ORIGINAL ARTICLE

Implementation of Examining Inter Rectus Distance of Post-Partum Women with Diastasis Recti Abdominalis

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ABSTRACT

Introduction: To determine the value of shear wave elastography (SWE) in assessing abdominal wall muscles, including rectus abdominis (RA), external oblique muscle (EO), internal oblique muscle, and transversus abdominis (TrA) in patients with diastasis recti abdominis (DRA) and healthy controls. **Methods:** From October 2018 to December 2019, 36 postpartum DRA patients and 24 nulliparous healthy women were identifed. Inter-rectus distance (IRD) measurements were taken by B-mode ultrasound. Shear wave speed (SWS) values were acquired by one operator at ten specifc locations. Clinical and ultrasound variables, including demographics, IRD, muscle thickness, and muscle SWS, were compared between the two groups using Student's t test or Fisher's exact test. Pearson correlation analyses were conducted for the variables of IRD, muscle thickness, and SWS in the 36 DRA patients. **Results:** The maximum diameter of recti abdominus separation was located at the umbilicus in DRA patients (4.59±1.14 cm). The SWS value was signifcantly lower in the RA (p=0.003) and higher in the TrA muscle (p < 0,001) in DRA patients compared with the age-matched controls. However, SWS in both muscles (RA and TrA) showed a statistically positive correlation with IRD (p<0,05) In addition, the SWS value in EO statistically decreased in DRA patients compared with the healthy controls (1.65±0.15 vs. 1.79±0.14, p=0.001). **Conclusion:** The application of SWE to abdominal wall muscles in DRA patients is feasible. The correlation between SWS value and IRD in RA should be interpreted with caution.

Keywords: Postnatal period, Diastasis recti abdominis, Linea alba, Abdominal wall muscle

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INTRODUCTION

Diastasis recti abdominals (DRA) is the enlargement of the distance between the edges of the recti abdominis along the linea alba with no facial defect (1, 2). Normally, the rectus muscles are fused at the midline with no more than 1 to 2 cm separation (3). A significant number of women are affected by DRA during the pre- natal and postnatal periods (4), resulting in functional problems, such as back pain and hernia (5).

Clinically, DRA is evaluated by finger breadth. The widths of the two recti abdominis muscles are assessed by palpation 4.5 cm above and 4.5 cm below the umbilicus, along the linea alba (6). Separation is observed most commonly at the umbilicus. A width greater than or equal to the width of two fingers is defined as DRA (5). No separation or a width of less than two fingers is defined as no DRA. However, in the past twenty years, the reliability of palpation has been debated (1, 3, 4). Therefore, prior studies investigated the application of advanced imaging technology, like B-mode ultrasound (US), on the evaluation of inter-rectus distance (IRD) measurement. Most studies demonstrate the superior accuracy and validity of imaging tools compared to palpation (7–9).

Clinical management of DRA is challenging (10). Based on the pathophysiology described by Baumann et al. (11), the combination of physiotherapy and surgical repair has the potential to improve the anatomical divarication and the laxity of the ventral abdominal muscles. In other words, the preoperative assessment of DRA is not solely a distance measurement problem. Individual preoperative evaluation of physiologic tension is important. Up to now, conventional modalities, including B-mode ultrasound, computed tomography, and magnetic resonance imaging, have been used to assess the IRD, but no functional biomechanical property evaluation was available. Therefore, an objective imaging assessment of the intrinsic abdominal muscle characteristics, such as the elasticity, is needed to predict successful treatment and disease progression.

In recent years, ultrasound shear wave elastography

(SWE) has been increasingly used to measure physiologic and pathologic muscle behavior due to its non-invasiveness, high accuracy, user-friendliness, and availability in commercial ultrasound scanners (12–14). However, no convincing evidence in the current literature has established the application of SWE for detecting muscle properties in DRA patients. Based on our previous study of SWE in incisional hernia patients (15), we hypothesize that the elasticity in rectus abdominis (RA) of DRA patients is significantly lower than that in healthy controls, while the elasticity of lateral abdominal wall muscles, including the external oblique (EO) muscle, internal oblique (IO) muscle, or transversus abdominis (TrA), is comparatively higher. This study aimed to determine the utility of applying SWE to the evaluation of abdominal wall muscles, including rectus abdominis, external oblique muscle, internal oblique muscle, and transversus abdominis, in patients with DRA and healthy controls, to assist in clinical management. No study has been reported on the SWE of abdominal wall muscles in DRA patients.

MATERIALS AND METHODS

Samples

This study was reviewed and approved by the Institute Ethics Committee of UNUSA Informed consent forms were signed by all participants. The study protocol was registered in RSI Jemursari Clinical Registry Center. From October 2018 to December 2019, postpartum women suspected of DRA at the outpatient clinic in our institution were identified. Eligible subjects were recruited based on the following inclusion criteria: 1) age between 18 and 60 y/o; 2) IRD greater than or equal to 2-finger width on palpation, irrespective of the locations along the midline, measured in the standard supine crock- lying position with arms crossed over the chest; and 3) full-term fetus. The exclusion criteria for all postpartum women were as follows: (1) additional history of abdominal surgery or injury (except cesarean section); (2) chronic or degenerative pathology of the muscle (e.g., autoimmune myositis); (3) abdominal rehabilitation of neuromuscular electrical stimulation within the previous 6 months; and (4) inadequate clinical and ultrasound (US) imaging data. Nulliparous age-matched women were recruited from the physicians and nurses at our institution to participate as healthy controls. The exclusion criteria for the healthy participants were similar to that for DRA patients, including age (< 18 and > 60 y/o), surgery, and history. The clinical variables of age, weight, and height were recorded for each subject.

