REVIEW ARTICLE

Antenatal MRI in Clinical Practice: An Update

[1]Nitin P Ghonge, [2]Sanchita Dube

[1]Consultant Radiologist, Diwanchand Satyapal Aggarwal Imaging Research Center, Kasturba Gandhi Marg, New Delhi, India

[2]Consultant Obstetrician and Gynecologist, Apollo Hospital, Noida, Uttar Pradesh, India

Correspondence: Nitin P Ghonge, Consultant Radiologist, Diwanchand Satyapal Aggarwal Imaging Research Center, 10B, Kasturba Gandhi Marg, New Delhi-110001, India, e-mail: drnitinghonge@rediffmail.com

ABSTRACT

By definition, antenatal MRI is the MR imaging during state of gestation without causing any significant risk to ongoing pregnancy and the fetus. MRI is in a unique advantageous position during antenatal period where ultrasound often provides limited information and CT is usually avoided due to radiation-related risks. The indications of antenatal MRI can be sub-divided into fetal indications, maternal obstetric indications and maternal non-obstetric indications. Antenatal MRI offers better anticipation of prognosis and facilitates parental counseling by accurate characterization of disease process and detection of concomitant anomalies. Ultrasound will however, remain the primary fetal imaging modality and MRI is not likely to replace its role in fetal imaging because of the proven utility, widespread availability and relatively low cost of ultrasound. But under specific clinical conditions, where Ultrasound does not provide adequate information, MRI is bliss and is a useful adjunct to ultrasound.

The specific clinical indications where MRI proved to be more useful include fetal anomaly screening in high risk/precious pregnancy, oligohydramnios / maternal obesity, fetal CNS assessment, characterization of fetal mass, assessment of fetal spine, delineation of fetal alimentary tract and other abdominal viscera, conjoint twin assessment, prior to antenatal intra-uterine fetal surgery or ex-utero intra-partum procedure. MRI indications which are presently at relatively experimental stage include non-invasive MR spectroscopy to detect antenatal fetal hypoxia and lung maturity status. Apart from this, the role of Diffusion-weighted MRI in antenatal imaging of placenta and fetal kidneys/lungs is also likely to emerge in near future. In addition, antenatal MRI also evaluates the maternal pelvis and provides vital information about fetal-pelvic disproportion.

By virtue of recent advances in MR technology and the need to practice evidence-based medicine, antenatal MRI is now rapidly moving from the realms of select academic medical centers into community practice in India. The article provides a brief update on antenatal MRI in routine clinical practice.

Keywords: Antenatal MRI, Fetal imaging.

INTRODUCTION

Antenatal Magnetic Resonance Imaging (MRI) involves imaging of maternal body regions during state of gestation without causing any significant risk to ongoing pregnancy, fetus and its environment. MRI offers unique opportunity to diagnose and evaluate conditions specific to antenatal period where ultrasound (US) provides limited information and computed tomography (CT) is usually avoided due to radiation-related risks. The indications of antenatal MRI can be subdivided into fetal indications, maternal obstetric indications and maternal nonobstetric indications. For fetal indications, MRI is advised either to confirm an anomaly detected on ultrasound or for intensive screening in a high-risk/precious pregnancy. The antenatal MRI for maternal indications is usually advised when the imaging could not be deferred till the end of pregnancy and is essentially guided by the clinical urgency of establishing the diagnosis without adversely affecting the fetus and its environment.

Ultrasonography will remain the primary fetal imaging modality and MRI is not likely to replace its role in fetal imaging because of the proven utility, widespread availability and relatively low cost of ultrasound. But under specific clinical conditions, where ultrasonography does not provide adequate information, MRI is a bliss and a useful adjunct to ultrasound.[1] The limitations of ultrasonography include small field of view, limited soft tissue contrast, beam attenuation by maternal obesity, poor image quality in oligohydramnios and limited evaluation of fetal CNS in late gestation because of calvarial ossification, apart from interobserver variation. Excellent soft tissue contrast resolution and multiplaner imaging capability of MRI offer precise information about fetal structural details, which ultrasound cannot provide owing to its inherent limitations.

