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Measurement of the Normal Optic Chiasm on Coronal MR Images

Andrew L. Wagner, F. Reed Murtagh, Ken S. Hazlett, and John A. Arrington

PURPOSE: To develop an objective method for measuring the optic chiasm and to document its normal range in size. **METHODS:** Measurements of the height and area of the optic chiasm, made on coronal T1-weighted MR images with the use of commercially available region-of-interest software, were obtained in 114 healthy subjects who had a total of 123 MR studies. A normal range and standard deviation were calculated, and the information was broken down by age and sex. **RESULTS:** The mean area of the optic chiasm was 43.7 mm², with a standard deviation of 5.21. The mean width was 14.0 mm, with a standard deviation of 1.68. **CONCLUSION:** The area and width of the optic chiasm can be measured with the use of commercially available software, which allows an objective estimate of the chiasm's size. Knowledge of the normal size range of the optic chiasm can be helpful in the early detection of some disorders.

Index terms: Optic chiasm; Brain, anatomy; Brain, measurement

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The optic chiasm is an important landmark when interpreting magnetic resonance (MR) examinations of the brain. A small chiasm can be an indication of several disorders, the most common of which is septooptic dysplasia (1), and a large chiasm can be the result of glioma, meningioma, lymphoma, or hemorrhage (2). The diagnosis of atrophy or enlargement of the chiasm has largely been made by "gestalt" interpretation, and is therefore highly subjective and variable among observers. We retrospectively reviewed 123 coronal MR images of the healthy brain and measured the width and area of the optic chiasm to determine a range of normal values. These figures can potentially aid in the early detection of infiltrating processes of the chiasm and can be used in cases in which the diagnosis of optic chiasm atrophy is uncertain.

Materials and Methods

We retrospectively reviewed 150 cranial MR studies that had been obtained at our institution over a period of 18

months and that had been interpreted as normal. No patient had suspected visual or endocrine abnormalities. All the examinations had been performed with a 1.5-T General Electric (Milwaukee, Wis) Signa or 1.5-T Siemens (Cary, NC) Somatom MR system using routine imaging protocols, with additional 3-mm T1-weighted contiguous coronal sections used for measurements. Either noncontrast or contrast-enhanced images were used. In 27 cases, artifacts produced by patient motion or technical factors prevented adequate visualization of the optic chiasm, and these examinations were removed from the study. The 123 studies were obtained in 62 men and 54 women, 18 to 82 years old; all images adequately showed the optic chiasm. Nine patients had more than one study. Values from these patients were averaged and put into the study as one set of measurements; they also served as an internal control to calculate estimated error of this technique.

The studies were transferred to a Sun (Mountain View, Calif) workstation, at which the width, height, and area of the optic chiasm were measured using region-of-interest (ROI) software from ISG systems (Toronto, Canada). In a majority of cases (82%), there was one image in which the optic chiasm and proximal optic nerves were clearly seen as a horizontally aligned dumbbell-shaped object, and this image was used for the measurements. The image window was standardized to that used for filming and was measured by means of a thresholding technique. The marked area was then compared with the original image by masking the threshold application to confirm that the correct area was being measured. In cases in which the chiasm appeared on more than one section, we used the image in which the chiasm was the largest. The horizontal width and

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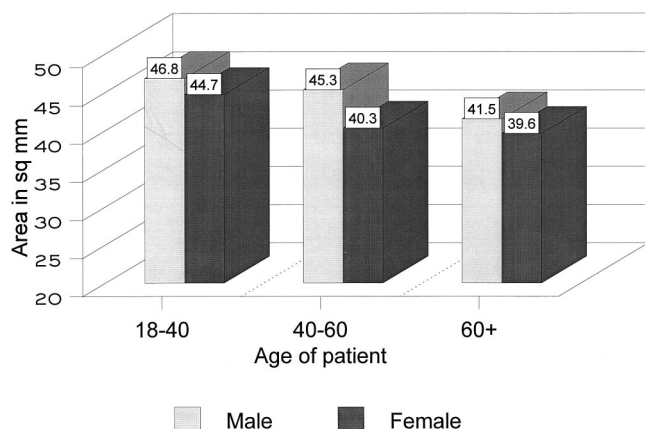


Fig 1. Mean area of the optic chiasm by age and sex.

the height of the central portion of the chiasm were measured using standard point-of-interest software and the area was calculated by means of an ROI program. During the course of the project it was found that the chiasm height was so small that it led to significant intraobserver and interobserver error. In addition, the point measured was an arbitrary one, as the chiasm is quite variable in height across its width. This measurement was subsequently dropped from the study, leaving width and area as the relevant measurements.

