciate the principles upon which these methods are based (1) the combined optical effect of two obliquely crossed cylinders, and (2) the shape of the image of the immediate source of light (image of retinoscopic lamp through the mirror) on the patient's retina, and its rôle in retinoscopy have to be considered.

Obliquely crossed cylinders, and their implication for "cylinder retinoscopy"

Historical.—In his classical book Jackson (1896) stresses the importance of the systematic use of cylinders. The retinoscopic test cannot be regarded as complete if the cylinder such as is required to correct the astigmatism is not placed before the eye, and then the test repeated so as to ascertain whether the astigmatism has been accurately corrected. He described also the effect of a cylinder placed in a wrong axis, and gave its interpretation.

In 1903 Duane¹ pleaded for the systematic use of cylinders. He gave this description: If the cylinder is in the wrong axis the shadow makes a skew or oblique movement. When this happens the axis has to be shifted one way or the other until the obliquity disappears. The right strength of the trial cylinder is found by changing the cylinder until reversal takes place. Duane said further that although the use of cylinders is more circumstantial, in the end it saves time by shortening the subjective test.

The use of cylinders in retinoscopy, however, in spite of the spirited efforts of Jackson, Duane and others did not gain popularity and it remained the method of few ophthalmologists only. This is reflected by the fact that The American Encyclopedia of Ophthalmology (1918) gives relatively little space to the use of cylinders.

The position changed since 1920 after the works of Lindner^{8, 9}, Krämer^{7a, 7b}, and others, when the implications of oblique cylinder ideas (put forward by Jackson) were presented in a simple way, and the rules of "cylinder-retinoscopy" were laid down.

The effect of obliquely crossed cylinders is shown in Table I. Each vertical column stands for a group, and not for a single combination only. For instance $\frac{c. + 1}{c. + 1}$ (column I) stands for all cases where the cylinders are of equal power, and the real power can be calculated simply by multiplication. In the case of $\frac{c. + 0.5}{c. + 0.5}$

TABLE I

		I	II	III	IV	V	VI		
	$\frac{F_1}{F_2}$	+1.0 cyl. +1.0 cyl.	+1.12 cyl. +1.0 cyl.	+1.25 cyl. +1.0 cyl.	+1.5 cyl. +1.0 cyl.	+1.75 cyl. +1.0 cyl.	+2.0 cyl. +1.0 cyl.		
A	Axis of 90°	S. +1.0 C. 0.0	S. +1.0 C. +0.12 0°	S. +1.0 C. +0.25 0°	S. +1.0 C. +0.5 0°	S. +1.0 C. +0.75 0°	S. +1.0 C. +1.0 0°	90°	A
B	85°	S. +0.91 C. +0.175 42½°	S. +0.95 C. +0.22 25½°	S. +0.96 C. +0.32 16½°	S. +0.97 C. +0.55 9½°	S. +0.99 C. +0.77 6½°	S. +0.98 C. +1.05 5°	85°	B
C	80°	S. +0.83 C. +0.34 40°	S. +0.85 C. +0.4 31°	S. +0.87 C. +0.5 25°	S. +0.94 C. +0.62 16°	S. +0.95 C. +0.86 11°	S. +0.97 C. +1.1 8½°	80°	C
D	75°	S. +0.74 C. +0.52 37½°	S. +0.78 C. +0.56 31½°	S. +0.81 C. +0.63 26½°	S. +0.85 C. +0.81 19°	S. +0.87 C. +1.01 14½°	S. +0.88 C. +1.24 12°	75°	D
E	70°	S. +0.67 C. +0.65 35°	S. +0.65 C. +0.8 30½°	S. +0.72 C. +0.85 28°	S. +0.76 C. +0.98 22°	S. +0.8 C. +1.15 16½°	S. +0.83 C. +1.4 14°	70°	E
F	60°	S. +0.5 C. +1.0 30°	S. +0.5 C. +1.1 27°	S. +0.55 C. +1.15 24½°	S. +0.6 C. +1.3 20½°	S. +0.62 C. +1.5 17°	S. +0.65 C. +1.75 15°	60°	F
G	50°	S. +0.35 C. +1.3 25°	S. +0.35 C. +1.4 22°	S. +0.4 C. +1.45 20½°	S. +0.44 C. +1.62 17½°	S. +0.44 C. +1.82 15½°	S. +0.45 C. +2.1 14°	50°	G
H	40°	S. +0.23 C. +1.55 20°	S. +0.24 C. +1.65 18°	S. +0.26 C. +1.72 17°	S. +0.29 C. +1.92 15°	S. +0.3 C. +2.15 13½°	S. +0.35 C. +2.4 12°	40°	H
I	30°	S. +0.12 C. +1.75 15°	S. +0.13 C. +1.9 14°	S. +0.15 C. +1.95 12½°	S. +0.15 C. +2.2 12°	S. +0.17 C. +2.4 10½°	S. +0.18 C. +2.65 9°	30°	I
J	20°	S. +0.1 C. +1.8 10°	S. +0.06 C. +2.0 9°	S. +0.07 C. +2.1 8½°	S. +0.07 C. +2.35 7½°	S. +0.08 C. +2.58 7°	S. +0.1 C. +2.85 6°	20°	J
K	10°	S. +0.025 C. +1.95 5°	S. +0.01 C. +2.1 4½°	S. +0.02 C. +2.2 4½°	S. +0.025 C. +2.45 4°	S. +0.025 C. +2.7 3½°	S. +0.02 C. +2.95 3°	10°	K
L	0°	S. 0 C. +2 0°	S. 0 C. +2.12 0°	S. 0 C. +2.25 0°	S. 0 C. +2.5 0°	S. 0 C. +2.75 0°	S. 0 C. +3 0°	0°	L
Difference between $\frac{F_1}{F_2}$		0 %	12.5 %	25 %	50 %	75 %	100 %		

