

# Homonymous quadrantanopia respecting the horizontal meridian

## A feature of striate and extrastriate cortical disease

Robert M. McFadzean, FRCOphth; and Donald M. Hadley, PhD, FRCR

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**Article abstract**—It has been proposed that homonymous quadrantanopic visual field loss that respects the horizontal meridian is a pathognomonic sign of extrastriate cortical disease. However, two patients with this sign are reported—one with a rare striate and the other with an extrastriate lesion of the visual cortex. It is therefore hypothesized that a homonymous quadrantanopia respecting the horizontal meridian may indicate striate and/or extrastriate cortical disease.

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In 1909 the first map of the representation of the visual field in the occipital striate cortex was published<sup>1</sup> in which the superior and inferior visual fields were separated by the representation of the horizontal meridian along the base of the calcarine fissure. Initial reports of homonymous quadrantanopic visual field defects respecting the horizontal meridian concerned soldiers with penetrating injuries of the cranium sustained in the First World War.<sup>2</sup> These defects were the result of damage to the occipital striate cortex, and they shared the remarkable distinguishing feature of a sharp and steep demarcation along the horizontal meridian. Six of the seven original cases affected the superior bank of the calcarine fissure with a corresponding inferior homonymous quadrantanopia, and in only one patient was a superior homonymous quadrantanopia described.

The paucity of superior visual field loss was attributed to a likely fatal outcome in most inferior calcarine traumatic lesions, owing to concomitant laceration of the dural sinuses. These patients supported the concept that the superior and inferior visual fields were localized to the inferior and superior calcarine banks respectively, separated by the representation of the horizontal meridian along the base of the calcarine fissure. However, this proposal was challenged when doubts were expressed about the possibility of a traumatic lesion of one calcarine bank leaving the other unharmed.<sup>3,4</sup> Such projectile trauma would be required to respect the wavering representation of the horizontal meridian in the base of the calcarine fissure, a highly improbable scenario.

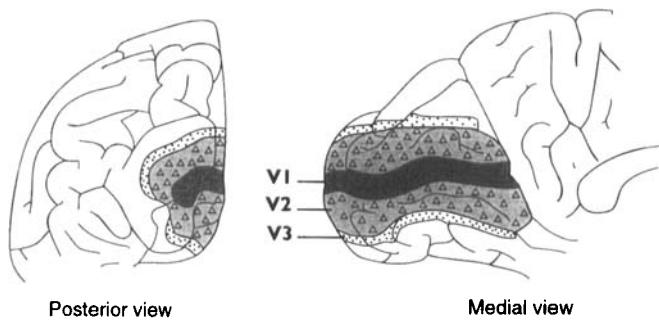
Subsequently, an additional report of two soldiers traumatized by a missile injury to the optic radia-

tion<sup>5</sup> noted that the resultant homonymous quadrantanopia also respected the horizontal meridian, giving rise to the postulate that fibers in the optic radiation representing the superior and inferior visual fields were physically separated from each other by an anatomic interval. This interval would permit respect for the horizontal meridian in the consequential visual field defect. Thus, a relatively irregular lesion could nevertheless produce a well-defined quadrantanopia with a sharp horizontal border. Furthermore, other authors suggested that the anatomic interval was due to splitting of the optic radiations into superior and inferior divisions by the posterior horn of the lateral ventricle<sup>3</sup> and the interposition of macular fibers between those representing the superior and the inferior visual fields.<sup>4</sup> Thereafter, homonymous quadrantanopias respecting the horizontal meridian were attributed to lesions of the optic radiations, and superior or inferior striate lesions were thought to be characterized by an irregular horizontal border. Unfortunately no anatomic evidence has emerged to support this proposed anatomic interval. Indeed, studies in the cat demonstrate that the optic radiations form a continuous sheet of fibers without separation of those fibers representing the superior and inferior visual fields.<sup>6</sup> Temporal lobe lesions could damage Meyer's loop, giving rise to a superior homonymous quadrantanopia, and parietal lobe lesions produce an inferior homonymous quadrantanopia, but such optic radiational field defects had sloping borders that failed to respect precisely the horizontal meridian and were often incongruous.<sup>7</sup>