Results

The area of the optic chiasm as calculated in this study ranged from 32.2 mm² to 58.5 mm², with a mean of 43.7 mm², a median of 42.0 mm², and a standard deviation (SD) of 5.21. Breakdown by age and sex showed an expected decrease in the area of the chiasm as patients got older, as well a small decrease in the area in women (Fig 1).

The width of the chiasm ranged from 10.3 mm to 18.3 mm, with a mean of 14.0 mm, a median of 13.5 mm, and an SD of 1.68. There was a decrease in width with increasing age, although correlation with sex yielded no significant difference (Fig 2).

Comparison of the measurements in subjects who had more than one study showed less than an 8% difference in calculated area and width using this protocol. In 15 patients (12%), the studies were recalculated twice by the original reader as well as once by a second reader, and variability was calculated. These computations yielded an approximate 5% interobserver variation and less than a 7% intraobserver variation, which were taken to indicate an expected variability in the technique.

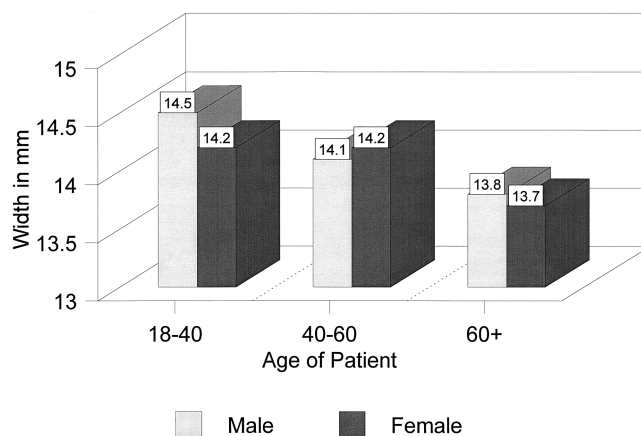


Fig 2. Mean width of the optic chiasm by age and sex.

Discussion

The optic chiasm can be atrophied or hypoplastic to some extent in a number of conditions, such as septo-optic dysplasia, optic nerve atrophy, and ischemia due to cerebrovascular disease, which might be expected in an aging population. The most common of these is septo-optic dysplasia, which has been further categorized into two subsets, each with different clinical findings and embryologic origin (1). However, because of the lack of MR criteria, it can be difficult to distinguish between mild to moderate hypoplasia of the optic chiasm and a chiasm that is at the lower limits of normal. The same lack of objective criteria exists in cases of enlargement of the optic chiasm, which is usually indicative of glioma but can also be seen in hemorrhage and lymphoma (2).

Studies of the normal optic anatomy have been performed using both computed tomography (CT) and MR imaging (3-6), and MR imaging has proved to be the method of choice for examining the optic chiasm, especially coronal high-field T1-weighted imaging, which seems to depict the anatomy to the best advantage. Brodsky et al (7) reported that identification of optic nerve hypoplasia on MR images significantly matched clinical diagnosis on both coronal and sagittal studies; however, they relied on subjective grading to determine whether the nerves were normal or small. Parravano et al (8) described optic chiasm and nerve sizes in normal and abnormal brains but relied on measurements of the height and width made with handheld digital calipers. We think that computers offer a more accurate measurement. Our computer-based measurements were close to their