SAFETY AND ETHICAL CONCERNS

The first antenatal MRI was done as early as in 1983. The evolution of antenatal MRI in fetal imaging was initially hampered due to fetal movement related degradation of the image quality. But the advent of faster MRI sequences had significantly improved the image quality, and the growth of antenatal MRI has rapidly gained momentum.[2,3] The safety of antenatal MRI is well established and now recommended by all the apex societies in fetal medicine during the 2nd and 3rd trimester.[4] To ensure further safety, antenatal MRI in 1st

trimester is usually not advocated for fetal indications. For maternal indication, MRI in 1st trimester is usually guided by the risk-benefit analysis based on the clinical parameters. The Prenatal Diagnostic Techniques (Regulation and Prevention of Misuse) Amendment Rules, 2003 make it compulsory for the institutions and centers doing antenatal MRI and MR spectroscopy to register with the appropriate authorities of the Indian government, so as to prevent any misuse of these techniques.

PATIENT SELECTION AND PREPARATION

The patients are usually offered the option of antenatal MRI following detection of an anomaly on 11 to 14 weeks scan or level 2 ultrasound scan at 18 to 22 weeks. The role of antenatal MRI here is confirmation of the anomaly diagnosed on ultrasound, and for characterization and further evaluation in terms of anatomical delineation, extent and prognosis. Antenatal MRI may also be advised in high-risk categories like with clinical history of anomaly in previous child even when no definite abnormality is detected on ultrasound or in intermediate/low-risk settings when an isolated parameter is abnormal on ultrasound like presence of fetal ventriculomegaly. In patients where level 2 ultrasound scan is not done during appropriate time, ultrasound evaluation of fetal brain in late pregnancy is difficult and suboptimal due to advanced calvarial ossification, and antenatal MRI remains the only option. Antenatal MRI for maternal indications can be advised during any trimester of pregnancy depending upon the risk-benefit analysis in an individual case.

While scheduling an antenatal MRI, it is important to understand the fetal chronobiology so as to minimize the effect of fetal movements and to optimize the image quality. As the fetal life is found to have definite 'active' and 'quiet' phases,[5] it is desirable to schedule an antenatal MRI during the afternoon hours, approximately 3 to 4 hours following the maternal meals when fetus is in calm phase. The mother is made to walk 10 to 15 minutes before the MRI to further reduce the fetal movements during the examination. With less fetal movements, the image quality significantly improves and at the same time the examination time is less. No maternal sedation is given for the antenatal MRI at our center. The mother is made to empty her urinary bladder before the examination. No external intravenous, oral or rectal contrast is administered to the patient for antenatal MRI, as the safety of these contrast agents is not established during pregnancy. The examination in usually done in supine position in early pregnancy, the left lateral position is often preferred in late pregnancy so as to avoid inferior vena cava compression.

IMAGE ACQUISITION PROTOCOL

MRI studies are performed on a 1.5 T MR unit (Avanto, Siemens Medical Solutions) using a phased-array body coil at our center. The scan protocol for antenatal MRI includes an initial localizing coronal and axial T2-weighted HASTE sequences along the maternal planes. Subsequently, the imaging planes are tailored according to fetal lie/position and the indication of the scan. A good quality detailed ultrasound scan is an important prerequisite to optimize an antenatal MRI in terms of image quality, scan duration and overall performance.[2,3] The fetus is scanned in axial, coronal and sagittal planes using thin T1 and T2-weighted images. Half-fourier Acquired Single-shot Turbo Spin Echo [HASTE] and Fast Imaging with Steady-state Precession [trueFISP] sequences are used for acquiring T2 weighted images. Fast Low-angle Shot (FLASH) and Volumetric Interpolated Breath-hold (VIBE) sequences are used for acquisition of T1-weighted images. We perform 'orbit-centric' planning for optimally symmetric brain images.[6] An average antenatal MRI usually takes less than 15 to 20 minutes.

IMAGE INTERPRETATION AND CLINICAL APPLICATION

The image interpretation usually starts with assessment on wide field-of-view 'global' images (Fig. 1). The number, location, lie and presentation of fetus is analyzed at the outset. The status of placenta, umbilical cord and amniotic fluid are assessed in terms of size, signal intensity and morphology. The maternal urinary bladder, distal ureters, uterine wall, cervix and vagina are also closely evaluated. Subsequently, the interpretation is focused on the specific clinical indication for the antenatal MRI and is primarily based on small field-of-view 'dedicated' images (Figs 2A and B).

