Fiber tracking performed in the fetal brain

Medical University of Vienna realizes advanced in utero fiber tracking
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The Medical University of Vienna (Austria) established its fetal MRI program in 1998 under the direction of Daniela Prayer, MD, now the head of its neuroradiology program. Collaborating with obstetricians all over Austria, the University has gained in both referrals and expertise, and now routinely performs fetal MR exams. Many of these include fiber tracking studies, according to Dr. Kasprian.
Gregor Kasprian, MD, department of Neuro and Musculoskeletal Radiology, says fiber tracking uses Diffusion Tensor Imaging (DTI) to measure the degree and directionality of water motion in certain tissue.

“The main difference in the fetal brain,” he says, “is that there is little or no myelin in most of the brain regions. We adapt our DTI sequence for the fetal brain and the unmyelinated tissue.”

Fetal fiber tracking yields valuable information
There are three types of cases in which fiber tracking is very useful, says Dr. Kasprian. One is so-called clastic lesions, such as acquired fetal brain lesions, infarction and parenchymal defects. “By characterizing the connections and trajectories of these structures, we can tell what functional deficits might be expected.”

“The second type of case is structural brain malformations, such as in fetuses where the corpus callosum is missing,” he says. “We can now visualize abnormally oriented fiber tracks, which helps us to further discriminate different types of brain malformations and give a more specific diagnosis.”

The last group is metabolic diseases. The mother usually compensates for these, but conditions such as white matter disorders may manifest in utero. “With this technique we can quantify the diffusion in the fetal brain, and decide whether it might be an issue of maturation, or whether it is abnormal,” Dr. Kasprian explains.

**In utero DTI of lobar holoprosencephaly**
After sonographic suspicion of a major fetal brain malformation, a young pregnant woman was referred for a fetal MRI exam at 33 gestational weeks. The figures show different commissural and projection pathways in a fetal brain with holoprosencephaly. The tractography results are projected onto coregistered axial T2 TSE images. Note the prominent anterior commissure (pink), the partially developed hippocampal commissure (blue), the corticospinal tracts (green) and frontopontine trajectories (yellow). DTI and tractography offer new insights into the connectivity of the malformed fetal brain in utero and in vivo, which will further help to characterize these pathologies in a more specific way.

The fetal MR exam was done on Intera 1.5T with the mother in supine position and using the 5-element SENSE Cardiac coil. The dedicated fetal neuroimaging exam includes multiplanar orthogonal T2-weighted scans and axial DTI with 16 encoding directions, b-values 0 and 700 s/mm², reconstructed voxel size 0.94 x 0.94 x 3 mm, acquired in 1:50 min.
Motion challenges can be overcome
The main challenge in fetal fiber tracking is motion, both fetal and maternal. Dr. Kasprian’s sequence takes about 90 seconds, and he generally doesn’t use sedation. “It helps if the head of the fetus is already in the lower pelvis, so motion is limited. If the head is in breech position, it is below the mother’s diaphragm and moves with the mother’s breathing.”

His approach is to limit acquisition time. “We use a DTI sequence with 16 gradient encoding directions, and a reconstructed voxel size of 0.94 x 0.94 x 3 mm,” he explains. “By using an asymmetric voxel size, acquired in an axial plane, we reduce the imaging time. We also use SENSE imaging, which contributes to a shorter acquisition time, and is very worthwhile in this technique.”

The results are well worth the extra efforts. “Fiber tracking gives us information we cannot get with any other imaging technique,” says Dr. Kasprian.

Dr. Kasprian uses Philips Achieva 1.5T with release 2.5 software and the 5-channel SENSE Cardiac coil. “We are really happy with the Philips system; it’s very user-friendly,” he says. “We can look at the very small structures of the fetal brain on the huge flat screen color monitor. So far, the most beautiful in utero DTI images that I’ve seen have come from Philips scanners.”

References
G Kasprian, G Amann, J Panotopoulos, F M Kainberger, D Prayer, I M Noebauer RSNA 2010, trainee research prize winner

In utero DTI of fetal intracranial tumor
After sonographic suspicion of a large fetal intracranial hemorrhage, a fetal MR imaging examination was planned at 27 gestational weeks (GW). The figures show the 3D tractography results coregistered with a T2-weighted sequence. The bilateral sensorimotor tracts (green) are severely displaced by the the giant intracranial mass. The corpus callosum (blue) appears deformed, due to the extreme midline shift. The corticospinal pathways (green) are projected onto a 2D T2-weighted image at the level of the fetal brainstem (last figure).

In summary, DTI and tractography depict the intact but displaced morphology of the fetal sensorimotor pathways. This case of a giant intracranial tumor illustrates the potential of these techniques to visualize the connectivity of the fetal brain and offer insights into brain structures, which cannot be obtained by conventional fetal MR sequences alone. Knowledge about the integrity of sensorimotor tracts may be of clinical value and may help to predict potential neurological sequelae of any prenatal CNS pathology.