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Utilizing magnetic resonance imaging for more accurate detection of brain abnormalities: case reviews

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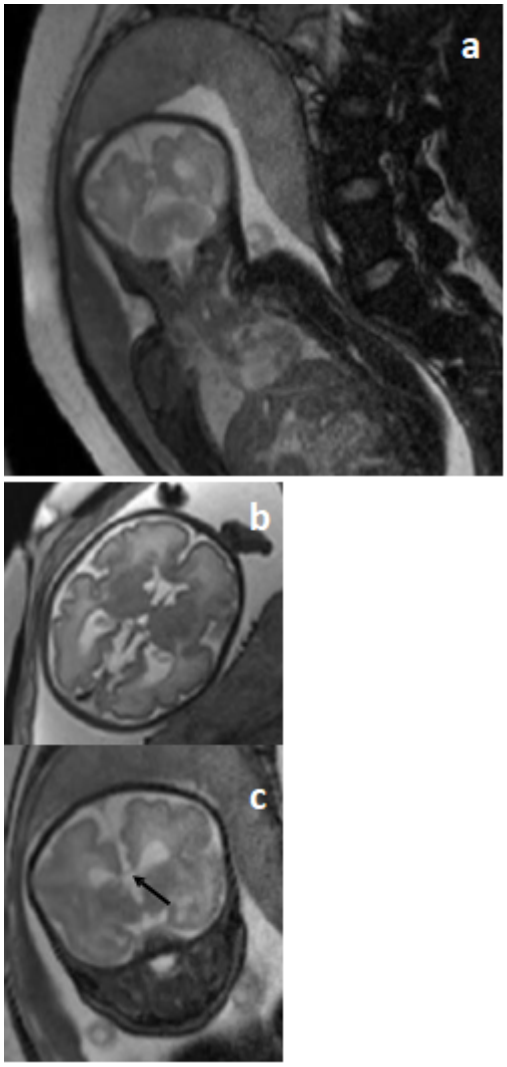
Abstract

Magnetic resonance imaging is well known in all medicine specialities and is widely used to recognise derivations and anomalities that can not be seen using other techniques. Ultrasound is a routine test for fetuses because of its advantages: convenience; availability; affordability; real-time interpretation by the operator; it is better for calcified lesion, i.e. brain, liver, and placenta; real-time guidance of invasive diagnostic and therapeutic procedures, but in some cases additional diagnostic information is needed. Sonographic assessment of fetal brain is a challenge because the view is obstructed by two bony plates: fetal skull and maternal pelvis. Suspicion of fetal central nervous system anomalies is the most common indication of fetal magnetic resonance imaging. It provides significant information during pregnancy because of it‘s advantages: excellent tissue contrast for detection of subtle changes; large field of view for simultaneous evaluation of the whole fetal body and relationship with maternal structures; not limited by fetal position, ossification, oligohydramnios, or maternal obesity; off-line interpretation by pediatric neurologist or radiologist. Compared to US it is statistically known that MRI improves quality of diagnostics from <70% to >92%. (Meridian study).
Our focus is on comparing magnetic resonance imaging and ultrasound methods to detect corpus callosum agenesis, after which diagnosis can be established and expected outcomes can be explored.

Keywords: magnetic resonance imaging; ultrasound; fetus; brain abnormalities

CASE REPORTS

Case 1
Woman. 27 year old. 22 weeks pregnant. Suspected corpus callosum agenesis of the fetus during US exam. Agenesis of the corpus callosum was confirmed with magnetic resonance imaging. Half Fourier single-shot turbo spin echo (HASTE) has been performed. No 1 a,b ,c



