Magnetic resonance imaging (MRI) and computerized tomography (CT) have added a new dimension in the diagnosis and management of ocular and orbital diseases. Although CT is more widely used, MRI is the modality of choice in select conditions and can be complimentary to CT in certain situations. The diagnostic yield is best when the ophthalmologist and radiologist work together. Ophthalmologists should be able to interpret these complex imaging modalities as better clinical correlation is then possible. In this article, we attempt to describe the basic principles of MRI and its interpretation, avoiding confusing technical terms.

**Key words:** Interpretation, magnetic resonance imaging, orbit, ophthalmology

Magnetic resonance imaging (MRI) is being increasingly used as an important imaging tool in ophthalmology. Appropriate interpretation of MRI, like CT, allows us to discern the location, extent and configuration of orbital lesions and their effect on adjacent structures. This facilitates formulating a reasonable differential diagnosis and planning appropriate management including the surgical approach. This article is an attempt to present to the reader, in a simplified manner, the technical aspects involved in looking at the MRI in the background of practical knowledge. We hope that at the end of reading this article the reader will be able to read MRI scans systematically and identify normal orbital structures and their varied appearances in different imaging sequences. We have also briefly addressed the imaging method of choice in specific clinical situations.

### Basic Principle of Magnetic Resonance Imaging

An MR imaging system consists of the following components:

1. A large magnet to generate the magnetic field
2. Radiofrequency (RF) coils to transmit /receive radio frequency pulses into / from the body part being imaged
3. A computer to reconstruct the radio signals into the final image [Fig. 1].

The larger head coil is used to image brain and orbits. Smaller surface coils give more exquisite anatomic details, but can image only more superficial tissues and cannot image the whole brain [Fig. 1].

When the human body is placed in a strong magnetic field, the protons in the hydrogen atoms in the body act like tiny dipoles and align along the direction of the magnetic field [Fig. 2a], being either parallel or antiparallel to the field (longitudinal magnetization). They also rotate (precess) around their own axes in accordance to the strength of the magnetic field [Fig. 2b]. Normally they precess in different phases. When a RF pulse is applied, these tiny dipoles are tilted off the equilibrium and start to precess in phase with one another [Fig. 2ci]. When application of the RF pulse is stopped, the longitudinal magnetization along the axis of the main magnet is regained with time (called T1-relaxation). The protons also start to precess out-of-phase (T2-relaxation) [Fig. 2cii]. T1 and T2 relaxation times depend on the composition of the tissue and also the environment in which the tissue is situated.

When they revert back to their resting state, they emit the extra energy they have gained, in the form of weak RF signals (called echo) which is then received by receiver coils. The signal is finally processed using high speed computers. The emitted signal varies according to the T1 and T2 relaxation times of the tissue.[1]

Images in MRI can be obtained in different ways to bring out the inherent differences in the tissues. Signal intensities on T1W, T2W and proton density-weighted images relate to specific tissue characteristics. Variable image contrast can be achieved by using different pulse sequences and by changing the imaging parameters. A pulse sequence is determined by the specific number, strength and timing of the RF and gradient pulses. The two most important imaging parameters are the repetition time (TR) and the echo time (TE). The TR is the time between consecutive 90° RF pulses. The TE is the time between the initial 90° RF pulse and the time the echo is read.

### Basic Image Sequences

**T1- weighted (T1W) images** – Tissues with shorter T1-relaxation times like fat appear brighter than those with longer T1-relaxation like water/vitreous/CSF.
**T2-weighted (T2W) images** – Tissues with longer T2-relaxation like water/vitreous/CSF, appear brighter than tissues with shorter T2-relaxation like blood products.

**Fluid attenuation inversion recovery (FLAIR)** – signal from fluid can be suppressed using the FLAIR sequence. FLAIR is especially useful in demyelinating conditions where the white matter hyperintensities on T2W images are better appreciated when the bright signal from the adjacent CSF in the ventricles is nulled.

**Proton-density (PD)-weighted images** – The signal is lower where there is less dense packing of protons, like in fluids. This was used in evaluating periventricular white matter pathology, like multiple sclerosis, making use of the contrast between the hyperintense plaques and hypointense CSF. However, now, the FLAIR sequence has largely replaced the PD image in brain imaging.