Antenatal MRI for fetal imaging is a useful tool for evaluation of almost all body regions except fetal heart, which is still a challenge. The specific clinical indications where MRI proved to be more useful include fetal anomaly screening in high-risk/precious pregnancy, oligohydramnios, fetal CNS assessment (mainly in late gestation), confirmation of fetal ascites, characterization of fetal chest/abdominal mass, accurate

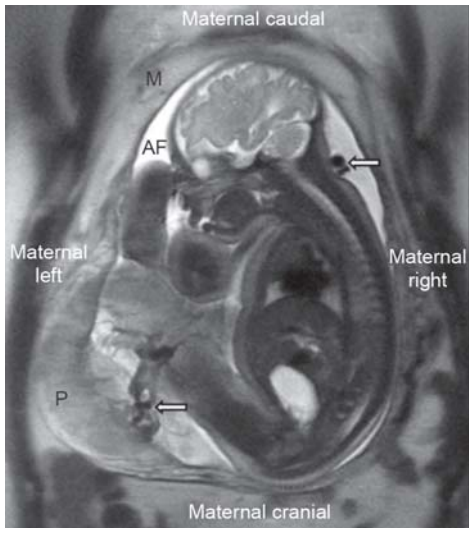


Fig. 1: Sagittal T2-weighted wide field-of-view 'global' MR image acquired using HASTE sequence (craniocaudal inverted image) at 24 weeks' gestation. Uterine myometrium (M), placenta (P), umbilical cord (arrows), amniotic fluid (AF) and gross fetal orientation is evident in this image

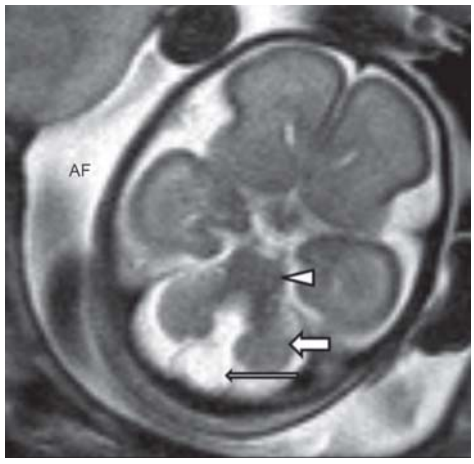


Fig. 2A: Axial T2-weighted small field-of-view 'dedicated' MR image acquired using HASTE sequence at 24 weeks' gestation. Normal posterior fossa structures including pons (arrowhead) and cerebellar hemispheres (arrow) are well visualized in this fetus with mega cisterna magna (long arrow). AF: Amniotic fluid

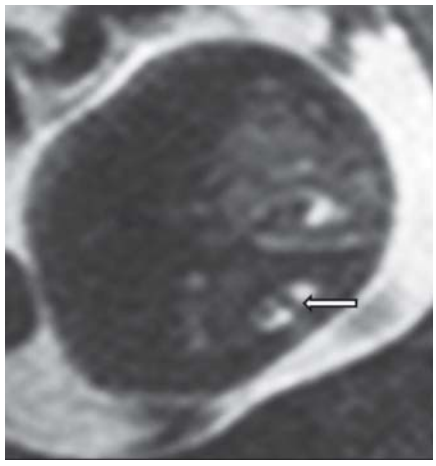


Fig. 3A: Axial T2-weighted MR image acquired using trueFISP sequence at 28 weeks' gestation. Duplication of the spinal cord is seen in this fetus with diastematomyelia (arrow)

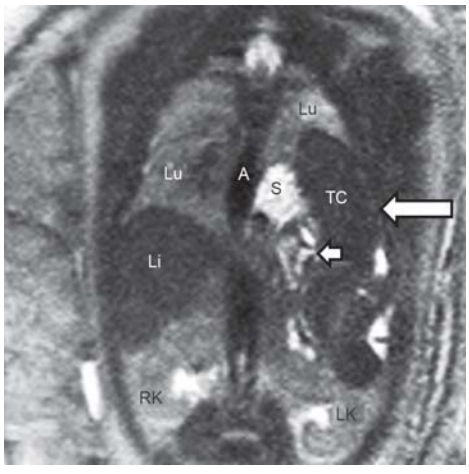


Fig. 2B: Axial T2-weighted small field-of-view 'dedicated' MR image acquired using HASTE sequence at 24 weeks' gestation. Intrathoracic herniation of abdominal viscera including stomach (S), transverse colon (TC) and small bowel (small arrow) is seen in this fetus with congenital diaphragmatic hernia (arrow). Li: Liver, Lu: Lung, RK: Right Kidney, LK: Left Kidney, A: Aorta