The angle of the resulting astigmatism starts from the axis of the stronger cylinder which is the zero point.

The values were taken from curves in the paper "A note on the transposition on obliquely crossed cylinders" by H. H. Emsley.² Small errors may be present in some of the values from curves drawn to so small a scale. This, however, has no significance to the conclusions drawn. My thanks are due to Mr. H. H. Emsley for filling in the values of 85° and 75°, and for making slight corrections in some of the other values.

the multiplication factor is 0.5, and in case of $\frac{c.+3}{c.+3}$ the multiplication factor is 3, *i.e.*, the power of the cylinders. Column (IV) $\frac{c.+1.5}{c.+1.0}$ represents all cases where the ratio between the two cylinders is one to one and a half, *i.e.*, $\frac{c.+3}{c.+2}$ or $\frac{c.+4.5}{c.+3.0}$ etc. The real optical power of the combination is obtained by multiplication with the dioptrical power of the weaker cylinder.

Table I shows that in case of obliquely crossed cylinders a new sphero-cylindrical combination is obtained and (1) if the two cylinders are of *equal* power (vert. column I) the axis of the resulting cylinder halves the angle formed by the axes of the crossed cylinders. For instance in the case of $\frac{c.+1}{c.+1}$ crossed at 60° the axis of the resulting cylinder will fall at 30° .

(2) If the cylinders are of *unequal* power the axis of the resulting cylinder will not halve the angle formed by the axes of the obliquely crossed cylinders, but it deviates toward the axis of the stronger cylinder. In horizontal column "B" (85°) it is seen that the axis of the resulting cylinder varies from 42.5° to 5° , as the ratio of the two cylinders increases from one to one, to two to one.

These data can be applied to *all* cases of astigmatism, to myopic as well as to hypermetropic, if it is assumed that the cylinder component of the eye is a plus cylinder. Cases where a minus cylinder is required need cause no difficulty as every minus cylinder can be expressed as a combination of a plus cylinder and a minus sphere of equal power. In the case of a myopic astigmatism the more myopic meridian should be corrected with spheres and then a plus cylinder used. By this justifiable simplification the effect of obliquely crossed plus and minus cylinders, and of two obliquely crossed minus cylinders can be omitted.*

In making practical use of the oblique cylinder ideas in retinoscopy it is important that the compound astigmatism of the eye should first be converted into a simple one by placing the required spheres before the eye, *i.e.*, the one principal meridian should be at the point of reversal.

