REVIEW OF LITERATURE
MRI PHYSICS

Hydrogen (protons) present in the body are randomly arranged. When they are put inside a magnet they get aligned. Radio frequency pulses are sent from the scanner. The radio waves knock the nuclei of the atoms in the body out of their normal position. As the nuclei realign back into proper position, they send out radio signals. These signals are analyzed and converted into an image of the part of the body being examined.

Fast spin echo (FSE) is one of the most important recent advances in MRI, originally called RARE (Rapid acquisition with relaxation enhancement)\textsuperscript{11}. In FSE the 90\textdegree\ pulse is followed by a train of 180\textdegree\ pulses. The Echo train length or turbo factor is the number of 180\textdegree\ pulses. The essential difference between conventional spin Echo (CSE) and Fast spin Echo is that in CSE all echoes in a train are preceded by a single value of the phase encoding gradient, whereas in FSE each echo in the train is preceded by a different value of the phase encoding gradient. Because each value of the phase encoding gradient corresponds to a separate line in K space, the result is that K space is filled much faster\textsuperscript{11}. HASTE or SSFSE employs FSE and half Fouier transformation to get ultra fast images\textsuperscript{11,18}.

Single shot Fast spin echo (SSFSE) sequence is commonly used for fetal imaging because it produces high tissue contrast for T2 weighted imaging.
Besides it is less prone for motion artifact. The other sequences used are FIESTA (GE) or true FISP (Seimens) for T2 weighting and FLASH for T1 weighting\textsuperscript{12-13}.

**ARTIFACTS**

Artifacts are defined as false information carried from the tissue being imaged and mimics as a pathological entity. Prior knowledge of all these artifacts is very important for interpreting the images accurately, which helps in better diagnosis.

Artifacts that can occur while performing fetal MRI\textsuperscript{11,18} are as follows:

**Motion artifacts**

- **Bulk Motion**
- **Fluid motion**
- Repeat visualization of structure or non visualization of a structure
- Aliasing (wrap around)
- Susceptibility artifact
- Partial volume artifact
MOTION ARTIFACT

Motion affects all fetal MR examinations because of the combination of maternal motion (whole body, breathing, bowel peristalsis and arterial pulsations) and fetal motion. Because images are obtained very fast with a sequence less than a minute, SSFSE imaging allows for diagnostic quality imaging despite motion.

**Bulk motion:** Maternal motion results in motion of the entire field of view during the imaging sequence and generally results in blurring of the entire image, with ghost images in the phase encoding direction. If bulk motion is present, one should instruct patient to keep still, but if the patient is moving during imaging, a breath hold could be helpful.

**Fluid motion:** This artifact is characterized by a signal void that occurs in fluid. Fluid motion occurs when spins excited by a slice – selective radio frequency pulse change position with respect to the slice or spatial encoding gradients before their signals are recorded. Motion artifacts can be seen in amniotic fluid, cerebrospinal fluid and fetal urine.

Because fetal imaging is typically performed with single shot sequences, only the slice that was obtained during motion is affected. If the affected slices are not in the region of interest, then the sequence does not need to be repeated.
REPEAT VISUALIZATION OF STRUCTURE OR NON-VISUALISATION OF A STRUCTURE

If the fetus moves during the sequence and the movement is in plane with imaging, it is possible that a portion of anatomy will be seen more than once. Eg. Leg or arm appears in two places in the same sequence. More commonly an extremity moves out of the image plane during the sequence acquisition and is not visualized.

ALIASING (WRAP AROUND)

This artifact can be identified when anatomic structures that extend outside the field of view in the phase encoding direction appear to “wrap around” into the opposite side of image. Depending on the anatomy and placement of field of view, the “wrapped” anatomy may overlie and obscure other anatomy. Any excited tissue outside the field of view still gives signal during readout, but tissue outside the field of view has acquired a phase identical to a position outside field of view. The method for eliminating this artifact is to increase the field of view so that it contains all maternal anatomy.

SUSCEPTIBILITY ARTIFACT

It is characterized by localized distortions of the geometry or intensity of the image caused by inhomogeneities in magnetic field ($B_0$). Spatial distortion results from long range field gradients, where $B_0$ varies over scales that span many voxels. These changes in $B_0$ cause the spins in different voxels to have
slightly different precessional frequency of spins, these alterations in frequency can make the signal from spins in one location seem to come from a different position, which results in geometric distortion of image. Susceptibility artifact is rare with SSFSE imaging, but it can occur. To overcome this artifact, shimming should be performed to improve the magnetic field homogeneity, using shorter TE sequences and increasing read out band width.