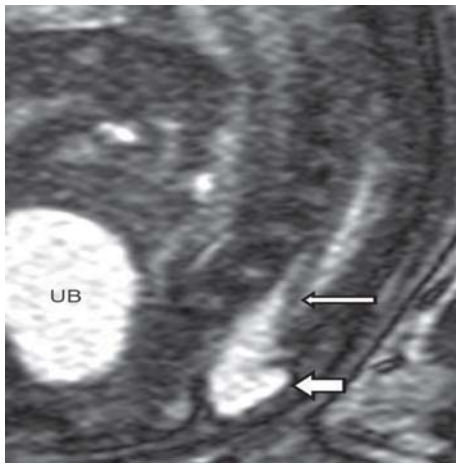
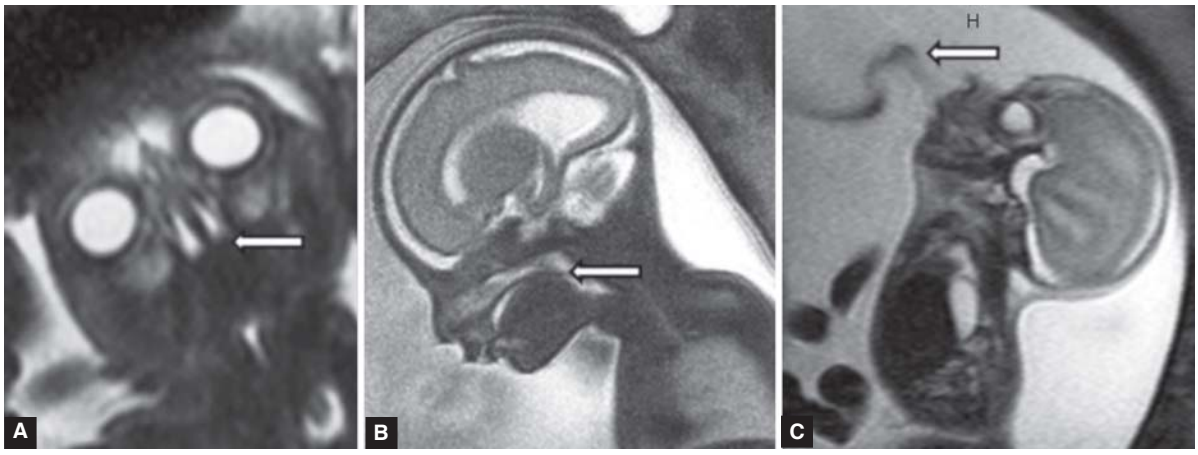


Fig. 3B: Sagittal T2-weighted MR image acquired using HASTE sequence at 26 weeks' gestation. Tethering of the lower end of spinal cord (long arrow) is seen in this fetus with terminal myelocystocele (arrow). UB: Urinary bladder

assessment of fetal spine, delineation of fetal alimentary and urinary tract and other abdominal viscera, conjoint twin assessment, prior to antenatal intrauterine fetal surgery and exutero intrapartum procedure (EXIT). The role of antenatal MRI in the assessment of fetal central nervous system and spine is unmatched owing to accurate characterization of disease process and detection of additional anomalies. The availability of comprehensive information regarding the fetal anomaly helps in deciding the neurodevelopmental prognosis and facilitates better parental counseling. In a commonly encountered clinical circumstance, when ultrasound showed presence of 'ventriculomegaly' or 'corpus callosum agenesis', the issue of vital importance is whether these conditions are isolated or otherwise. Antenatal MRI detected additional abnormalities in as high as 63% of these cases which significantly alter the outcome.[7] The development of fetal CNS occurs according to predictable, programed sequence and MRI is in a unique position to keep an eye on the chronology of vital events. MRI is helpful in early diagnosis of defects in neural tube closure/sulcation/gyration/myelination, occurrence of intracranial ischemic events and aberrations in normal development of ventricular system, corpus callosum and posterior fossa structures. The defects in normal development of fetal spine are precisely defined including diastematomyelia and cord tethering, as MRI can evaluate the spinal cord in addition to complete length of vertebral column (Figs 3A and B). Evaluation of fetal face and neck structures including fetal thyroid glands is also feasible (Figs 4A and B). The normal fetal swallowing is often seen as an area of flow void in amniotic fluid (Fig. 4C).