Following a literature review of 57 patients with homonymous quadrantanopia respecting the horizontal meridian and an MR study of two patients, it

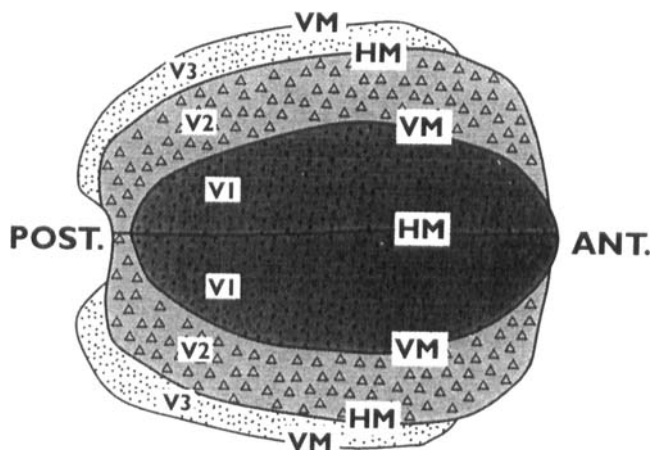
From the Departments of Neuro-ophthalmology (Dr. McFadzean) and Neuroradiology (Dr. Hadley), Institute of Neurological Sciences, Glasgow, Scotland. Received February 7, 1997. Accepted in final form July 7, 1997.

Address correspondence and reprint requests to Dr. Robert McFadzean, Department of Neuro-ophthalmology, Institute of Neurological Sciences, Southern General Hospital, 1345 Govan Road, Glasgow, G51 4TF.



**Figure 1.** Schematic diagram of the occipital cortex showing the arrangement of V1, V2, and V3. Most of V1 is buried within the calcarine fissure. (Reproduced with permission of the authors and Oxford University Press. From Horton JC, Hoyt WF. Quadrantic visual field defects. A hallmark of lesions in the extra-striate (V2/V3) cortex. *Brain* 1991;114:1703–1718.)

was proposed that such visual field loss was a hallmark of an extrastriate cortical lesion.<sup>8</sup> The concept was based on animal studies<sup>9–14</sup> that demonstrated that the extrastriate visual area 2 (V2) completely surrounds the primary striate cortex (V1), except anteriorly where the monocular temporal crescent is represented (figure 1). The representation of the vertical meridian is shared along the common border between V1 and V2 (figure 2). The extrastriate visual area 3 (V3) is similarly wrapped around V1 and V2, with the representation of the horizontal meridian sharing a common border with V2 and the vertical meridian delimiting the outer border of V3 (see figure 2). In this fashion, V2 and V3 are split along the horizontal meridian into superior and inferior calcarine banks, representing the inferior and superior quadrants respectively of the contralateral



**Figure 2.** Schematic map corresponding to figure 1 that shows V1, V2, and V3 within the occipital cortex. The horizontal meridian (HM) is shown at the base of the calcarine fissure and defines the outer limit of V2. The vertical meridian (VM) defines the outer limits of V1 and V3. (Adapted with permission of the authors and Oxford University Press. From Horton JC, Hoyt WF. Quadrantic visual field defects. A hallmark of lesions in the extra-striate (V2/V3) cortex. *Brain* 1991;114:1703–1718.)