**GIBBS RINGING ARTIFACT**

It is also called as truncation artifact. It is characterized by bright and dark lines running parallel to a short signal interface that diminish quickly away from the boundary that causes them. It occurs when the echo has not decayed to zero at the edges of the acquisition window, so it is most often seen when small image acquisition matrix is used.

This can be reduced by increasing the resolution of image or by applying a filter to the reconstructed image. However, increasing resolution requires either longer imaging times or reduced image SNR, whereas filtering reduces the resolution of the reconstructed image.

**PARTIAL VOLUME ARTIFACT**

As in all tomographic imaging, if only a portion of an anatomic region is in slice, partial volume artifact can occur. In obstetric imaging, this artifact can include structures outside the fetus Eg. Placenta.
NORMAL FETAL MRI ANATOMY

Depiction of normal fetal anatomy in the early second trimester MR scans is limited by the size of the fetus. The head, lungs, liver and extremities can be visualized. By 26 weeks gestation, the entire head, abdomen and extremities can be clearly imaged. High contrast provided by T2 weighted imaging - Single shot fast spin echo (SSFSE) sequences provides excellent anatomic detail of most fetal structures.

I. CENTRAL NERVOUS SYSTEM

MR evaluation of central nervous system development often lags behind neuroanatomic landmarks. Fetal brain has high water content (40%) vs 20% in adult, which allows the excellent tissue contrast resolution with SSFSE T2 weighted images.

Sulcation:

Sulcal development is a marker of cortical maturation and used as an indicator of fetal maturity. Levine and Barnes found that sulcation landmarks appeared in the order predicted by anatomic studies, but with lag of 0-8 weeks (Mean 1.9 weeks).

Earliest to form is the interhemispheric fissure, which is present in all normal fetuses examined at 14 weeks. The sylvian fissure begins as a shallow depression at 14 weeks and later becomes grooved by 16 weeks. The areas around the Rolandic and sylvian fissures become convoluted earlier than other
fissures of the frontal, temporal, parietal and occipital lobes. Major occipital gyri are present by 18 – 19 weeks.

Appearance of cingulate gyrus is variable and generally present by 26th week. Further progression of sulcation occurs after the 26 weeks and continues through the end of gestation.

**Myelination and parenchymal layering pattern:**

Myelination proceeds in an orderly fashion within the developing fetus and neonate and is not complete until approximately the second year of life. Beginning at around 29 weeks, myelination progresses cephalad from spinal cord upto brainstem and reaches the internal capsule, corona radiata and other supratentorial white matter tracts at the end of gestation.

The Cerebral cortex is made up of six layers of cells that are formed by 20 weeks. Lan et al 6 evaluated 25 normal fetuses between 12 and 38 weeks gestational age and showed that at the end of 23rd week, three layers were clearly visible within cortex on HASTE – sequences.

1. Germinal matrix is innermost – Hypointense
2. Middle layer (neurological cells) – Hyperintense
3. Outer layer immature cortex – Hypointense
The in-vivo three-layer pattern lasts until approximately the 28th week, after which time the germinal matrix becomes thinner with a rarefaction of cells.

The corpus callosum is fully formed by 20 weeks, but myelination occurs much later. The basal ganglia and thalami are best seen after 26 weeks and are of slightly lower signal intensity than cortical white matter.

**Ventricular size and extra cerebral spaces**

*Cordoza et al*²⁵ sonographically evaluated 100 healthy fetuses between the gestational age of 14 and 38 weeks. They found that the normal diameter remained stable through gestation, with average measurements of 7.6 ± 0.6mm. An upper limit of 10mm was set, above which ventriculomegaly was defined as being present. Measurement of atrial diameter probably is more reliable on sonography, where prescribed plane of measurement can be obtained during real time scanning.

The ventricular atria may appear prominent in the fetus, particularly during the early second trimester. The ventricle to brain mean diameter ratio decreases progressively throughout gestation from > 0.5 before 20 weeks. It decreases rapidly to < 0.5 after 20 weeks, with more gradual decrease thereafter to near childhood proportions with a ratio approaching 0.35 – 0.4 beginning at around 30 weeks. This ratio was measured at the level of angle of frontal
horns. Slit like ventricles, particularly of the frontal horns are seen towards the end of gestation.