The implications of Table I for retinoscopy with cylinders are the following: (a) Column I represents the cases when the eye cylinder and the trial cylinder are of equal power, *i.e.*, the correcting cylinder is of the right strength. At 90° (Column IA) the resulting power is s.+1.0. If, however, the trial cylinder is in

* The largest angle in Table I is 90° , as this is the maximum which can occur. An angle of 110° , *e.g.*, is equal 70° starting from 180° .

a wrong axis either through carelessness or placed purposely so, the combined optical effect of the eye-cylinder and trial-cylinder will give other dioptrical values. If the resulting astigmatism is in any meridian more than 1.0D., it means over-correction, *i.e.*, myopia, and if less than 1.0D. it means under-correction, *i.e.*, un-corrected hypermetropia. For instance if c.+1.0 is placed at 75° (Table I, column ID)

$$\begin{array}{r} s.+0.74 \\ c.+0.52 \end{array} \begin{array}{l} \text{is obtained which can be written in the usual way} \\ /37.5^\circ \end{array} \quad \begin{array}{r} +0.26 \\ 57^\circ +0.74 \end{array}$$

The +0.74 spherical element of this combination leaves 0.26D. uncorrected hypermetropia in that meridian, while 0.52D. cylinder element over-corrects the meridian 127.5° by 0.26D. and an equally mixed astigmatism results

$$\begin{array}{r} -0.26 \\ 57^\circ +0.26 \\ 127^\circ \end{array}$$

To correct the hypermetropic element of this resulting astigmatism a plus cylinder at 127.5° would be required.

If other values of column I are analysed in the same way, it will be seen that *in all cases an equally mixed astigmatism* is produced, and the axis of the resulting cylinder falls at the halving angle formed by the axes of the eye cylinder and trial cylinder.

Column I shows further that the amount of this new astigmatism increases with the error of the axis of the trial cylinder. In order to elicit a noticeable amount of resulting astigmatism in case of weak cylinders it may be necessary to place the trial cylinder at a false angle up to 20 to 30°, while in cases of stronger cylinders (above 2.5D.) a few degrees are sufficient.

Horizontal column "A" from II to VI represents cases where there is an under or over-correction but the axis of the trial cylinder is correct. And here—as can be seen in the table—no change in the apparent principal meridians occurs. In horizontal columns "B" to "L" from II to VI, the trial cylinder is in the wrong axis and is of wrong power. In case of an error of 5° (column B) the axis of the resulting astigmatism varies from 25.5° to 5°, and the angle becomes smaller with the increase of the under resp. over-correction. If the ratio between eye-cylinder and trial-cylinder is 1 : 1.12, *i.e.*, one eighth under or over-correction, the axis of the resulting astigmatism falls at 25°. At the increase of the ratio to 1 : 1.5 it falls at 11°. In case of under-correction, *i.e.*, where the eye-cylinder is stronger than the correcting cylinder, the axis of the resulting astigmatism will fall nearer to the axis of the eye cylinder, and in over-correction it will fall nearer to the axis of the trial cylinder. The axis of the stronger cylinder is always the "zero" point, and the angles given in the table start from here. If in a case of refraction

$$\begin{array}{r} 0.0D. \\ +1.5D \end{array}$$

insufficient strength, *e.g.*, +1.0D. is placed at 85°, the axis of the

resulting astigmatism will fall at 11° , starting from 0° , the position of the axis of the eye-cylinder which is here the stronger cylinder. But if a too-strong trial-cylinder, *e.g.*, $+2.25D$. be placed at 85° the axis of the resulting astigmatism falls at 74° , *i.e.*, 11° starting from 85° the position of the trial-cylinder which is here the stronger cylinder.

From a clinical point of view it is important to know that the wrong axis of a *plus* trial cylinder can be corrected if it is turned toward the axis of that *plus* cylinder which would correct the hypermetropic component of the resulting astigmatism (Jackson).

And this may be termed as the "plus axis" of the resulting astigmatism. This is in accordance with the everyday practice to mark the position of the axis of the astigmatism, and its character in terms of the required cylinder to correct it.*

In the example on page 209 the cylinder of the right strength is placed in the wrong axis of 75° instead of 90° . The position of the plus cylinder required to correct the resulting astigmatism (plus axis) would be $127\frac{1}{2}^\circ$. The trial cylinder has to be turned in that direction, *i.e.*, towards its correct direction, and at 90° the resulting astigmatism will disappear. If the cylinder is turned a little further the resulting astigmatism will appear on the other side of the vertical.

