Multi-dimensional Evaluation of Diastasis Recti Abdominis by Ultrasound during Different Pregnancy and Perinatal Period

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Research Article

Keywords: Diastasis recti abdominis, Ultrasound, Shear wave elastography

Posted Date: December 12th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-2345945/v1

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Abstract

Background

To explore the application value of two-dimensional ultrasound and shear wave elastography (SWE) in the evaluation of diastasis recti abdominis (DRA) in different dimensions during perinatal period.

Methods

From June 2021 to September 2022, 26 cases of the first trimester (< 14 weeks), 36 cases of 14–27 weeks, 36 cases of 28–34 weeks, 32 cases of 35–38 weeks, 45 cases of postpartum 42 days and 27 cases of postpartum 3 months were identified. Inter-rectus distance (IRD) and muscle thickness measurements were taken by B-mode ultrasound. SWE values were acquired by two operators. IRD, thickness and SWE, were compared during different period using one-way ANOVA or Kruskal-Wallis. Spearman correlation analyses were conducted for the variables of IRD, thickness, BMI, neonatal weight, delivery mode, and SWE. Bland-Altman plot was used to analyze SWE of rectus abdominis as a reliability index.

Results

IRD and SWE did not return to the early level ($P<0.001$, $P<0.001$), but the muscle thickness had no significant difference ($P=0.211$). SWE was negatively correlated with IRD ($r=-0.515$), positively correlated with muscle thickness ($r=0.408$), negatively correlated with BMI ($r=-0.296$), but not significantly correlated with neonatal weight and delivery mode ($P=0.147$, 0.648). Bland-Altman plot showed that different operators have better consistency.

Conclusions

Multi-dimensional evaluation of DRA by ultrasound is feasible. IRD and SWE values can be used to evaluate the recovery of postpartum DRA, and the combination of them can objectively reflect the morphological and functional severity of DRA.

Background

Diastasis recti abdominis (DRA), a separation of the paired rectus abdominis muscles $^1$, and is an abnormality of the anterior abdominal wall. Rectus in posture, stable torso, pelvis, breathing, defecation, delivery and support abdominal organs plays an important role$^2$. DRA can affect the aesthetic degree, chronic continuous progress to abdominal wall function obstacle, will cause serious influence to patients’ physical and mental health, such as chronic low back pain, abdominal organs shift and umbilical
hernia\cite{3}. DRA is most common in perinatal women\cite{4}. Studies have shown that the prevalence of DRA in the third trimester, 6–8 weeks postpartum and 12–14 weeks postpartum can reach 100%, 52.4% and 53.6%, respectively \cite{5}. In recent years, the general improvement of people's health awareness and postpartum rehabilitation awareness, DRA has attracted more and more attention. However, most literature reports are limited to the study of inter-rectus distance (IRD), which fails to comprehensively and objectively evaluate the changes and functional biomechanical of DRA, which is not conducive to guiding clinical intervention and treatment in time. Different from the changes in IRD, some scholars believe that the changes in muscle tension and elasticity of rectus abdominis may be the root cause of whether DRA can recover itself and affect the clinical efficacy \cite{6}. Shear wave elastography (SWE) can sensitively and accurately evaluate the elastic characteristics of tissues\cite{7}. It can provide some help to detect the functional biomechanics of rectus abdominis. Therefore, 2D ultrasound combined with SWE was used in this study to evaluate the multi-dimensional changes in the IRD, muscle thickness and elastic characteristics of rectus abdominis muscle in perinatal women at different periods, providing an important reference for the comprehensive evaluation of DRA in perinatal women.

**Methods**

**Participants**

From June 2021 to September 2022, a total of 202 pregnant women were examined in our hospital, 26 cases of early pregnancy (<14 weeks), 36 cases of 14–27 weeks, 36 cases of 28–34 weeks, 32 cases of 35–38 weeks, 45 cases of postpartum 42 days and 27 cases of postpartum 3 months were identified. Women who were between the ages of 18 and 38 years old. Eligible subjects were recruited based on the following inclusion criteria: 1) Single fetus, primipara; 2) No complications such as diabetes or hypertension; 3) Normal cognitive ability, can cooperate to complete the study; and 4) The informed consent of the subjects was obtained. The exclusion criteria were as follows: (1) Congenital abdominal wall dysplasia; (2) Abnormal lumbosacral spine; (3) Patients with a history of abdominal surgery and pelvic trauma; (4) Patients with a history of neuromuscular disease; and (5) Previous body mass reduction > 10 kg.

