OPEN

PRS GLOBAL OPEN

ORIGINAL ARTICLE
Reconstructive

Occurrence of Diastasis of the Rectus Abdominis Muscles in Patients with Medial Pectus Excavatum

Jaime Anger, MD, PhD*
Jose Ribas M. de Campos, MD, PhD†‡

Background: Since 1994, we have used soft silicone blocks sculpted intraoperatively to correct pectus excavatum in male patients. This technique involves a horizontal access incision in the region of the lower edge of the sternum. During the dissection to expose the sternum, we observed a constant diastasis of the rectus abdominis muscle and changes of the anatomy at its superior insertion. There is no report on this association.
Methods: Male patients with untreated medial pectus excavatum with indication for silicone block correction were enrolled. Age, weight, height, and the presence of other associated conditions were noted. Ultrasound examination was performed. During the surgery, the width of the linea alba was evaluated and the anatomical positioning of the insertion of rectus abdominis muscle was noted.
Results: From 2017 to 2019, 10 patients were submitted to surgery. The mean age was 27 years. All patients presented diastasis at the preoperative physical examination. Imaging examination reports showed diastasis of the rectus abdominis muscle: seven partial epigastric separations and three total separations, two of which were associated with umbilical hernia. The intraoperative findings showed the line alba with a minimum of 23 mm and a maximum of 45 mm width at 4 cm from the xiphoid process edge. The muscle borders presented a curved lateral deviation up to the insertion in the costal arches with a distance ranging from 35 mm to 60 mm.
Conclusions: This study confirms the anatomical alterations of the superior portion of the rectus abdominis muscle. The authors discuss the surgical consequences and suggest that the semiology of rectus abdominis muscle is an important preoperative action in pectus excavatum patients. *(Plast Reconstr Surg Glob Open 2022;10:e4028; doi: 10.1097/GOX.0000000000004028; Published online 10 January 2022.)*

INTRODUCTION

Congenital deformities of the chest wall involve various musculoskeletal defects that alter the symmetrical contour of the thorax. Pectus excavatum (PE) is the name used when there is a depression of the sternum and costal cartilages in the anterior chest wall. The most frequent alteration occurs in the medial region of the anterior thorax involving half or two-thirds of the lower portion of the sternum with the maximum recess located at the junction of the thorax and the abdomen. This anomaly is more common in men.[1]

Surgical options include mobilizing the osteo-cartilaginous tissues to place them in the desired position[2,3] or filling the existing cavity, with silicone being the most frequently used material.[1,4–7]

The minimally invasive bone mobilization surgery described by Nuss is the most used procedure.[2] In mild deformities, surgical correction with alloplastic filling is indicated. Since 1994, we have used solid low hardness silicone block (Shore A 10–30), which after sterilization can be trimmed during the surgery and molded according to the real space encountered. In 2014, we published our surgical experience on a total of 54 cases.[5] This technique involves a medial horizontal surgical access of between 6 and 10 cm through the skin 2 cm below the lower edge of the sternum. When we recognized the anatomical structures during surgery for patients with pectus excavatum with medial depression of the sternum, we observed the presence of a constant separation of more than 20 mm of

*From the *Plastic Surgery Division, Surgery Department, Hospital Israelita Albert Einstein, Sao Paulo, Brazil; and †Thoracic Surgery Division, Surgery Department, Hospital Israelita Albert Einstein; and ‡Thoracic Surgery Department, Medical School, University of Sao Paulo, Sao Paulo, Brazil.*

Received for publication September 1, 2021; accepted November 9, 2021.

Drs. Jaime Anger and Jose Ribas M. de Campos contributed equally to this work.

DOI: 10.1097/GOX.0000000000004028

Disclosure: *The authors have no financial interest to declare in relation to the content of this article.*

the rectus abdominis muscles (RAM) and of changes in the insertion of its upper border, bilaterally. These data agreed with the initial physical examination that indicated the abnormal separation of the RAMs mainly in the epigastrium region. There is no report on this association, which is what motivated this research to evaluate the incidence of diastasis of the rectus abdominis muscles (DRAM) in patients with medial PE.

