MR imaging can often provide useful information when ultrasonography (US) is inconclusive. MR can provide improved anatomical resolution when US is limited by patient size, fetal presentation, or oligohydramnios. Another advantage to MR is that intracranial brain imaging is not impacted by calvarium, which allows clear identification of the cortex, subarachnoid space (Girard and Gambarelli, 2001; Fogliarini et al., 2005b, a) and posterior fossa (Adamsbaum et al., 2005). MRI can be performed several times during the course of pregnancy, which permits the documentation of the natural history of brain injury over gestational age (Brunel et al., 2004). MR imaging, which is also an excellent alternative to autopsy, may be a valuable adjunct to autopsy for fetuses with central nervous system (CNS) anomalies (Woodward et al., 1997; Griffiths et al., 2005). MRI is usually performed because of abnormal US findings: Ventricular dilatation is the most frequent indication (40% of cases) followed by suspicion of a central nervous system (CNS) malformation (31% of cases) or brain injury (Girard et al., 2001a; Girard et al., 2001b; Girard and Huisman, 2005; Girard et al., 2006). Obviously those conditions can overlap since an increased ventricular size may result from destruction, malformation, hydrocephalus, destruction and hydrocephalus, malformation and destruction. MRI is extremely helpful in the evaluation of ventriculomegaly because, compared to US, it has greater sensitivity in the detection of associated brain lesions (Girard et al., 2003b).

MRI is commonly performed after a normal brain ultrasound within the following contexts (Girard et al., 2001a; Girard et al., 2001b): 1) familial disorders (tuberous sclerosis, neurofibromatosis type 1, siblings with malformation of cortical development, siblings with inborn error of metabolism); 2) maternal (acute gestational/maternal event, infections, coagulation disorders); 3) fetal (twin pregnancy, fetuses presenting with extracerebral multiple malformations that can be associated with brain lesions such as the association
thoracic lymphangioma and megalencephaly, and cardiac malformation that can lead to leukomalacia).

MRI is not usually indicated in cases of intrauterine growth restriction (IUGR). However, it can provide useful information when IUGR is associated with progressive microcephaly or other abnormalities, such as fetal hydrops or arthrogryposis.

Ideally, MRI is performed at a neuroradiological unit at a tertiary care facility after US performed by a dedicated neurosonographer (Malinger et al., 2004). Because intracranial anomalies can be missed in the second trimester, MRI is optimally performed in the late-second or third trimester (Malinger et al., 2002b).

Brain malformations are characterized by their specific morphological changes, whereas brain injury displays abnormal signal, irregular ventricular wall, lack of brain layering, absence of the normal signal of cortex and white matter, absence of maturation milestones (Girard et al., 2001a; Girard et al., 2001b; Girard et al., 2003a; Brunel et al., 2004; Girard and Huisman, 2005). However, these criteria may overlap because destruction of the brain may be associated with a malformation. Vascular malformation can lead to brain destruction. Some malformations show abnormal signal such as lipoma, tuber and white matter lesions in tuberous sclerosis (Bourneville’s disease).

Many CNS malformations can be identified in utero. Some malformations, however, may be difficult to identify such as micropolygyria (MPG) below 24 weeks, lobar holoprosencephaley, partial commissural agenesis, and histogenetic disorders of the posterior fossa (Fogliarini et al., 2005a). Malformations are usually classified following the different steps in brain development: disorders of neurulation, of diverticulation, commissural agenesis, disorders of histogenesis, and miscellaneous that include extracerebral cyst, vascular malformations, craniosynostosis. However some points merit emphasis.

Corpus callosum agenesis (CCA) is the more frequent malformation. Absence of the corpus callosum and of the other commissures is a nonspecific finding that is part of more than 70 syndromes (Norman). The important feature is the absence, or the defect, of the corpus callosum and of the associated hippocampal commissure. The resulting deformity of the ventricular complex (lateral ventricles away from each other and from the midline, posteriorly enlarged) is characteristic and easy to identify on fetal brain MRI (Raybaud et al., 2003). However it may be very difficult to achieve the overall evaluation of CCA by MR until after delivery. This limitation is particularly true in cases of partial agenesis involving an interhemispheric cyst that, through its mass effect, can prevent the detection of associated malformation of the cortical development (MCD) (Girard et al., 2001b).
Disorders of diverticulation include holoprosencephalies and posterior fossa cysts. Holoprosencephalies are classified as alobar, semilobar and lobar. In lobar holoprosencephaly, the cleavage of the cerebral hemispheres is almost complete but fusion of the cortex is seen either at the level of the fronto-basal area or at the level of the vertex. This latter form is called syntelencephaly or middle interhemispheric variant of holoprosencephaly. Lobar holoprosencephaly is the most difficult form to identify \textit{in utero} compared to the alobar and semilobar forms.

MRI is very helpful in cystic malformations of the posterior fossa, in which it is better able than US to detect whether the dural structures, mostly the tentorium, are normally positioned or not (Raybaud et al., 2003). Posterior fossa cyst is a frequent indication of MRI \textit{in utero} because the cerebrospinal fluid (CSF) spaces in the posterior fossa are normally large. The Dandy-Walker malformation with either closed or open cyst is characterized by an elevated tentorium (well above the inion), the bulging of the parieto-occipital vault, the partial or total absence of the vermis. The retrocerebellar pouch (expansion of the Blake’s pouch) also shows a tentorium that is too high with a normal development of the vermis and is part of the Dandy continuum (Adamsbaum et al., 2005). In contrast a small posterior fossa is seen in Chiari 2 malformation. A normally positioned tentorium is seen in malformations within a posterior fossa of normal size, such as histogenetic disorders of the posterior fossa.