In case of an under-correction where the ratio between trial-cylinder and eye-cylinder is $1 : 1.5$ such as a case of $\begin{smallmatrix} 00 \\ +1.5 \\ 90^\circ \end{smallmatrix}$, and a too weak cylinder $c. +1.0$ is placed at 80° (Table I,

IVC) resulting in $\frac{s. + 0.94}{c. + 0.62/16^\circ}$ $\begin{smallmatrix} 156 \\ +100^\circ 94 \end{smallmatrix}$

The spherical element of $0.94D$. leaves $0.56D$. uncorrected, *i.e.*, hypermetropia, while the resulting cylinder $c. +0.62D$. will over-correct by $0.06D$. the meridian at right angle, producing $0.06D$. myopia $\begin{smallmatrix} -006 \\ +106^\circ 54 \end{smallmatrix}$. An un-equally mixed astigmatism is

thus elicited, the *plus* axis of which falls nearer to the axis of the trial cylinder. In the same case if a too strong cylinder say $+2.25D$. is placed before the eye at 80° the ratio remains $1 : 1.5$, and

the optical power of the resulting astigmatism will be $\frac{s. + 1.41}{c. + 0.93/16^\circ \dagger}$.

The axis of the resulting astigmatism starts from the axis of the cylinder, from 80° , and falls at 64° $\begin{smallmatrix} 154^\circ & +141 \\ 64^\circ & +234 \end{smallmatrix} = \begin{smallmatrix} 154^\circ & +009 \\ 64^\circ & -084 \end{smallmatrix}$ The plus

axis of this resulting astigmatism is at 154° . In a case of over-correction the plus-axis of the resulting astigmatism falls farther away from the axis of the trial cylinder.

* The axis of the resulting astigmatism must not be confused with the axis of the cylinder to correct it. The latter is at right angle to the former.

† (Table I, IVC, multiplied by 1.5 , the optical power of the weaker cylinder).

As can be seen Jackson's rule holds true for all cases, in under-, and over-correction as well as when the trial cylinder is of the right strength; and the wrong axis of a plus trial cylinder can be corrected by turning it towards the plus axis, or turning it away from the minus axis of the resulting astigmatism.

Rules of cylinder-retinoscopy summarized after Lindner⁹:

(1) *Power.*—If the trial cylinder is of right power, but in a wrong axis, the resulting astigmatism will be (a) an equally mixed one, and (b) its plus axis will fall at right angle to the halving angle of that formed by the axes of eye-cylinder and trial-cylinder.

If a plus trial-cylinder is too strong the resulting plus axis will fall farther away from the axis of the trial cylinder: and if too weak the resulting plus axis will fall nearer to the axis of the trial-cylinder. The character of the resulting astigmatism will be an unequally mixed one, with a more marked myopic character in the first case, and more marked hypermetropic character in the second.

(2) *Axis.*—If trial cylinders of different strength are placed before the eye purposely in a false meridian, the axis of the resulting astigmatism will vary with each cylinder (column B to L places II to VI), whereas *if the axis is correct* (column A II to VI) *the trial cylinders of different strength will cause no change in the apparent axis of the astigmatism.*

For checking the axis and the power simultaneously Percival¹¹ suggested the following test: A trial cylinder of $\frac{7}{8}$ th of the power really required is placed before the eye, and while the error of its axis be 5° , the plus axis of the resulting astigmatism will suggest six times as great an error (column IIA in Table I).

The shape of the retinal image of the light source and its rôle in streak retinoscopy

During retinoscopy not only the image of the light-source, but also that of the mirror is formed on the patient's retina. Image and source correspond to each other in shape and direction. If the source is circular its image will be circular in eyes with spherical refraction, and elongated in case of astigmatism. The direction of this elongated light-patch on the patient's retina depends upon the direction of the axis of astigmatism. If on the other hand the light-source is a lineal or a long one, and its position, e.g., vertical, its retinal image will be long and vertical. In an astigmatic eye the position and the shape of the retinal image remains the same as that of the source, but it becomes somewhat distorted. For instance in an eye with hypermetropic astigmatism with the rule the axis of the eye-cylinder is at 180° , and having its optical effect at right angles, the retinal image will, therefore, be elongated in the vertical direction. The retinal image will

become longer and thinner, and if the light-source is a straight-line incandescent element of an electric bulb, the retinal image will be a very distinct and brilliant line. If, however, the axis of the eye-cylinder be vertical (astigmatism against the rule), the retinal image of the vertical source will become a broader light-band, and its brightness will be poor as compared to the previous one. In both cases, however, the outlines will be rectangular. But if the position of the eye-cylinder be oblique, the width of the retinal image will be broader than in the first case, and narrower than in the second, its ends will have no right angles, and the slope of the ends of the image will depend on the angle formed by the light-source and the axis of the cylinder.

