Prenatal diagnosis of fetal lung maturity by magnetic resonance imaging

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Abstract

Objective: To evaluate the usefulness of magnetic resonance imaging (MRI) for prenatal diagnosis of fetal lung maturity.

Materials and Methods: The subjects comprised 28 singleton fetuses, and underwent MRI in the 3rd trimester (32.71±3.00 wks). After obtaining axial and coronal scout images of the whole pelvis, we obtained a transverse image, a coronal image and a sagittal image of fetuses with a half-Fourier acquisition single-shot turbo-spin-echo (HASTE) sequence, determined the intensity level of the fetal lung (right: RL, left: LL). The intensity level of background outside of the maternal body was obtained as the control intensity level (CL). The contrast value (CV) of each fetal lung was calculated by the numerical formula; CV=(RL or LL−CL)/CL. We evaluated the changes of CV during the 3rd trimester and relationship between CV and gestational weeks.

Results: There was no significant correlation between gestational weeks and RL (P=.3887), LL (P=.2367). There was a significant increase in both right and left CV (RCV: P=.0108, LCV: P=.0165) with gestational age.

Conclusion: It was suggested that the fetal lung maturation could be diagnosed with HASTE using the CV formula.

Introduction

Magnetic resonance imaging (MRI) is used together with ultrasonography (US) to obtain information on fetal evaluation, but there are limitations for the latter caused by maternal obesity, oligohydramnios or the fetal position. Since MRI can enable detailed anatomical assessment under such conditions, the number of MRI examinations has risen steadily.

The first report of MRI in pregnancy appeared in 1983. Previous MRI images were affected by image degradation caused by artifacts due to fetal movement and maternal breathing. Maternal sedation or fetal paralysis was sometimes required to decrease fetal motion because of the long scan time. In the 1990s, faster imaging sequences were developed including echo planar imaging (EPI), single shot fast spin echo (SSFSE) and half-Fourier acquisition single-shot turbo-spin-echo (HASTE). Recent advances on ultra-fast MRI techniques have decreased artifacts dramatically. This technique has changed MRI evaluation of fetal anatomy, especially the demonstration of normal fetal brain development and the definition of suspected brain abnormalities found on US. In the evaluation of congenital...
diaphragmatic hernia (CDH). MRI has been used to assess fetal lung volume and the amount of liver herniation. The presence of liver herniation and the volume of liver within the chest using the liver/diaphragm ratio helped predict the outcome in left-sided CDH. In the evaluation of fetal giant neck masses, MRI is valuable for planning the therapeutic strategy for life threatening airway obstruction. MRI has also made an impact on the evaluation of the fetal brain, especially about the development of the fetal brain and the various types of fetal ventriculomegaly.

MRI has therefore been considered to be useful for the diagnosis of fetal anatomical abnormalities. On the other hand, some reports have suggested that low-intensity fetal lung on MRI might suggest a diagnosis of pulmonary hypoplasia. Fetal lung maturity is usually diagnosed based on the amniotic lecithin/sphingomyelin ratio, which requires amniocentesis. If the intensity of fetal lung on MRI reflected its maturity, fetal lung maturity could be evaluated non-invasively.

In this study, we investigated the change of intensity of fetal lung images on MRI as the basic evaluation of the diagnosis of the fetal lung maturity by MRI after 27 weeks of gestation.

Materials and methods

The subjects comprised 28 singleton fetuses. On fetal US, 11 women were suspected of having major fetal malformations consisting of hydrocephalus (n = 2), intracranial teratoma (n = 1), esophageal atresia (n = 2), duodenal atresia (n = 3), myelomeningocele (n = 1), achondrogenesis (n = 1) and polycystic kidney (n = 1). Two women without fetal abnormalities had placental previa (n = 1) and myoma uteri (n = 1). After the obtaining informed consent, the pregnant women underwent MRI in the 3rd trimester (27–37 weeks’ gestation, mean: 32.71 ± 3.00 weeks).

All MRI were obtained on a 1.5 Tesla super conductive system (1.5 Magnetom Symphony, Siemens, Erlangen, Germany) that used a body phased-array coil. No premedication was given.