**Equipment**

Ultrasound images were obtained using a high-end scanner (Aixplorer, Supersonic Imagine, France) equipped with an SWE mode. The scanner was coupled with a linear array probe (SL15-4), MSK/Muscle condition was selected for 2D ultrasound and SWE examination.

**Procedure**

Participants were positioned in supine, and the distance between the supra-umbilicus (4.5cm above the umbilicus) to the sub-umbilicus (4.5 cm below the umbilicus) was measured on the transverse section
between the two sides of the rectus abdominis. The maximum distance between the rectus abdominis as the main observation section, and the image was frozen after quality was stable. Playback, select qualified images for measurement and observation. The IRD and the thickness of rectus abdominis at the thickest part of both sides were recorded (Fig. 1; Fig. 2). To make the probe position standard, the measuring site was marked on the skin with a marker. For patients with large DRA, ultrasound wide-field imaging mode was used. At the horizontal cross-section, two operators respectively used SWE to measure the Young's modulus of the rectus abdominis on both sides (Fig. 3).

Start SWE mode. The probe avoids pressurization, and the region of interest (ROI) is set to the size of (10 mm) × (15 mm). The depth of the ROI is about 1.0 ~ 2.5 cm. The image was frozen and the Q-BOX function was activated to measure Young's modulus of the muscle tissue in the ROI. The diameter was set as 4mm in the early and postnatal period and 3mm in the middle and late pregnancy. The system automatically calculated the average Young's modulus of the muscle tissue in the Q-BOX region. The qualified of SWE image is as follows: (1) the image is clear, and almost all the color signal boxes are filled with color and the color is stable; (2) normal muscle tissue is uniform blue; and (3) no obvious compression artifacts. Repeat the above operation for more than three times. After excluding unqualified images, the mean SWE value of the three times represented the final SWE value of the muscle. In this study, the IDR 20mm was defined as DRA[8].

The rectus abdominis tests were conducted by doctor A, whose working for more than 5 years. Another doctor B, whose working for more than 2 years, performed SWE again to determine the Young's modulus of rectus abdominis.

**Statistical analysis**

Statistical analyses were performed using IBM SPSS Statistics (v.27; IBM Corp, Armonk, New York). The results are presented as mean ± standard deviation for the numerical variables of IRD, muscle thickness and Young's modulus. Count data is expressed as a percentage (%). IRD, muscle thickness and Young's modulus, were compared during different period using one-way ANOVA or Kruskal-Wallis. Bonferroni test was used for multiple comparisons between groups. The muscle thickness and Young's modulus of the left and right rectus abdominis were compared by independent-samples t test or Mann-Whitney U test. Spearman correlation analyses were conducted for the variables of IRD, muscle thickness, BMI, neonatal weight, delivery mode, and SWE in the 202 cases. Bland-Altman plot was used to analyze SWE of rectus abdominis as a reliability index. A P value < 0.05 indicated a significant difference.

**Results**

**Comparison of the IRD, muscle thickness and SWE of rectus abdominis**
The IRD, muscle thickness and SWE values of six different periods were compared, and pairwise comparisons were made between each period. There were significant differences among different pregnancy periods ($P=0.000$, $P<0.001$, $P<0.001$).

There was no obvious separation of rectus abdominis muscles in the first trimester, while the differences were statistically significant compared with other periods ($P=0.000$, $0.000$, $0.000$, $0.000$, $<0.001$). IRD widened with the increase of gestational age, DRA occurred in the third trimester (100%, 68/68). At 42 days postpartum, IRD was significantly lower than that of the third trimester ($P=0.016, 0.000$), but it still did not return to the normal range. At 3 months postpartum, most of IRD could return to the normal range (55.56%, 15/27), but it was still difficult to return to the early pregnancy level ($P<0.001$) (Table 1; Fig. 4).

