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Original Article

Morphometric evaluation of the linea alba in fresh corpses [☆]

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ARTICLE INFO

Article history:

Received 19 February 2024

Accepted 17 March 2024

Available online 26 March 2024

Keywords:

Linea alba

Diastasis recti abdominis

Intra-rectus distance

Abdominal rectus muscle

ABSTRACT

Purpose: Diastasis recti abdominis is an increase in the distance between the medial borders of the two rectus muscles. It is most often triggered after intra-abdominal pressure increases, such as postpartum or in obesity. Most publications are based on radiological studies or are done in certain subgroups, without unanimous reference values of the distance between the rectus abdominis or standardization.

Methods: Forty-one cadavers were studied. Exclusion criteria: signs of abdominal trauma, major burns, presence of scar from previous abdominal surgery, clinical signs of abdominal hernia, and identification of hernia during cadaver dissection. Linea alba (LA) length, width, and thickness were measured with a flexible tape measure and digital caliper. Anatomical landmarks were established, and subdivisions were described based on them to compare the cadavers.

Results: Sex and age had little effect on LA width, thickness, or length. Obesity (compared to normal weight) was the only variable that promoted an increase in the LA width ($p < 0.01$). The

[☆] Trial registration This study was conducted after approval of the Brazilian Committee of Ethics on Research checking copy 095,986/2014, CAAE: 37,709,814.9.0000.5125 under the local Committee on Hospital Felício Rocho/MG.

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<https://doi.org/10.1016/j.jpra.2024.03.005>

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supraumbilical length varied with the total height of the evaluated cadavers ($p < 0.01$), but the infraumbilical length did not ($p = 0.11$). *Conclusion:* The general statistical results of this study, regarding the evaluation of LA measurements in cadavers, showed that ethnicity, sex, and age have little effect on the width, thickness, or length of the LA. LA width differed significantly with abdominal circumference.

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Introduction

Diastasis recti abdominis is the increase in the distance between the medial edges of the rectus abdominis muscles. Thus, after discussing the use of this terminology, Boxer and Jones¹ suggested that the best way to define diastasis would be the distance between the inner edges of the rectus abdominis muscles.

Diastasis recti abdominis is most commonly triggered after increased intra-abdominal pressure, such as postpartum or obesity. Several ways of evaluating the linea alba (LA) have been described, but most publications were based on radiological studies or were done in subgroups, without agreeing upon the reference values of the distance between the rectus abdominis and without any standardization of diagnostic evaluation. Since most studies performed in vivo have evaluated subgroups, such as pregnant or postpartum women, through indirect evaluations, such as ultrasound or computed tomography (CT), the present study aims to propose a comprehensive evaluation that can be used both in routine clinical practice and for research purposes.^{2,3}

Objectives

To demonstrate the diversity of measurements of the LA in the general population, through a study of fresh cadavers, and correlate them with factors known to alter its anatomical conformation, seeking a more comprehensive description of the LA based on the width, length, and thickness.

Methods

The study was approved by the ethics and research committee of the Teaching Institution and the Institute of Forensic Medicine of Belo Horizonte. All data were collected with the prior authorization of family members, who signed the free and informed consent form, and the study design was approved by the ethics and research committee (Resolutions 466 of 2012 and 510 of 2016).

The study was conducted between June and October 2016 with a total of 41 cadavers. The exclusion criteria were signs of abdominal trauma, major burns, presence of scars from previous abdominal surgeries, clinical signs of abdominal hernia, and identification of hernias during cadaveric dissection.

The LA length, width, and thickness were measured with a flexible tape measure and digital caliper. Anatomical references were preestablished for the evaluation of LA (Figure 1), from which subdivisions were described for the purpose of comparison between cadavers.

All information collected in this study was entered into SPSS software for Windows, version 21. These data were first analyzed for frequency and then revised to identify any typing errors and ensure the reliability of the information. Qualitative variables were compared by the chi-squared test. Student's *t*-test (for two groups, e.g., sex) and analysis of variance (for three groups, e.g., race) were used for comparisons between quantitative variables. The correlations between groups were analyzed by Pearson's correlation test. All comparisons were considered significant at $p < 0.05$.



Figure 1. Materials used during the evaluation of the linea alba, focusing on the evaluation of width, thickness, and length. Evaluation of the length of the linea alba with a flexible tape measure and the thickness and width of the linea alba with a digital caliper.

Table 1
Demographic aspects of the dissected cadavers.