Instrument

Ultrasound images were obtained using a high-end scanner (Aixplorer, Supersonic Imagine, France) equipped with an SWE mode (general preset). The scanner was coupled with a linear array probe (SL10-2, Supersonic Imagine, and France). Elastography was performed to evalu- ate tissue elasticity. Elasticity is the tendency of tissue to resist deformation against an applied force or to resume its original shape after removal of this force. A higher elastic modulus correlates with a higher resistance to deformation and an increased stiffness (16). Shear wave speed is a quantitative measure of tissue stiffness and can be converted to shear modulus using the following equation:

$$\mu_s = C^2\rho$$

μ is shear modulus; C_s is shear wave speed (SWS) in this equation; and ρ is density, which can be assumed to be 1000 kg/m^3 for all soft tissues (17). Higher speed values are associated with increased tissue stiffness. A senior radiologist (XW) with 10 years of experience in abdominal and musculoskeletal ultrasound imaging) per- formed the IRD measurement on B-mode US and SWS measurement on SWE.

Data collection

The DRA patients underwent B-mode US examination of their anterior rectus abdominis sheath to evaluate the width of rectus diastasis. To standardize the position of the transducer, each measurement location was marked on the skin when the participant was resting in the supine position, with their arms across their chests. Addition- ally, special attention was paid to the pressure imposed on the probe to avoid reflexive responses from the participants. A thick gel layer was applied to replace the air gap between the US transducer and the targeted region.

According to the European Hernia Society (EHS) classification of midline incisional hernias (3), the tranducer was placed transversely along the midline at five specific locations identified with skin markers in the following order: subxiphoidal, epigastric, umbilical, infraumbilical, and suprapubic location. The afore mentioned locations were recorded as M1, M2, M3, M4, M5, respectively. Using the medial margins of both rectus abdominis muscles, the inter-rectus distance could be clearly identified, from one side of the anterior recti sheath to the corresponding position of its counterpart on the other side. Measurements were taken with an on- screen caliper to the nearest 0.1 cm. Finally, the maximum diastasis was recorded as the width of the recti abdominus separation in this study.

Further assessment of anatomical variations of rectus abdominis muscle diastasis by B-mode US was made based on a recent study by Corvino et al. (18), including the following five patterns: open only above the navel, open only below the navel, open at the navel level, open completely but wider above the navel, and open completely but wider below the navel.

Shear wave elastography measurement

After the IRD measurements, SWE was measured in the DRA patients and healthy nulliparous participants. Tissue SWS of the RA and lateral muscles (EO, IO, and TrA) were bilaterally measured. Based on our previous

experience (15) and the suggestions of Rath et a. (19), SWE measurements were taken on both the left and right sides of the abdomen as per the following guidelines:
1. Three locations were identified on eacfl side of tfle RA region, tfle supraumbilicus (4.5 cm above tfle umbilicus), umbilicus, and subumbilicus (4.5 cm below tfle umbilicus).
2. Two locations were identified on eacfl side of tfle abdomen along tfle anterior axillary line equidistant between tfle costal margin at tfle level of tfle nintfl rib and a point anterior to tfle anterior superior iliac spine.

Each measurement was initiated with a B-mode acquisition of the muscle. The transducer was placed with light pressure to obtain the transverse view of the target muscle. To maximize intra-operator reliability and minimize the duration of transducer repositioning at the same location in each subject, 10 waterproof skin landmarks were drawn with a marker under 2D-mode monitoring by the same operator before SWE. The depth was set to optimize the target muscle centrally. Muscle thickness was obtained by measuring the length.

Ethical Clearance
This study was granted by Research Ethics Committee from Universitas Nahdlatul Ulama Surabaya, number 093/EC/KEPK/UNUSA/2019.

RESULTS

A power analysis was performed to determine the number of patients needed. We assumed that the mean value for mean trunk rotation torque was 37 (N·m) in DRA patients and 45.3 (N·m) in non-DRA patients, based on the data reported by Hills et al. (21). The probability was 80 percent that the study would detect a difference of 8.3, based on a standard deviation of 3.6, the mean trunk rotation torque, and a two-sided 0.05 significance level. Thus, 44 subjects (22 patients and 22 controls) were required for this retrospective study. Accordingly, 24 nulliparous healthy women were recruited for this study. From October 2018 to December 2019, 42 postpartum women suspected of DRA at our outpatient clinic were identified. After removing 6 patients, 36 patients were enrolled for the final analysis. Among the excluded patients were (a) 2 patients with IRD less than 2-finger width, (b) 1 patient with additional surgical history except for cesarean section, (c) 1 patient with recent abdominal rehabilitation of neuromuscular electrical stimulation, and (d) 2 patients without adequate ultrasound data. Table I shows the frequency distribution of respondents according to age, parity and degree of abdominal rectal diastasis.

