CHANGES IN THE VISUAL FIELDS IN GLAUCOMA: STATIC AND KINETIC PERIMETRY IN 2,000 PATIENTS*

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INTRODUCTION

STATIC AND KINETIC PERIMETRY, AS DESCRIBED BY AULHORN AND HARMS,[1] ARE used to investigate the visual field in glaucoma. With these forms of perimetry one can establish precisely whether a glaucomatous field defect is present and can record accurately any deterioration of the visual field.

This report is based on the analysis of 3700 central visual fields of 2,000 patients referred for glaucoma evaluation during the past 10 years.

PATIENTS AND METHODS

Age-range of the patients was 15 to 75 years. Fields were accepted into the study, to a total of 2,000 patients, if the static and kinetic tests corresponded and if responses by the patient were considered reliable.

All patients were tested while wearing their best refraction correction, appropriately adjusted for age. Testing was performed with a Tubinger oculus perimeter (Fig 1) in a darkened room. Fixation and background lights were at constant values, while the target light changed intensity. Standard luminescent levels for the oculus perimeter are shown in Table I.

Static perimetry. A technique was employed that quarters the visual field perfectly. A stationary target light was increased or decreased in intensity, one log unit per second, to record the retinal threshold; starting from fixation and working out to 30°, every second degree along the 45° and 135° meridians was tested.

Kinetic perimetry. A stimulus was moved from the non-seeing zone (30°) toward fixation until the patient indicated he could see the test object. Three isopters of the visual field were recorded, indicating the contours of the field and defects in it: two encircled the blind spot and one did not. The intensity of the target light used to plot the outer isopter was determined by

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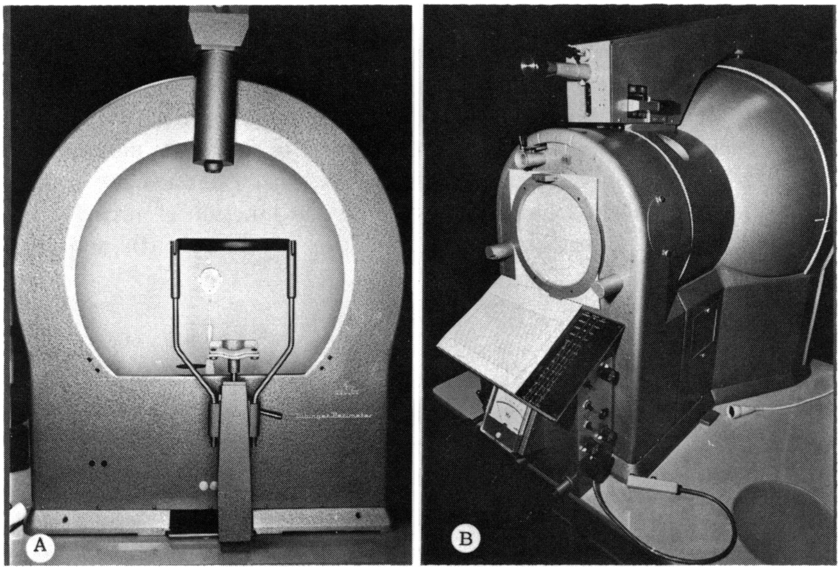

FIGURE 1
Tubinger oculus perimeter. A: Front and B: back of the apparatus.

an average of four threshold lights (1 from each meridian), at 20° from fixation. One, two or three units of light intensity was subtracted from this to outline the first isopter approximately 20° from fixation (encircling the blind spot). After further subtraction, the second isopter (that just bared the blind spot) was plotted, and then a third isopter (inside the blind spot) was plotted.

DEFINITIONS OF PATHOLOGIC CHANGES

The static curve of retinal threshold was considered abnormal if it 'dipped' five units (1 log) and correlated with the corresponding scotoma in the kinetic field. If the threshold is not depressed to the base line the defect is relative, but if depressed to the base line it is absolute.

Glaucomatous changes in the central visual fields were defined as para-

TABLE I: CONDITIONS FOR TESTING WITH THE OCULUS PERIMETER

	Fixation	Background	Target
Intensity (asb*)	100	20	1000 to 0.1
Color	Red	White	White
Size	1 degree		10 minutes

*asb, apostilb.

central (from fixation to 10°), bjerrum (between 10° and 20° from fixation), or peripheral (between 20° and 30° from fixation). The site was designated depending upon which region the majority of the scotoma occurred. Relative and absolute glaucomatous defects were classified as follows: Peripheral constriction, Bjerrum and paracentral scotomas, enlargement of the blind spot, nasal steps, arcuate defects of the nerve-fiber bundle, temporal steps, Ring scotomas (formed by the junction of superior and inferior arcuate scotomas; a step develops at this point), advanced glaucoma.

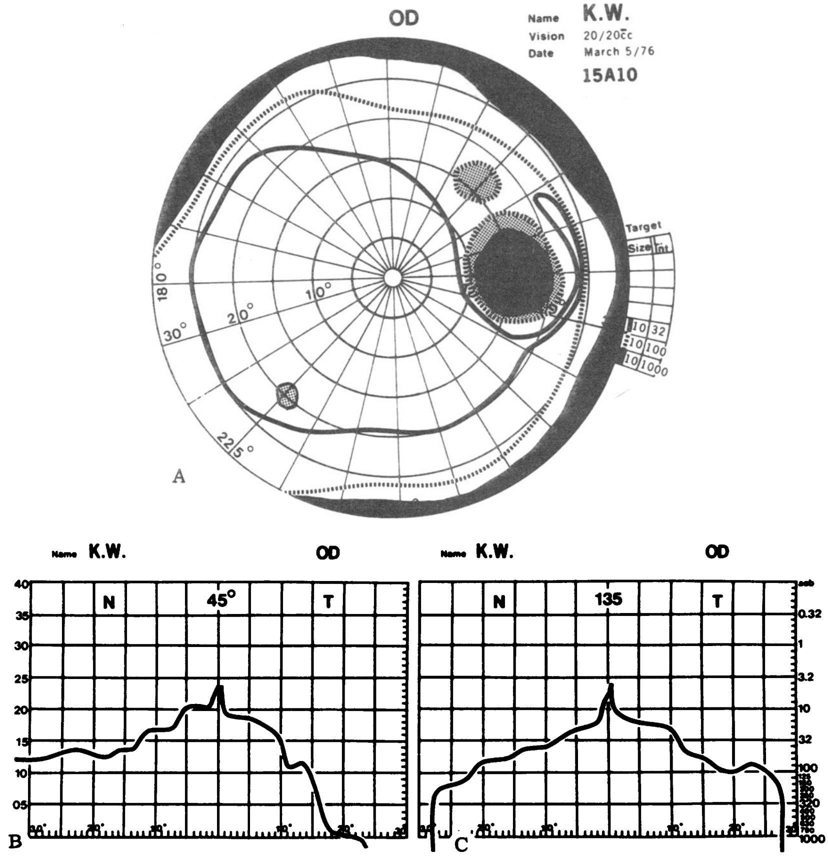

FIGURE 2

A: Kinetic perimetry, showing significant absolute constriction. B: Static perimetry demonstrates absolute peripheral depression.

