Cervical Attenuation as a Measure of Preterm Delivery: Impact of Different Region of Interest Sizes*

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Abstract— **One to five transvaginal ultrasound scans were taken of 63 women to estimate the microstructural changes in cervix using ultrasonic attenuation. Spectral log difference algorithm showed a clear decrease in attenuation as the time to delivery comes closer. The decrease in attenuation occurs earlier in preterm birth compared to full term birth which can be used as a predictor for preterm birth. Attenuation estimate did not improve as the ROI size increased.**

I. INTRODUCTION

Preterm birth is defined as birth of the baby before 37 completed weeks of gestational age; it is the leading cause of infant mortality worldwide according to World Health Organization. In the United States, it is the second main contributor to infant mortality[1]. According to Centers for Disease Control and Prevention 35% of infant deaths in 2009 were related to preterm birth. Cervical length and a previous history of preterm birth are the best indicators currently available for predicting preterm birth. Cervical length shows good result in patients with a history of preterm birth[2], but fails in the case of no previous preterm birth[3], [4]. As the time of delivery comes closer the collagen rich cervix transforms from a hard structure to a soft, extensible structure. Ultrasonic attenuation can be used to detect these microstructural changes in cervix as attenuation is related to tissue stiffness, collagen and water concentration of tissues[5], [6], [7], [8], [9]. Our previous studies in both animals and humans have shown that ultrasonic attenuation relates with collagen remodeling of the cervix, gestation age of pregnancy and time to delivery[10], [11], [12], [13]. The aim of this study is to see if preterm cases can be properly identified.

II. MATERIALS AND METHODS

Sixty-three pregnant African-American women were recruited for this study. The eligibility criteria for recruitment were: greater than 18 years of age; can read, write and understand English; should not have any immune disorder; should not use steroids or have pre-existing diabetes. Women were excluded from the study if they had an anomalous fetus or were too ill to give informed consent. One to five transvaginal ultrasound scans were taken at a planned interval of 20, 24, 28, 32, 36 weeks gestation, ±1 week during pregnancy to estimate ultrasonic attenuation of the cervical region. A Gammex (Gammex Inc., Middleton, WI) tissue-mimicking reference phantom was scanned immediately after each cervical scan, using the same ultrasound system settings,. The reference phantom had a known attenuation of 0.5 dB/cm-MHz give by the manufacturer which was verified by independent validation measurements taken in our laboratory. A calibrated phantom is used so as to cancel out the dependence of spectral power on diffraction term[14].

Ultrasonic data was obtained from a z.one, Zonare ultrasound system, saved and converted to IQ (in-phase quadrature) data. IQ data was taken for the cervix and the reference phantom at 3 center frequencies (i. e., 4, 5 and 8 MHz). After converting the IQ data to RF data, the RF data was windowed into smaller regions of interest (ROIs) to estimate the attenuation throughout the entire cervix. In earlier studies[13], the most homogeneous appearing rectangular region of the cervix was selected from the gray scale image. However, due to concerns of ROI selection bias and measure reproducibility a different approach was taken in this study which was to select the entire cervical region using a polygon.

For this study, the spectral log difference algorithm was used to estimate attenuation values in side the cervix. Among the different algorithms, spectral log difference was selected because it is least susceptible to the natural heterogeneity of biological tissues[14], [15]. Our previous studies have shown that a minimum of 15 echo scans in the lateral direction and 14 to 15 pulse lengths in the axial direction are required for a standard deviation of less than 25% when using the spectral log difference method[15]. In this study we decided to use 15 and 20 echo scans in the lateral direction and 14 and 17.5 pulse lengths in the axial direction. The spectral log difference methodology has been briefly described [12].

The spectral log difference method estimates the ultrasonic attenuation value by calculating the slope of the straight line that fits the log ratio (difference between log spectra) of the two power spectra from the proximal and the distal segments of the region of interest[12]. The attenuation map for the

*This work was partially supported in parts by the Irving Harris Foundation, the University of Illinois College of Nursing Internal Research Support Program, and the University of Illinois Center for Clinical and Translational Science (NIH grant UL1TR000050).

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selected cervical region was then overlaid on the B-mode image.

III. RESULTS

Some patients scans were missed or not taken at the planned time due to preterm birth, missed appointments, moved away, or delivery for medical indications. If the gestation age at the time of the scan lied between 16-22 weeks it was treated as scan 1, 23-26 weeks as scan 2, 27-30 weeks as scan 3, 31-34 weeks as scan 4, 35 week onwards as scan 5. 53 women had a full term birth whereas 10 women had preterm birth.