MRI identification of histogenetic disorders, which are rarely suspected on US, can enable genetic counseling for future pregnancies (Barkovich and Raybaud, 2004). These abnormalities can be summarized as: 1) disturbance in cell proliferation with abnormal cell differentiation leading to microlissencephalies, cortical dysplasia with balloon cells, tuberous sclerosis, hemimegalencephaly; 2) disturbance in cell migration resulting in heterotopia, lissencephalies (agyria-pachygyria), and congenital muscular dystrophy and 3) disturbance in late migration and organization of the cortex leading to micropolygyria, schizencephaly and focal dysplasia without balloon cells. Microcephaly describes a small head and brain. Diagnosis is usually made in the last trimester provided the head circumference is 3 standard deviations below the mean. The frontal lobes are underdeveloped, with obliquity of the lateral ventricles, and a simplified cortical pattern. Abnormal development of the frontal lobes is difficult to depict in early pregnancy since the normal development of the frontal lobes is achieved around term. Of the malformations of the cortex, micropolygyria (MPG) is the most frequent malformation encountered \textit{in utero}. From mid- to end of the third trimester, MRI features are familiar and similar to what is known from the \textit{ex utero} period. MPG appears on MRI as packed and serrated microgyri, with an irregular cortex-white matter junction.
Aberrant sulci, atrophy and white matter abnormalities such as gliosis are also seen. In young fetuses, however, the identification of the malformation is difficult and even impossible around 20-21 weeks. MRI appearances include the absence of the normal signal of the cortex (especially on T1 WI), the presence of sulci at the surface of the brain that are not expected according to the GA, and the irregular surface of the cerebral hemisphere (Girard and Gambarelli, 2004; Fogliarini et al., 2005a). It may be necessary in young fetuses to repeat MRI several weeks after the initial referral in order to get more familiar images of MPG. Disturbances of histogenesis in the posterior fossa are not common (Adamsbaum et al., 2005; Fogliarini et al., 2005a), possibly because US is not able to suspect these types of malformation. Extremely severe pontocerebellar hypoplasia is easy to identify with poor development of the cerebellar hemispheres and persistent brainstem flexure that mimic an arrested brain at the embryonic period. Severe hypoplasia, which is of poor prognosis, manifests as small cerebellar hemispheres with shallow brainstem and absence of the anterior bulging of the pons. Cerebellar hypoplasia may be seen with normal bulge of the pons, especially when unilateral, making the distinction from necrosis challenging.

Ventriculomegaly is a major indication of MRI of the fetal CNS. It may be caused by malformation, destruction of the brain, and, less commonly, by tumors. It is also seen in numerous syndromes in which it involves the frontal horns with a square and sharp shape of ventricular walls. An apparent mechanism for ventricular dilatation is not always found in utero. The prognosis for ventriculomegaly in the fetus is variable. Findings indicative of a more favorable outcome include late diagnosis in the third trimester, slow evolution, a ventricle-hemisphere ratio of no more than 50% of normal and isolated ventriculomegaly. Isolated mild ventriculomegaly (whether unilateral or bilateral) is highly challenging because developmental delay ranges from 0% to 36%. The underlying mechanism of isolated ventriculomegaly (Girard et al., 2003b) can be related to fetal hypoxia (7%), early stages of benign external hydrocephalus (16%) (Girard and Raybaud, 2001), and possible subtle changes of the white matter that are undetectable by conventional MRI.

Subependymal cysts are encountered in numerous diseases. When congenital, they may be the result of hemorrhage, hypoxic-ischemic damage, or neurotropic infection. They have been reported in association with congenital viral infections (mainly cytomegalovirus and rubella), metabolic disorders (especially Zellweger syndrome) (Cuillier et al., 2004), chromosomal abnormalities (Epelman et al., 2006), and maternal cocaine consumption. However, subependymal cysts may be an isolated finding in otherwise healthy newborns (Malinger et al., 2002a). Etiopathogeny is still unknown (Gilles and Gomez, 2005).
A number of conditions can lead to destruction of the fetal brain (Girard et al., 2003a), such as hypoxia, congenital infection (especially toxoplasmosis and cytomegalovirus infections), malformation (vascular and heart malformations), pregnancies at risk of brain damage, inherited inborn error of metabolism, especially mitochondrial diseases, and tumors. The chronic response of the brain, or the combination of chronic and acute response, are more commonly seen than an acute response alone (Barkovich and Girard, 2003; Girard et al., 2003a), as opposed to what is seen in the neonatal period, because the physiologic conditions are completely different. Calcifications and malformation of the cortex are most likely seen in cases of congenital infection but not exclusively because hypoxia-ischemia is known to interfere with cortical organization, as in cases of twin-to-twin-transfusion syndrome when death of a co-twin occurred earlier than 20 weeks of gestation. Chronic responses often manifest as mild ventriculomegaly, with irregular ventricular wall, nodular and irregular germinal matrix.

References