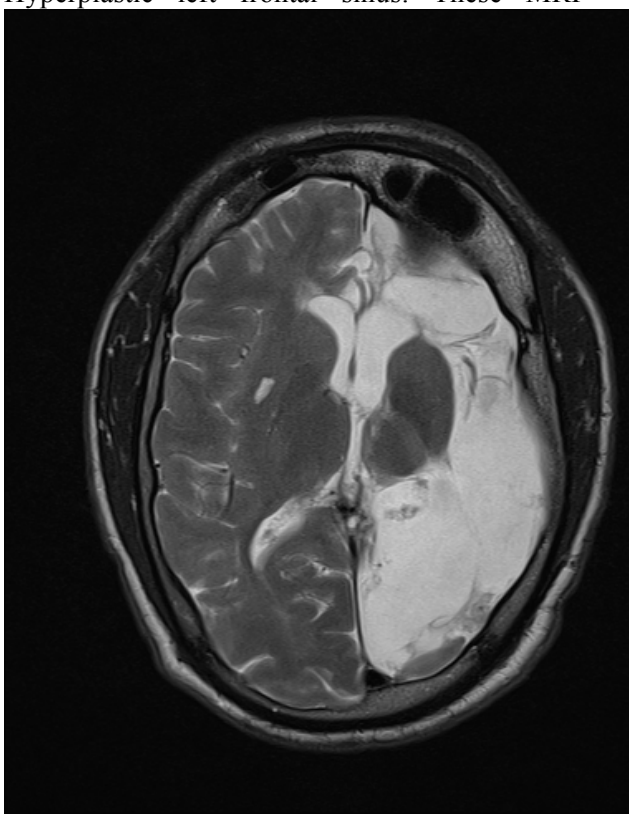
figNo1 Half Fourier single-shot turbo spin echo (HASTE) of the fetus body – the corpus callosum agenesis.
1a axial view , T2 cor view of the head reveals the corpus callosum agenesis. The woman was sent to deliver to the tertiary care Vilnius University Santaros clinics hospital.

Case 2

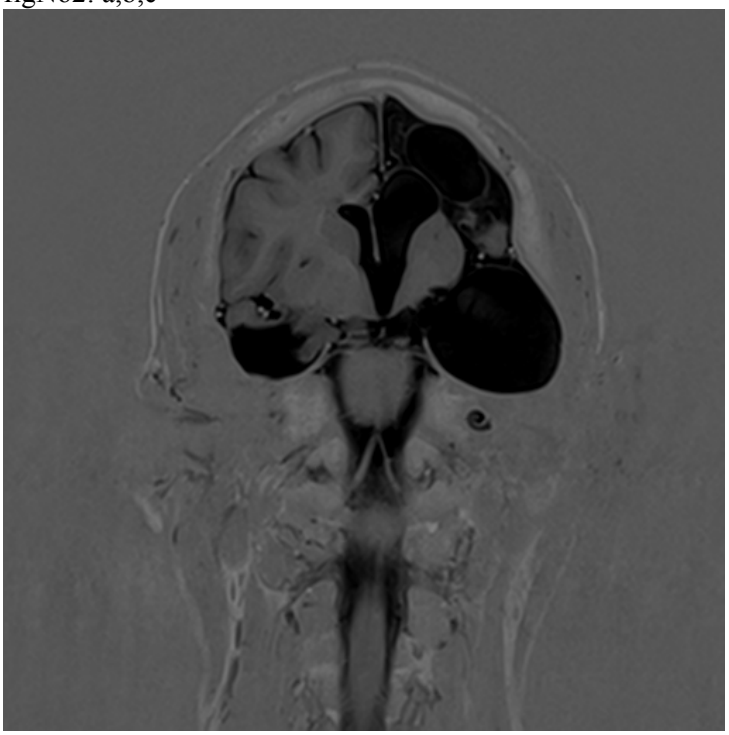
A 22 year-old male presented to a neurologist due to recurrent epileptic seizures. According to the patient's mother, onset is usually in the evenings presenting with head and eye movements to the left. Episodes typically last from 30 to 60 minutes and occur about once a week. The first seizure of this nature occured 3 years ago. The patient experienced seizures in childhood, which presented with frequent blinking of the eyes and jerking of the head to the left. At that time he was diagnosed with structural epilepsy and prescribed Topiramate. After 10 years of effective treatment, the patient discontinued the medication and for the next ten years there was no recurrent episode of seizures. The patient has a history of herpetic encephalitis at 3 months old and was diagnosed with severe mental retardation, autism and behavioral disorder. He is currently taking Zuclopenthixol (50 mg tablets prescribed by his psychiatrist). Throughout the neurologist consultation, the patient swayed back and forth; he would begin to walk, suddenly laugh, make a lot of stereotypical movements, when asked showed his tongue, and showed his hands. After being given a leaflet he put it into his mouth and then dropped it on the floor, then proceeded to take off his shoes and throw them onto the floor. The patient remained nonverbal. He was able to actively move his hands and feet, his tendon reflexes on both sides are abnormally brisk, and pathological reflexes on both sides are present. A more in depth examination was not possible due to the patient's status. An EEG was not practically possible as the patient would not follow instructions, and was both distracted and