RESULTS

Glaucomatous changes were found in 417 (11.3%) of the 3700 visual fields of the 2000 patients tested.

PERIPHERAL CONSTRICTION

Absolute peripheral constriction was noted in 39 fields. In addition, 12 eyes had relative defects in the bjerrum and/or paracentral region and 6 had absolute scotomas.

Figure 2 shows significant absolute constriction demonstrated by kinetic perimetry, and absolute peripheral depression demonstrated by static perimetry, in one eye.

BJERRUM SCOTOMAS

Bjerrum islands were the commonest major defect, occurring in 143 fields. These scotomas were classified according to their mode of occurrence—singly, in pairs, or in groups. Their location, and the incidence of accompanying defects, are shown in Table II.

Single bjerrum islands were found in 66 fields. They were located

TABLE II: LOCATION OF 143 SOLITARY, PAIRS, AND GROUPS OF RELATIVE BJERRUM SCOTOMAS, AND INCIDENCE OF ACCOMPANYING DEFECTS

	Scotomas		
	Single	Double (pairs)	Multiple (groups)
No. of fields affected	66	43	34
Site of scotomas			
Upper half, both quadrants		9	
Lower half, both quadrants		2	
Temporal half, both quadrants		14	14
Upper temporal quadrant	45	5	
Lower temporal quadrant	13	1	
Upper nasal quadrant	5		
Lower nasal quadrant	3		
Upper temporal/lower nasal quadrant		12	
Three quadrants			16
All quadrants			4
Accompanying defects			
Nasal steps	9	4	4
Other	3	1	7

temporally in 58, most of them (45) in the upper temporal quadrant. Only eight were in the nasal region. There was an additional defect in 12 fields; nine of these defects were nasal steps.

Double bjerrum islands were present in 43 fields. In 14 both were in the temporal half only, and in 12 the islands were in the upper temporal and lower nasal quadrants. In no case were both islands in the nasal region. Only five fields contained an additional defect; this was a nasal step in four.

Multiple bjerrum scotomas were seen in 34 fields. They were limited to the temporal half in 14 and distributed in all quadrants in four. The others were scattered. An additional defect was present in 11 fields; only four of these defects were nasal steps.

Figure 3 shows bjerrum islands demonstrated by kinetic perimetry and static perimetry.

PARACENTRAL SCOTOMAS

Thirty fields contained paracentral scotomas, 18 relative and 12 absolute, as shown in Table III. Fourteen were entirely in the temporal region and only eight were in the nasal region. Fourteen fields contained additional defects, only five of which were nasal steps.

Demonstration of paracentral scotoma by static and kinetic perimetry is shown in Fig 4.

RELATIVE ENLARGEMENT OF THE BLIND SPOT

Nasal Steps

A nasal step was apparent in 59 fields, as shown in Table IV.

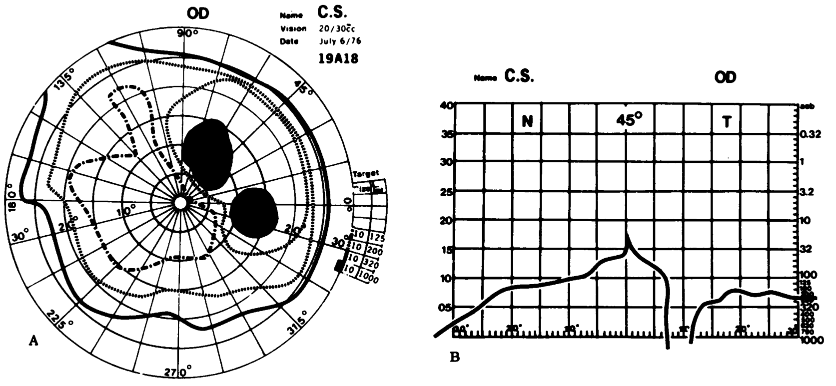

FIGURE 3

A: Kinetic perimetry shows an absolute bjerrum island, indicating early glaucoma, and B: static perimetry shows the bjerrum island sharply demarcated.

TABLE III: MODE OF OCCURRENCE AND LOCATION OF 30 PARACENTRAL SCOTOMAS, AND INCIDENCE OF ACCOMPANYING DEFECTS

	Relative Scotomas (n = 18)	Absolute Scotomas (n = 12)
Single scotomas		
Temporal half	7	7
Nasal half	4	2
Multiple scotomas		
Temporal and nasal quadrants	5	3
Nasal half	2	0
Accompanying defects		
Nasal steps	3	2
Other	2	6

Relative. The nasal step was relative in 29 fields. It was solitary in 10 and accompanied by another defect in 19; in two cases the other defect was an arcuate scotoma. Various shapes of step were seen: only one agreed with 'wedge/right angle/obtuse'; 19 were mainly curved or wedge-shaped. In 28 fields the step was recorded in all isopters; 23 were below horizontal (Fig 5).