**Fat-suppressed images** - Bright signal from intraorbital fat can mask the signal and enhancement of pathology. This problem can be overcome by suppressing the signal of fat by special fat suppression sequences. There are different methods of achieving this.[5]

**Postcontrast images** – Gadolinium chelates are paramagnetic and cause shortening of T1-relaxation times, which results in brighter areas on T1W images. Therefore postcontrast images are always obtained with T1 weighting. Gadolinium does not cross the blood brain barrier (BBB) and hence does not cause enhancement in the brain when BBB is intact. When the BBB is disrupted, gadolinium diffuses into the interstitial spaces resulting in their enhancement. The optic nerve does not normally enhance.

**Diffusion-weighted images (DWI)** – Main application of DWI in the brain is to look for acute infarct. When there is cytotoxic edema, the cells swell and there is restriction of diffusion in the extracellular space. This is reflected as bright signal on DWI. Acute infarcts are seen as areas of restricted diffusion (bright signal).

**Heavily T2W images** – This sequence helps in better visualization and tracing the course of the cisternal portions of the cranial nerves (useful in cases of suspected 3rd nerve palsy).

**Magnetic resonance angiography (MRA)**: By using certain techniques, the intracranial vessels and aneurysms alone can be demonstrated after subtracting the images of the brain parenchyma with or without injecting gadolinium.

**Magnetic resonance venography (MRV)**: Similar to MRA, images of the dural venous sinuses can be obtained with or without injecting gadolinium.

### Imaging Protocol

Routine imaging of the orbit should include:
- Thin section (3 mm or less) axial and coronal T2W images of the orbit.
- Thin section fat saturated pre and postgadolinium axial and coronal images.
- The cavernous sinuses should be included in all the sequences.
- Routine imaging of the brain including T2W, FLAIR and T1W imaging.

Additional imaging can be done depending on the clinical situation. For e.g., MRV can be added if venous sinus thrombosis is suspected, MRA if posterior communicating artery aneurysm is suspected.

The specific sequence (T1W/ T2W/ fat suppression, etc) and the need for contrast study is decided by the radiologist. Therefore, it is essential to convey the suspected pathology clearly on the requisition for the MRI.

### Contraindications for Magnetic Resonance Imaging

1. Suspected metallic intraocular foreign bodies: Implants or foreign bodies that are strongly magnetic can move or dislodge.
2. Cardiac pacemaker and implanted cardiac defibrillator: Unexpected programming changes, failure to pace,
heating of the tissue adjacent to the device can occur. Newer MRI compatible ICDs can be used to prevent these complications.\textsuperscript{3}

3. MRI incompatible aneurysm clips: here again, the clips can be dislodged. However, newer aneurysm clips made of titanium are MRI compatible.

4. Implants: Cochlear, otologic, or ear implant.\textsuperscript{4}

5. Lid gold implants\textsuperscript{5} and metallic orbital floor implants\textsuperscript{6} are not contraindications once (few weeks) fibrosis around the implant has occurred.

Electrical voltages and currents can be induced in electrically conductive materials (leads, wires). This might result in heating of this material which can cause injury to human tissue.\textsuperscript{3}

Present data have not conclusively documented any deleterious effects of MRI on the developing fetus.\textsuperscript{11} Intravenous gadolinium is contraindicated during pregnancy and should be used only when absolutely essential.

Gadolinium agents should be used with caution in patients with renal failure due to the recent reports of development of nephrogenic systemic fibrosis in such patients.\textsuperscript{13}

Choice of Imaging (Magnetic Resonance Imaging/Computerized Tomography)

Before going into the interpretation of MRI it is essential to know what imaging has to be requested in a particular clinical situation. In certain situations CT and MRI are complimentary. An understanding of the advantages and disadvantages of MRI and CT\textsuperscript{1} for the suspected pathology is necessary. Table 1 shows some of the commonly encountered clinical situations wherein imaging is needed and the choice of imaging.

Interpreting Magnetic Resonance Images

While interpreting a MRI the following details have to be looked into:

Patient details, identification of right and left sides, imaging plane, sequence, slice thickness and whether contrast (gadolinium) has been used or not. If used, it is important to identify the corresponding pre and postcontrast images to look for enhancement.

Patient details: Age, sex, date of imaging along with the patient’s name/ hospital number is displayed in a corner of the film [Fig. 3].