After obtaining axial and coronal scout images of the whole pelvis, we obtained a transverse image, a coronal image and a sagittal image of fetuses with a HASTE sequence, determined the strength of signals in the lung mainly at the site where the bilateral lungs were most clearly depicted and determined the contrast value (CV) to conduct a relative evaluation of the signal imaging parameters of the HASTE sequence. The conditions after HASTE sequence were an effective TE of 60.0/1 msec, 30–35 cm field of view, 213 × 256 matrix and 7 mm slice thickness (image acquisition time about 20 sec), Figure 1, Figures 2. After the images were transferred to a computer, the intensity level of the fetal lung (right lung intensity level: RL, left lung intensity level: LL) and control intensity level was calculated. Since the control intensity level (CL) was set to the part of the least noise on the surface of the image showing lung signal values, it could inevitably be obtained from the background outside of the maternal body.

CV between RL or LL, and CL (CV between RL and LL: RCV, CV between LL and CL: LCV) was calculated from the intensity levels of the fetal lungs and the control area by the following numerical formulae;

$$\text{RCV} = (\text{RL} - \text{CL}) / \text{CL}$$
LCV = (LL - CL) / CL

Statistical analysis was performed by linear regression analysis of RL, LL and CL in relation to actual gestational weeks. A P value of less than 0.05 was taken to be indicative of a statistically significant differences.

Results

Figure 3 shows the results of the intensity levels of the background outside of the maternal body (= CL). There is a high degree of scatter in all images despite using the same material.

Figures 4 and 5 show the variations in RL and LL. Figures 6 and 7 show the variation of RCV and LCV in relation to gestational weeks. There were no significant correlations between gestational weeks and RL (P = .3887), or LL (P = .2367). There was a significant increase in both right and left CV (RCV: P = .0108, LCV: P = .0165) with gestational age.

Fig. 3 Variance of intensity levels of maternal background.

Fig. 4 Correlation between RL and gestational weeks. (Y = 1.497 + 0.435 X ; r2 = .027)

Fig. 5 Correlation between LL and gestational weeks. (Y = 2.644 + 0.539 X ; r2 = .05)

Fig. 6 Correlation between RCV and gestational weeks. (Y = -20.258 + 1.091X ; r2 = .225)

Fig. 7 Correlation between LCV and gestational weeks. (Y = 19.213 - 1.346X + 0.037 X^2 ; r2 = .218)
Discussion

In images of the adult lung, MRI has only been used as an auxiliary to computed tomography (CT) in spite of its analyzing capacity for tissue and contrast. The reasons for this are,
1) low water content,
2) artifact by heart beat and breathing,
3) acute decrease of signal by non-uniformity of the magnetic field accompanied with the susceptibility effect.

Because the recent advance of MRI has shortened the imaging time, however, the influence of artifacts or susceptibility effect has been decreased.

As in MRI for adults, fetal evaluation has benefited by the development of MRI sequencing. As the lung develops, there is an increase in water content and a rise in the phospholipid concentrations related to surfactant production. This results in a shortening of the T1 and T2 relaxation times of the lung tissue. It has been reported that low-intensity fetal lung suggested hypoplastic lungs. Based on a study with EPI, Duncan et al. demonstrated the progressive changes which take place in the fetal lungs between 20 weeks gestation and term. They suggested that there was a significant relationship between gestational age and lung volume, MRI parameters T1 and T2. They also demonstrated that there was a significant relationship between lung volume and T1 and T2.

We therefore considered that MRI has great potential for the functional analysis of the fetal organ. However, because the functional difference among MRI machines, the method of imaging or the signal levels from the fetal organs various greatly, it is difficult to evaluate the signal level of each organ correctly. A new marker is required to judge the MRI signals to evaluate correctly regardless of a variation in conditions. The part of the image with least noise on the MRI image is the background outside of the maternal body. First, we examined whether or not this control intensity level was constant on each image. Since all images were taken with one machine at one setting in the present study, we anticipated that there would be no great disparity in the control intensity level. As shown in Figure 3, however, great disparities were observed in the background signal value (mean±SD: 43.5±25.4, range: 8.0 to 134.3, dispersion: 645.1). This suggests that the MRI signal values may be greatly affected by the conditions of imaging and the technician. If the MRI signal values in the right and left lungs were therefore directly plotted for each week of gestation, as shown in Figures 4 and 5, it would be impossible to observe any relationship between the signal values and the period of gestation. From this, we considered it necessary to correct the signal values obtained from the lung with the control intensity level.