Absolute. There was an absolute defect in 30 fields, solitary in 14 and another defect in 16; in five cases the other defect was an arcuate scotoma. Only one absolute nasal step agreed with 'wedge/right angle/obtuse'; the majority were of various shapes. Those in the peripheral regon had no pattern in any isopter; however, those extending into the paracentral region had pushed the isopters to 10° from fixation, leaving an area too small for any pattern to occur. In 28 fields the defect was in all isopters; in 15

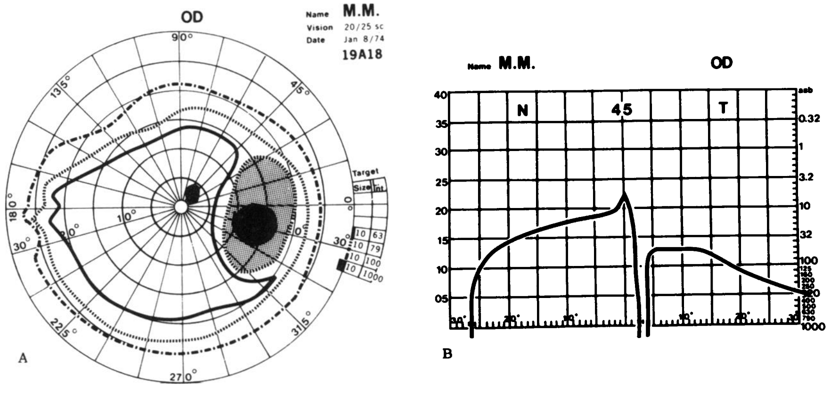

FIGURE 4
A: Kinetic and B: static perimetry demonstrate a 3-degree temporal paracentral scotoma.

TABLE IV: CHARACTERISTICS OF 59 NASAL STEPS AND ACCOMPANYING DEFECTS

	Nasal Steps	
	Relative (n = 29)	Absolute (n = 30)
Extent of Step		
Three isopters	28	28
Two isopters	1	1
One isopter	0	1
Shape of step		
Horizontal	0	12
Wedge/right angle/obtuse angle	1	1
Three isopters, curved or wedge-shaped	19	0
Varied	9	17
Location of step		
Below horizontal	23	15
Above horizontal	5	13
Along meridian	1	2
Accompanying defects		
Bjerrum islands	13	0
Arcuate scotomas	2	5
Other	4	11

TABLE V: CHARACTERISTICS OF ARCUATE DEFECTS OF NERVE-FIBER BUNDLES AND OF ACCOMPANYING DEFECTS

	Not connected to blind spot		Extending from blind spot	Broken through to periphery
	Relative (n = 10)	Absolute (n = 8)	(n = 18)	(n = 17)
Location of defect				
Upper field	6	5	16	11
Lower field	1	3	2	6
Upper and lower fields	3	0	0	0
Width of defect				
Geater nasally	2	4	6	12
Greater temporally	2	0	6	2
Symmetrical	6	4	6	3
Horizontal delineation	1	3	9	11
Accompanying defects				
Scattered; relative	4	0	0	0
Absolute	1	4	4	2
Other	0	2	1	2

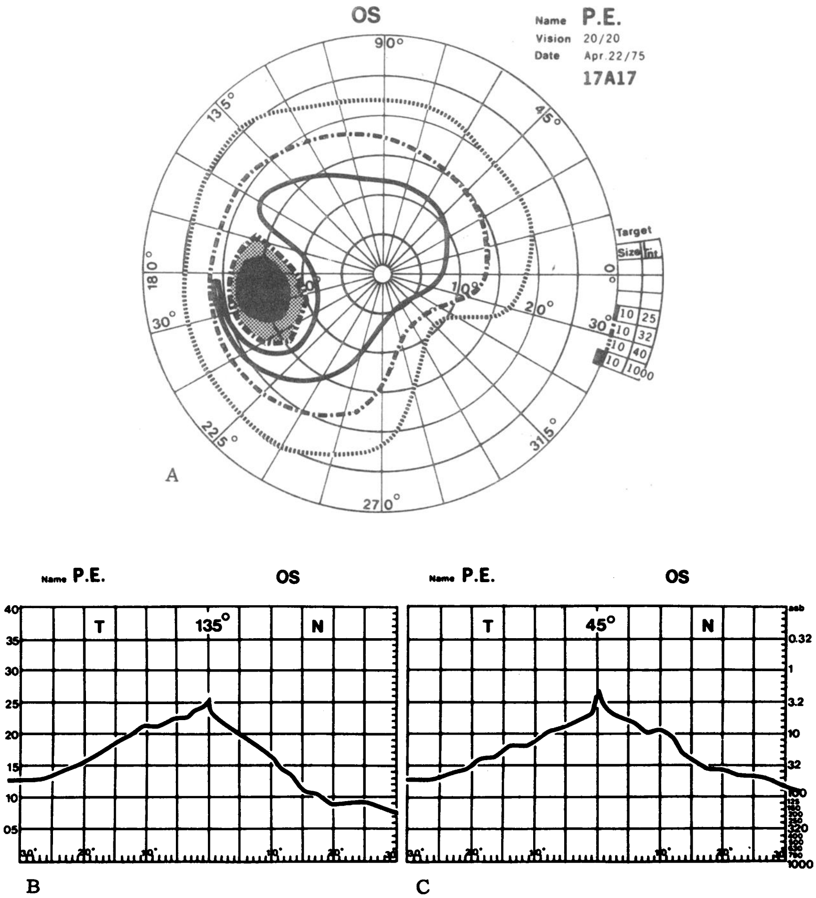

FIGURE 5

A: Kinetic and B & C: Static perimetry show inferior nasal step. Static perimetry has different thresholds at nasal 30 degrees.

it was below horizontal, in 13 it was above, and in the other two it was at the horizontal (Fig 6).

ARCUATE DEFECTS OF THE NERVE-FIBER BUNDLE

In 53 fields there was a defect of the nerve-fiber bundle, as shown in Table V. These arcuate scotomas were divided into three categories: not connected to the blind spot (relative and absolute); extending to the blind spot; and broken through to the periphery.

Ten arcuate scotomas were relative. Six of these showed no differences in

TABLE VI: CHARACTERISTICS OF 58 FIELDS WITH ADVANCED GLAUCOMA

Constricted to 0° to 10°: n = 22		
Remnant of vision:	Temporal island	11
	Nasal island	5
	Other	6
Three-quadrant loss: n = 13		
Vision remaining:	Upper temporal	2
	Lower temporal	4
	Upper nasal	4
	Lower nasal	3
Half-field loss: n = 22		
	Upper half	13
	Lower half	3
	Temporal half	1
	Nasal half	5
Linear loss (straight through midfield)		1

width temporally and nasally (Fig 7), but four of the eight that had become absolute were wider on the nasal side. Horizontal cut-off was uncommon in relative scotomas (in only one) but had occurred in three of the eight absolute scotomas. There was a tendency for these scotomas to occur superiorly.