Laterality: Either the left or the right side is indicated on the image [Fig. 3].

Imaging sequence and slice thickness: Details are displayed in a corner of the image [Fig. 3].

Identifying the Basic Sequences when Viewing the Images

T1W images
Fluids like CSF or vitreous appear hypointense or dark. Grey matter of the brain will be hypointense as compared to white matter (‘grey is grey and white is white’) [Fig. 4].

T2W images
Fluids like vitreous and CSF appear bright. White matter is hypointense compared to grey matter (‘grey is white and white is grey’) [Fig. 5].

FLAIR images
T2 FLAIR – Grey and white matter appearances are similar to T2W. CSF is dark as in T1W images due to suppression or nulling of the high signal intensity of fluid in FLAIR (fluid attenuating) sequence [Fig. 6].

Fat-saturation sequences
Subcutaneous and intraorbital fat produce bright signal [Fig. 7].
| Clinical findings          | Suspected pathology                                                                 | CT/MRI/MRV/MRA                  | Comments                                                                                                                                                                                                 |
|---------------------------|-------------------------------------------------------------------------------------|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Proptosis                 | Suspected Thyroid orbitopathy, Orbital pseudotumor, Orbital cellulitis               | CT / MRI                        | CT is often sufficient. MRI to be considered if orbital apex or cavernous sinus involvement is suspected.                                                                                               |
|                           | Suspected non-vascular orbital space occupying lesion                                 | CT and/or MRI                   | CT may be generally sufficient. CT better suited if calcification, bony erosion or hyperostosis (meningioma) suspected; MRI may be necessary in few cases look for optic nerve involvement and intracranial extension |
|                           | Suspected Arterio-Venous malformations                                               | MRI                             | Doppler study helps to determine high/low flow characteristics.                                                                                                                                       |
|                           | Orbital varix                                                                        | MRI                             | MRI in prone position can show the distensibility of the varix.                                                                                                                                     |
|                           | Carotico-cavernous fistula                                                           | MRI or MRA with MRA             | Doppler study of superior ophthalmic vein can also help.                                                                                                                                             |
|                           | Orbital Cysticercosis                                                               | Ultrasound/CT/MRI               | Scolex seen on ultrasound/CT/MRI. MRI better suited for diagnosis during various stages of evolution; However CT picks up calcification better.*                                         |
|                           | Retinoblastoma                                                                      | Diagnostic purpose              | Detection of calcification is better on CT than MRI.                                                                                                                                                 |
|                           | To look for extent of optic nerve involvement/intracranial spread                     | MRI                             | Better evaluation of the soft tissue involvement and for trilateral retinoblastoma (pinealoblastoma)                                                                                                  |
| Dermoid cyst              | Bone erosion                                                                        | CT MRI                          | CT picks up bone erosion better. But, MRI can help in delineating the intracranial extension.                                                                                                        |
| Traumatic optic neuropathy| Fracture of optic canal / bone fragment impinging optic nerve                         | CT                              | Bony fragment better delineated on CT.                                                                                                                                                                 |
| Optic atrophy             | Pituitary tumors / any compressive lesion along visual pathway                       | MRI                             | Intra-cranial and intra-canicular portions of optic nerve better assessed on MRI                                                                                                                      |
| Papilloedema (B/L disc oedema) | Intracranial space occupying lesion or Benign intracranial hypertension               | MRI with MRV                    | To look for dural venous sinus thrombosis or stenosis causing raised intracranial tension.                                                                                                            |
| Optic neuritis (U/L disc oedema) | Demyelination / Intracranial space occupying lesion                                   | MRI                             | MRI is the imaging of choice to look for associated white matter abnormality and also to assess the optic nerves. Useful sequences: FLAIR, STIR, Fat- suppressed, contrast enhanced |
| Isolated 3rd nerve palsy  | Posterior communicating artery (PCA) aneurysm                                        | MRI with MRA/CTA                 | Both MRA and CTA have similar sensitivity (98%) to detect PCA aneurysms. MRA has slightly lower sensitivity for aneurysms less than 5mm in size. Catheter angiography remains the gold standard. |
| Multiple cranial nerve palsies | Cavum sinus lesion / Basal meningitis                                                 | MRI                             | Optic nerve and cavernous sinus better studied on MRI. Heavily T2W images—to depict intracranial course of the nerves. Plain and post contrast fat saturated thin sections through the cavernous sinuses |
| Penetrating trauma        | Suspected intraocular / orbital foreign body(FB)                                     | CT                              | MRI contraindicated if metallic FB is suspected or if nature of FB is unknown. However MRI better suited for wooden foreign bodies compared to CT. |
| Unexplained decreased visual acuity | Pituitary pathology Cortical blindness                                                | MRI                             | To look for any space occupying lesions or white matter lesions.                                                                                                                                     |