The qualitative and quantitative assessment of fetal lungs is feasible with antenatal MRI, which provides vital clues regarding the fetal lung maturity and pulmonary hypoplasia.[8]



Figs 4A to C: (A) Coronal T2-weighted MR image acquired using trueFISP sequence at 20 weeks' gestation. Fetal nasal cavity and nasal septum are seen in this image (arrow), (B) sagittal T2-weighted MR image acquired using trueFISP sequence at 20 weeks' gestation. Fetal soft palate, nasopharynx and oropharynx are seen in this image (arrow), (C) sagittal T2-weighted MR image acquired using HASTE sequence at 20 weeks' gestation. Flow void (arrow) is generated in this image due to normal fetal swallowing

In congenital diaphragmatic hernia, mere ultrasound-based diagnosis is not enough and the antenatal MRI is often unavoidable. MRI helps in accurate evaluation of the hernia contents as intrathoracic herniation of liver anticipates poor prognosis. Similarly, the compression effects of herniated abdominal structures over the lungs could be precisely defined. The ability of MRI to delineate the distribution of meconium in fetal bowel on T1-weighted images helps in better assessment of fetal gastrointestinal system (Figs 5A and B). High-quality T1-weighted imaging with 3D data acquisition also facilitates 3D MR colonography of the fetuses.[9] Antenatal MRI is also useful in accurate characterization of fetal abdominal mass lesion and evaluation of abdominal wall defects (Figs 6A and B). Other specific clinical queries, which could be consistently answered with the use of antenatal MRI in fetal abdomen include diagnosis of congenital fetal hemochromatosis, identifying renal vs extrarenal origin of abdominal mass lesion, differentiating multicystic dysplastic kidney from renal tumor, evaluation of fetal megacystis and differentiating pelviureteric obstruction, vesicoureteric reflux disease and posterior urethral valve. In addition, antenatal MRI also evaluates the maternal bony and soft tissue pelvis and provides vital information about fetal-pelvic disproportion in the same sitting.

Antenatal MRI for maternal indications includes a long list of obstetric and nonobstetric conditions. The former mainly includes adnexal torsion, degenerated leiomyoma, concealed antepartum hemorrhage, pregnancy with mullerian anomaly and placental adhesive disorders. In patients with placental adhesive disorders, MR imaging is most clearly indicated when US findings are ambiguous or there is a posterior placenta.[10] Accurate prenatal identification of this condition allows optimal management because timing and site of delivery, availability of blood products, and support of skilled anesthesia and surgical team can be arranged in advance. Homogenous signal intensity of the placenta makes possibility of placental adhesive disorders unlikely. The latter category mainly includes intracranial dural sinus thrombosis, hypertensive encephalopathy, pulmonary

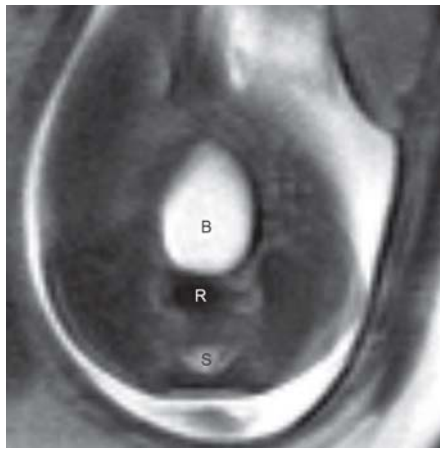


Fig. 5A: Axial T2-weighted MR image acquired using HASTE sequence at 30 weeks' gestation. Normal urinary bladder (B) and spinal canal (S) are seen as hyperintense structure, while the rectum (R) shows hypointense signal intensity

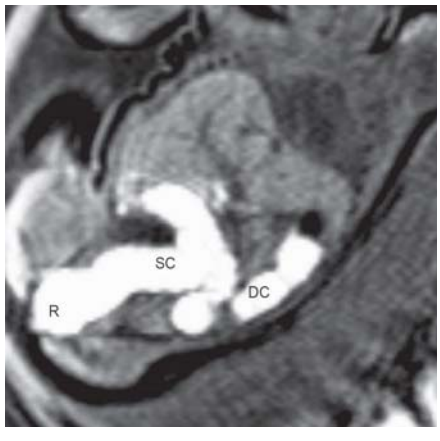


Fig. 5B: Coronal T1-weighted MR image acquired using VIBE sequence at 34 weeks. Descending colon (DC), sigmoid colon (SC) and rectum (R) shows hyperintense signal intensity up to the distal part in this fetus with nonimmune hydrops, who was suspected to have anorectal malformation on ultrasound. The meconium filling up to the distal part of rectum, however ruled out any major anorectal malformation on MRI in this fetus