In 18 fields an arcuate scotoma was connected with the blind spot (Fig 8). Six scotomas were narrower on the temporal side; nine had horizontal delineation on the nasal half, and 16 were above horizontal.

In 17 fields an arcuate scotoma had broken through to the periphery. Twelve of these scotomas were narrower on the temporal side, 11 had horizontal delineation, and 11 were located above horizontal.

ADVANCED GLAUCOMA

Fifty-eight eyes had advanced glaucoma (Fig 9). In 22, the central 0-10° was the only remaining vision. In 16 fields, constricted within 10° there was a remnant of vision elsewhere—a temporal island or temporal portion of the periphery in 11 and a nasal remnant in five. Another 22 fields had lost half of the field, most commonly (in 13 cases) the upper half; three had lost the lower field, five the nasal half, and one the temporal area (Table VI). Thirteen had only one quadrant of vision remaining: there was no particular pattern of location.

ABSOLUTE ENLARGEMENT OF THE BLIND SPOT

The blind spot was enlarged in 12 fields, circularly in 10. Nine fields contained an additional relative defect. Four of these were absolute scotomas; the remaining five were relative bjerrum islands and paracentral islands.

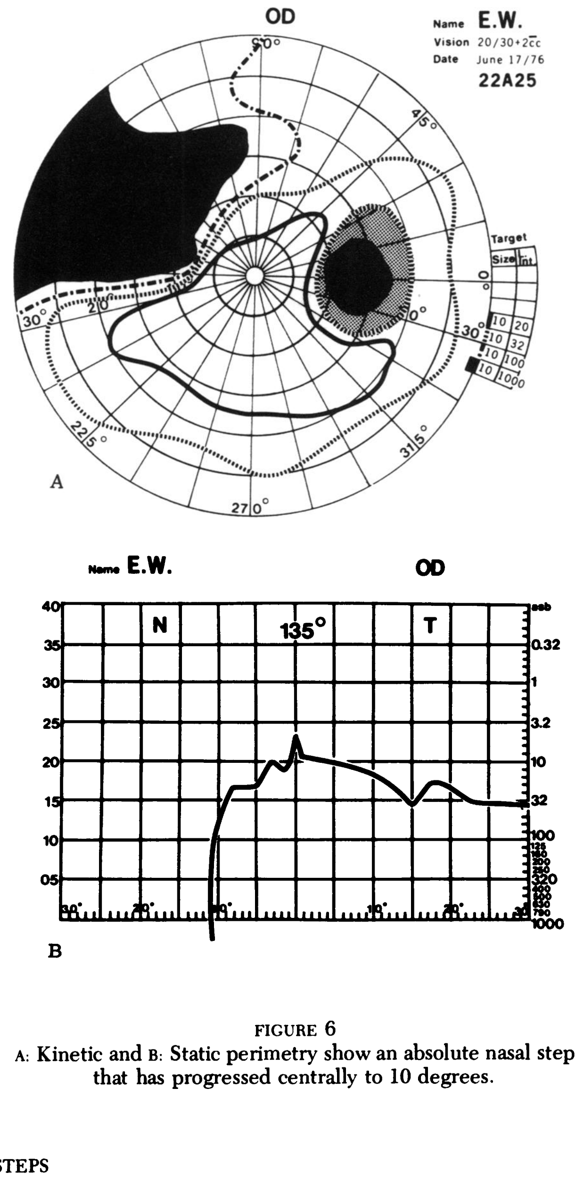

FIGURE 6
A: Kinetic and B: Static perimetry show an absolute nasal step that has progressed centrally to 10 degrees.

TEMPORAL STEPS

A temporal step had developed in 11 fields, relative in two and absolute in nine. In six fields the absolute temporal step was joined to the blind spot, in two it was not, and in one the step had originated from the periphery and was developing inward to join the blind spot.

OTHER SCOTOMAS

Centrocecal scotoma had developed in two cases.

Peripheral island scotoma, located between 20° and 30° from fixation, was present in six fields; four of the lesions were relative and one was absolute.

Ring scotoma was an uncommon defect; it was detected in only four fields.

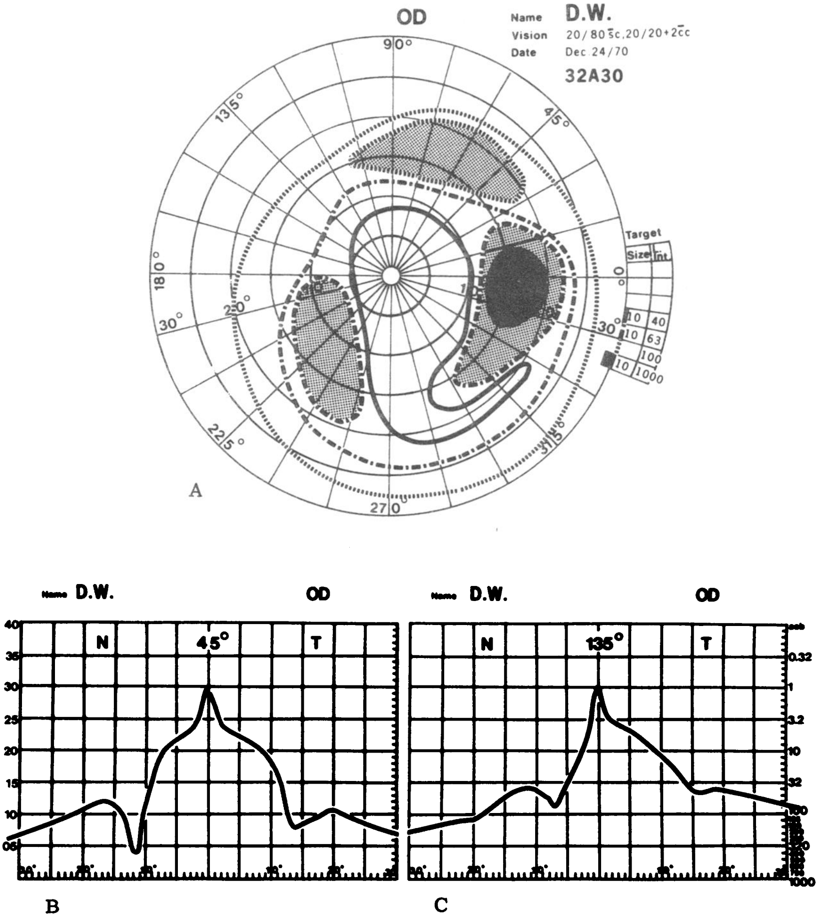

FIGURE 7

A: Kinetic and B & C: static perimetry show superior and inferior relative arcuate scotomas of the same width and affecting both the upper temporal and lower nasal regions.

