



# Current Role of Fetal Magnetic Resonance Imaging in Neurologic Anomalies

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Magnetic resonance imaging (MRI) is used increasingly to image the fetus when important questions remain unanswered after ultrasonography, which might occur particularly with abnormal amniotic fluid volumes, difficult fetal lie or position, and maternal obesity. Ultrasonography also has limitations due to sound attenuation by bone, such as within the cranium and spine, and therefore MRI has a real advantage in delineating potentially complex neuroanatomical relationships. This article outlines current MRI protocols for evaluation of the fetal neural axis, describes indications for the use of MRI in the fetal brain and spine, and provides examples to illustrate the uses of available fetal sequences.

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## Introduction

Magnetic resonance imaging (MRI) is being increasingly used to image the fetal central nervous system, either when there is increased risk for neurodevelopmental disabilities or when an abnormality is detected on antenatal ultrasound (US). The literature to date has demonstrated that fetal MRI demonstrates abnormalities not apparent on antenatal US in approximately 20% of cases.<sup>1</sup> More importantly, the identification of abnormalities by fetal MRI can influence clinical decision making regarding management of pregnancy, in utero therapy, and birth plan.

This article briefly reviews routine sequences used to evaluate the fetal central nervous system, as well as additional sequences that can be useful in specific settings. We then discuss the normal developmental anatomy of the fetus, neuroanatomical indications for fetal MRI, and differential diagnosis, illustrating the role of fetal MRI with several case examples.

At our institution, routine fetal evaluations of the neural axis include T2-weighted single shot fast spin echo sequences with interleaved 3-5-mm slices in axial, sagittal, and coronal planes; gradient echo T1-weighted, and T2-weighted echoplanar imaging (EPI), of the brain with 3-5-mm slice thickness in

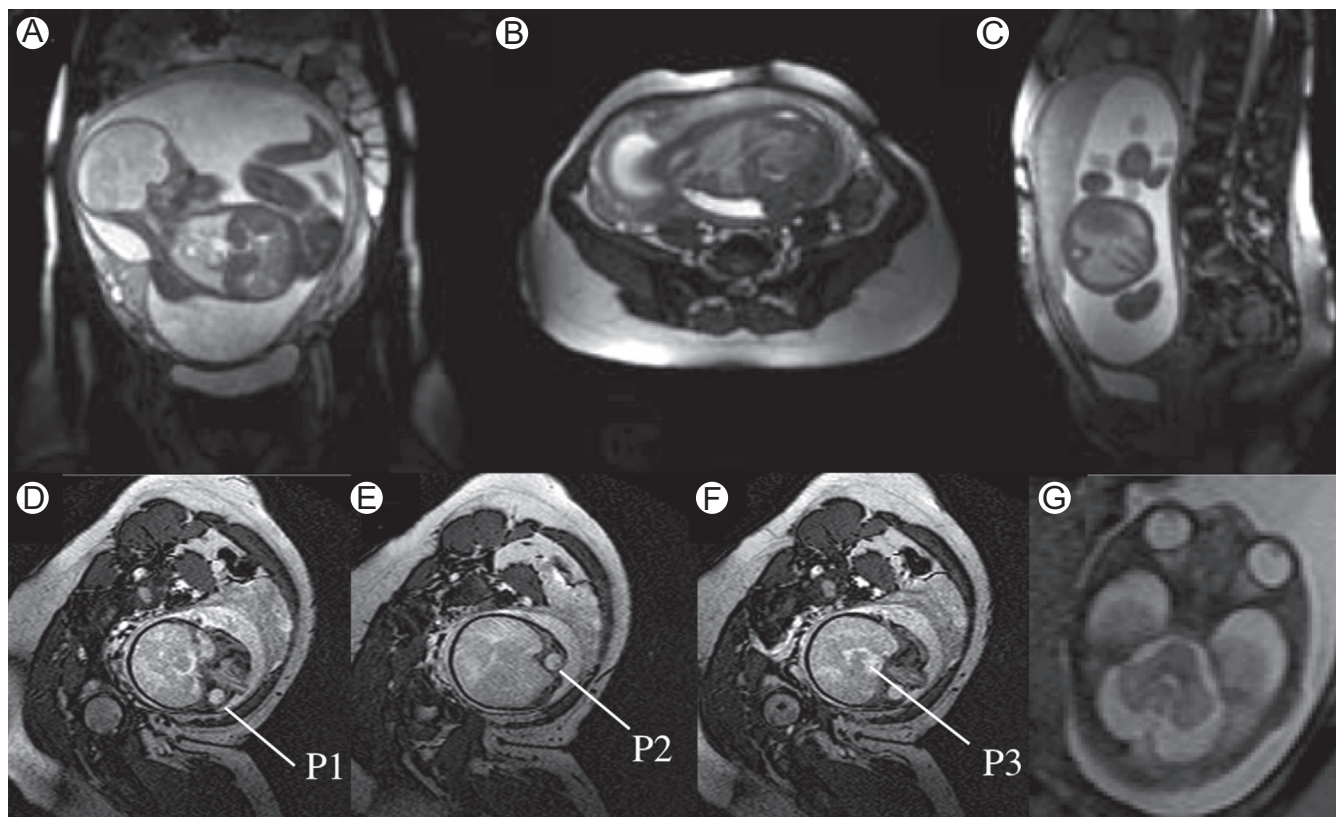
the axial plane; diffusion-weighted imaging (DWI) and apparent diffusion coefficient axial images of the brain with interleaved 4-5-mm slices; sagittal steady state free precession of the brain and axial, sagittal, and coronal planes through the spine with interleaved 3-5-mm slices. These sequences are acquired after localizer images have identified 3 anatomical points in the fetus from which to create standardized anatomical planes (Fig. 1). Axial T1-weighted images are primarily used to evaluate high-signal blood products and fat if applicable. EPI adds sensitivity for hemorrhage. Advanced techniques such as MR diffusion tensor imaging and MR spectroscopy are primarily research tools at present.