<table>
<thead>
<tr>
<th>Findings</th>
<th>IRD (mm)</th>
<th>Thickness (mm)</th>
<th>SWE (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;14 weeks (n=26)</td>
<td>14.19±5.51</td>
<td>9.83±0.95</td>
<td>14.60±2.55</td>
</tr>
<tr>
<td>14-27 weeks (n=36)</td>
<td>29.62±4.93</td>
<td>8.25±0.83</td>
<td>11.37±2.81</td>
</tr>
<tr>
<td>28-34 weeks (n=36)</td>
<td>41.66±6.78</td>
<td>8.04±0.91</td>
<td>10.04±2.37</td>
</tr>
<tr>
<td>35-38 weeks (n=32)</td>
<td>52.27±6.18</td>
<td>6.32±0.78</td>
<td>8.40±1.99</td>
</tr>
<tr>
<td>42 days postpartum (n=45)</td>
<td>32.96±5.51</td>
<td>8.62±0.95</td>
<td>10.04±1.62</td>
</tr>
<tr>
<td>3 months postpartum (n=27)</td>
<td>22.96±6.81</td>
<td>9.49±1.01</td>
<td>10.27±2.68</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>statistic</th>
<th>$H=158.927$</th>
<th>$F=56.099$</th>
<th>$H=61.668$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P$</td>
<td>0.000</td>
<td>$&lt;0.001$</td>
<td>$&lt;0.001$</td>
</tr>
</tbody>
</table>

(Compared with <14 weeks, $^a P<0.05$; Compared with 14-27 weeks, $^b P<0.05$; Compared with 28-34 weeks, $^c P<0.05$; Compared with 35-38 weeks, $^d P<0.05$; Compared with 42 days postpartum, $^e P<0.05$)

The rectus abdominis muscle thickness in the first trimester was significantly different from that in other trimesters ($P<0.001$, $<0.001$, $<0.001$, $<0.001$), but there was no significant difference compared with that in the 3 months postpartum ($P=0.211$) (Table 1; Fig. 5).

There was no significant difference in the SWE of rectus abdominis between the left and right sides of pregnant women ($P=0.211$). With the increase of gestational age, the SWE of rectus abdominis decreased, and the difference was statistically significant compared with the first trimester ($P=0.005$, $<0.001$, $<0.001$), and it recovered slowly postpartum. There was a significant difference between 42 days postpartum and 35–38 weeks ($P=0.04$), but no significant difference between 42 days and 3 months.
postpartum ($P=1.000$). Therefore, the recovery was faster at 42 days postpartum, and the elasticity of rectus abdominis muscle in 3 months postpartum has not yet returned to the early pregnancy level ($P<0.001$) (Table 1; Fig. 6).

**DRA at the maximum region in different pregnancy periods**

The region of maximum maternal separation in the six periods of DRA was compared. Among the 202 pregnant women, 149 cases had DRA. DRA mainly occurred in umbilical region (81.21%, 121/149), a few cases had supra-umbilicus region (14.09%, 21/149), and a few cases had sub-umbilical region (4.70%, 7/149) (Table 2).

<table>
<thead>
<tr>
<th>Findings</th>
<th>the maximum region of DRA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>supra umbilicus [n(%)]</td>
</tr>
<tr>
<td>&lt;14 weeks (n=4)</td>
<td>2(50.00)</td>
</tr>
<tr>
<td>14-27 weeks (n=28)</td>
<td>3(12.00)</td>
</tr>
<tr>
<td>28-34 weeks (n=36)</td>
<td>5(13.89)</td>
</tr>
<tr>
<td>35-38 weeks (n=32)</td>
<td>6(18.75)</td>
</tr>
<tr>
<td>42 days postpartum (n=34)</td>
<td>3(8.82)</td>
</tr>
<tr>
<td>3 months postpartum (n=15)</td>
<td>2(13.33)</td>
</tr>
<tr>
<td>n=149</td>
<td>21(14.09)</td>
</tr>
</tbody>
</table>

**The Difference Between Postpartum 3 Months And First Trimester**

Compared with the first trimester, the IRD and SWE of rectus abdominis were still difficult to restore, and the difference was statistically significant ($Z=4.264$, $P<0.001$, $Z=5.294$, $P<0.001$), but there was no significant difference in the muscle thickness ($t=1.267$, $P=0.211$) (Tables 3).
Table 3
Comparison of the IRD, muscle thickness and SWE during the first trimester and 3 months postpartum

<table>
<thead>
<tr>
<th>Findings</th>
<th>IRD (mm)</th>
<th>Thickness (mm)</th>
<th>SWE(kPa)</th>
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<td>3 months postpartum (n = 27)</td>
<td>22.96 ± 6.81</td>
<td>9.49 ± 1.01</td>
<td>10.27 ± 2.68</td>
</tr>
<tr>
<td>statistic</td>
<td>Z=-4.264</td>
<td>t = 1.267</td>
<td>Z=-5.294</td>
</tr>
<tr>
<td>P</td>
<td>&lt;0.001</td>
<td>0.211</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Correlation Analysis Between SWE Of Rectus Abdominis And Other Indexes

The SWE of rectus abdominis was negatively correlated with IRD (r=−0.515). The SWE of rectus abdominis decreased with the increase of the IRD. The SWE of rectus abdominis was positively correlated with the muscle thickness (r = 0.408). A negative and weak correlation was found between BMI (r=−0.296). There was no significant correlation with neonatal weight and delivery mode (P = 0.147, 0.648) (Tables 4).