DISCUSSION

Peripheral constriction, which is a common accompaniment of glaucoma must not be ignored: as constriction progresses, so does the central scotoma. As 54% of absolute constrictions in the present study were solitary defects, it seems probable that an early stage of glaucoma is represented by relative constriction. However, the converse is not always true—peripheral constriction does not necessarily constitute evidence of developing glaucoma; its varied pathogenesis[2a,3] includes such factors as fatigue, lens

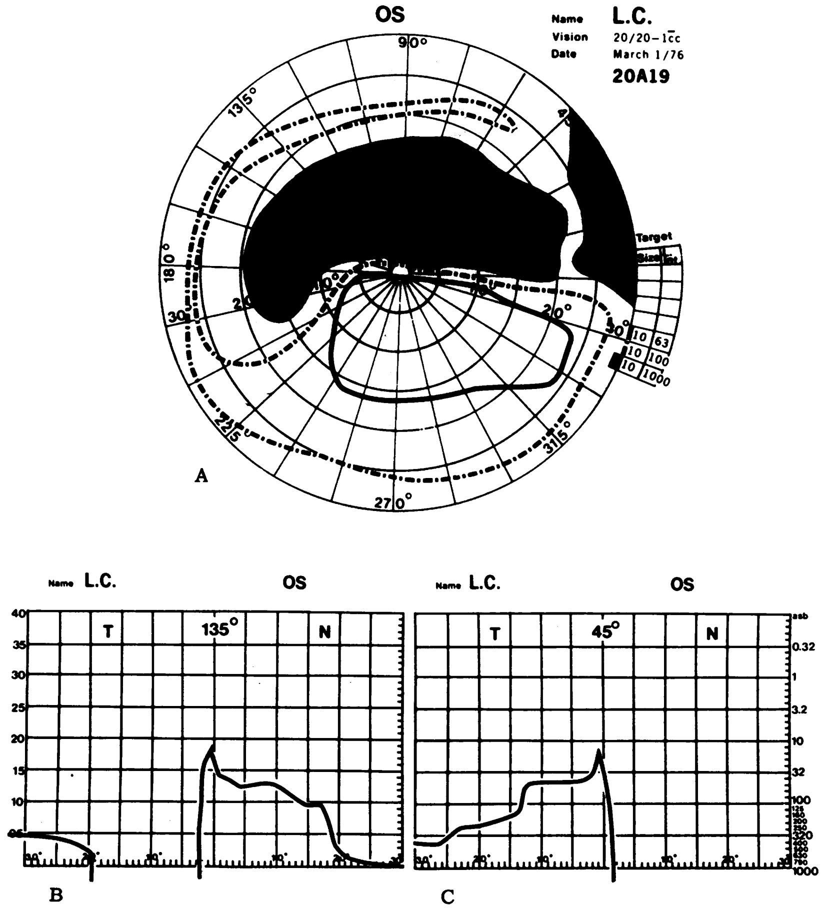

FIGURE 8

A: Kinetic and B & C: Static perimetry show both an arcuate scotoma and a nasal step. Arcuate scotoma is connected to the blind spot. Nasal step is connecting to the arcuate scotoma, as demonstrated by a nasal depression in the static profile.

opacities, uncorrected refractive errors, miosis, and aging. For example, the isopter decreases continuously with age, in many cases baring the blind spot.[4]

Static perimetry can be used to distinguish glaucomatous from nonglaucomatous peripheral constriction. When the latter is present the overall retinal threshold is depressed, whereas glaucomatous constriction is compatible with a good retinal threshold centrally over 10 ASB and only the peripheral part of the retinal threshold curve falls to the baseline (usually in all quadrants, but in some cases sparing the lower nasal regon). Thus, static

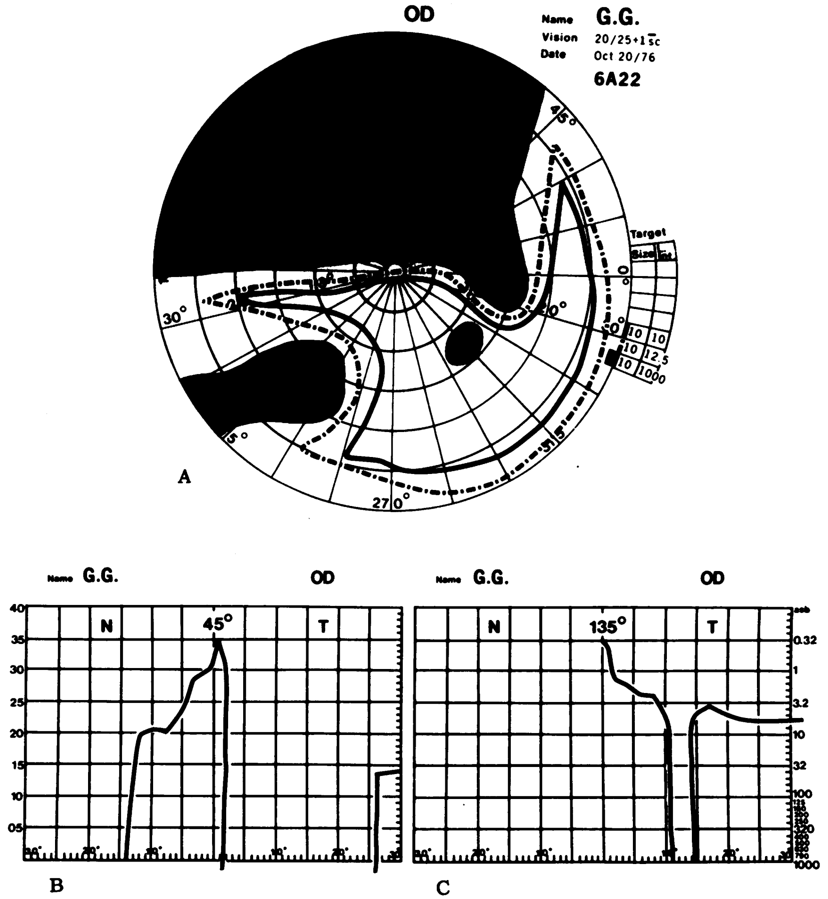

FIGURE 9

Advanced glaucoma defect. A: loss of the upper half of the visual field. Inferior nasal step and bjerrum island are about to coalesce, leaving a small central field and an inferior nasal island. B & C: Static perimetry shows absolute loss.

perimetry permits accurate evaluation of degree and significance of peripheral visual field constriction.