anxious. An MRI under anaesthesia was completed with i/v contrast in T1, T2, DWI and TOF regimen. The MRI revealed that the F, T, O lobes on the left hemisphere and T lobe on the right hemisphere are not developed; CSF density derivates with septum joining each other in their areas. Partial agenesis of corpus callosum. P lobe on the left present. Assymmetrical dilation of the lateral ventricles; HI ~45 mm, III ventricle ~ 7-10 mm, IV ventricle 9mm, midline. Normal signal of the pituitary gland. The left eye orbit is smaller than the right, with soft tissue signal masses located dorsally up to 6 mm in size. Convexity subarachnoid gaps unexpanded. Hyperplastic left frontal sinus. These MRI findings indicate: agenesis of the F, O, T lobes within the left side of the brain, masses of CSF density interconnected by septi. Partial agenesis of the corpus callosum. Assymetric lateral ventricles; left ventricle dilation most notably in the occipital (posterior) horn connecting with CSF gap within the O area. The left eye orbit is smaller than the right, with masses dorsally. Clinical diagnosis: structural epilepsy post herpetic encephalitis: focal motor seizures with impaired comprehension to be differentiated with neuroleptic induced dystonia. Additionally, the patient has severe mental retardation, autism, and behavioral disorder.

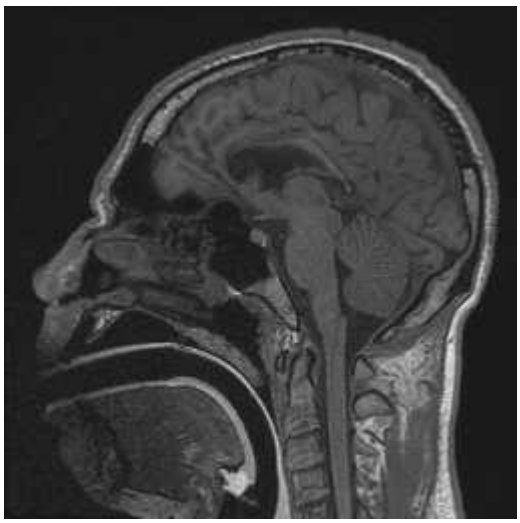
figNo2: a,b,c



2a: T1cor



2b: T2tse


2c: T1fld

CORPUS CALLOSUM DEVELOPMENT

Corpus callosum is the largest commissure connecting the cerebral hemispheres. The number of callosal fibers is already fixed around birth, but structural changes of the corpus callosum continue to occur during postnatal development due to fiber myelination, redirection, and pruning.(1) The corpus callosum is approximately 10 cm in length and is C-shaped. It is divided into four parts (anterior to posterior): rostrum (continuous with the lamina terminalis), genu, trunk/body, splenium.

The corpus callosum forms between 8 and 20 weeks of gestation.(2) This structure differentiates as a commissural plate within the lamina terminalis at 39 embryonic days. The plate acts as a passive bed for axonal passage and provides a preformed glial pathway to guide decussating growth cones of commissural axons. In the human embryo, the earliest callosal axons appear at 74 days, the genu and the splenium are recognized at 84 days, and adult morphology is achieved by 115 days. During the 3 months after birth, the size decreases, as a large proportion of the huge population of callosal axons (over 109 billion) is eliminated. This weeding out confines contacts between the hemispheres to certain cortical zones.(3)

An understanding of normal callosal development has become particularly important in the light of results of a recent study that show the corpus callosum is useful as an indicator of both congenital and degenerative brain disorders in children. (2)