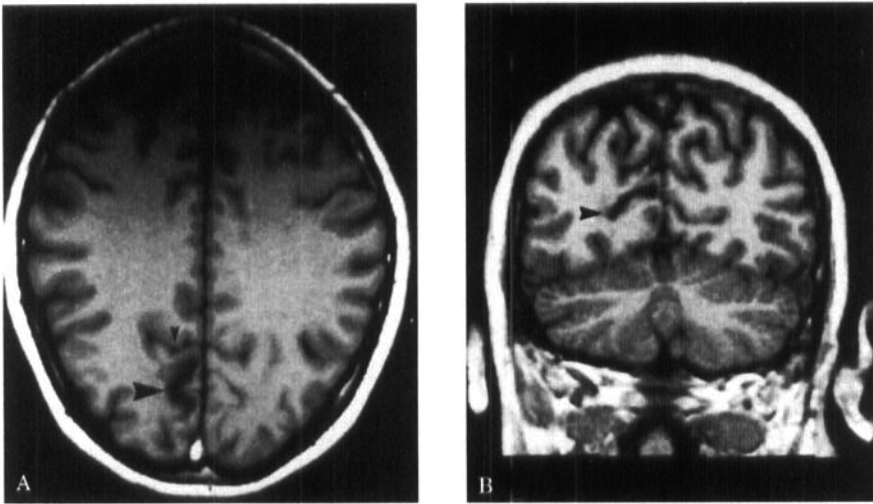
hemifield of vision. In the macaque monkey, the representation of the horizontal meridian continues from V1 into V2, but quickly splits a short distance from central fixation to outline the periphery of V2,<sup>12</sup> while V3 as it approaches the representation of the fovea is probably discontinuous.<sup>12,15,16</sup> Thus V2 becomes a mirror image of V1, sharing the representation of the vertical meridian; V3 becomes a mirror image of V2, sharing the representation of the horizontal meridian; and the outer perimeter of V3 is defined by the vertical meridian. Isoeccentricity contours appear to pass from V1 to V2 without interruption.<sup>13,17</sup> Consequently the visual field is continuously represented along any isoeccentricity contour line from V1 into V2 and V3. A lesion crossing the border between V1 and V2 or V2 and V3 damages cortical tissue sharing common retinotopic coordinates. Therefore, a lesion traversing the border between V2 and V3 would be characterized by a contralateral homonymous quadrantanopia with respect for the horizontal meridian.<sup>8</sup> Although such a lesion could have irregular margins, the resulting visual field loss would have a sharply defined, steep horizontal border, provided it crossed the representation of the horizontal meridian in the extrastriate cortex. This hypothesis proposes that such a perimetric feature is a hallmark of extrastriate disease.<sup>8</sup>

The present report concerns two patients, both of whom demonstrated an inferior homonymous quadrantanopia respecting the horizontal meridian as a feature of striate disease in one patient and extrastriate disease in the other.

**Methods.** Two patients with lesions affecting the occipital cortex were assessed using conventional Goldmann dynamic perimetry and MRI. Images of the occipital cortex were obtained in the sagittal oblique axial plane (i.e., in the plane of the calcarine fissure) and the oblique coronal plane (i.e., at a right angle to the plane of the calcarine fissure). Thus the anatomic relationship of the lesion to the calcarine fissure was identified. After correlation of the perimetric and imaging findings, a comparison was made with previously reported clinical cases of homonymous quadrantanopic visual field loss respecting the horizontal meridian and the available experimental evidence of the representation of the visual field in the striate/extrastriate occipital cortex. Particular attention was paid to known variation in the blood supply of the calcarine cortex.

**Results. Patient 1.** A 40-year-old man developed a right occipital infarct affecting the superior bank of the calcarine cortex and extending into the base of the calcarine fissure (figure 3). Goldmann dynamic perimetry demonstrated a left inferior homonymous quadrantanopia that respected absolutely the horizontal meridian and did not extend fully to the vertical meridian (figure 4).