*Clinical Radiology 2003;58(2):154-156, †Radiology 2001;219:739-749, ‡AJNR Am J Neuroradiol 2002;23:1187-1198, §Orbit 2008;27(2):131-3.

in T1W images. Nulling of the signal produced by the fat can be appreciated in fat suppressed sequences [Fig. 8].

**Contrast-enhancement**

Bright signal from fat can mask the enhancement of pathology on nonfat suppressed post contrast T1W images [Fig. 9]. Hence postcontrast images with fat suppression are required to study pathology better [Fig. 10].

**Imaging Plane**

Routinely, axial and coronal images are obtained. From sagittal
Figure 3: T2W axial section of the orbit. Patient details and date of scan are encircled in the top right-hand corner. The side marked LPF represents the left and the unmarked side denotes the right side. Imaging sequence and slice thickness is displayed as marked within the square box at the bottom left hand corner.

Figure 4: T1W axial section of orbit and brain. Vitreous and CSF in subarachnoid space and ventricles are hypointense (arrow heads). Grey matter (single arrow) is hypointense as compared to white matter (double arrows). Intraorbital and subcutaneous fat are of high signal intensity (curved arrow).

Figure 5: T2W axial section of the orbit and brain. Vitreous and CSF in subarachnoid space and ventricles are hyperintense (arrow heads). Grey matter (single arrow) is hyperintense as compared to white matter (double arrows). Intraorbital and subcutaneous fat are of intermediate signal intensity of (curved arrows).

Figure 6: T2W/FLAIR axial section of the orbit and brain. Vitreous and CSF in subarachnoid space and ventricles are hypointense (arrow heads). Grey matter (single arrow) is hyperintense as compared to white matter (double arrows).

Figure 7: T1W axial image of the orbit showing bright signal of the intraorbital (arrows) and subcutaneous fat (arrow head).

Figure 8: T1W fat-suppressed axial image of the orbit showing nulling of the signal from the intraorbital and subcutaneous fat (arrows).
localizer images, axial sections are planned parallel to the optic nerve and coronal sections, perpendicular to the axial plane [Fig. 11].

The axial section showing both medial and lateral recti and the optic nerve denotes the plane of midorbit [Fig. 12]. The medial and lateral recti, optic nerve are seen in their entire extent on the axial sections. Extent of lesions superiorly/inferiorly can be assessed in relation to this plane. The globe and lens [Fig. 12] are also well demonstrated. Superior ophthalmic vein and lacrimal glands are important structures that have to be identified in the more superior sections [Fig. 13]. Lacrimal gland is located in the superolateral aspect of the orbit and appears isointense to grey matter on both T1W and T2W images. On fat-suppressed images, it appears bright against the hypointensity of the suppressed fat and shows good enhancement postgadolinium [Fig. 10]. In the sections through the inferior orbit, the inferior rectus, ethmoid, sphenoid and cavernous sinus are to be identified [Fig. 14].

On serially viewing the coronal sections from anterior to posterior, the eyelids are initially seen followed by the globe with anterior chamber and lens [Fig. 15]. The extraocular muscles (EOM) can be seen in cross-section [Fig. 16] anteriorly from their insertion to the globe up to their origin at the orbital apex. The retrobulbar space, optic nerve as well as the EOM are seen in the sections passing through the posterior orbit [Fig. 17]. Superior oblique [Fig. 17] and inferior oblique [Fig. 15] muscles are better demonstrated on the coronal images.

Sagittal imaging can also be done when required, to assess relationship of any lesion to the adjacent structures.

Tilting of the head during positioning for MRI causes asymmetric appearances of the two orbits. This has to be kept in mind during interpretation.

