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Seminars in
ROENTGENOLOGY

Fetal Magnetic Resonance Imaging

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Prenatal fetal screening and diagnostics is considered to be a matter of course for expecting mothers. Next to the routine evaluation of the fetal position, fetal size, heart rhythm, and numerous serological as well as hematological blood tests, an exact evaluation of the fetal anatomy became part of the standard prenatal diagnostic workup.

Historically, many different approaches and diagnostic techniques have been used to image the unborn fetus:

- Initially plain radiography of the maternal abdomen was used to study the fetus (Fig. 1). This technique allowed only evaluation of the fetal skeleton and fetal position in the uterus, and the use of ionizing radiation (X-rays) bears a significant risk to the developing fetus. Presently, conventional radiography or fetography is only used for a very limited number of indications, eg, lethal bone dysplasias.
- Amniography was one of the first imaging modalities that allowed direct intrauterine visualization of the soft-tissue contours of the fetus. This effect was achieved by injecting radio-opaque contrast into the amniotic cavity followed by abdominal radiographs. The contrast outlined the fetal contours and consequently allowed study of fetal soft-tissue lesions, eg, myelomeningoceles. Amniography was quickly abandoned because of its invasive character in combination with the possible deleterious effects of X-rays to the fetus.
- The development of ultrasonography (US) in the early 1970s revolutionized prenatal diagnostics. For the first time, it was possible to study the fetus in high anatomical detail without any potential side effects of X-rays. In addition, the real-time characteristics of US allowed study of dynamic functions of the fetus such as fetal cardiac activity, fetal blood flow, fetal swallowing, or fetal motion in general. In addition, US is low cost, is widely available, can be performed bedside, is well accepted by the expecting parents, and can be used to guide amniocentesis. With the continuous development of US hardware and software, US became the number one imaging modality for the diagnostic screening and workup of pregnancies.

Prenatal diagnosis of a possible fetal pathology by US, a positive family history of inherited disorders, or a younger sibling with a malformation may require additional alternative diagnostics to either confirm, correct, or precisely specify diagnosis. Amniocentesis or chorionic villus biopsy allows screening for many genetic disorders and metabolic diseases. Unfortunately not all congenital disorders can be detected by chromosomal analysis. The need for an additional, more precise, and/or specific imaging modality is obvious. This is especially evident for pathologies of the central nervous system (CNS). The fetal skull prevents a detailed evaluation of the complex neuronal migration, cortical organization, and progressing white matter myelination. Complex three-dimensional pathologies of the respiratory, gastrointestinal, and urogenital system may also require additional diagnostic workup or confirmation to counsel pregnancy, plan delivery, optimize pre-, peri-, and postnatal care and to counsel the parents for future pregnancies. The small field-of-view of US does not allow imaging the fetus in one single view later in pregnancy. This makes the identification of multilevel, complex pathologies or malformations of the chest and abdomen difficult. Intrauterine "fetal respiration" limits or may even prevent exact organ delineation with US. This may be especially cumbersome in complex fetal malformations or pathologies. Finally, fetal US is highly operator dependent. These limitations require an alternative imaging modality.

Magnetic resonance imaging (MRI) is especially well suited to serve as secondary imaging modality to examine the fetus intrauterine. MRI does not use ionizing radiation, has a high spatial and contrast resolution, and may generate different image contrasts (T1- and T2-weighted imaging). Fetal functional and dynamic information is supplied by a variety of functional sequences, and complex, multi-organ, multilevel fetal pathologies can easily be examined due to the large field-of-view and multiple imaging planes. In addition, information can be collected about fetal position, anatomy of the umbilical cord, amount of amniotic fluid, maternal uterus, ovaries, and birth canal.[1-5] Initially, long acquisition times of

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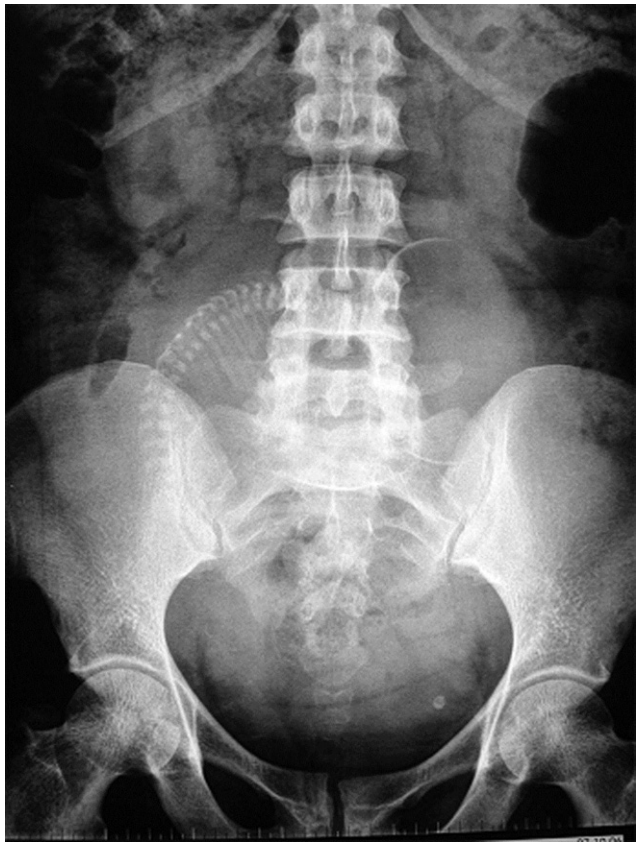