The cervical attenuation for the full term and preterm births are plotted against the gestation age for the five scans as seen in Fig. 1(a).These attenuation values have been calculated for 14 pulse length and 15 echoes. The average value of attenuation for each scan is also plotted against the average gestational age at each scan for both the full term and preterm births. The macro structural changes in cervix do not start happening before the very last few weeks from delivery. Since the major change in cervix takes place close to the time of delivery, it is more relevant to look at the change in attenuation in the last few weeks as the cervix prepares for delivery. All the attenuation values which had gestation age less than 30 were averaged and treated as reference to study the change in attenuation value from 30 week onwards.Fig. 1(b) shows the change in attenuation value over the last 10 weeks from delivery for both full term and preterm cases. A best fit line is also shown for both the full term and preterm birth. Fig. 2(a) shows the attenuation value of all scans and the average attenuation value against gestational age for 14 pulse length and 20 echoes. The change in attenuation value over the last 10 weeks from delivery is shown in Fig. 2(b). Similarly, Fig. 3(a) and 3(b) present the same information about 17.5 pulse length and 15 echoes. Fig. 4(a) and 4(b) show the attenuation values for 17.5 pulse length and 20 echoes. The change in attenuation with respect to time to delivery can be quantified in terms of the slope and the y-intercept of the best fit line. These slope and intercept values for Fig. 1(b), 2(b), 3(b), 4(b) are presented in Table I, these values are for full term births. Table II shows the slope and intercept values for preterm births.

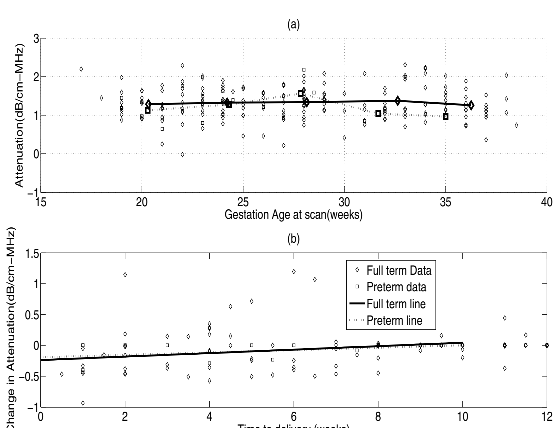

Fig. 1. (a) Average attenuation values versus average gestation age for the 5 scans, (b) Change in attenuation over the last 10 weeks of delivery for 14 pulse lengths and 15 echoes.

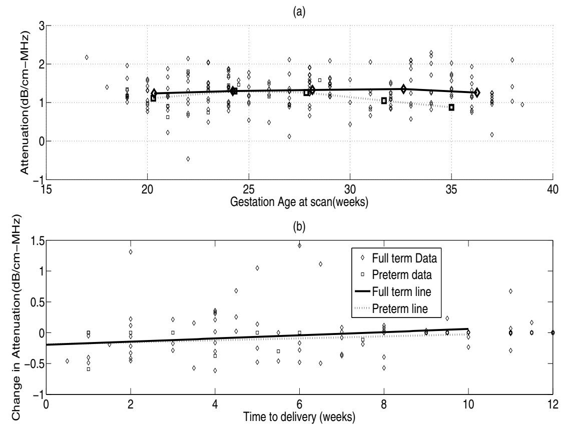

Fig. 2. (a) Average attenuation values versus average gestation age for the 5 scans, (b) Change in attenuation over the last 10 weeks of delivery for 14 pulse lengths and 20 echoes.

IV. DISCUSSION

In Fig. 1(a) we see that the mean attenuation value(for full term birth) almost remains constant for the first four scan but decreases for the fifth scan which is closest to delivery. The attenuation value of the fourth scan was 1.373 dB/cm-MHz and decreases to 1.258 dB/cm-MHz for the fifth scan. This decrease in attenuation value represents the changes in the cervix as it prepares to deliver. However the preterm birth attenuation values starts decreasing as early as 3rd scan, this shows how the cervix is preparing for a preterm delivery.Also the average attenuation values at scan 4 and scan 5 are much lower than the corresponding values of scan 4 and scan 5 for full term birth. From Fig. 1(b) we can see that the y-intercept and slope of the best fit line for full term and preterm are very close to each other.

As the size of ROI increases the standard deviation decreases [15]. Since we want to maximize our number of estimate as well as the size of the ROI too, the optimum solution is to use pulse length of 14,17.5 and 15,20 echoes. At higher pulse length and echoes we get very few estimates of attenuation, hence they are avoided. From Table I and Table II we can see that the slope and y-intercept for both the preterm and full term birth don't vary much as the pulse length and the number of echoes is changed. Although we expect to see better results by using higher pulse lengths and echoes , we don't see them because of the lower number of estimates with bigger ROI.