**Posterior fossa:**

Cerebellar folia anatomically develop between 12 and 16 weeks. Folia development is seen with MRI at 16 weeks. Prior to this time, the developing cerebellum and vermis appears as a homogenous collection of tissue devoid of folia and grey white matter differentiation.

*Stazzone et al*²⁶ documented folial proliferation at 23-26 weeks, a process that progressed with advanced gestational age throughout gestation. Folia appear as undulating bands of alternating high and low signal intensity. By 26-27 weeks, three layers can be seen within the cerebellum, the outer cortex is thin and hypointense, middle thicker is hyperintense and corresponds to white matter and inner hypointense layer lining the fourth ventricle corresponds to dentate nucleus.

The conspicuity of the different layers of cerebellum was less as compared to cerebral cortex. One likely explanation is the smaller size of cerebellum resulting in lower contrast resolution seen on MRI.

*Stazzone et al*²⁶ reported that tectum and medial longitudinal fasciculus are visible by 20 weeks in all fetuses as areas of low signal intensity within the posterior aspect of brainstem. It is possible that some of the low signal intensity seen posteriorly in the medulla, pons and midbrain is due to an MR
artifact rather than depicting early myelination changes of infratentorial white matter tracks. The middle cerebellar peduncles are best seen on axial cuts and appear hypointense, typically visible by 24 weeks.

**Spine and spinal cord**

Spinal cord can be difficult to visualize early in gestation because of its small size. Distinction of the spinal cord from the cerebrospinal fluid can be made beginning in the early second trimester. The conus medullaris, when visualized, terminates at the level of kidneys.

**II. THORAX AND HEART**

Fetal lungs fill with secretions as they develop. Fetal lungs show lower signal intensity than the surrounding amniotic fluid during the first and early second trimesters. The lungs are moderately hyperintense on single-shot fast spin echo images and hypointense on T1 weighted fast spin-echo images because they contain amniotic fluid.

As time passes, they show high signal intensity, only slightly lower than that of amniotic fluid in third trimester. This signal intensity analysis has the potential to serve as a guide to fetal maturity. Pulmonary vessels are initially not visible, but against the background of developing hyperintensity of lungs they are seen hypointense linear structures.
Cardiac evaluation remains limited due to inherent motion. Fetal motion, rapid heart rate and variability of fetal heart rate make gated sequences impractical in the fetus. Occasionally, the interventricular septum and atrioventricular valves can be visualized, but a satisfactory four-chamber view as can be obtained with sonography is not routinely visualized.

When filled with amniotic fluid, the esophagus is visible as a posterior thoracic structure with a tubular shape and a hyperintense signal. Trachea also may be seen as a high signal intensity tubular structure. The diaphragm is clearly visible as a thin hypointense structure and separating the abdomen from thorax on coronal and sagittal images.

III. ABDOMEN

Liver appears homogenous with relatively low-to-intermediate signal intensity on T2 weighted images. Gall bladder usually can be identified due to high-intensity bile contents. The spleen is of similar signal intensity compared to the hepatic parenchyma, which at times renders its visualization challenging, particularly in younger gestational age fetuses. For analysis of liver position, as in cases of congenital diaphragmatic hernia, T1 – weighted images are helpful because the liver parenchyma is of high signal intensity on these sequences and therefore easily differentiated from the darker surrounding lung.
The stomach is conspicuous with its high signal intensity fluid contents, as are jejunal loops, which allow for easy identification. The stomach is easily recognized as a saccular structure. The signal intensity of the proximal small intestine is different from that of distal small intestine and colon. The former appears hyperintense on single shot fast spin echo images and hypointense on T1 weighted images whereas the latter appears hypointense on single shot fast spin echo images and hyperintense on T1 weighted image. The amniotic fluid in the proximal small intestine and meconium in the distal small intestine and colon cause these signal intensity differences. The high signal on T1 weighted images reflect the signal characteristics of meconium as it accumulates with advancing gestation.

IV RETROPERITONEUM

As the fetus develops, the lower signal intensity renal cortex can be distinguished from the higher signal intensity medulla (Corticomedullary differentiation). Urinary bladder is easily recognized as a fluid filled structure in the pelvis, which is hyperintense.

