1.5T in vivo 1H MRS for evaluation of fetal lung maturity: technical feasibility study

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Introduction

Several studies indicate that single voxel ^{1}H magnetic resonance spectroscopy (MRS) can be useful in evaluating fetal lung maturity in vivo [1,2]. The production of surfactant, a choline-containing compound, serves as the indicator. While MRS can be performed to detect these compounds in the fetal lung and amniotic fluid, it is not clear whether adequate signal to noise (SNR) is achievable or if motion effects can be overcome. Here, we describe a study to determine if conventional MRS techniques can be used to evaluate fetal lung maturity. It is shown that the fundamental limit of SNR requires imaging parameters at the edge of clinical feasibility while motion effects can be reduced by efficient data acquisition and post-processing methods.

Methods

In vivo spectroscopy acquisition and motion correction: For spectroscopy of the amniotic fluid and fetal lung, the sequence was divided into sections composed of 1 minute acquisitions (TR/TE = 1000/144 or 35 ms) where between each sections, an SSFSE sequence is played to evaluate and adjust for fetal position. These sections are repeated for at least 4 times for both fluid and lung. On several occasions, these 1 minute sections were further divided into four 15 second continuous segments where each small segment was collected using breath-holding to minimize motion from the mother. (Number of fetuses scanned: 8, average gestational age at scan: 37±1.5 weeks). Spectroscopy data from each TR were stored and processed individually. Prior to summing the individual spectra, water frequency was realigned to restore any frequency shifts due to motion.

SNR study: To estimate the achievable SNR for our in vivo protocols, samples of the amniotic fluid in two patients were collected and tested ex vivo on a 1.5 T clinical magnet using a 3-inch surface coil. The distance of the sample from the coil was adjusted so that the SNR from the localizer images matched the SNR obtained from in vivo cases. Using similar imaging parameters to the in vivo cases, the imaging time was then varied and SNR values were recorded. This approach was used to determine parameters such as scan time and voxel size needed to achieve particular SNR values for in vivo exams. As a reference to identify the compounds within the collected amniotic fluid, HR-MAS (high resolution magic angle spinning) spectra were obtained using an 11.7T Varian INOVE spectrometer.

Results

Results pertaining to the ex vivo amniotic fluid experiments are illustrated in Fig. 1. In the upper row, ex vivo spectra collected from the 1.5T scanner are given showing the lactate doublet. Unfortunately, given these scan parameters, no choline containing compounds could be identified. Ex vivo 11.7 T spectra from the same sample is also shown in Fig. 1(d). The HR-MAS data clearly show that there are indeed choline containing compounds, but at a much smaller magnitude than lactate. The achievable SNR for the detection of lactate peak in in vivo cases was analogized using the results of Fig. 1 and is shown in Fig. 2, where plots of scan time versus voxel size to detect lactate at a certain SNR given different amniotic fluid SNR as measured by the localizer is given. A representative localizer image showing the placement of the region of interest to calculate the SNR is also given. As an example, given an amniotic fluid SNR ≈ 20, one can expect to detect lactate with SNR ≈ 4 using a 12cc voxel size and 5 minute spectroscopy acquisition. In this regard, to detect choline with smaller signal levels compared to lactate, the imaging time or voxel size would need to be substantially increased. Although inter-subject variability of the choline peak can exist, especially for those with and without lung maturity, our HR-MAS from all our subjects revealed smaller levels of choline compared to lactate. The plot given here serves as a general guideline for imaging parameter determination when performing in vivo fluid spectroscopy. Typical SNR of localizer images in in vivo amniotic fluid resulted in the range of 5 – 20.

While the SNR plot of Fig. 2 present challenges in successful detection of the metabolites, a case where lactate was detected in the fluids and also presumably choline in the lung is given in Fig. 3. The figure shows increased SNR gained by applying a frequency alignment step prior to averaging. Without this step, the detection can be limited as seen in the case of the choline peak obtained from the lung. The imaging parameters for both of the acquisitions were 9 cc voxel size with an acquisition time of approximately 10 minutes. The use of a breath-hold during 1 minute scans resulted in a slight increase in signal intensity for lung scans (~10%) and fluid scans (~3-5%) compared to scans without breath-holding.

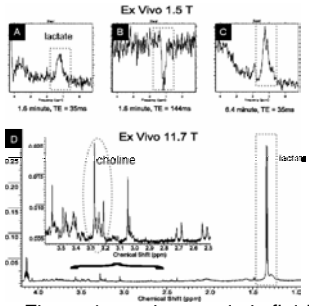

Figure 1. ex vivo amniotic fluid

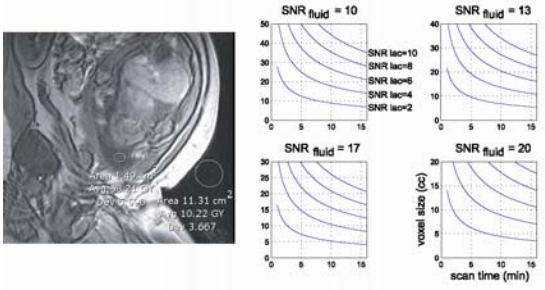

Figure 2. Estimated achievable SNR

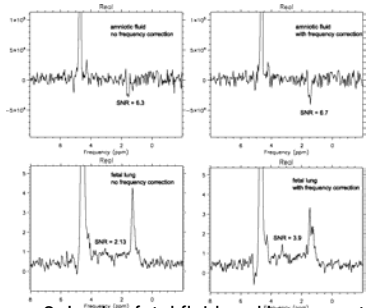

Figure 3. In vivo fetal fluid and lung spectra

Conclusion

We have conducted a feasibility study of performing in vivo MR spectroscopy for the evaluation of fetal lung maturity. It is shown that while motion effects can be partially overcome, the availability of SNR is the critical limiting factor. Studies performed on amniotic fluid suggest imaging parameters that are at the edge of clinical feasibility. While the situation seems to be the same for direct lung imaging, additional studies on lung imaging needs to be performed to confirm this.

References

[1] Fenton BW, et al, Obstet Gynecol 95:457, 2000

[2] Clifton MS, et al, J Pediatr Surg 41:768, 2006