Table I: Frequency distribution of respondents according to age, parity and degree of abdominal rectal diastasis (n=63)

Age	Frequency	Percentage (%)
Age		
≤ 20	5	6.7
21 - 35	25	83.3
≥ 36	3 0	10
Parity		
Primipara	29	16.7
Multipara	34	83.3
Degree of abdominal rectal diastasis		
DDR is normal	29	16.7
DDR is not normal	34	83.3

DISCUSSION

Ultrasound is becoming more popular in the evaluation of different musculoskeletal abnormalities with excellent reproducibility (22). With the recent developments in ultrasound elastography, it is now possible to quantitatively evaluate the stiffness of muscle (12–14). There are several ultrasound elastography methods investigated around the world in the past twenty years, including strain elastography, acoustic radiation force impulse, shear wave elastography, and transient elastography (23). As a semiquantitative approach, strain ratio values generated by strain elastography depend significantly on reference and target region of interest being above the same tissue, while not influenced by depth (24). Shear wave speeds would probably decrease with increasing scanning depth (24). Comparatively, more recent studies demonstrated that, in terms of inter- or intra-operator variability, shear wave elastography is a more reliable and widely used tool for quantitatively assessing muscle stiffness (25–29). The main purpose of this study was to compare elasticity of abdominal wall musculature in individuals with and without DRA. Partially consistent with the first part of our hypothesis, we found a significantly lower SWS in the RA ($p = 0.003$) and a higher SWS in the TrA muscle ($p < 0.001$) in participants with DRA compared with the age-matched control group without previous pregnancy. However, the correlation between muscle elasticity and IRD should be interpreted with caution. As SWS in both muscles were positively correlated with IRD ($p < 0.05$), the greater the IRD, the higher the SWS in RA. In addition, the value of SWS in EO unexpectedly decreased in DRA patients (1.65±0.15 vs. 1.79±0.14, $p=0.001$). To the best of our knowledge, the present study is the first to reveal these findings about muscle elasticity in DRA patients based on the 10-location setting. The reliability of IRD measurement in postpartum women using B-mode ultrasound has been widely validated by multiple studies in the past decade (7–9). In response to our primary goal of muscle elasticity assessment, the ICC values obtained in the current study indicate moderate to high intra-operator reliability, especially for the RA and TrA muscles. This finding was in agreement with our previous study of SWE in incisional hernia patients (15). However, it was noted that the ICC values for EO and IO were relatively lower, which might be attributed to the impact of patient breathing on superficial oblique muscles (30). The maximum separation distance was located at the umbilicus, which is in line with the DRA classification system suggested by Rath et al. (19). Contrary to Liaw's finding, no inter-rectus separation was found among the 24 nulliparous healthy subjects, irrespective of the locations along the midline (M1–M5). Of note, the mean age of the control subjects differed between the two studies (31.9±4. 1 vs. 26.7±4.7 mm). However, both studies complied with the commonly accepted definition of DRA, with no more than 1 to 2 cm separation (3). Our study is unique in the use of SWE in 10-location settings to better quantify the elasticity of abdominal muscles in an objective approach. Given the current evidence of morphological changes and abdominal muscle functional deficits present during pregnancy (8), a group of nulliparous healthy women was enrolled as controls in this study. Generally, the range of SWS values acquired in the four abdominal wall muscles (0.85–2.08 m/s) was similar to the values reported by others (15, 25–28). From a biomechanical viewpoint, the abdominopelvic cavity is a cylinder enveloped by muscles, tendons, and bony structures. According to Pascal's principle (31), any pressure generated within the abdominopelvic cavity is transmitted equally to the walls of that cavity. In response to increased abdominal pressure, the muscular abdominal wall contracts to generate counter-pressure. If intraabdominal pressure exceeds abdominal wall pressure, the abdominal wall will rupture at its weakest point, causing herniation. Correspondingly, the rectus abdominis in DRA patients, which is considered the margin of the weakest point, displayed a lower SWS value than that in healthy controls, especially for the locations above and at the umbilicus. Tis difference in muscle elasticity should be considered when making treatment plans that include a combination of physiotherapy and surgical repair (11). However, subgroup analysis in 36 DRA patients showed a positive correlation between IRD and SWS. Tis can be explained by the biomechanical and pathological changes in muscle fibers as the inter-rectus separation increases (25–27). The composition of the RA, including muscle fibers, connective tissue, and adipose tissue infiltration, might vary at different stages of DRA progression, resulting in changes in shear wave speed at the later stage. Converse to our results in incisional hernia patients (15), the SWS of the EO muscle in DRA patients decreased in comparison with healthy subjects. Tis decrease mainly resulted from the biological and physical differences between the two studies.

CONCLUSION

The application of SWE to abdominal wall muscles in DRA patients is feasible. The correlation between SWS value and IRD in RA should be interpreted with caution.

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