In the present study, we used the CV between the signal levels of fetal lung and the background as a method of correction. The picture quality of the MR image was evaluated with the strength of signal determining the contrast value and the noise determining the instability of the strength of signals in one voxel. The signal noise ratio (SNR := signal/noise) is a measure for evaluation of the image, but only a high SNR is insufficient for actual imaging diagnosis. For diagnostic imaging, it is important to differentiate degrees of contrast in different regions such as in lesions and normal tissues. The contrast value of an image is defined as the ratio of the difference between the signals in two different tissues. We chose the maternal background as the control, because it has the least noise. We considered it possible to compare the signal values of the lungs by calculating the contrast ratio irrespective of conditions.

In the present study, the signal value itself obtained from the MR image showed no correlation with the progress of gestation, but the contrast value increased with the progress of gestation. No offspring showed any respiratory disorder after birth and subsequently showed stable respiration. Since the offspring showed normal lung maturation, it was indicated that the contrast value increased with the maturation of the lung. Duncan et al. showed this change by EPI and suggested that the water content in the lung increased with the progress of gestation. However, although they determined the signal values with EPI, they did not correct them with the control intensity level. We cannot determine whether or not the correlation between the signal values in the lung and the progress of gestation shown by the method of Duncan et al. is attributable to determination with EPI. We conducted the same examination with the HASTE but observed a significant correlation by correcting with the contrast. There is a possibility that a more significant correlation can be observed by correcting the EPI in relation to the contrast value. In addition, it was suggested that by using the contrast value the maturation of lung could be diagnosed with the HASTE as with the EPI.

However, the best under reflecting maturation of the lungs during pregnancy best at present is the L/S ratio. In fact, CV calculated in this study has many problems to resolve. For example, one case of CV in 29 weeks gestation showed higher CV level than ones of 37 weeks gestation. Moreover, almost cases in this study had clinical abnormality, such as the fetal anormaly. It will be required many normal cases to decide the more correct CV in every gestational week, and it is important to purchase the changes in every case.

In order to clarify whether the CV determined with
the HASTE correctly reflects the L/S ratio, the correlation between the L/S ratio in the amniotic fluid and the CV shall be examined. L/S ratio requires amniocentesis, which is invasive to mothers and babies. If CV has good correlation to L/S ratio, we can get the information of fetal lung maturity with non-invasive method. Neonatal respiratory problems remain an important cause of mortality and morbidity. Diagnosis of fetal lung maturity with MRI will be useful to decide to deliver an infant prior to 34 weeks gestation in the clinical field, like as preterm premature rupture of membrane (PROM) cases. It will be the subjects in future to increase patients and to explore the correlation with CV and the L/S ratio.

Conclusion

By using MRI, we suggested the physiological change in the fetal lung maturation could be demonstrated. This fact has great possibility to decide the timing of delivery on preterm PROM cases.

Reference

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MRIによる胎児肺成熟の出生前診断

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【要旨】MRIによる胎児肺成熟の出生前診断に関して検討した。妊娠27週以降の単胎妊娠28症例に対しMRI(HASTE法)を施行し、胎児肺を撮影した。母体外の背景のintensityをコントロールとし(control intensity level: CL)、胎児の左右肺のintensity(right lung intensity level: RL, left lung intensity level: LL)とCLとのコントラストを算出した(right lung contrast value: RCV, left lung contrast value: LCV)。RL, LLと妊娠週数及びRCV, LCVと妊娠週数の相関を求めたところ、RL, LLは妊娠週数に有意な相関を認めなかった(P=.3887, .2367)が、RCV, LCVは妊娠週数が増加するに従って、有意に増加した(P=.0108, .0165)。現在、MRIは胎児形態診断に有用であり頻用されているが、形態診断のみならず、機能診断にも有用である可能性が示された。

〈Key words〉出生前診断、胎児肺、成熟度、MRI