FIG. 1.

Photograph of a strip lamp.

A, normal photograph. B, add +1.0 cyl. axis 180°.
C, add +1.0 cyl. axis 90°. D, add +1.0 cyl. axis oblique.

These conditions are true only for the case when one of the meridians is emmetropic, if, however, the astigmatism is compound, the retinal image becomes more blurred, and the differences on rotating the light-source or cylinder will be less defined.

When using a lineal or long (non-circular) light-source for retinoscopy a change in the apparent principal meridians of the astigmatism may be noticed. The following experiment shows the conditions: If a strong cylinder +10.0D. is placed on a vertical line with its axis at 90°, and, now, the cylinder is moved away from the line (the observer's eye should be about 60-70 cm. from the line) it will be noticed at a certain distance that the vertical line makes a turn of half a circle. This turning round is *sudden*, and at that point of reversal the eye and the vertical line are conjugated foci. If, now, this experiment is repeated so that the axis of the cylinder is at 80° *i.e.*, the axis of the cylinder and the vertical line form an angle of 10°; and the cylinder is moved as before, the position of the vertical line appears to rotate *gradually*,

and the apparent direction of the line will depend upon the distance of the cylinder from the line. If now the observer's eye moves towards the cylinder, this apparent rotation occurs in the reverse direction until the line appears in its original position¹². The apparent position, *i.e.*, the degree of rotation of the line depends upon the distance of the cylinder from the line and from the observer's eye, and upon the dioptric power of the cylinder.

If a long light-source (filament of a streak-retinoscope, or oblong shaped, or lineal lamp) is used for retinoscopy, and the direction of the source does not coincide with that of the principal meridian of the astigmatism, the direction of the retinoscopic shadow movement may show a rotation, causing a change in the apparent axis of the astigmatism. The reason of this is similar to that of the previous experiment. If the observer moves nearer or farther from the eye, or if the observer is at one metre distance but spectacle lenses are placed before the patient's eye by which the refraction of the eye is altered, this rotation may appear.

In clinical retinoscopy this may be a potential source of error in estimating the axis of astigmatism. If the mirror is driven along a meridian that does not coincide with one of the principal meridians the reflex moves along a new meridian which is different from the principal meridians and from the direction of the swinging of the mirror. In an astigmatic eye the retinal image of a circular light-source is an elongated one, and therefore this apparent change of the axis of the astigmatism may appear even with circular sources. But it is particularly marked if the light-source is a long or lineal one. The first calculations of this rotation of the reflex movement were made by Borschke (1904). In the more available recent works reference to the mathematics of this phenomenon can be found in H. H. Emsley: *Visual Optics*, p. 547³.

The lineal light-source can be used for checking the axis and the amount of the astigmatism. The basis of checking the axis is that the rotation, or change of the direction of the shadow-movement occurs only when the lineal or long light-source is not in the axis of the astigmatism, and it does not occur if the position of the light-source coincides with one of the principal meridians. Therefore the lamp has to be rotated into a position when this change does not occur any more when new lenses are placed before the eye, or when the distance between observer and patient is altered; and that position of the streak will indicate the principal meridian. For checking the amount of the astigmatism the streak is placed purposely in a wrong axis (see later), and this method of checking the amount of astigmatism can be compared with the trial cylinder placed in a wrong axis (p. 211).

From a historical point of view it is interesting that the use of a

lineal retinal image for ascertaining the principal meridians of the astigmatism was first described by E. Jackson (1895) and by this he laid the foundation-stone of streak-retinoscopy. The following quotation will illustrate this :

When the observer's eye is placed at the point of reversal for one meridian, the retinal image becomes greatly magnified in the direction of that meridian, while comparatively little magnified in the direction at right angles to it. Each point of the retina then appears in the pupil as a line running in the direction of that principal meridian, giving a band-like appearance of the light in the pupil. The direction of this light-band is always that of the principal meridian at whose point of reversal it is seen.

For example : Refr. $\frac{1}{2}$ and plane mirror is used. At half a metre from the eye the mirror will be at the point of reversal for the vertical meridian. Now if the source of light be placed as close to the mirror as possible the rays from it will be the more accurately focused upon the retina in the vertical meridian, and more diffused horizontally, so that the real form of the retinal light-area will be rather that of a *horizontal* line or band.