Table 4
Correlation analysis between SWE and other indexes

<table>
<thead>
<tr>
<th>Findings</th>
<th>SWE</th>
<th>r</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRD</td>
<td>-0.515*</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>-0.296*</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>Thickness</td>
<td>0.408*</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>Neonatal weight</td>
<td>0.173</td>
<td>0.147</td>
<td></td>
</tr>
<tr>
<td>Delivery mode</td>
<td>0.055</td>
<td>0.648</td>
<td></td>
</tr>
</tbody>
</table>

Observer Consistency Test Of SWE Of Rectus Abdominis

Bland-Altman plots showed that most of the points were distributed within the range of the upper and lower limits of 95% agreement, indicating that there was good consistency between different operators by
Discussion

DRA is an extremely common condition in perinatal women. Changes in the elasticity of connective tissue caused by hormonal changes during pregnancy (increased secretion of relaxin, progesterone, and estrogen), uterine dilatation caused by fetal growth, and continuous increase in intra-abdominal pressure leaded to increased IRD\(^9\). In agreement with other researchers\(^5\), the incidence of DRA in late pregnancy is as high as 100\%, and 55.6\% still have DRA at 12 weeks postpartum. Ultrasound is becoming increasingly popular in the evaluation of musculoskeletal abnormalities with excellent reproducibility\(^10\). With the developments of elastography ultrasound, it is now possible to quantitatively evaluate the functional biomechanics of muscle\(^11\text{-}13\). And SWE is a more reliable and widely used tool for quantitative assessment of muscle functional biomechanics\(^14\text{-}18\). In this study, 2D ultrasound combined with SWE was used to evaluate the condition of DRA in different pregnancy and perinatal period, aiming to compare the changes in IRD, muscle thickness and elastic characteristics of rectus abdominis in perinatal period, and to find out the internal influence of pregnancy factors on DRA. The IRD, muscle thickness and SWE of the rectus abdominis are different in different gestational weeks.

It is easy to understand that the IRD increases with gestational weeks, the muscle thickness decreases with gestational weeks. While SWE decreased with the increase of gestational weeks. It can be explained by the biomechanical and pathological changes in muscle fibers as the IRD increases\(^14\text{-}16\). The composition of the rectus abdominis, including muscle fibers, connective tissue, and adipose tissue, might vary at different stages of DRA progression, resulting in changes in SWE. And elasticity is the tendency of tissue to resist deformation against an external force, or to resume its original state after the external force is removed. A higher the elastic modulus correlates with a higher the resistance to deformation and an increased stiffness\(^19\). With the increase of gestational age, the stretching degree of the rectus abdominis muscle increases, leading to the damage of the rectus abdominis muscle function, the decrease of deformation ability, and the decrease of elasticity. After delivery, the rectus abdominis muscle releases the compression, and the elasticity gradually recovers. Similar to the finding by He et al.\(^6\) that DRA patients had lower SWS values of the rectus abdominis muscle. And in line with other researchers\(^20,21\), SWE provides a direct estimate of muscle strength. Since the treatment options of DRA depends not only on the degree of separation, but the flaccidity of the anterior abdominal\(^22\), and accurate and objective assessment of muscle elasticity may potentially assist in the clinical management.

The maximum separation distance is located at the umbilicus, a few are supraumbilical separation, and very few are subumbilical separation, which is in line with previous studies\(^23,24\) and the DRA classification system suggested by Rath et al.\(^25\). The reason may be related to the difference in the type and content of collagen fibers in the upper and lower umbilical regions. There are more collagen fibers in the subumbilical region than in the supraumbilical region, and most of them are type III collagen fibers,
which can provide greater elasticity\cite{26}. Therefore, the rectus abdominis in the subumbilical region is not easy to be separated. And the aponeurosis of the internal oblique is connected with the aponeurosis of the external oblique to form the anterior lamina of the rectus abdominis. In addition, the aponeurosis of the transverse abdominis is located behind the rectus abdominis sheath at the cranial level, and appears in front of the rectus abdominis sheath with other fatty muscles at the caudal level to protect the rectus abdominis muscle\cite{27}, which makes it difficult to separate the rectus abdominis muscle.