Paracentral scotomas, initially described by Traquair[5] and Peter[6] and confirmed by Aulhorn and Harms[1] and Drance et al,[7] are among the earliest apparent field changes in glaucoma. Usually, these small scotomas occur singly on the nasal side of fixation and are not connected to the blind spot. In the present study, only 8 of 30 scotomas had developed in the nasal field alone. Although Harms and Aulhorn[1] reported that 20% of glaucomatous defects detected by them were paracentral scotomas, the present incidence was only 7.2% (30 fields with paracentral scotoma, of 416 fields with defects). Furthermore, the lesion was a paracentral scotoma in only 10% of the visual fields with scotoma not connected to the blind spot—small isolated defects that in many cases are difficult to locate and outline except with static and kinetic perimetry.

Bjerrum and paracentral scotomas have been described as elongated circumferentially and, when paracentral, narrower on the temporal side of the field.[8] A bjerrum scotoma is said to develop from small spot-like defects that enlarge by arcuate spread;[5] the islands are reported to merge on the temporal side and then extend into the nasal region as far as the horizontal meridian, forming an arcuate scotoma.[1] In the present study, the vast majority of islands initially were circular—not elongated circumferentially—with no difference in the nasal and temporal portions. However, these islands did elongate in an arc, joining to form an arcuate scotoma that eventually reached the nasal horizontal meridian and connected to the blind spot.

The upper temporal region, particularly the bjerrum, is the area at greatest risk for early glaucomatous defects—60% of all bjerrum islands (single, double, and multiple) involved the temporal half of the field, and nearly 70% of the single ones were in the upper temporal area. The location of paracentral scotomas was of similar distribution: almost half of the relative lesions and more than half of the absolute paracentral islands involved the temporal field alone. This is contrary to previous reports, which state that paracentral scotomas are commonest on the nasal side of the field.[1,2a,3,8]

The commonest accompaniment of a bjerrum island was another bjerrum island, which was present in 77 of 143 cases. The commonest unrelated additional defect was a nasal step, which had developed in 17 of 28 fields containing a bjerrum island and five of 13 that contained a paracentral scotoma.

In the paracentral areas there were 18 relative and 12 absolute scotoma fields; this contrasts with the bjerrum area, in which there were 143 relative and only four absolute scotoma fields and where relative scotomas remained unchanged much longer. Thus, although the bjerrum region is the most susceptible initial risk area, it appears to have greater resistance to further damage than the paracentral region.

In three-quarters of the cases, relative enlargement of the blind spot in the kinetic field did not correspond to the static field. Most people, particularly the elderly, will have baring of the blind spot when the isopter contracts from just beyond to within the blind spot. This relative change, unless accompanied by another scotoma, is too vague to use diagnostically. However, absolute enlargement of the blind spot in an eye with elevated ocular pressure is significant: in 75% of such cases there is at least one other defect. Thus it is the associated defects that distinguish the glaucoma eye from normal eyes that have physiological cupping; the latter have a larger blind spot than normal[9] and the defect tends to be familial.

Nasal steps—depressions at the horizontal raphe—indicate glaucomatous defects, but nasal depressions are said to be of little value in diagnosing glaucoma,[2a] as only 1.6% solitary lesions have been reported.[8] It is believed that they always occur with another scotoma,[10] most commonly early or advanced[1] arcuate,[8] bjerrum island,[3] or paracentral scotomas.[1,8] The shape of a nasal step is determined by its location: in the periphery these steps are wedge-shaped, in the bjerrum they are right-angled, and in the paracentral area they are obtuse-angled. Nasal steps are thought to devleop in some isopters only.[8]

In the present study, relative nasal steps appeared to represent an early stage of the glaucoma. They occurred chiefly with small bjerrum-island scotomas but almost 33% were solitary. Their shape did not accord with the 'wedge/right angle/obtuse' theory, being mainly curved or wedge-shaped. The great majority were below horizontal, confirming that the earliest risk areas are the upper temporal and lower nasal; further confirmation of this lies in the location of 12 double bjerrum-island fields in these two regions.

Many of the absolute nasal steps were solitary; a few (but a greater percentage than of relative steps) were accompanied by arcuate defects. Shape bore no apparent relation to isopter; half of these steps were located inferiorly.

Nasal steps, relative and absolute, had similar accompanying defects. The only differences appeared to be that these defects were multiple when accompanying extension of the step into the paracentral field, and more loss of the upper nasal field when the step was absolute. In summary, I believe that the relative and absolute stages of nasal steps provide useful clues to change in glaucomatous field, but that (contrary to Harms and Aulhorn's observation) they can occur alone.

Others have documented a preponderance of considerable narrowing of arcuate scotomas temporally and sharp demarcation of the horizontal,[8] most commonly above fixation[2] and beginning with a nasal paracentral scotoma.[11] In the present study, defects of the nerve-fiber bundle were slightly but not significantly commoner in the upper field and there was no evidence that these defects of the nerve-fiber bundle had begun in the paracentral regions on the nasal side. The findings do indicate, however, that horizontal demarcation occurs only in the final stage of arcuate break-through, and that the nasal portion of a scotoma does not widen until this advanced stage (Fig 10).