Now from the observer's position, the retina is most magnified in the vertical direction, and this vertical magnification would cause a point of light on the retina to appear as a vertical band in the pupil, but, with the light-area really in the form of a horizontal band, the effect of the vertical magnification is largely neutralized, and the appearance in the pupil may be quite indefinite.

The band-like appearance can be brought out if, while keeping the observer's eye and mirror in the same position, the original source of light is pushed off from the mirror one half metre; the immediate source then retracts correspondingly behind the mirror, and approaches the position of the point of reversal in the horizontal meridian, one metre from the eye.

With the light and mirror in this relation to the eye, the rays are perfectly focused upon the retina in the horizontal meridian and diffused in the vertical meridian, so that the real form of the retinal area of light is a *vertical line or band*. This vertical line or band being viewed from the point of reversal of the vertical meridian where it will be greatly magnified in the vertical direction, and but slightly magnified in the horizontal direction gives rise to the appearance of the most distinct vertical band of light in the pupil. And, under these conditions, the presence of the astigmatism and the direction of one of its principal meridians is most clearly and accurately revealed.

Of this description it is clear that the lineal retinal image elicited in an ingenious way can be regarded as the first form of streak-retinoscopy.

Wolff's instrument (1896), in which the electric bulb is rotatable and by that the lineal incandescent element of the bulb can be brought in any position, made a further advance. By rotation of the electric bulb the lineal retinal image is easily obtained, and there is no need to place the immediate source in the point of reversal of the other principal meridian. The construction of Wolff's instrument is essentially the same as that of the modern streak retinoscopes Purvis, Reid, etc. A strong convex lens and a mirror at 45° project the image of the filament to the patient's eye. Wolff¹⁴ advised that the lamp should be focused so that a long broad light-patch should fall on the patient's face, and by turning the bulb this light-patch can be rotated. Wolff claimed that by the use of this instrument the axis of the astigmatism can be determined to an accuracy of one degree, and the refraction to one eighth of a dioptré.

Recently, however, the focusing is set so that the light-patch on the patient's face is narrow, about the diameter of the pupil. This light-streak gives a bright lineal retinal image which can be seen in the pupil as the streak reflex. If the instrument is focused so that the filament-image falls in front of the patient's pupil between the retinoscopic mirror and the patient's eye the retinoscope is used as a concave mirror, and if the filament-image falls behind the patient's pupil it will act as a plane mirror. Commonly it is used as a plane mirror.

While in Wolff's focusing the emphasis was on the shadow movement, now it is put on the behaviour of the streak-reflex. The point of reversal is determined in the usual way by the disappearance of the "with" or "against" movement of the streak-reflex. At the point of reversal the streak-reflex disappears and the pupil becomes filled with light. This change is marked and easy to observe.

Method of examination : The streak is thrown on the pupil, and should be moved at right angles to its length. If the streak is set horizontally it has to be moved up and down, and if vertically, from left to right or vice versa. The characteristics of the reflex are then noted. Is it wide or narrow, clear cut or indistinct, has it the same characteristics in all meridians? In higher degrees of ametropia the retinal image of the filament becomes less distinct, or the streak character becomes unrecognisable. In the proximity of the point of reversal the streak-reflex gains in distinctness, and if no astigmatism is present, the thickness of the streak-reflex will be the same in all meridians if the bulb is turned round¹³. On the other hand in astigmatic eyes the thickness of the streak will vary in different meridians. In a compound hypermetropic astigmatism with the rule, for instance, $+1\frac{1}{2}$ first a "with" movement is

seen in all directions, and the streak-reflex will be fairly wide, it will appear more markedly in the vertical meridian. First the refraction of the vertical meridian is determined, and for this the streak is placed in a horizontal position. If the position is not 180° but deviates slightly, *e.g.*, 10° or 170° , the movement of the reflex, or of the shadow, will not coincide with the swinging of the retinoscope. This new direction of the reflex-movement will vary with the power of the lens placed before the eye, or if the distance between patient and examiner is altered. On the other hand if the position of the streak is at 180° this change in the direction of the reflex-movement will not appear. At the point of reversal the streak-reflex will disappear and the pupil will be filled with light. If now the streak is turned at 90° the streak-reflex appears as a clear, thin and well defined line. The linear retinal image is now corresponding to B in Fig. 1.

The axis of the astigmatism can be ascertained in a more direct way than described in the preceding paragraph. When the observer's eye is placed at the point of reversal of the less hypermetropic meridian there will be a noticeable break between the direction of the streak-reflex in the pupil and the projection of the filament on the iris unless the streak lies in the principal meridian of the astigmatism, when this break disappears.