	Absolute	Mean	Standard deviation	%
Sex	<i>m</i> = 29 <i>f</i> = 12 41			
Age (years)		45.4	19.5	
Eutrophic:	29			70.7
Abdominal circumference < 94 (male) or <80 (female) (mm)				
Overweight:	6			14.6
Abdominal circumference 95–102 (male) or 81–88 (female) (mm)				
Obese	6			14.6
Abdominal circumference > 102 (male) >88 (female) (mm)				100
Time of death (hours)	4 – 11	6.7	1.5	

Data presenting demographic aspects of the studied population, illustrating trends and patterns of the dissected corpses.

Reference points for LA evaluation: xiphoid process (Point A), upper border of the umbilicus (Point B), lower border of the umbilical scar (Point C), and upper border of the pubic symphysis (Point D). Reference intervals for comparison between subjects: total length from the xiphoid process to the pubic symphysis (Interval A-D). Supraumbilical length: from the xiphoid process to the upper edge of the umbilicus (Interval A-B). Circumference of the umbilicus and umbilicus diameter (Interval B-C). Intraumbilical length: from the lower border of the umbilicus to the pubic symphysis (Interval C-D; [Figure 2](#)).

Results

A total of 41 cadavers were studied, and their characteristics are described in [Table 1](#). The length, width, and thickness results are described in [Figure 3](#).

Preestablished evaluation points for the LA in cadavers were point 1, under the xiphoid process; point 2, in the mid-range between the xiphoid process and the umbilicus; point 3, above the umbilicus; point 4, below the umbilicus; point 5 on the midpoint between the umbilicus and the pubic

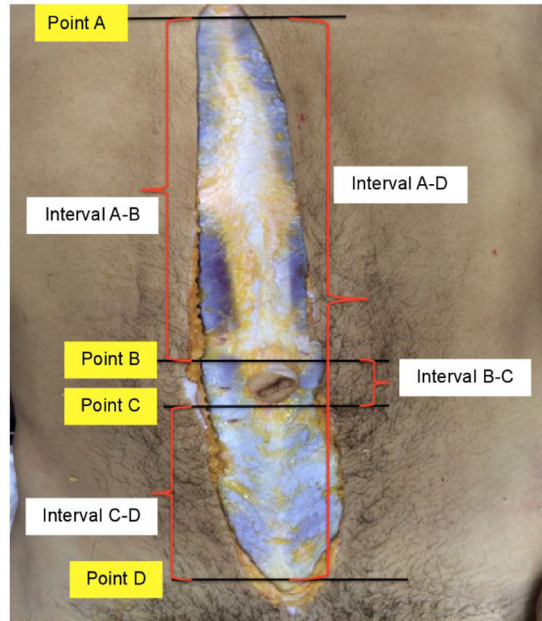


Figure 2. Anatomical references and intervals for comparison between the study subjects. Reference points for linea alba evaluation: xiphoid process (Point A), upper border of the umbilicus (Point B), lower border of the umbilical scar (Point C), and upper border of the pubic symphysis (Point D). Reference intervals for comparison between subjects: total length from the xiphoid process to the pubic symphysis (Interval A-D). Supraumbilical length: from the xiphoid process to the upper edge of the umbilicus (Interval A-B). Circumference of the umbilicus and umbilicus diameter (Interval B-C). Infraumbilical length: from the lower border of the umbilicus to the pubic symphysis (Interval C-D).

symphysis; and point 6, right up the pubic symphysis, as demonstrated in [Figure 3](#). The width, thickness, and length of the LA were evaluated in the [Figure 3](#) in median and standard deviation, and the correlation between thickness and width with abdominal circumference is demonstrated in [Figure 4](#).

In the analysis of the correlations, it was found that there was no significant correlation between the width and the supraumbilical thickness, and there was no correlation between the width or thickness at the predetermined infraumbilical points or total width (mean of the total sum of widths) and organ thickness ($p > 0.05$). Therefore, the width of LA did not affect the thickness of the organ at any point.

It was observed, however, that the larger the abdominal circumference, the greater the LA width. This association was significant when comparing the overweight and obese abdominal circumference groups to the normal-weight group on either the supraumbilical ($p = 0.03$) or the infraumbilical LA width ($p = 0.01$) or the average width at all the referenced points ($p < 0.01$), as demonstrated in [Figure 4](#).

When comparing the thickness of the LA in obese and overweight patients with eutrophic cadavers, no significant difference was observed in the infraumbilical, supraumbilical, or the mean LA thickness. Thus, it is possible to infer that circumference does not influence the thickness of the LA.

When these same points were analyzed according to age, no significant differences were observed ($p > 0.05$). The width, thickness, and length of LA did not vary with the age of the subject at death.