In a study of 51 fetuses at 20 weeks or greater gestational age, Shinmoto et al\(^27\) reported that male genitalia (scrotum and penis) often are recognized, but female genitalia hardly ever identified.
Plate1

T2 weighted images obtained using SSFSE sequence showing the normal brain in a 30 week fetus
Plate 2

T2 weighted images showing the normal thorax in a 30 week fetus
Plate 3

T2 weighted images showing the normal fetal abdomen
V. MUSCULOSKELETAL SYSTEM

Visualisation of extremities commonly is limited by obliquity of image plane as an entire limb often is not in a plane that allows it to be completely imaged in one or two consecutive images. In the third trimester, the epiphyses of long bones tend to appear hyperintense and shaft appears hypointense.

I. UMBILICAL CORD AND AMNIOTIC FLUID

Amniotic fluid appears hyperintense. With motion, the fluid may appear dark and lines created by artifact from motion occasionally may be seen. Umbilical cord with flow void can be seen as a coiled structure freely floating within amniotic fluid. Its placental and fetal insertion sites can be visualized in a majority of fetuses. Two umbilical arteries can be identified in cross section as they course on either side of bladder.

HISTORICAL PERSPECTIVE

ULTRASOUND:

Ultrasound is the primary and most valuable screening modality of choice for intrauterine fetal imaging. Ultrasound has come a long way from where it started in 1960’s to its recent time of high resolution imaging. Ian Donald first invented measurement of biparietal diameter in 1961 and James Willocks, basing on improvements in electronic caliper system further expanded it. Gestational sac as early as 5 weeks on ultrasound was first
described by Ian Donald and Macvier team in 1965 using a B-mode ultrasound
1,28.

The ability to recognize and confirm the presence of fetal cardiac motion in early pregnancy from 7 weeks onwards by locating fetus first with a B-mode ultrasound and then heartbeat observed with a directed beam in A and M-Mode was shown by Hugh Robinson in Glasgow in 197728. This breakthrough has profound implication in the management of early pregnancy bleeding and threatened miscarriages.

In 1973, Hugh Robinson in Glasgow described measurement of fetal crown – lump length 28. Life size magnification of images had become possible with the newer machines, which enabled accurate measurements to be made on early embryos.

First anencephalic fetus at 17 weeks was reported using a static B-scan by Campbell in 1972 and he later reported spina bifida in 197528. Further, in the same year, Campbell group introduced the measurement of abdominal circumference, which has then remained the most important single parameter to assess fetal weight and nutrition. Circumference measurements of the fetal trunk were considered superior to diameter measurements as the former is less affected by changes in shape of fetal body.

The intervention of the real time scanner enabled much more effective diagnosis of many fetal malformations and in particular cardiac anomalies,
which hitherto had been impossible to diagnose accurately. Fetal sonography and prenatal diagnosis had emerged as the ‘new’ science in obstetrics and fetal medicine. Eric Sanerberi and Peter Cooperberg in Vancouver, Canada first described fetal yolk sac in 1980 using real time scanner\textsuperscript{28}.

Common anomalies that were considered “straight forward” to diagnose at that time included anencephaly, hydrocephalus, exomphalos, duodenal atresia, polycystic kidneys and hydrops fetalis. Most difficult areas of diagnosis of malformations were fetal face, fetal extremities and fetal heart.

The diagnostic accuracy progressively improved with more experience and better resolution machines. With the advent of newer high resolution scanners and transvaginal transducer the diagnosis of these and other more suitable conditions were achieved at an earlier gestational age, moving from the third trimester of pregnancy to second and later on to the first trimester in the latter half of the 1990’s. High resolution ultrasound has improved the axial and lateral resolution and made it easier to detect subtle congenital anomalies, which were difficult to characterize on previous scanners.

\textbf{Advantages of Ultrasound} \textsuperscript{8}

1) Easy availability

2) Low cost

3) Real time capabilities

4) Identify vast majority of clinically significant fetal anomalies
However, in certain cases ultrasound was not accurate and sufficient to predict outcome because of the following limitations.

1. Limited soft tissue acoustic contrast
2. Beam attenuation by adipose tissue (maternal obesity)
3. Poor image quality in oligohydromios
4. Limited visualization of the posterior fossa after 33 weeks gestation because of calvarial ossification.
5. Operator dependence

Magnetic resonance imaging is increasingly used as a complementary imaging modality in pregnancy because of following advantages:

1. No ionizing radiation
2. Provides excellent soft tissue contrast
3. Superior resolution
4. Multi planar capability.
5. Large field of view allowing better depiction of anatomy in fetuses with large and complex anomalies.
FETAL MRI

Smith et al \(^2\) in 1983 first described MRI of women during pregnancy. Initial obstetric application was primarily related to maternal and placental abnormalities. To reduce fetal movements and improve imaging quality, investigators have sedated fetuses by administering benzodiazepine \(^3\) to the mother and have induced fetal paralysis by injecting pancuronium bromide \(^4\) directly into the fetus by using an amniocentesis needle.