PATIENTS AND METHODS

This is a Hospital Israelita Albert Einstein review board–approved prospective study (CAAE 63181616.7.0000.0071). The patients signed a specific informed consent. We selected male patients, with no age limit, whose first consultation was after January 1, 2017, and who had a diagnosis of medial PE and were not submitted to any previous treatment, whether surgical or nonsurgical, including the use of compressive external bracing and vacuum bell therapy, were first treated by the authors, and for whom surgical correction was indicated and performed with the use of solid silicone block.[5]

At the first consultation, the patient's age, weight, height, the presence of other associated conditions, and the possible muscular changes of the thorax and abdomen were noted. The dimensions of the medial depression of the thorax were recorded. The physical examination of the RAM was performed in a supine position with the knees flexed 30 degrees, initially with the head straight and then flexed to the maximum. The presence or absence of separation of the rectus abdominis muscles, and whether it was complete or partial was noted. Cases with partial separation were classified as epigastric or hypogastric. Ultrasound imaging of the abdomen was requested, and this included a study of the abdominal wall. An evaluation of the presence or absence of diastasis of the RAMs was conducted. If present, the evaluation of the dimensions of the separation was also carried out. For this study, we reported only the presence and the absence of DRAM, defined if the distance between the edges of the muscles was greater than 20 mm, and whether the DRAM was total or partial.

The patients underwent surgery under general anesthesia, by the same anesthesiologist and using the same anesthesia technique, which involves the use of Rocuronium (0.6 mg/kg dose body weight) as the neuromuscular blocking drug. The patient was placed supine, with the arms along the thorax.

The surgical technique involved the use of intraoperatively-moldable silicone block implants, in accordance with the previously described technique using a horizontal access route, located 2 cm below the xiphoid process.[5] To begin, the depressed area was demarcated, and the position of the muscles was determined by physical examination. A transverse incision (6 cm length) was done in the medial epigastric area, 2 cm below the xyphoid. Once the incision in the skin and subcutaneous tissue was made and the linea alba was determined, detachment was made vertically up to the edge of the sternum and in a lateral direction, bilaterally, until the limits of the demarcated depression were reached. The detachment was performed below the access path for up to 2 cm. At this point, the anatomy of the RAMs was identified. Their anatomical position and the details of their superior insertion were noted. The dimensions of the distance (in mm) between the medial edges of the RAMs were recorded with a surgical caliper calibrated in millimeters. Two measurements

Takeaways

Question: Is there a correlation between diastasis of the rectus abdominis muscles and medial pectus excavatum?

Findings: All studied patients presented diastasis. The average of the linea alba width at the costal arch insertion was 4.3 cm.

Meaning: The diastasis of the rectus abdominis muscles may interfere with the aesthetic contour in pectus excavatum patients. We must discuss the importance of its correction.