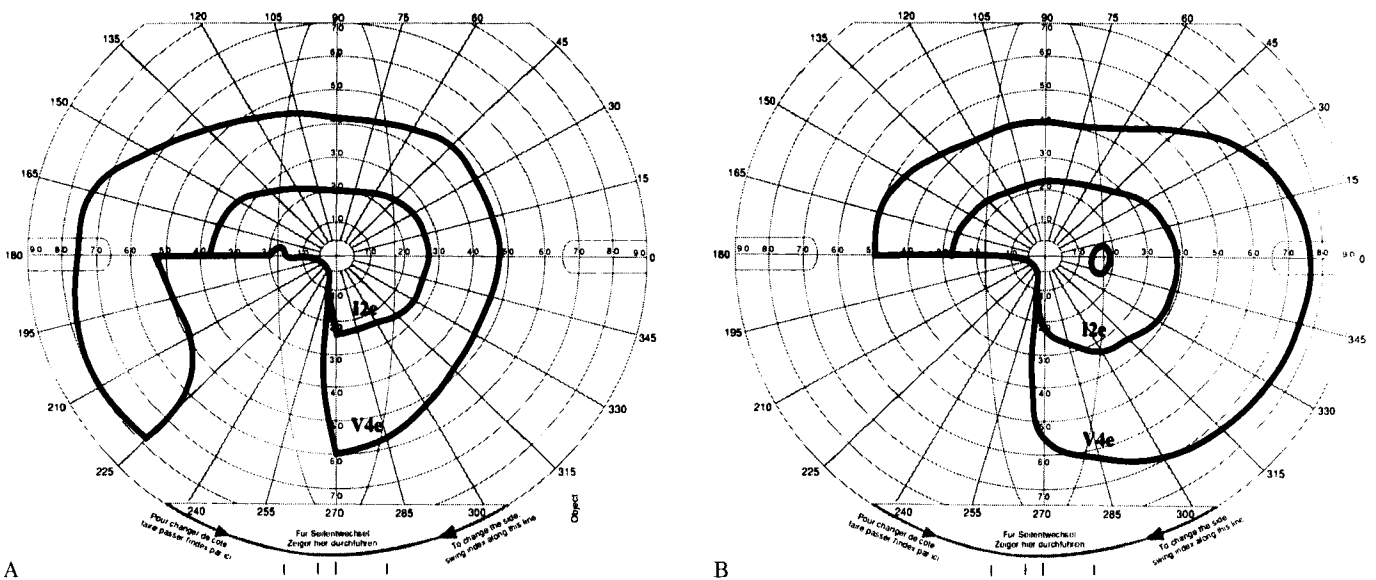
**Patient 2.** A 48-year-old man developed a spontaneous right occipital hematoma, which resolved, leaving cerebromalacia in the right superior extrastriate cortex (figure 5). Goldmann dynamic perimetry demonstrated a left inferior homonymous quadrantanopia with respect for the horizontal meridian (figure 6).



**Figure 3.** (A, B) (A) T1-weighted (spin echo, 580/14) 5-mm-thick oblique axial section parallel to the calcarine fissure and (B) a high-definition, T1-weighted, thin (1-mm) 3D-MPRAGE (10/4; 12 deg) coronal section at a right angle to the calcarine fissure shows a right striatal infarct (large arrowhead) localized to the superior bank of the calcarine cortex and extending to the base of the calcarine fissure. The parieto-occipital fissure is indicated by the small arrowhead in the oblique axial section (A).

**Discussion.** Patient 1 appears to demonstrate that it is possible for a lesion affecting the superior bank of the calcarine fissure to produce a contralateral inferior homonymous quadrantanopia respecting the horizontal meridian, in spite of the irregular and wavering course adopted by the base of the calcarine fissure. The pathology in this patient was presumed to be an occipital infarct and it is in its vascular etiology that the explanation for the visual field configuration lies. The course and distribution of the arteries supplying the visual cortex were studied in 32 normal brains,<sup>18</sup> when it was found that the whole visual area, defined as the extent of the occipital cortex in which the stria of Gennari is seen using a dissector's loupe, was supplied by the calcarine artery alone in some individuals. More usually, there

were supplementary branches from one or more other arteries, namely the posterior temporal and the parieto-occipital branches of the posterior cerebral artery and the occipital branch of the middle cerebral artery. The distribution of the calcarine artery was somewhat variable, but in six brains it was found to divide into superior and inferior divisions running longitudinally in relation to the calcarine fissure. In two specimens these vessels appeared to share equally in the supply of the visual area; in other words, the superior calcarine bank was supplied solely by the superior division of the calcarine artery and the inferior calcarine bank was supplied solely by the inferior division of the calcarine artery, with complete respect for the representation of the horizontal meridian at the base of the calcarine fis-