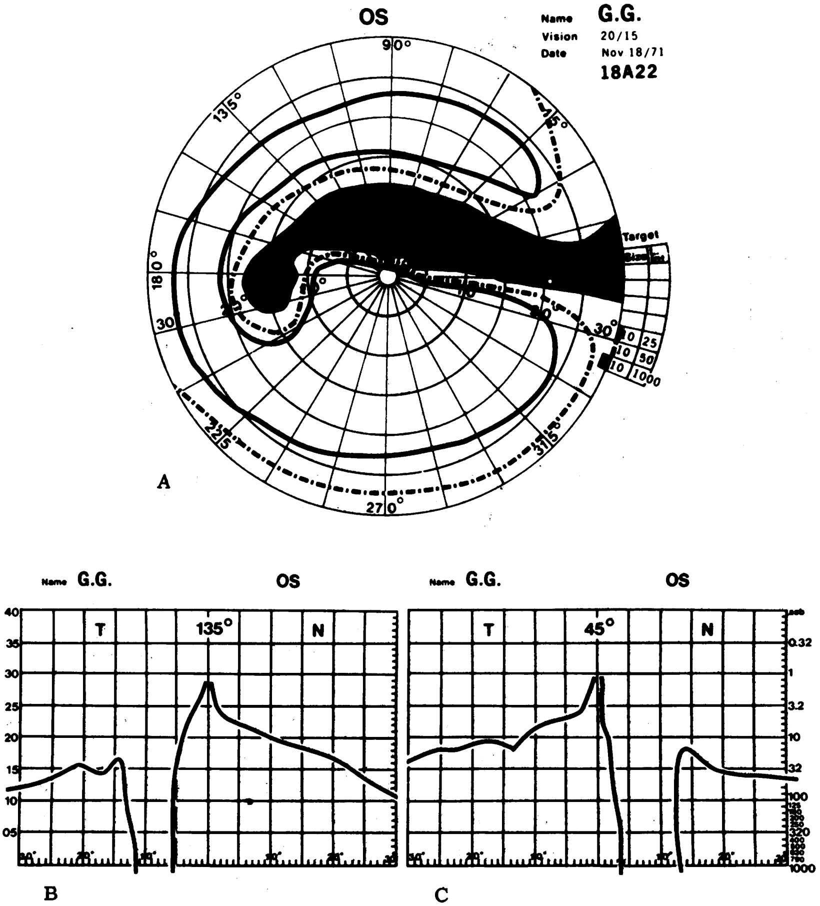

FIGURE 10

A: Kinetic and B & C: Static perimetry show a defect of the nerve-fiber bundle that has broken through to the periphery. It is of horizontal delineation, the nasal portion being wider.

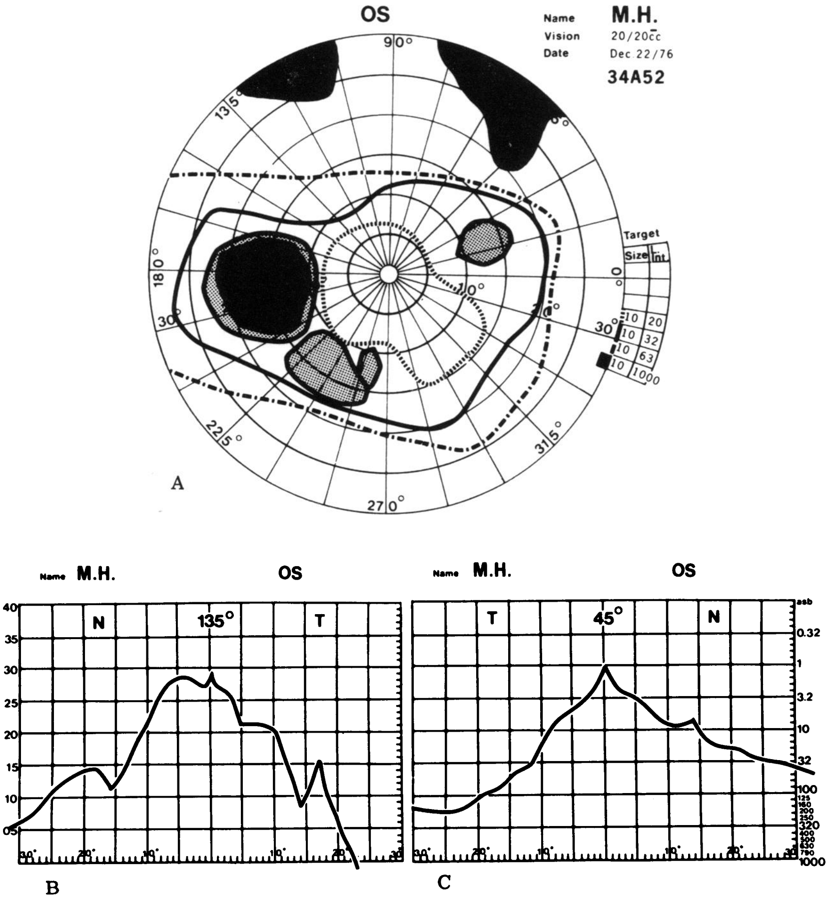

FIGURE 11

A: Kinetic and B & C: Static perimetry shows significant enlargement of the blind spot. This is associated with relative bjerrum islands and absolute segmental constriction.

Advanced glaucoma was characterized by absolute constriction of the central visual field to at least 10° and/or the loss of half to three-quarters of the visual field. It has been thought that, when central vision is lost, a small temporal island is the only remnant of vision.[3,12] In this study, however, central fixation was the last portion of the field to withstand the effects of elevated intraocular pressure and few eyes had a remnant of vision temporally.