The amount of astigmatism can be determined by using spheres or cylinders.

In streak-retinoscopy the axis and the power can be ascertained by a method which shows certain similarity with cylinder-retinoscopy.

(a) *Axis*.—This can be ascertained in the two ways just described (1) by the apparent change of the reflex movement if the streak is placed in a wrong axis. This is comparable with cylinder-retinoscopy where the cylinder placed in a wrong axis shows a resulting astigmatism the axis of which will vary by altering the power of the cylinders. (2) By the break between the projection of the filament on the patient's iris and the streak-reflex in the pupil.

An easy and demonstrative way of ascertaining the axis of cylinders of higher power is the following: When the amount of astigmatism has been determined the cylinder is placed before the eye. It will now be observed that if the cylinder is in the correct position the streak reflex has disappeared. But if the cylinder is in a wrong axis the streak-reflex re-appears in a new direction, and by turning the cylinder one side or other around its correct position the streak-reflex will move. The axis of a plus trial cylinder has to be turned toward the streak-reflex, which indicates the plus axis of the resulting astigmatism.

The streak reflex is more marked in hypermetropic astigmatism

than in myopic ones, therefore it was suggested¹³ to correct with spheres the more myopic meridian and use plus cylinders.

(b) *Power*.—For checking the power the filament is focused so that it should give a broad light-band of about 2 cm. width on the patient's face, and in contra-distinction to the streak-reflex, the shadow movement has to be observed. The basis of the test is the following: If the retinoscopic mirror is at the point of reversal of one of the two focal lines whatever the direction of the light-source or light-band, and whatever the direction of the swinging of the mirror may be, the shadow will travel in the direction of the other principal meridian. Expressed in other terms this means that the reflex is *compelled* to move in the one principal meridian if the mirror is placed at the point of reversal of the other principal meridian (*Zwangsläufigkeit der Schattenbewegung*). Now if the examiner has any doubt whether the true power of lens had been put before the patient's eye, he can ascertain it by turning the streak deliberately into a wrong axis. If the power of the lens is correct the shadow movement will not change its direction, it remains in the principal meridian. With this method spherical lenses are used for the test. In cylinder-retinoscopy the corresponding method is that the cylinder is turned into a wrong axis and the position of the resulting astigmatism, and its character are used for ascertaining the correct strength of the cylinder.

Different instruments and their use: As has been shown, in the streak-retinoscope the lineal or band-like character of the light-source is utilized. Any ordinary circular light-source can be converted into an elongated image by means of a cylindrical mirror, and Borschke, and MacNab constructed such retinoscopes. Borschke's retinoscope consists of a plano-cylindrical lens of +0.75D. power, and is silvered on the plano side. Through the cylindrical mirror the immediate light source becomes band-like. Besides this Borschke proposed a square form of the mirror, so as to cause a straight edged light-patch or rather a straight edged shadow on the patient's retina. The mirror projects an oblong light-patch. In higher degrees of ametropia the pupil will be lit up as soon as the edge of the light-patch reaches it. However, as the point of reversal is approached, the pupil will remain dark during the greater part, except the central area of the light-patch. In case of a quadratic mirror with a side-length of 40 mm., the pupil is lit up by the edge of the reflection if the amount of ametropia is about 4D. The size of the pupil has an influence on this estimation. With a narrow pupil the required lenses are stronger. Borschke's retinoscope has to be turned in such a position that the edge of the shadow, and the direction of the reflex-movement in the pupil coincide with the position of the light-band on the patient's face.

According to the *Amer. Encyclop. of Ophthal.*¹⁰ in Angus MacNab's "automatic" or "consult the cut" retinoscope the mirror is cylindrical, and the effect on the illuminated area of the fundus is to produce a band of light instead of an image of the lamp. By means of milled wheels the mirror is allowed to rotate and the band of light on the fundus can be made to lie in the axis of the astigmatism. After a little practice the localization of the axis can be made to within five degrees, a matter of importance in examining young children. In a personal communication Mr. R. R. James⁵ writes "Angus MacNab used a sort of refraction mirror which threw a beam of light in slit form, and he used to swear by it in estimating astigmatism and its axis."

I have tried plano and also concave cylindrical mirrors and experience has proved their usefulness.