In Fig. 2(a) the average attenuation value decreases from 1.350 dB/cm-MHz to 1.260 dB/cm-MHz as we go from scan 4 to 5 in case of full term birth. For the preterm birth the attenuation value starts decreasing from scan 3 itself , as seen in Fig. 1(a) also. Although unlike Fig. 1(a) the scan 5 value

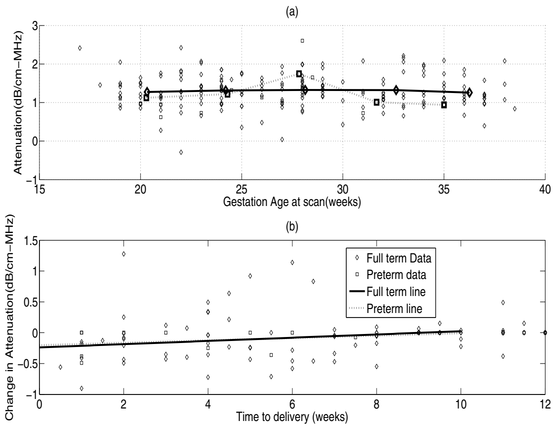

Fig. 3. (a) Average attenuation values versus average gestation age for the 5 scans, (b) Change in attenuation over the last 10 weeks of delivery for 17.5 pulse lengths and 15 echoes.

is lower than scan 4, whereas in Fig. 1(a) the 4th and 5th scan values are almost constant. This can be explained by the increased number of echo lines. Also we notice that the scan 3 value in Fig. 1(a) is higher than the full term value at scan 3, whereas in Fig. 2(a) the scan 3 attenuation value is almost similar for both full term and preterm birth. So as the number of echo lines increases the attenuation value become more stable and in tune with our expected results. The change in attenuation value shown in Fig. 2(b) is very similar to what we have in Fig. 1(b). This implies that the change in attenuation value is independent of the ROI size which makes change in attenuation value a better predictor for preterm birth as smaller ROI sizes can be used which brings in more variability in attenuation estimates.

For Fig. 3(a) the average attenuation value falls from 1.321 dB/cm-MHz to 1.257 dB/cm-MHz from scan 4 to 5, for the full term case. Although we would have expected a sharper fall as the ROI size increases but we don't observe it, which

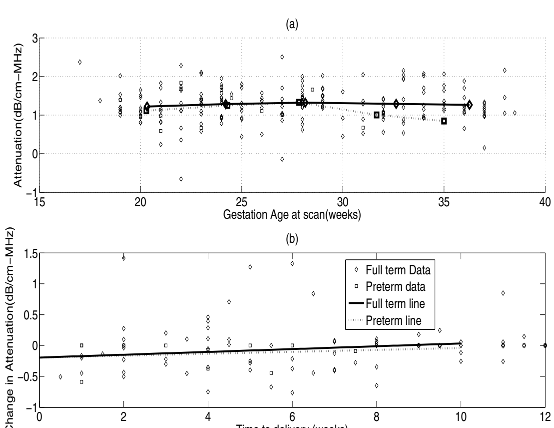

Fig. 4. (a) Average attenuation values versus average gestation age for the 5 scans, (b) Change in attenuation over the last 10 weeks of delivery for 17.5 pulse lengths and 20 echoes.

TABLE I

SLOPE AND INTERCEPT VALUES FOR FULL TERM

#Pulse length	#Echos	Slope	Y-intercept(dB/cm-MHz)
14	15	0.028	-0.238
14	20	0.026	-0.196
17.5	15	0.026	-0.239
17.5	20	0.023	-0.195

can be explained by the lower number of estimates. The preterm birth case shows very similar trend as Fig. 1(a), the attenuation value rises for scan 3 and then falls rapidly for scan 4 and almost becomes constant for scan 5. The change in attenuation value is also very similar to previous cases in terms of slope and y-intercept.

For Fig. 4(a) the average attenuation value decreases from 1.289 dB/cm-MHz to 1.266 dB/cm-MHz from scan 4 to 5, for the full term case. This is the lowest decrease we have seen amongst all the cases and can be explained by the decreasing number of attenuation estimates. Irrespective of that the preterm cases do much better. The usual rise in attenuation value which is seen for 15 echo lines (Fig. 1(a),3(a)) is not seen in this case, simmilar to Fig. 2(a). the full term and preterm attenuation values almost overlap each other until the 3rd scan. After the 3rd scan the preterm attenuation value starts falling whereas the full term attenuation value remains constant. For scan 5 the preterm value falls further unlike what was previously seen and might be an artifact of the lower number of estimates. The attenuation values can be used as a preterm predictor as they are almost constant till scan 3 and then falls of to show the changes in cervix as it remodel from a firm (high attenuation) to a supple soft structure (low attenuation). The same can be observed from the change in attenuation values also but the change becomes more relevant as it is independent of the ROI size.

V. CONCLUSIONS

Attenuation can be used to predict the micro structural changes occurring in cervix as the time of delivery draws closer. The change in ROI size does not impact the estimate of attenuation as the variation in estimates and inter patient variability is still high. Better signal processing techniques are required to show a clear decrease in attenuation for the full term cases. The small sample size of preterm cases eliminates lot of inter patient variability and hence more preterm cases are needed for more reliable understanding of the decrease in attenuation values.

TABLE II

SLOPE AND INTERCEPT VALUES FOR PRETERM

#Pulse length	#Echos	Slope	Y-intercept(dB/cm-MHz)
14	15	0.019	-0.193
14	20	0.016	-0.188
17.5	15	0.019	-0.203
17.5	20	0.015	-0.195

ACKNOWLEDGMENT

The authors would like to thank Rush University Medical Center for their help and expertise in acquiring the transvaginal ultrasound scans of all the patients.

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