**Figure 4.** A = left, B = right. Goldmann dynamic perimetry shows a left inferior homonymous quadrantanopia that respects the horizontal meridian but does not extend fully to the vertical meridian. Note sparing of the left temporal crescent corresponding to the intact striate cortex adjacent to the right parieto-occipital fissure (small arrowhead) in figure 3A. The V<sub>4e</sub> isopter refers to the threshold determined using a 1,000-apostilb test spot measuring 64 mm<sup>2</sup>, and the I<sub>2e</sub> isopter refers to a 100-apostilb test spot measuring 0.25 mm<sup>2</sup>. The hemispheric bowl is positioned 33 cm from the eye with a background luminance of 31.5 apostilb.

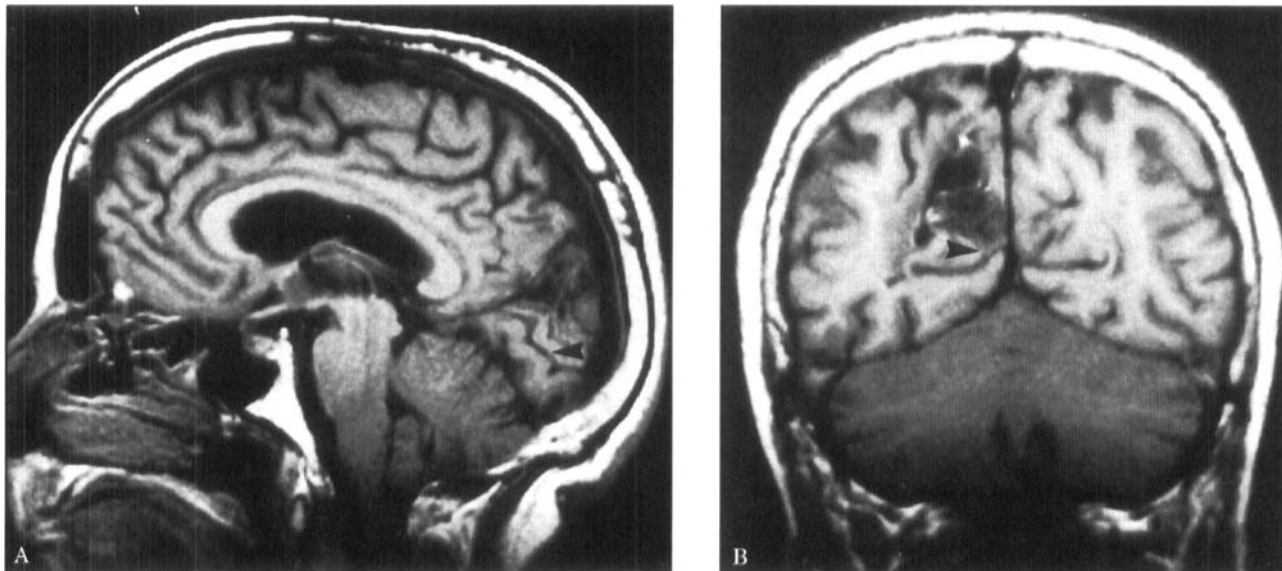


Figure 5. (A, B) T1-weighted (spin echo, 550/14) 5-mm-thick right parasagittal (A) and coronal (B) sections show cerebral malacia in the right superior extrastriate cortex. Note sparing of the superior bank of the calcarine fissure (arrowhead).