There is an increasing trend toward imaging the fetus at 3 T in many institutions. It has been demonstrated that the added signal returned from a 3-T magnet allows improved tissue discrimination for imaging of the brain, musculoskeletal system, and abdomen compared with a 1.5-T magnet.<sup>2-4</sup> The quest for better anatomical evaluation of the fetus, in particular the developing fetal brain, has led to increasing use of 3-T magnets for fetal imaging.<sup>5</sup> However, it is not clear that the potential increased detection rate of subtle malformations adds incremental value. Questions also remain regarding largely theoretical injury to the fetus at higher field strength. Although there is little direct evidence of harm from short-term exposure to high magnetic fields, there is concern that increased energy deposition from excitation and refocusing of radiofrequency pulses results in an excessive heating effect, which could potentially damage fetal tissue. The United States Food and Drug Administration sets a 4 W/kg specific absorption rate (SAR) limit for the maternal

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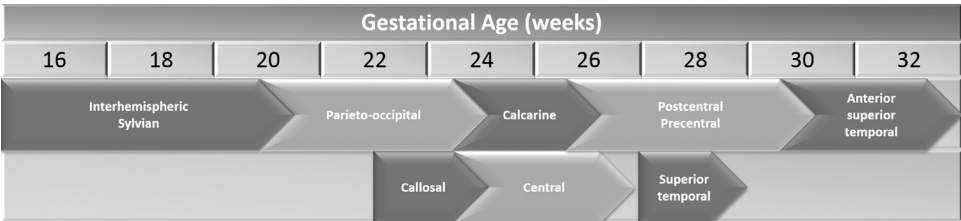
**Figure 1** Localizer imaging with scan plane planning. GRE coronal (A), axial (B), and sagittal (C) localizers. Positioning of 3 points in space to create an axial plane of the head using the lenses (D and E) and pons (F) results in a true axial if there is no interval fetal motion (G). GRE, gradient refocused echo.

whole body. It is difficult to predict local SAR values, however, and it is known that heating effects are greater away from the center of the body, so effects may be exacerbated depending on fetal lie or gestational age.<sup>6</sup> No one knows an appropriate SAR limit for a fetus. Furthermore, although 3-T imaging has the potential to provide better anatomical delineation, many artifacts that can significantly degrade imaging are exaggerated.<sup>5</sup>

MRI Evaluation of the Normal Fetal Brain

Given that fetal MRI is essentially analogous to imaging embryology, it is critical to understand the normal development and appearance of the brain during gestation. Specifically, dating of the brain can be determined by the appearance of the germinal matrix, the brain parenchyma, and the

sulcation pattern. The fetal neurons develop from the germinal matrix, a cell-dense layer that lies immediately adjacent to the ventricular walls. This high neuronal density produces low signal on T2 and higher signal on T1-weighted imaging. The adjacent fetal white matter demonstrates opposite signal characteristics (high T2 and lower T1 signal) because of its high water content and lack of myelination. Neurons from the germinal matrix migrate from the ventricular wall to the surface of the brain during the second trimester. The visualization of the interpositioned migrating cells produces a 5-layered appearance between 20-28 weeks gestation.<sup>7</sup> The germinal matrix regresses in the third trimester, persisting in the roof of the temporal horns and the lateral walls of the occipital horns until 33 weeks gestation, and in the caudothalamic groove for several months postnatally. Brain sulcation also follows a predictable pattern and is a measure of fetal maturity (Fig. 2). A delay in sulcation is suspicious for underlying



**Figure 2** Gyral maturation. Timeline of sulcation of the normal fetal brain.

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