CORPUS CALLOSUM AGENESIS

A reported incidence of the corpus callosum agenesis is raging between 0.5 and 70 in 10,000.(4) This anomaly is characterized by a partial or complete absence of an area of the brain that connects the two cerebral hemispheres. Two types of corpus callosum agenesis can be distinguished morphologically: ACC type 1, in which axons form but are unable to cross the midline; they consecutively form large aberrant fiber bundles known as Probst bundles along the medial hemispheric walls. ACC type 2, in which commissural axons fail to form; therefore, no Probst bundles are found.(4) It can be seen as an isolated condition or in association with other brain abnormalities or physical or medical conditions. These conditions include: Seizures; Abnormal head and facial features; Brain anomalies (i.e. hydrocephalus, Arnold-chiari malformation, or migration disorders); Syndromes (i.e. Aicardi or Andermann); Genetic disorders, chromosomal rearrangements; Cognitive impairments (i.e. mental retardation and/or learning disorders); Behavioral disorders such as attention deficit disorder (ADD), attention deficit hyperactivity disorder (ADHD), obsessive/compulsive disorder (OCD), autism or autistic-like behaviors. In general terms, three clinical patterns seem to be relatively common:

- Severe neuropsychiatric deficit, usually seen in complex brain malformative diseases in which CCA is only one feature (and often not the most relevant one, in terms of consequent disability);
- other neurodevelopmental diseases, including autism spectrum disorders, without a well-defined role of CCA in the etiology of the disorder
- apparently benign conditions, with IQ in the normal range but relevant neuropsychological deficits. (5)

CAUSES OF THE FETUS CORPUS CALLOSUM AGENESIS

It is difficult to determine the reason of this brain malformation, although there are some known factors, for example, genetic disorders

autosomal-dominant, autosomal recessive and X-linked inheritance and gene mutations or chromosomal rearrangements.(6) This anomaly can occur because of prenatal infection (7) or injury that affects the development of the fetus brain. Moreover, in humans, fetal alcohol syndrome, (8) and maternal diabetes (9) are reported to cause callosal anomalies. Agenesis of the corpus callosum can be detected prenatally by routine sonography, for which the important signs include absence of the cavum septum pellucidum, colpocephaly, high-riding third ventricle, and widening of the interhemispheric fissure. Fetal MR imaging is clinically helpful in suspected cases of ACC because it can confirm that the callosum is absent. Moreover, other conditions that are associated with agenesis of the corpus callosum are best detected by fetal MRI.

ULTRASOUND

Sonographic demonstration of corpus callosum agenesis requires adequate angles of insonation. Clear visualization can only be seen in mid – sagittal and mid – coronal scans of the fetal brain. These views require a meticulous scanning technique, but can be obtained with standart transabdominal ultrasound in most fetuses in breech position or transverse lie. In fetuses in the vertex presentation, transvaginal ultrasound is the technique of choice. (10) In prenatal diagnosis 3D ultrasound offers a number of advantages over conventional 2D ultrasound in the assessment of fetal neuroanatomy The most recent 3D/4D ultrasound technology facilitates volume ultrasound examinations also for less experienced operators, while giving the examiner the opportunity to identify both normal and abnormal fetal structures in the most appropriate imaging mode. Simultaneous presentation of the 3 orthogonal planes provides detailed information that is valuable in cases of normal corpus callosum development and in corpus callosum pathologies. In the second and third trimester the multiplanar display mode is helpful in identifying pathological brain structures such as partial or complete agenesis of the corpus callosum, hypoplasia or hyperplasia. The prenatal diagnosis and outcome of corpus callosum underdevelopment has only rarely been reported in the literature and the data do not reach statistical significance. (11)

MRI USAGE AND METHODS

The first MRI performed during pregnancy was reported in 1983, to confirm placenta accreta suspected from clinical history and ultrasound findings. The indications to perform MRI during pregnancy have been progressively extended to other fetal conditions. Agenesis of the corpus callosum, once thought to be a rare cerebral malformation, is more frequently diagnosed with modern neuroimaging techniques; occurring in 1:4000 births. Sonography has historically relied on indirect signs of callosal agenesis, such as absence of the cavum septi pellucidi and ventricular morphology, while magnetic resonance imaging directly visualizises the corpus callosum on a midline sagittal magnetic resonance image. (12)