Figure 1 Plain radiography of the abdomen or fetography. The ossified fetal skeleton is depicted: the fetal spine is seen located to the right, the fetal skull is to the left.

MRI prevented adequate imaging of the moving fetus intrauterine (Fig. 2A). With the development of ultrafast MRI sequences, it became possible to examine the fetus intrauterine without the need for fetal sedation (Fig. 2B). In the past decade, MRI has become an important second line imaging tool to image the fetus intrauterine. High-resolution anatomical imaging can be combined with a variety of functional sequences including diffusion-weighted imaging, ^{1}H-magnetic resonance spectroscopy, and functional MRI.[4,6-10] Fetal MRI is used to confirm, complete, or correct findings seen on prenatal ultrasound.

Currently, fetal MRI is a widely accepted second line imaging modality in the examination of normal and pathological development of the fetal CNS.[1-5,7,8,11-13] The detailed information rendered by fetal MRI frequently allows an early identification of complex lesions.[14] With better coil designs and pulse sequences, fetal MRI is also extending into the field of pathologies involving the chest and abdomen.[15,16]

In the current review, we discuss how to perform fetal MRI, give practical tips and tricks, present the normal and pathological anatomy, list the most frequent indications for fetal MRI, summarize pitfalls, and briefly touch the future perspectives of fetal MRI.

How to Perform Fetal MRI

Preparation and Positioning

The pregnant mother and her partner should be extensively informed about the details of the fetal MRI examination including how it is performed, why it is done, and what the possible side effects can be. In addition, in our experience it is extremely advantageous to inform the pregnant mother and her partner in advance that the results of the fetal MRI will not be communicated to them by the radiologist after the completion of the fetal MRI examination. The MRI findings should be evaluated in conjunction with the other available prenatal diagnostics (US, chromosomal analysis), preferably in the setting of an interdisciplinary meeting. This meeting should involve pediatric radiologists, obstetricians, neonatologists, pediatricians, and additional experts such as pediatric

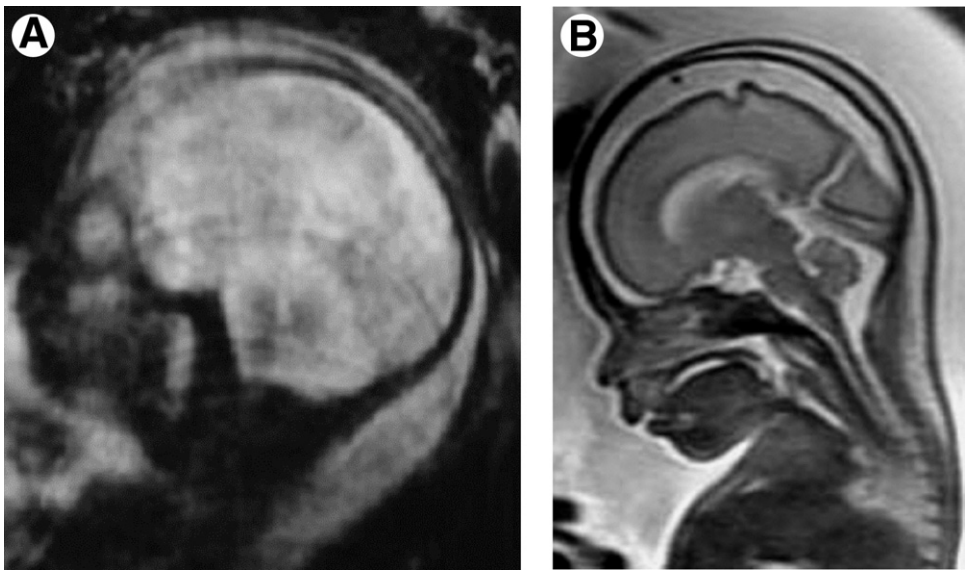

Figure 2 (A) Sagittal T2-weighted fast-spin echo MRI. The long acquisition time and fetal motion result in a blurred image of the fetal brain. (B) Ultrafast T2-weighted SSFSE enables a "picture freeze" of the fetus. The anatomy of the fetal brain is well displayed.