**Normal Anatomy of the Orbit**

MRI is best suited to study the soft tissues of the orbit. The
Figure 13: T2W axial section through the superior orbit showing the superior ophthalmic vein (arrow head), superior rectus (double arrows). In the same section, lacrimal glands (single arrows) are well seen.

Figure 14: T2W axial section through the inferior orbit showing the inferior rectus (arrow head), inferior portion of the globe (G), ethmoid air cells (E), sphenoid sinus (S), cavernous sinus (white outlines 1 and 2) and flow void of internal carotid artery (arrow).

Figure 15: T2W coronal section through the anterior orbit showing the globe (single arrow), lens (arrow head) and the inferior oblique (double arrow).

Figure 16: T2W coronal section through the globe showing the vitreous (V), lacrimal gland (L), medial rectus (arrow head), inferior rectus (single arrow) and superior rectus (double arrow).

Figure 17: T2W coronal section posterior to the globe showing the intraconal space (within the circle 1), optic nerve (*), inferior rectus (short single arrow), medial rectus (arrow head), superior oblique (double arrow heads), superior rectus (double arrow), superior ophthalmic vein (long white arrow), lateral rectus (LR), T-turbinates and sinuses (E-ethmoid, M-maxillary).

Figure 18: (a) T2W axial and post contrast fat suppressed axial images showing intraocular tumor – retinoblastoma (white arrow heads), with extension along the optic nerve (white arrow). (b) T2W coronal and post contrast fat suppressed axial images showing intraconal mass with enhancement (cavernous hemangioma). Asterix and arrow heads show the lesion.
signal intensities, enhancement and other features like regular borders and homogenous appearance of the normal EOM and retrobulbar fat help in identifying the normal and abnormal structures. There are guidelines and measurements of normal EOM as well as optic nerve and superior ophthalmic vein. These measurements are useful in conditions with bilateral affection as in thyroid ophthalmopathy. But in general, it is best to compare the abnormal side with the normal side with respect to size, borders, regularity, homogeneity and enhancement characteristics. Comparison along serial sections is needed to get an overall picture as head tilt may cause an apparent asymmetry. Table 3 shows the signal characteristics of normal ocular structures in different imaging sequences.

When dealing with orbital pathology, it is important to actively look for the surgical space of the orbit that the lesion occupies – whether preseptal, postseptal, intraconal, extraconal or subperiosteal. Correlating the location of the pathology on serial images of coronal and axial sections in relationship to the extraocular muscles and the bony orbit, is essential in determining the surgical space that the pathology is located in as well as its extent and relationship with surrounding structures [Figs. 18, 19]. This helps in formulating a reasonable differential diagnoses and appropriate management including deciding the surgical approach.

Although the ophthalmologist's area of interest is mainly the orbit and optic nerve up to its intracranial portion, it is important to know the MRI appearance of the optic chiasm [Fig. 20], pituitary gland, carotids, cavernous sinuses and the paranasal sinuses [Figs. 14, 17].

Normal anterior pituitary is isointense to grey matter and posterior pituitary or neurohypophysis is seen as a bright focus on T1W images (best seen in T1W sagittal images) [Fig. 21]. Normal pituitary gland varies in size with the age of the patient and is best seen on thin section, small field of view (FOV) T1W and T2W sagittal and coronal images [Fig. 22]. The high signal intensity of posterior pituitary is due to the neurosecretory granules. The pituitary stalk is seen extending from the hypothalamus to the anterior third of the pituitary gland. It is oriented obliquely on the sagittal images and is usually in the midline on the coronal images [Fig. 21]. As the pituitary lacks BBB, normal pituitary and stalk enhance brightly [Fig. 23].

The internal carotid artery (ICA) [Fig. 14] including its bifurcation into anterior cerebral artery (ACA) and middle cerebral artery (MCA) are seen well [Figs. 22, 23] on the coronal images at the level of the pituitary gland and cavernous sinuses. The cavernous sinus is best depicted on coronal T2W and T1W images after administration of gadolinium. Cavernous sinuses are located laterally on each side of the sella [Fig. 14], inclusive of the internal carotid arteries (ICA), cranial nerves III, IV, V1, V2, VI. The dural wall is seen as a thin hypointense line on the lateral aspect. On T2W images, the cavernous sinuses appear hypointense due to the flow voids in the ICAs [Fig. 14]. On postgadolinium images, the ICAs and cavernous sinuses,