For fetal anatomy assessment, a 1.5-Tesla machine with a fast T2-weighted single-shot technique is recommended for image requisition of common fetal abnormalities. Individual judgment needs to be applied when considering usage of a 3-Tesla machine. Gadolinium MRI contrast is not recommended during pregnancy. MRI should be avoided in the first half of pregnancy due to small fetal structures and motion artifacts. Assessment of fetal cerebral cortex can be achieved with MRI in the third trimester. For appropriate clinical implementation of MRI, it is important that obstetricians are adequately informed of the basic principles, proper indications, potential additional benefits, limitations, and risks of MRI to the fetus. Standard MRI sequence for fetal assessment is a single-shot T2-weighted sequence; which provides excellent soft tissue characterization. There are several acronyms depending on the equipment manufacturer, including half Fourier rapid acceleration with relaxation enhancement (RARE), single-shot fast spin echo (SSFSE), singleshot turbo spin echo (single-shot TSE), extended-phase conjugate -symmetry rapid spin echo sequence (EXPRESS), half Fourier single-shot turbo spin echo (HASTE), and fast advanced spin echo (FASE) sequences. T1-weighted MRI sequence

protocol is more appropriate for lesions with fat, calcification, or hemorrhage. It is particularly useful for imaging of fetal brain. Slice images from thre orthogonal planes are acquired. Generally, slice thickness of 3–4 mm provides optimal signal in the region of interest without significant partial volume averaging. Sequences that are considered to be "standard" for fetal assessment include T2, T1, echo planar imaging (EPI) (for fetal bone assessment), fluid attenuated inversion recovery (FLAIR) (to detect subarachnoid hemorrhage), diffusion weighed imaging (DWI) (to detect intracerebral hemorrhage), and MR spectrometry (for fetal lung assessment). Magnetic field strengths of 1.5 and 3 Tesla have been studied for imaging of the human fetus. Image construction using 3-Tesla magnetic field strength provides better anatomical delineation of the fetus, which is particularly useful for imaging of fetal brain, as well as functional MRI. The 3-Tesla machine is very sensitive to fetal movement, which results in significant motion artifacts, especially if MRI is performed in the first half of a pregnancy.(13)

GIVING BIRTH AND CARE OF THE INFANT

Long-term neurodevelopmental outcome is expected to be normal in approximately 75% of isolated corpus callosum agenesis cases. This means that continuation of pregnancy can be preferred. (14) Thus, termination of pregnancy is sometimes recommended when non-isolated ACC is diagnosed, however, this option varies by country. (15) Adequate counseling is important in this case, to evaluate the various arguments in favour of and against termination.

In continuing pregnancies, delivery should be performed in multidisciplinary centres for the benefit of the infant. Magnetic resonance imaging is very important tool to diagnose the corpus callosum agenesis before delivery to evaluate the fetus after birth by a multidisciplinary team of experienced clinicians involving neonatologists, neuroradiologists, neurologists and geneticists.. It is important to look for the presence of dysmorphic features that are specific to some of the associated syndromes and the presence of cardiac, skeletal and genitourinary abnormalities. Neuroimaging with MRI is imperative in confirming the diagnosis and to establish the presence of other CNS abnormalities. The family should be offered genetic counselling and these infants need long-term multidisciplinary follow-up to assess development and address other comorbidities such as epilepsy and feeding problems. (16)

EXPECTED OUTCOMES

The symptoms of agenesis of the corpus callosum can become more evident as a child grows into adolescence and young adulthood. Parents of individuals with CCA and relatively normal neuropsychiatric conditions consistently describe impaired social skills and poor personal insight as the features that interfere most prominently with the daily lives of their children. Specific traits include emotional immaturity, lack of introspection, impaired social competence, general deficits in social judgement and planning, and poor communication of emotions. Consequently, these patients often have impoverished and superficial relationships, suffer social isolation, and have interpersonal conflict both at home and at school due to misinterpretation of social clues. A counseling should be offered to parents and teachers to help them finding ways to approach and help these children, without being stopped by their neuropsychological deficits but trying to overcome them with adequate strategies. Neuropsychological testing can be used as a guide to tailor the appropriate rehabilitative treatment, together with an attention to the specific needs of that given patient, and also in order to improve compliance. (17)

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