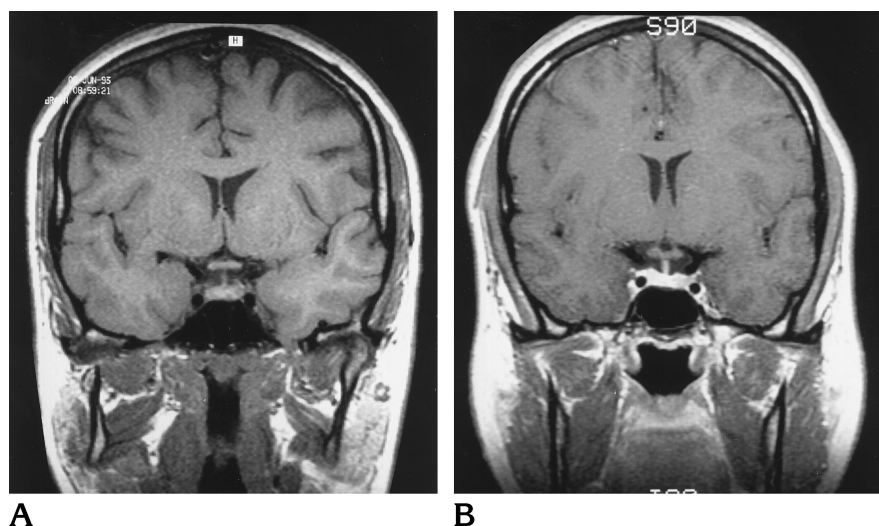


Fig 3. Coronal T1-weighted MR images (620/15/2 [repetition time/echo time/excitations]) in two patients show the dumbbell-shaped optic chiasm. This classic shape is seen in most patients when using 3-mm contiguous sections.

data with respect to the width of the chiasm, although we chose to measure the cross-sectional area as well.

The three-dimensional shape of the chiasm makes it a difficult organ to measure. We believe that the most accurate measurements can be made on T1-weighted MR images, as the chiasm is seen best on this sequence in our opinion, and that the cross-sectional area obtained is representative of the chiasm as a whole (Fig 3). In addition, coronal T1-weighted images of the brain are a standard sequence in imaging the chiasm and sella. Use of a selected image from a coronal MR study of the chiasm allows this structure to be seen and measured without having to determine reproducible anterior and posterior cut-off points, which would be necessary on axial images. Although there may be some variation due to differences in sections among studies, we think that use of the section on which the chiasm is largest will minimize error.

Our intention was to measure the optic chiasm on a presumed standard T1-weighted coronal MR image, and it was assumed that the image size was comparable to actual anatomic size, although that could not be proved without an autopsy study. The calculated measurement of the normal optic chiasm on MR sections can be used as a comparative standard by which to detect relatively smaller or larger chiasms, regardless of whether the measurements are in exact ratio to the actual nerve.

The potential for error does exist when using the method of windowing and thresholding as

a means of measurement. Partial volume effect can alter the measurements among observers if the windowing technique is not similar. This error will get larger with wider sections, which is why 3-mm sections were used in this study. Presumably, thinner sections would increase edge sharpness and decrease measuring error even more, but they would be impractical from a time-management standpoint as well as for decreasing the signal-to-noise ratio.

In the nine patients who were imaged more than once, the values obtained from the different studies differed by less than 8%. These values correspond well with previous work, which showed less than a 10% interobserver and intraobserver error when using this software to measure the volume of brain tumors (N. F. Imam, R. Murtagh, unpublished data, 1992). Not all studies are suitable for this calculation, such as those with enough motion or noise to make the margins of the chiasm indistinct. However, in 82% of our patients, the images had enough detail to make reproducible determination of the borders possible, and no special imaging of the sella was necessary.

Studies comparing subjective and objective diagnoses of hypoplasia of the optic chiasm would be interesting, although the small values involved in measuring moderate to severe hypoplasia would decrease the intraobserver reproducibility when using ROI software. This would not affect comparison between normal and abnormally enlarged chiasms.

This study provides a range of values for both the area and width of the normal optic chiasm

as measured on coronal MR images. These measurements can be calculated with any of the multitude of commercial software currently available, and most MR units now in use have the capabilities to furnish the ROI measurements used in this study. Reference to these values can help determine whether an optic chiasm is outside the range of normal limits, thus potentially increasing the chance of detecting early occult disease and of diagnosing mild septo-optic dysplasia. Our study suggests that optic chiasms with an area on coronal MR images between 33.3 mm^2 and 54.1 mm^2 (2 SD from the mean) and a width between 10.6 mm and 17.4 mm (2 SD from the mean) can be considered definitely normal. Chiasms outside these ranges should be considered abnormal and prompt further investigation.

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