Technical advances in MRI of non-CNS fetal structures

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1. Introduction

US is the modality of choice for routine fetal screening. Fast single-shot MR sequences have proved to be an useful imaging method in evaluating equivocal sonographic findings or assessing fetus with suspected anomaly which requires further clarification for management [1-3]. Most studies used T2-weighted sequences such as Half-Fourier single-shot turbo spin echo (HASTE, SSFSE) or fast-field echo (true-FISP, balanced FFE) [4-7]. More recently, some advanced sequences have been proposed such as diffusion-weighted MRI, real-time (cine 2D) sequences or spectroscopy [8-14]

2. Techniques for fetal thoraco-abdominal MRI

The women are positioned in supine position or on the left side to improve their comfort during examination. A combination of phased-array coils is used with 4 anterior elements placed transversally and 4 posterior (spinal) elements.
The basic MRI protocol consisted of T2-weighted sequence following the 3 planes of the fetal body (HASTE (Half Fourier Acquisition Single Shot Turbo Spin Echo) and/or True-FISP (Fast Imaging with Steady Precession, bFFE, bTFE)) associated with T1-weighted fast gradient echo (FLASH 2D) sequence in the coronal and sagittal planes. All sequences are performed with a breath hold technique. The entire examination time do not exceed 20 minutes.
Additional sequences like diffusion-weighted MRI, hydrography or spectro-MRI sequences are used in some indications (cf. infra).

3. Fetal hydrography [15,16]

The basic property of the single-shot RARE (Rapid Acquisition with Relaxation Enhancement) sequence is the fast acquisition of fluid-selective images as either a projection image or a slice depending on the thickness of the acquired slab. A single-shot RARE sequence using a thick slab projection for image acquisition offers one projection image after positioning a slab for the volume of interest. Like the multislice HASTE sequence, the single-shot RARE sequence uses one excitation pulse with multiple refocusing pulses. The thick slab RARE sequence is used for MR cholangiopancreatography or MR urography. MR hydrography is characterized by the visualization of slowly flowing or stationary fluids in high-signal-density bright structures, against a dark background with a very low signal density. The resulting images consist almost entirely of fluid-containing structures, i.e. esophagus, stomach, small bowel, gallbladder, bladder and urinary tract if dilated, oro-tracheo-bronchial tree and cystic lesions, presented very clearly as white on black. Using a single thick slice protocol, this 2D method gives excellent information on the global relationship between high water containing lesions and other anatomical structures.

Compared to thin multislice HASTE sequence, the thick slab RARE sequence does not show additional abnormalities but displays an overall estimation of the tracheobronchial tract, the upper GI tract and the urinary tract. Moreover, thick slab RARE images are highly correlated with post natal imaging such as thoraco-abdominal plain films and cystography. The thick slab RARE sequence is very fast (less than 5 seconds) and may therefore be repeated several times in a row to avoid motion artifact.

4. Diffusion-weighted MRI

Diffusion-weighted magnetic resonance imaging (DW-MRI) is used to show molecular diffusion, i.e. the brownian motion of the spins in biologic tissues. The apparent diffusion coefficient (ADC) is calculated from DW-MR images and this quantitative parameter combines the effects of capillary perfusion and water diffusion in the extracellular extravascular space. DW-MRI has proved to be a useful tool for the evaluation of brain lesions such as in acute strokes, and the technique is now being applied to other organs,
including the kidneys. The diffusion characteristics of the kidney may provide information on the mechanism of various diseases studied on adults and animals. DW-MRI sequence is a spin echo echo-planar imaging (SE EPI) single shot sequence. The diffusion gradient b values were applied in three orthogonal directions to minimize the effects of diffusion anisotropy. This sequence was performed with a free breathing technique. Recently, normal values of fetal brain ADC [17], fetal kidney ADC [10,13,18] and normal values of pediatric kidneys ADC have been reported [19]. Few publications have depicted fetal lung diffusion [11,12]. Evaluation of the ADC value of fetal kidneys is feasible and, in addition to morphological exploration, may be a non-invasive means with which to further explore the fetal kidney. These is a the large variability of ADC values at each gestational age. The correlation between ADC values (lung and/or kidney) and gestational age is controversial.

5. **Real-time (cine 2D) sequences**

Improvement of parallel data acquisition has reduced MR scanning time and allows real-time MRI (cine 2D mode) [14]. This technique using steady-state acquisition (2D FIESTA, cine true-FISP) may be interesting in fetal cardiac pathologies and is already used to explore esophagus or bowel peristaltism.

6. **Spectro-MR**

Monovoxel proton spectroscopy can also be performed in utero but this technique, used for lung, liver or amniotic fluid analysis, is not yet employed in a routine clinical protocol [8,9,20].

7. **Indications of fetal non-CNS MR examinations**

Fetal MRI is useful in all thoracic abnormalities and can clearly demonstrate the anatomical relationship between the lesion and adjacent organs. Fetal MRI allows correct diagnosis of congenital diaphragmatic hernia and evaluation of the consequences on pulmonary growth. Other pulmonary malformations, such as cystic adenomatoid malformation, sequestration and bronchogenic cysts, can also be easily identified. Pulmonary maturation is more difficult to appreciate but some advances with functional sequences (diffusion-weighted sequence and
spectroscopy) seem to be interesting [8,9,20-23]. Fetal cardiac MRI is being used in research protocols and is not yet employed in a routine clinical approach [24]. Real-time (cine 2D) sequences are going to be available in such indications [14].

Fetal MR imaging can accurately diagnose a wide variety of urinary tract disorders and must be seen as a valuable complementary tool to ultrasound in the assessment of the urinary system, particularly in cases of inconclusive ultrasound findings [4,7]. Complementary to ultrasonography, prenatal MRI can help further characterize bowel obstruction, abdominal mass and genital abnormalities [25].

Postmortem magnetic resonance imaging (MRI) may be an alternative to conventional fetal autopsy [26].

8. Conclusion

Fetal MRI in non-CNS structures can be an helpful complement to US, especially in thoracic pathologies. Technical advances, such as diffusion, spectroscopy, real-time sequences are interesting ways of research.

References