During the early 1990’s, fetal MRI was revolutionized by the development of single-shot rapid acquisition sequence with refocussed echoes \(^5\)\(^-\)\(^7\). Single shot rapid acquisition with refocussed echoes is a high quality T2 weighted sequence that has a slice acquisition time of less than a second, thus effectively ‘freezing’ fetal motion. Because of high contrast provided by T2 weighted imaging, Single shot fast spin echo (General Electric Medical Systems, ‘Mil Waukee’) or Half Fourier acquisition single-shot turbo spin echo (Siemens Medical Solution, Erlangen) sequence provides excellent anatomic details of most fetal structures.

Prior Ultrasound before MRI is necessary for the following reasons \(^8\):

1. To document fetal cardiac activity and to rule out fetal cardiac anomalies

2. To document physiology of fetus like biophysical profile
3. To assess limbs

4. To get biometry

5. Helpful in proper placement of surface / body coils.

Deborah Levine, Hiroto Hatau et al (1996) studied the fetal anatomy by the fast MR sequences. Fifteen women whose fetuses were at 14-33 weeks gestations were imaged with breath hold MR sequences. Imaging was performed using HASTE (Half Fourier acquisition single-shot turbo spin echo), Turbo spin echo and FLASH (Fast Low Angle Shot Sequences). Of the three different techniques, they preferred HASTE technique. The T2 weighting is ideal for delineating fetal organs without artifacts arising from maternal and fetal motion.

Yasuyuki yamashita et al (1997) studied eighteen women with complicated pregnancies as revealed on sonogram during the second and third trimesters (16-30 weeks) by using HASTE sequence. They stated that visualization of fetal brain, visceral organs (Lung, heart, liver, kidney and bladder) extremities and umbilical cord on HASTE sequence was significantly better than on fast low – angle shot or turbo spin echo sequences. In the brain, the white grey white matter distinction, gyrus formation and myelination of brain were clearly revealed by HASTE sequence. Pathologic processes including fetal abnormalities like anomalies of central nervous system (n=5), placenta previa (n=2), ascites (n=1) and transverse lie in the third trimester (n=1) were clearly
seen on HASTE imaging. The peak specific absorption rate for RF exposure in these studies was < 1.52/kg. They concluded that in situations when sonography is suggestive but not definitive, MR imaging with HASTE sequence allows clear fetal imaging with high $T_2$ weighted contrast.

**Deborah Levine and Patrick D.Barnes et al** \(^7\) (1998) evaluated the normal appearance of fetal anatomy, the conspicuity of fetal organs, the reproducibility of images and the limitations to image quality with the use of half Fourier single –shot rapid acquisition with relaxation enhancement (RARE) sequence. They studied 54 features of 49 pregnancies that underwent MR imaging. They concluded that fetal anatomy was well depicted in fetuses over 20 weeks. In gestational age of 20 weeks or less fetal anatomy was less defined owing to the small size of organ and fetal motion.

**Deborah Levine and Patrick D.barnes et al**\(^9\) 1999 evaluated the appearance of normal fetal cortical development in utero and compared it with appearance of abnormal cortical development. They performed magnetic resonance image of brain in 53 normal and 40 abnormal fetuses at 14-38 weeks gestational age. The gestational ages at the time of MR visualization of the fissures or sulci were compared with the gestational age guidelines based on neuroanatomic studies. They showed that in normal fetuses, the sulcation landmarks appeared on MR images in order predicted by using anatomic studies. There was 0-8 weeks lag in visualization of sulci on MR imaging as compared to their visualization on anatomic specimens. They concluded that fetal cortical
maturation at MR imaging follows a predictable course that is slightly delayed as compared with the described in neuroanatomic specimens.