### Table 3: Signal characteristics of normal ocular structures in different imaging sequences

| Ocular structure                                      | Signal intensity on T1-weighted images* | Signal intensity on T2-weighted images* | Enhancement on postcontrast images* | Additional comments                                      |
|--------------------------------------------------------|----------------------------------------|----------------------------------------|-----------------------------------|----------------------------------------------------------|
| Sclera, choroid, retina (seen as a single coat)        | Hyperintense (bright/white)            | Hypointense (Dark/black)               | Nil                               | The three coats cannot be distinguished separately on routine imaging |
| Aqueous                                                | Hypointense (dark/black)               | Hyperintense (bright/white)            | Nil                               |                                                          |
| Lens                                                   | Hyperintense (bright/white)            | Low (grey)                             | Nil                               | Normal biconvex appearance                                |
| Vitreous                                                | Hypointense (dark/black)               | Hyperintense (bright/white)            | Nil                               |                                                          |
| Extraocular muscles (EOM)                             | Intermediate (grey)                    | Intermediate (grey)                    | Enhance brightly                   |                                                          |
| Orbital fat                                            | Hyperintense (bright/white)            | Intermediate (grey)                    | Nil                               | Normally homogenous appearance                            |
| Optic nerve                                            | Isointense to cerebral white matter (grey) | Isointense to cerebral white matter (grey) | Should not enhance normally. It can be compared to the EOM. |
| Optic nerve sheath with CSF around the optic nerve     | Hypointense (dark/black)               | Hyperintense (bright/white)            | Nil                               |                                                          |
| Lacrimal gland                                         | Isointense with grey matter (grey)     | Isointense with grey matter (grey)     | Enhances brightly                  |                                                          |
| Bone                                                   | Signal void (dark)                     | Signal void (dark)                     | Nil                               | Better studied on CT                                       |
| CSF                                                    | Hypointense (dark/black)               | Hyperintense (bright/white)            | Nil                               |                                                          |

*All descriptions of signal intensity (hypo/hyper) are made in comparison with the reference tissue. Intracranially, the reference tissue is the grey matter of the brain and extracranially the skeletal muscles.
Figure 19: (a) T2W and postcontrast fat suppressed coronal images showing extraconal enhancing masses-leukemic deposits. White arrows and arrow heads show the lesion. (b) T2 and post contrast T1W axial images showing subperiosteal abscess. Arrow, arrow head and asterix show the lesion.

Figure 20: T2W axial section with fat suppression showing the optic chiasm (white long arrows). The optic nerve (double arrows) with CSF in the optic nerve sheath (arrow head) giving a bright signal on T2 similar to the vitreous.

Figure 21: T1W midline sagittal section showing showing the optic chiasm (single arrow), pituitary infundibulum (single arrow head) and pituitary gland (multiple arrow heads).

Figure 22: T1W coronal section at the level of the pituitary showing optic chiasm (short arrows), pituitary infundibulum (single arrow-head), pituitary gland (multiple arrow-heads), ICA in the cavernous sinus (long arrows). The circled area shows the bifurcation of right ICA into ACA and MCA.

Figure 23: T1W postcontrast coronal image through the pituitary showing optic chiasm (short arrows), pituitary infundibulum (single arrow head), pituitary gland (multiple arrow heads) and ICA (long arrow) in the cavernous sinus (white outline 1). The circled area 2 shows the bifurcation of right ICA into MCA and ACA.

except the cranial nerves show bright contrast enhancement [Fig. 23]. The cranial nerves in the cavernous sinuses can be identified only when high-resolution imaging is done. Usually, the lateral margins of the cavernous sinuses are concave or flat and they are nearly symmetrical. Any convexity or bulging of the margins, asymmetry and heterogenous enhancement should raise suspicion of pathology.

Conclusions

In conclusion, we hope that at the end of reading this article, the reader is able to develop a systematic approach in interpreting MRI images and feels comfortable in looking at the various imaging sequences and the varied appearance of the normal ocular structures in these sequences. We would also wish to emphasize the need to provide details of relevant clinical data and suspected lesion to the radiologist so that the appropriate MRI imaging sequences can be obtained. The ophthalmologist
is best suited to correlate the imaging findings with the clinical data and arrive at the most likely diagnosis.

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