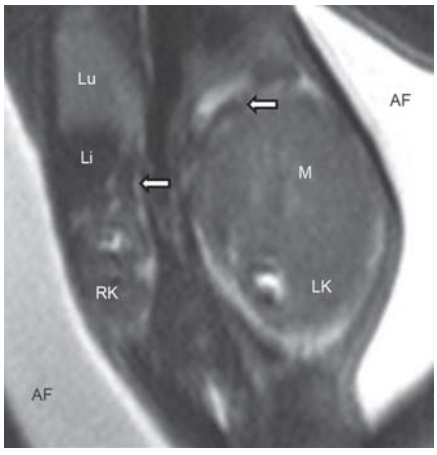


Fig. 6A: Coronal T2-weighted MR image acquired using trueFISP sequence at 18 weeks' gestation. Large solid mass lesion (M) of left renal origin is seen in this fetus with polyhydramnios. Both adrenal glands are separately identified (arrows). Left renal artery is also dilated (not shown) in this fetus with mesoblastic nephroma. Li: Liver, Lu: Lung, RK: Right kidney, LK: Left kidney, AF: Amniotic fluid

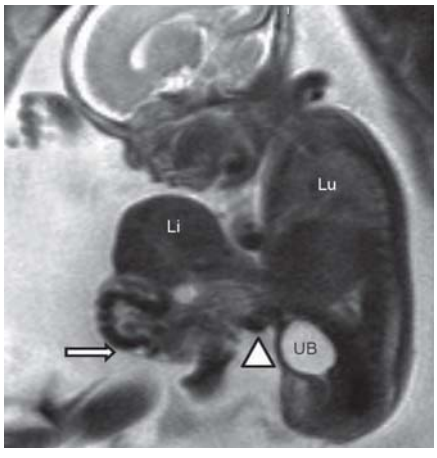


Fig. 6B: Sagittal T2-weighted MR image acquired using HASTE sequence at 19 weeks' gestation. Large anterior abdominal wall defect is seen in this fetus with omphalocele (arrowhead). Herniated intra-abdominal structures are confined by a thin membrane (arrow). Li: Liver, Lu: Lung, UB: Urinary bladder

thromboembolism, pneumonias and acute abdominal conditions like appendicitis, cholecystitis and pyelonephritis. Acute appendicitis is the most common nonobstetric cause of acute abdominal pain in pregnancy. A fetal loss rate of less than 2% is observed with an unruptured inflamed appendix, which increases to more than 30% with appendicular perforation. The diagnosis is often difficult because nausea, emesis and leukocytosis, which are commonly seen with acute appendicitis, even occurs physiologically during pregnancy and may be overlooked. The location of pain is also not typical due to anatomical alteration in the location of appendix during pregnancy.[11]

FUTURE OF ANTENATAL MRI

MRI indications, which are presently at experimental stage include noninvasive MR spectroscopy of fetal brain and urine to detect antenatal fetal hypoxia and noninvasive MR spectroscopy of amniotic fluid and lungs to detect fetal lung maturity.[12,13] MR spectroscopy of amniotic fluid for assessment of fetal environment is even expected to challenge the relevance of invasive amniocentesis in near future. Diffusion-weighted MRI is another potential application of MRI which is likely to revolutionize the noninvasive antenatal imaging. Diffusion-weighted imaging of fetal kidneys is reported to have a role in assessment of the renal parenchyma in fetuses with obstructive uropathy.[14] Diffusion-weighted imaging of placenta is currently being evaluated for early diagnosis of intrauterine growth retardation.[15]

CONCLUSION

By virtue of recent advances in MR technology and the need to practice evidence-based clinical medicine, antenatal MRI is now rapidly moving from the realm of select academic medical centers into community practice in India. It is vital to realize the role and relevance of antenatal MRI in routine clinical practice, so as to offer the state-of-the-art noninvasive imaging options to our patients and to attain the global standards in antenatal care.

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