**Deborah Levine, Patrick D. Barnes et al** ³¹ (1999) studied the role of ultrafast MR imaging using half Fourier single shot (RARE) technique in revealing fetal CNS anomalies. Gestational ages of patients were between 16 to 36 weeks. They concluded that there are certain limitations to ultrasound in the evaluation of fetal CNS, especially in cases of involvement of posterior fossa and subtle parenchymal abnormalities which could be missed. Fetal CNS MR imaging allows better evaluation of the cortical anatomy and improved diagnosis of CNS disorders.

**Fagus V, Coakley and Hedvig Hricak et al** ⁹ 1999 – evaluated the effect of magnetic resonance imaging findings on management of complex fetal disorders. They performed MR imaging of the fetus on 25 pregnant patients with gestational age ranging between 20-35 weeks in the age group of 20-42 years. Out of them 23 were singleton pregnancies and two twin pregnancies. Prior to MR imaging ultrasound was done for complex fetal disorders. They found out that MR imaging directly influenced fetal care in four (17.1%) of 24 cases by demonstrating congenital high airway obstruction syndrome, congenital hemochromatosis, unilateral cerebellar deficiency in association with congenital diaphragmatic hernia and severe facial disfigurement due to giant anterior neck masses. In eight (33%) cases, MR imaging provided supplementary findings – but did not affect fetal care. In 12 patients (50%)
cases, MR imaging confirmed ultrasound findings. They concluded that in cases of complex fetal disorders, MR imaging can be used to supplement or confirm US findings and may directly affect management.

Jessica W.T. Leung and Fergus V. Coakley et al (1999) – evaluated the role of prenatal MR imaging in cases of congenital diaphragmatic hernia. They stated that morbidity and mortality in isolated cases is caused primarily by pulmonary hypoplasia resulting from mechanical compression of developing lungs, so accurate diagnosis is critical for parental counseling. They showed that 83% of congenital diaphragmatic hernias are left sided. In 57% to 86% of left diaphragmatic hernias, the herniated viscera include a portion of liver, which is called as “Liver-up” position. Fetal liver appears hyperintense on T1 weighted images. MR imaging can also assess liver position which can be difficult to evaluate sonographically. They concluded that prenatal MR imaging can confirm the diagnosis of a congenital diaphragmatic hernia when sonographic findings are equivocal or atypical, especially if therapeutic abortion or fetal surgery is being considered. Fetal lung volume can be directly measured by MR imaging planimetry, allowing confirmation and quantification of pulmonary hypoplasia.

Hiroshi Shinmoto and Kyoko Kashima et al (2000) studied the role of MR imaging using Single – Short Fast Spin Echo Sequence (SSFSE) in diagnosing non-CNS fetal abnormalities. They stated that MR imaging provides information that supplements the information provided by ultrasound,
especially in cases of neck, chest and gastrointestinal lesions. Because of its large field of view, MR imaging allows evaluation of the relationship between a large lesion and adjacent structures. They concluded that superior tissue contrast, larger field of view and relative operator independence enable MR imaging to provide additional diagnostic information that may affect perinatal management.

**Madelyn M. and Anne M. Hubbard et al** (2000) studied the role of standard imaging protocol using ultra fast MR sequences to reveal adequately normal posterior fossa anatomy in fetuses. A total of 66 MR imaging studies of 63 fetuses of 16-39 weeks, gestational age were performed. All fetuses had normal brains and spines on prenatal sonography. Standard MR imaging protocol included axial, sagittal and coronal half-Fourier acquisitions single shot turbo spin echo (HASTE): Sagittal and coronal two dimensional fast low angle shot (FLASH) and axial turbo T1 weighted FLASH images through fetal brain. Fourth ventricle, cisterna magna, the vermis, the cerebellar hemispheres and brainstem were analyzed. They showed that posterior fossa anatomy was sufficiently well defined to exclude abnormalities of the fourth ventricle and cerebellar vermis in all cases. Because of high T2 weighting, good contrast enhancement and good signal to noise ratios, HASTE images provided the best anatomic definition of the posterior fossa.

**Anne M. Hubbard** (2001), studied the role of magnetic resonance imaging in diagnosing fetal thoracic abnormalities. They stated that fetal thoracic
abnormalities are increasingly being detected using prenatal ultrasound. Prenatal magnetic resonance imaging is an important adjunct in evaluation of fetal chest lesions. It can help in the better delineation of masses. They concluded that congenital anomalies of chest are not common. MRI is useful as an adjunct to prenatal ultrasound diagnosis to confirm an abnormality within the fetal chest. MRI is most helpful in those lesions that are atypical or very uncommon. It is also helpful in planning prenatal in utero interventions.