However, with increasing height, there was a significant increase ($p = 0.01$) in total LA length. The same relationship was observed for the supraumbilical length ($p < 0.01$). In contrast, the relationship between increased height and lower length was nonexpressive and nonsignificant ($r = 0.25$; $p = 0.11$).

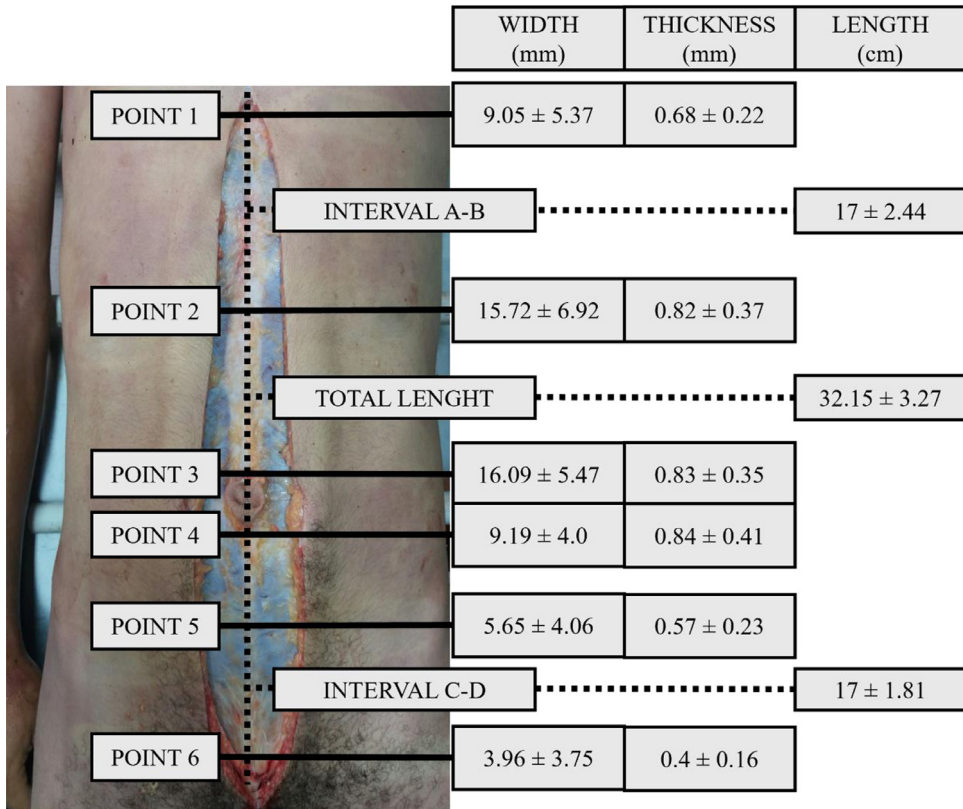


Figure 3. Illustrative diagram showing mean and standard deviation on pre-established points and intervals on linea alba. In the picture, the pre-established points are shown in full lines and over dotted lines, we measure the length on the intervals shown in previous pictures.

	Obese	Overweight	Normal waist	
Point 3 thickness (mm)	0.91	0.69	0.81	p>0.05
Point 4 thickness (mm)	0.78	0.56	0.6	p>0.05
Total thickness (mm)	0.84	0.62	0.71	p>0.05
Point 3 width (mm)	19.27	14.41	13.24	p=0.03
Point 4 width (mm)	11.32	4.94	5.97	p=0.01
Total width (mm)	19.27	14.47	13.24	p<0.01

Figure 4. Analysis of the midpoints of the supra- and infraumbilical measurements according to abdominal waist circumference (stratified by obesity classification for abdominal circumference). *ANOVA followed by Tukey’s test. Supraumbilical width: eutrophic vs. obese: $p = 0.02$. Infraumbilical width: eutrophic vs. obese: $p < 0.01$; overweight vs. obese: $p = 0.03$. Total width: eutrophic vs. obese: $p < 0.01$; overweight vs. obese: $p = 0.01$. Other comparisons: $p > 0.05$.

Discussion

In our study, the finding of non-correspondence of the distance between the layers of the rectus abdominis and the thickness of the LA was of great significance. Thus, even with an increase in abdominal circumference, which significantly widens the LA and can lead to diastasis, there was no

evidence that diastasis influences the thickness of the LA. Furthermore, we could observe that the longitudinal diameter varies concerning the height of the examined cadavers; however, when evaluated separately, the supraumbilical length varies significantly more than the infraumbilical diameter in those corpses.