sure. Consequently it was predicted that infarction of the superior calcarine bank with such a blood supply would result in a contralateral inferior homonymous quadrantanopia respecting the horizontal meridian, as in this case. Because it is not possible to image clinically the stria of Gennari, it cannot be stated conclusively that the infarction spared the extrastriate cortex. However, anatomic studies have shown that the medial exposed striate cortex extends 5 to 10 mm superior and inferior to the calcarine fissure, wider posteriorly than anteriorly, and tapering toward the junction of the parieto-occipital and calcarine fissures.<sup>18,19</sup> The width of this marginal part of the striate cortex varies from specimen to

specimen with the depth of the calcarine fissure, and with the presence and height of any gyri that may cross its floor.<sup>18</sup> In this case, the infarct did not extend onto the exposed medial striate cortex on MRI. Furthermore the inferior homonymous quadrantanopia did not extend to the vertical meridian, indicating that the lesion did not cross the V1/V2 border (see figure 2). It can therefore be safely assumed that this infarct was confined to the striate cortex.

At first sight it may seem surprising that other cases of striate cortical infarction with a homonymous quadrantanopia respecting the horizontal meridian have not been reported, as vascular lesions in this territory are not uncommon. However, in the

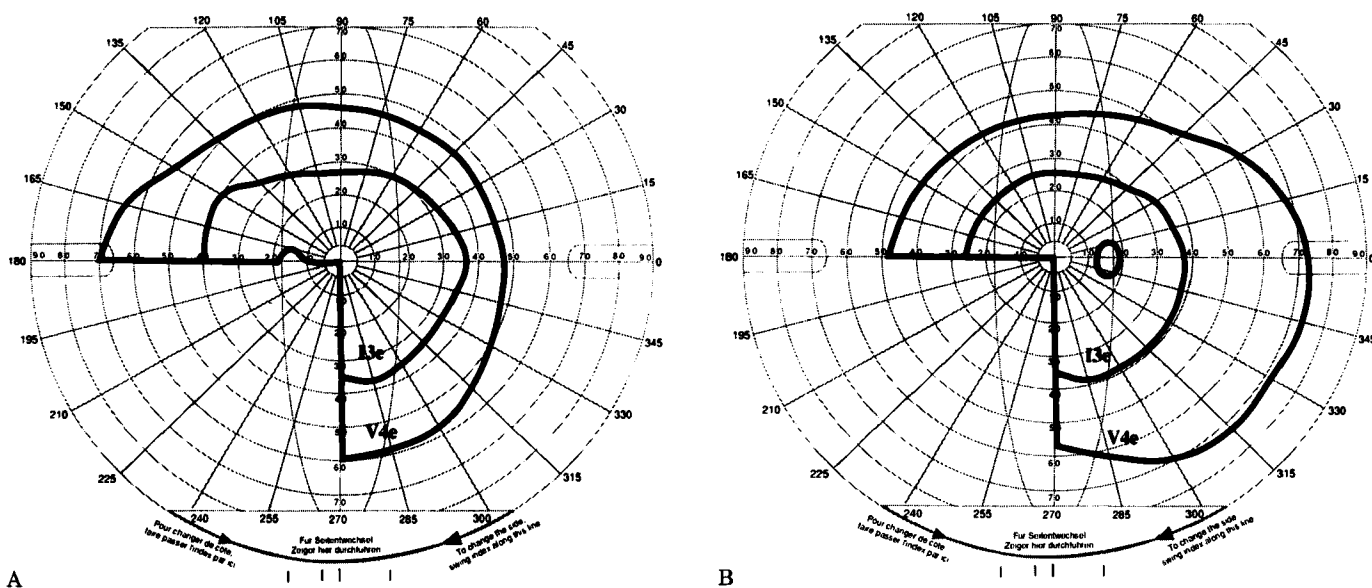


Figure 6. A = left, B = right. Goldmann dynamic perimetry shows a left inferior homonymous quadrantanopia with respect for the horizontal meridian. The  $V_{4e}$  isopter refers to the threshold determined using a 1,000-apostilb test spot measuring 64 mm<sup>2</sup>, and the  $I_{3e}$  isopter refers to a 315-apostilb test spot measuring 0.25 mm<sup>2</sup>. The hemispheric bowl is positioned 33 cm from the eye, with a background luminance of 31.5 apostilb.