Francoise Rypens and Metens et al\textsuperscript{34} (2001) studied the role of MR imaging in estimating fetal lung volume. They plotted normal fetal lung volume (FLV) obtained with fast spin echo magnetic resonance images against gestational age; to correlate lung growth and fetal presentation, sex and ultrasonographic biometric measurements and also to find its application in fetuses with thoraco-abdominal malformation. They concluded that in fetuses with normal lungs, FLV distribution against gestational age is a potential application in the evaluation fetuses with thoracic malformations, diaphragmatic hernia or oligohydramnios.

Deborah Levine and Carol E. Barnewolt et al \textsuperscript{35} (2003) studied the appearance fetal thoracic abnormalities at prenatal magnetic resonance imaging and determined whether MR imaging yielded information additional to that obtained by ultrasonography. Ultrasound and MR imaging data from 83 MR examinations of 74 fetuses with thoracic abnormalities were compared with respect to resulting changes in patient counseling and care. They showed that
MR imaging yielded additional information compared to US in 28 (30%) of 74 fetuses. Thoracic MR information affected care with regard to six (8%) of 74 fetuses.

Marie Cassart and Anne Massez et al\(^{36}\) (2004) evaluated the contribution of adding MRI findings to inconclusive sonographic data when assessing fetal urinary tract anomalies and in determining how this addition affects patient management of patient. They studied 16 third trimester fetuses in whom sonography suggested bilateral urinary tract abnormalities. They showed that addition of MRI to sonography modified the diagnosis in five fetuses. In four fetuses, the addition of MRI to sonography led to a diagnosis that modified the decision to continue or terminate the pregnancy. MRI combined with sonography may establish a more precise diagnosis and hence impact the decision to continue or terminate the pregnancy.

Mary C. Frates and Ada J. Jumar et al\(^{12}\) (2004) compared prenatal ultrasonography and magnetic resonance imaging for the diagnosis of fetal anomalies. MR was performed on 27 fetuses (28 diagnostic cases) with anomalies diagnosed at USG. Prenatal MR imaging was performed within 15 days of ultrasound. Prenatal ultrasound and MR imaging findings were compared with postnatal diagnosis. They concluded that, MR imaging is an valuable adjunct to prenatal ultrasound that may provide valuable information that could add to the prenatal evaluation and treatment of some fetal anomalies, particularly in those involving the central nervous system.
The first articles using MR signal intensity ratio to diagnose brain pathology in children were from Maezawa et al\textsuperscript{14} (1993) and Akiyama et al\textsuperscript{15} (1993). Maezawa et al derived the signal intensity ratio of gray/white matter in T1 and T2 WI for 87 children with various clinical entities. They observed that abnormal ratios were present in congenital hydrocephalus, inherited metabolic disorders and cerebral palsy. They concluded that measurement of the signal intensity ratio of gray/white matter is a practical way to evaluate delayed myelination. Akiyama et al studied the myelination and signal intensity of cerebral white matter around the lateral ventricles in periventricular leukomalacia in very low birth weight infants.

Ono J et al\textsuperscript{16} (1993) studied the myelination in cerebrum by visual inspection and transverse relaxation time (T2) calculated from double echo images. 23 paediatric cases who did not show intracranial structural changes on MR were studied and followed. They observed prolongation of T2 values in dysmyelinating disorders. They concluded that T2 value in the cerebral white matter allows more objective judgement than visual inspection of the myelination process.

In a study of 101 normal Japanese fetuses (2004), Seiji Abe et al\textsuperscript{17} presented the normograms of signal intensity of different parts of the brain at 26-39 weeks. Regions of interest were designated in the frontal lobe, corona radiata, optic radiation, thalamus, pons, cerebellar vermis and vitreous body. The signal intensity ratio was calculated by the signal intensity of each of these...
designated areas to that of the vitreous body and analysed in relation to gestational age. They observed that most of these regions showed a decline in signal intensity ratio after 34 weeks due to myelination. They concluded that the signal intensity ratio corresponded to the time course of progression of myelination in the previous histological reports.

Lee Brewerton et al. (2005) in their study on 157 fetuses presented the normograms of Lung to Liver Signal intensity Ratio. They concluded that there is a potential role for Lung to Liver Signal intensity Ratio in the antenatal diagnosis of lung hypoplasia, especially after 25 weeks.