In the slit retinoscope⁶ the band-like element is the slit, which covers all but a narrow rectangular part of the mirror, and it can be rotated in any meridian. For example in a compound hypermetropic astigmatism "with the rule" the slit should be placed in a vertical position. When the refraction in this meridian has been determined, the slit is put at right angles to the meridian examined, in this example at 180° , and it will be found that the shadow has a sharply defined edge. If the slit is not in the direction of the axis, the shadow edge becomes ill defined. This makes it possible to find the axis of the astigmatism by turning the slit into a position where the shadow edge becomes sharpest. Then comes the correction of the astigmatism. For this purpose the slit should be placed in the meridian determined, in the above example at 180° , and further lenses placed before the eye until the point of reversal is reached.

In the slit-retinoscope the only band-like element is the slit, resp. the shape of the mirror, and therefore the light-source used should be such as not to compete with the aperture effect. A small circular source, *e.g.*, the smallest opening of the Lister ophthalmoscopic bulb is best. An oblong or band-like light-source may be a disturbing factor if the position of the lamp does not coincide with the direction of the slit.

The shape of the light-source needs particular attention, as in the commonly used bulbs the incandescent element is not circular, and its projection is rather elongated. The incandescent element shines through the frosted glass of the pearl bulbs, and this may become a potential source of error not only with slit retinoscopes but with any other method as well.

The relation of these three types of instruments:—A band-like element which can be rotated is common to all. In the streak retinoscope the original source of light is lineal, in the

Borschke and MacNab retinoscopes the source image, *i.e.*, the immediate source of light is band-like, and finally in the slit retinoscope the band-like element is restricted to one of the apertures. A comparison of these instruments in practice had shown that the streak retinoscope is superior in cases with undilated pupil. A dense lens nucleus, however, may give rise to difficulties. In cases with dilated pupil the cylindrical and slit retinoscopes are more useful. With Borschke's plano-cylindrical mirror the pupillary light is brighter than with the concave-mirror type cylindrical retinoscopes, but with the latter the loss of brightness of the pupillary reflex is more than balanced by the presence of a relatively bright dot in the centre of the pupillary reflex which indicates the point of reversal very sharply.

By using different instruments one comes to realize that good results can be obtained with any one of them, and that cases not suitable for a particular instrument are relatively rare. There are, however, cases in which the point of reversal is not sharply marked with a certain type of retinoscope and the use of another instrument may be helpful. In the slit retinoscope the plano and concave mirrors are built in in pairs, and the change over from one mirror to the other takes no time.

Streak retinoscopy, including cylindrical mirrors and slit retinoscopes, gives more reliable results with the use of spherical lenses alone than ordinary retinoscopes, and this enhances their practical value, especially in the pressure of work of an out-patient department. The axis and the power can be determined easily. The position of the axis is indicated by the position of the streak or slit, and it can be read on the instrument provided it is held vertically, or it can be read off on the trial frame. The latter is especially easy when Thorington's axis finder disc is used in the trial frame.

Streak retinoscopes are suitable for cylinder-retinoscopy too, and the axis of the resulting astigmatism can be made very distinct by turning the streak or slit.

In conclusion it can be said with Jackson that the limits of accuracy of retinoscopy depend on details of its execution, and the skill and patience of the observer; but it does not require any rare natural qualifications, to carry it, for many eyes to the extreme limits of accuracy.

In a larger proportion of cases it will discriminate sharply between the lenses which really best correct the ametropia and others which appear to give equally good subjective results.⁴

Exact retinoscopy needs considerable experience, but a thorough understanding of the principles involved, and a patient study of the eyes—as well as the appreciation of binocular functions, such

as the phorias, anomalies of the vergencies, size of retinal images, and some other factors—will render the prescribing of spectacles less of an art and more of a science.

Summary

A table of the optical power of obliquely crossed cylinders, and the implications of oblique cylinder ideas for retinoscopy with cylinders are presented.

The basis of streak-retinoscopy is a band-like retinal image of the immediate source of light, which can be rotated in the principal meridians of astigmatism.

Similarities exist between cylinder-retinoscopy and streak-retinoscopy as regards ascertaining the axis and the amount of the required cylinder.

A survey of different instruments of the streak retinoscope group, and their practical use is given.

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A CASE OF ANGEOID STREAKS OF THE RETINA*

BY

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THIS condition must be somewhat rare for until I examined the present case, I had never seen one in my own hospital or private practice. Nor could I find any member of the Staff of the Birmingham Eye Hospital who had any personal knowledge of the

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