previously mentioned anatomic study,<sup>18</sup> only two of 32 specimens demonstrated an independent blood supply to the superior and inferior calcarine banks by an individual branch of the calcarine artery. In the remaining specimens there was an overlapping supply of the superior and inferior calcarine banks by several branches of the calcarine artery, by parieto-occipital and/or posterior temporal branches of the posterior cerebral artery, and by an occipital branch of the middle cerebral artery. Infarcts of any of these vessels—the more common scenario—would result in a visual field defect that failed to respect the horizontal meridian. Other less common pathologies encountered in the calcarine fissure, such as traumatic lesions, neoplasia, and abscesses, are extremely unlikely to respect the representation of the horizontal meridian in the base of the fissure. So far as we are aware, this is the first reported patient with a striate lesion confined to one calcarine bank causing a contralateral homonymous quadrantanopia respecting the horizontal meridian, but in view of the blood supply of the striate cortex, its unique nature is not surprising.

On the other hand, our second patient clearly illustrates the contention that extrastriate disease superior or inferior to the calcarine fissure may also produce an inferior or superior contralateral homonymous quadrantanopia that respects the horizontal meridian. Although the topography of V2 in the human visual cortex has not been defined, comparison with animal experiments inevitably leads one to the conclusion that the extent of the extrastriate infarct in our second patient would cross the V2/V3 boundary, where the horizontal meridian is also represented (see figure 2).<sup>9-14,20-22</sup> MRI in the sagittal and oblique coronal planes clearly demonstrates that the lesion stops well short of the calcarine fissure and the striate cortex. This patient therefore supports the extrastriate hypothesis.<sup>8</sup>

In the correlation of perimetric function with imaging morphology, it is important to obtain MR images of the occipital cortex in the sagittal, oblique axial (i.e., in the plane of the calcarine fissure), and the oblique coronal planes (i.e., at a right angle to the plane of the calcarine fissure), as in this study. The precise relationship of calcarine bank lesions to the base of the calcarine fissure can be readily identified by this means.

Regrettably the literature contains few reports of homonymous quadrantanopia of cortical origin correlated with neuropathologic findings, although the case of Dr. Mallory, the renowned Boston pathologist, provides support for the extrastriate hypothesis.<sup>23</sup> Mallory suffered an inferior calcarine bank infarct, mainly involving the extrastriate cortex but encroaching slightly into the V1 area. Perimetry demonstrated a left superior homonymous quadrantanopia precisely respecting the horizontal meridian. Although it involved the inferior striate cortex, this infarct did not extend histopathologically into the depth of the calcarine fissure. Thus, respect

for the horizontal meridian was a reflection of involvement of the V2/V3 border (see figure 2).

In humans there is considerable variation in the location and extent of the striate cortex<sup>19</sup> and it is not possible to recognize the stria of Genarri on MRI. Because precise determination of the location of the V1/V2 boundary is impossible clinically, there is a requirement for further neuropathologic studies to correlate perimetric, imaging, and autopsy findings. Future functional imaging studies may help to evaluate the representation of the visual field in the occipital cortex and the effect of lesions.

Thus, visual field loss in the form of a homonymous quadrantanopia respecting the horizontal meridian may reflect either striate and/or extrastriate occipital cortical disease. Detailed analysis of perimetric and imaging findings in our two patients provides clinical support for animal experimental evidence of the structural organization of visual areas V1, V2, and V3 in the striate and extrastriate occipital cortex.

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