The above findings confirm my belief that absolute enlargement of the blind spot is not significant unless enlarged in an arcuate direction[2b] or

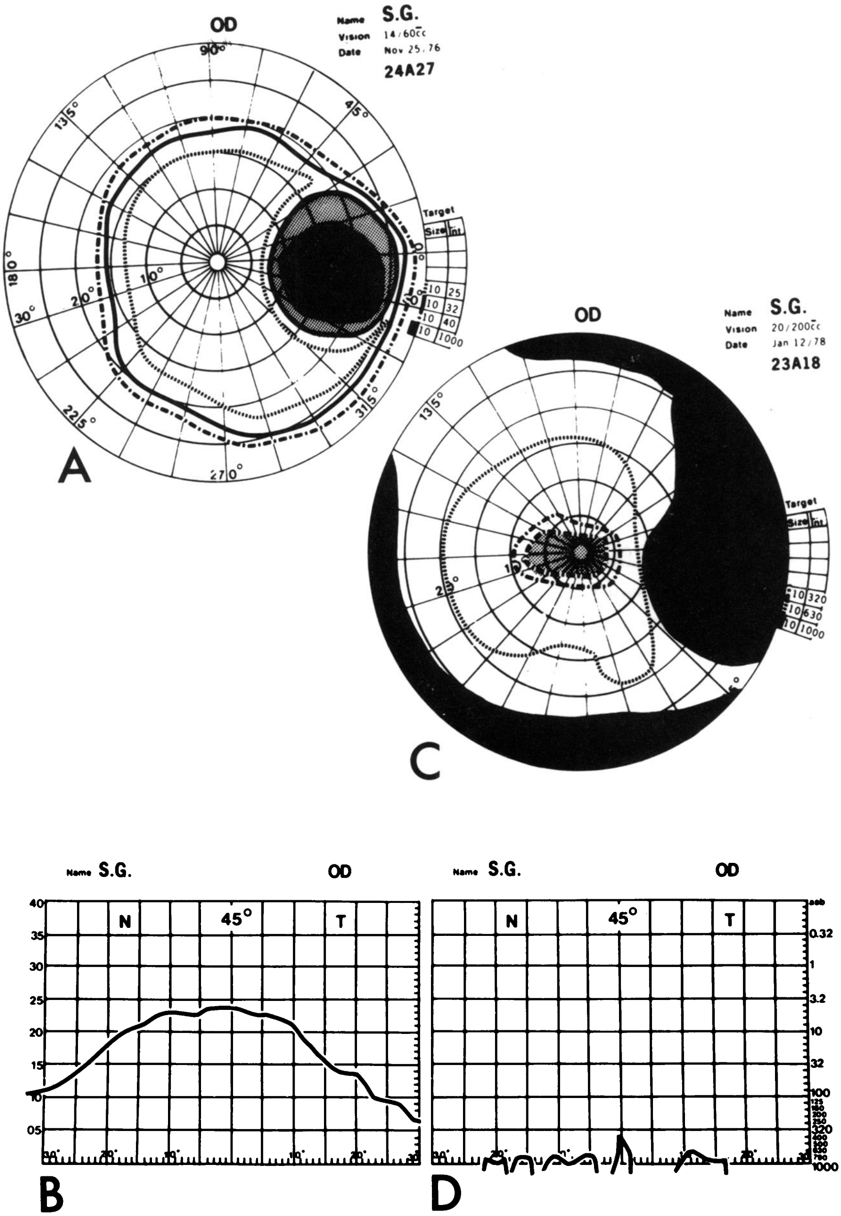

FIGURE 12

A & C: Kinetic and B & D: Static perimetry show absolute enlargement of the blind spot, together with a temporal step that is progressive peripherally.

associated with another scotoma. Admittedly, such lesions were not numerous,[6] but the majority had enlarged in circular fashion (Fig 11) and most of the accompanying defects were quite advanced.

Temporal steps are said to commonly accompany classical arcuate defects;[8] they may be cecopetal or cecofugal (i.e., extending from the periphery or from the blind spot, respectively).[13] In the present study this association with arcuate defects was absent. In one field the step originated in the periphery and progressed inward to join the blind spot (Fig 12), and in six of the nine with an absolute temporal step this was joined to the blind spot when first seen.

It has been hypothesized that vertical steps can develop in glaucomatous fields,[3] but none were seen in the present series of 2,000 cases. I believe this lesion to be more probably a sign of a neurologic disease.

SUMMARY

Static and kinetic fields were recorded with a Tubinger oculus perimeter, using dual techniques by which the findings of one can be verified by the other. This is far superior to methods that outline only one dimension; for example, the static eliminates certain adverse kinetic variables that may enable the patient to perceive the object prematurely—for example, speed and movement of the test object. Conversely, kinetic testing eliminates the static element of a set location, permitting the recording of several isopters with varied but accurately selected test-object luminosities; this contrasts with the usual ability to record only one or two isopters with selected test objects on the tangent.

Although a 'dip' of one log in the static was used to verify a defect in the kinetic field, in many cases a dip of lesser degree and its corresponding scotoma in this field were reproducible. This is sometimes difficult with a tangent screen. Naturally, the deeper the dip (that is, the lower the retinal threshold) the more severe the defect and the greater likelihood that it will advance to absolute scotoma.

The principal findings were as follows:

1. Most bjerrum islands were in the upper temporal region—the area at greatest risk. They were initially circular rather than elongated and were the same width throughout. If they were accompanied by another scotoma, this also was a bjerrum island.
2. Many paracentral islands were isolated defects. Initially, a higher proportion of these than of bjerrum islands were absolute.
3. Nasal steps showed no predilection for a particular isopter. Most were

curved or wedge-shaped. If they were accompanied by other defects, most of these were small islands rather than arcuate scotomas.

4. Defects of the nerve-fiber bundle had not originated from nasal paracentral scotomas. They evidenced no typical characteristics until they had broken through to the periphery, at which (advanced) stage there was a tendency for horizontal cut-off and widening of the nasal portion.
5. There was no evidence of association between temporal steps and arcuate scotomas.

This study has shown that advanced glaucoma consists in absolute constriction of the visual field, and that central fixation (in some cases accompanied by a temporal island of vision) is the last remnant to provide vision in a glaucomatous eye.

Initially, the upper temporal and lower nasal fields are affected by bjerrum islands. Those in the lower nasal area develop into relative nasal steps and seem to stabilize or develop very slowly. As the field worsens, absolute nasal steps in the upper field become more frequent and develop more rapidly than do those in the lower field. Defects of nerve-fiber bundles are commoner in the upper than the lower half of the fields and develop faster in the former than the latter region. This is corroborated by the finding of earlier loss of vision in the upper half of the field during later stages of blindness of glaucomatous eyes.

This study showed a further point of interst in the follow-up of patients with glaucoma. Few ophthalmologists attach importance to relative enlargement of the blind spot. In the present study, however, absolute circular enlargement constituted a major clue to deterioration of a field, in many cases being accompanied by one or more advanced defects in another area.

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