Gilleard and Brown⁴ classified diastasis as a separation greater than 15 mm in the supraumbilical region. In our study, there was no significant correlation between the distance between the rectus abdominis leaflets in people of different ages, considering subgroups of young adults at any of the preestablished points for evaluation of the LA. Beer et al.³ evaluated the measurements of LA width by ultrasonography in nulliparous women aged 20–45 years with a body mass index up to 30 kg/m² without weight loss greater than 10 kg after pregnancy, without abdominal surgery, and without abdominal wall hernia. Thus, standard width measurements were defined for LA in nonobese nulliparous women with measurements smaller than 15 mm near the xiphoid process, up to 22 mm at 3 cm above the umbilicus and up to 16 mm at 2 cm below the umbilicus.³ However, our study proposes a broader classification, based on the direct anatomical evaluation of the LA at six preestablished points (versus four in the cited study), which we came to through the evaluation of fresh cadavers of different sexes and body compositions.^{8,9}

Rath et al.² measured the width of the LA in vivo using these measurements by CT compared to the same measurements in cadavers. In the cadaveric study, its mean width was 1.72 (0.5–3.5) cm above the umbilicus, 2.25 (0.5–5.0) cm at the level of the umbilicus, and 0.66 (0.1–2.0) cm below the umbilicus. These measurements did not differ by age, sex, or body type in their series. The results obtained from the in vivo tomographic analysis were as follows: the mean width of the LA above the umbilicus was 8.3 mm ± 5.63 mm (versus 17 mm in the cadaveric study), 21.2 mm ± 8.07 mm at the level of the umbilical ring (versus 22.4 mm), and 9.3 mm ± 6.74 below the umbilicus (mean 6.6 mm in cadavers). Thus, there was a large difference between the two studies at the supraumbilical level. The authors defined the following as normal values for supraumbilical LA width: up to 45 years of age, 15–16 mm; after 45 years, 12–14 mm; at the level of the umbilical ring, 19–23 mm; infraumbilical: before 45 years of age, 5–6 mm, and after 45 years, 9–11 mm. The mean length of the LA in 40 dissected individuals was 29.11 cm (20–40).² Rath et al.² did not describe and did not appear to have homogeneity between the groups of cadavers studied and the group subjected to radiological study. Moreover, the patients did not undergo CT specifically for the study but for diagnostic investigation for a clinical trial.¹⁰

There is no consensus on the best definition of diastasis, and there are significant differences in the methods adopted by different authors in their attempt to conceptualize abdominis rectus diastasis. In addition, most of the proposed classifications were established in subgroups of female patients, hence, even in literature reviews could not agree to a classification.^{5,6}

With this purpose, in 2021, the European Hernia Society developed guidelines for the management of diastasis of the rectus abdominis. This classification considers the type of diastasis, whether it is secondary to pregnancy or not, and the distance between the rectus abdominis greater than 2 cm with or without hernia in the midline. Our study proposes an anatomical assessment in fresh cadavers, adding to future guidelines the information that the distance between the layers of the rectus abdominis does not influence the thickness of the LA. Therefore, we do not believe that diastasis of the rectus abdominis influences the fragility of the LA in patients who have not undergone abdominal surgery and do not have a primary ventral hernia.⁷

Conclusion

The general statistical results of this study, regarding the evaluation of LA measurements in cadavers, show that ethnicity, sex, and age have little effect on the width, thickness, or length of the LA. LA width differed significantly with abdominal circumference. Obesity (compared to normal weight) was the only variable that promoted an increase in the LA width ($p < 0.01$). Waist circumference and the width of the LA did not influence the thickness of the LA ($p > 0.05$).

The supraumbilical length of the LA differed with the total height of the cadavers evaluated ($p < 0.01$), though the infraumbilical length of the LA did not ($p = 0.11$). This demonstrates that

the supraumbilical length in the sample varies with height, while the infraumbilical length of the LA does not.

Limitations of the study

Since previous studies have not made it possible to standardize the evaluation of LA thickness or amplitude, it is not possible to estimate the prevalence of diastasis recti abdominis in the general population, and it is not possible to calculate the sample size before studies.

Funding

This paper had private funding by the authors and did not receive any other resource from financial organizations that could inappropriately influence our results.

Ethical approval

This study was conducted after approval of the Brazilian Ethical Committee for Research, registered on Hospital Felício Rocho under the Certificate of Presentation of Ethical Review number 37,709,814.9.0000.5125.

Declaration of competing interest

None of the authors and co-authors have a conflict of interest

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