Compared with the first trimester, the IRD and SWE are difficult to recover to the level of the first trimester, while the muscle thickness can recover to the level of the first trimester. Therefore, the thickness of the rectus abdominis muscle recovers faster than the IRD and elasticity of the rectus abdominis muscle, which is due to postpartum rectus abdominis is relieved has greater impact on the muscle thickness, while IRD and elasticity recover slowly. Therefore, the two ultrasound indexes can be used to evaluate the recovery of postpartum DRA, and the combination of them can objectively reflect the morphological and functional severity of DRA.

SWE was negatively correlated with IRD, positively correlated with muscle thickness, it may be because the IRD, muscle thickness and SWE changed with the change of pregnancy and perinatal period, the positive correlation between SWE and muscle thickness in the overall dataset may be explained by the significantly decreased muscle thickness with less volume of fibers in pregnancy women that leads to slower SWE propagation\cite{6}. Therefore, the correlation between SWE value and IRD should be interpreted with caution.

Two-dimensional ultrasound morphological examination is relatively mature, while the consistency of rectus abdominis by SWE applied by different operators has not been known. Therefore, in this study, two sonographers with different working years were designed to perform the elasticity detection of rectus abdominis, and the Bland-Altman plot showed that all data points were evenly distributed within the upper and lower limits of 95% consistency limits. That is, the elastic characteristics of rectus abdominis evaluated by different operators with SWE are consistent, which is easy to popularize and apply.

Nevertheless, this is a prospective longitudinal study with a small sample content, and a short postpartum follow-up time. In the future, it is expected to expand the sample content, and study the change of the IRD and elasticity in the whole pregnancy of the same pregnant woman, analyze the dynamic change of DRA in pregnant women, follow up longer postpartum period, so as to draw the receiver operating characteristic curve (ROC) of rectus abdominis SWE value. SWE was used to accurately predict the occurrence and severity of DRA, so as to guide clinical early intervention and promote early recovery of postpartum DRA.

**Conclusions**

In summary, multi-dimensional evaluation of DRA by ultrasound is feasible, compare the differences in the morphology and function of rectus abdominis muscle between pregnancy and postpartum,
comprehensively evaluate the occurrence and severity of postpartum DRA, and the difference in muscle
elasticity should be considered in the development of treatment regimens.

List Of Abbreviations

SWE
shear wave elastography
DRA
diastasis recti abdominis
IRD
Inter-rectus distance
ROI
region of interest
ROC
receiver operating characteristic curve

Declarations

Ethics approval and consent to participate The study involving human participants were reviewed and
approved by the ethics committee of the First Affiliated Hospital, and College of Clinical Medicine of
Henan University of Science and Technology and with the Helsinki Declaration of 1964 and later versions.
The patients/participants provided their written informed consent to participate in this study.

Consent for publication Not applicable.

Availability of data and materials The datasets used and/or analysed during the current study are
available from the corresponding author on reasonable request.

Competing interests The authors declare that they have no competing interests.

Funding This study was supported by Joint project of medical science and technology project of Henan
Province(No.LHGJ20220689).

Authors’ contributions All authors have contributed to the study’s conception and design. Material
preparation, data collection, and analysis were performed by XH G, YJ X, and SJ C. The first draft of the
manuscript was written by XH G and all authors commented on previous versions of the manuscript. All
authors read and approved the final manuscript.

Acknowledgements Not applicable.

References


**Figures**
Figure 1

Images of IRD in different pregnancy and perinatal periods (a: Pregnancy10w; b:27+0w; c:34+1w; d:36+4w; e: Postpartum 42 days; f: Postpartum 3 months).

Figure 2

Images of rectus abdominis thickness in different pregnancy and perinatal periods (a: Pregnancy10w; b:27+0w; c:34+1w; d:36+4w; e: Postpartum 42 days; f: Postpartum 3 months).
Figure 3

Images of SWE in different pregnancy and perinatal periods (a: Pregnancy 10w; b: 27+0w; c: 34+1w; d: 36+4w; e: Postpartum 42 days; f: Postpartum 3 months).
Figure 4

Box diagram of IRD during different pregnancy and perinatal period.
Figure 5

Box diagram of muscle thickness during different pregnancy and perinatal period.
Figure 6

Box diagram of SWE during different pregnancy and perinatal period.
Figure 7

Bland-Altman plots of SWE for physicians A and B.