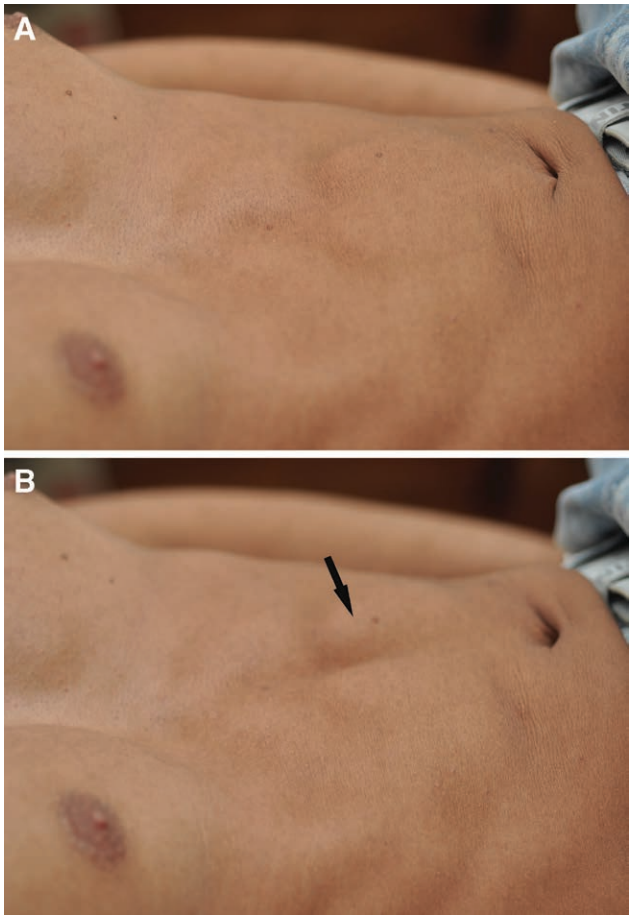

Fig. 1. Physical examination. A, The patient is in a supine position with the knees flexed 30 degrees, with the head straight. B, The patient is in a supine position with the knees flexed 30 degrees and the head flexed to the maximum. The black arrow indicates the visible muscle separation.

were made: the first at the insertion in the costal arches, and the second 2 cm below the level of the access incision.

RESULTS

From January 1, 2017 to August 21, 2020, 17 patients with an indication of medial PE correction with alloplastic material were treated, and seven patients were rejected from this study because five had an indication for surgical revision after other procedures, one had bars, and one had chest muscle abnormalities. The remaining 10 patients were between 17 and 32 years old, with an average age of 27 years. The average patient weight was 68 kg, average height 173 cm, and average BMI 22.8. All patients presented with RAM diastasis at the preoperative physical examination (Fig. 1). Ultrasonography imaging examinations were performed on all patients. All image reports showed muscular diastasis of RAM (Fig. 2): seven instances of partial epigastric separation, and three total separations, two of which were associated with umbilical hernia.

In the intraoperative evaluation, the separation of the rectus abdominis muscles in all patients at 2 cm below the incision level was a minimum of 23 mm and a maximum of 45 mm (an average of 23 mm). The separation widened as it went upward, with a curved lateral deviation up to the insertion in the costal arches, where the muscles had a protrusion and then a posterior descent with angulation until insertion in the anterior edge of the costal arches (Fig. 3). The distance between the medial edges of the RAM at the uppermost insertion in the costal arches was between 35 mm and 60 mm, an average of 43 mm (Table 1).

The two patients presenting umbilical hernia were submitted to surgical correction through a separated umbilical access. Isolated medial PE is an uncommon condition, and the number of primary patients treated with the use of silicone implants is even lower.[8] For this reason, the statistician team considered the study valid by reaching 10 patients with the constant presence of DRAM.

DISCUSSION

The linea alba is the fusion of aponeurosis of abdominal muscles and separates the two rectus abdominis muscles. This separation, when greater than 20 mm, characterizes DRAM.[9] However, normal and pathological separation varies according to the region between the xiphoid process and the pubis. Muysoms, in 2009, classified the midline of the anterior abdomen into five zones: subxiphoidal, epigastric, umbilical, infraumbilical, and suprapubic.[10] Most reports involving DRAM and its abnormalities involve the areas around the umbilical scar.[9] However, in 2009, Beer[11] studied the position of RAMs by ultrasound imaging in 150 nulliparous individuals aged between 20 and 45 years with a body mass of less than 30 and obtained the following results: 15 mm width at the xiphoid process, between 22 mm and 30 mm above the umbilicus, and 16 mm and 20 mm below the umbilicus. We can therefore affirm that the values found in this research demonstrate that all patients could be characterized as presenting DRAM. The RAMs are inserted in their upper portion in the fifth, sixth, and seventh costal arcs, with the fibers in vertical position. The curve deviation and the increase of the muscle

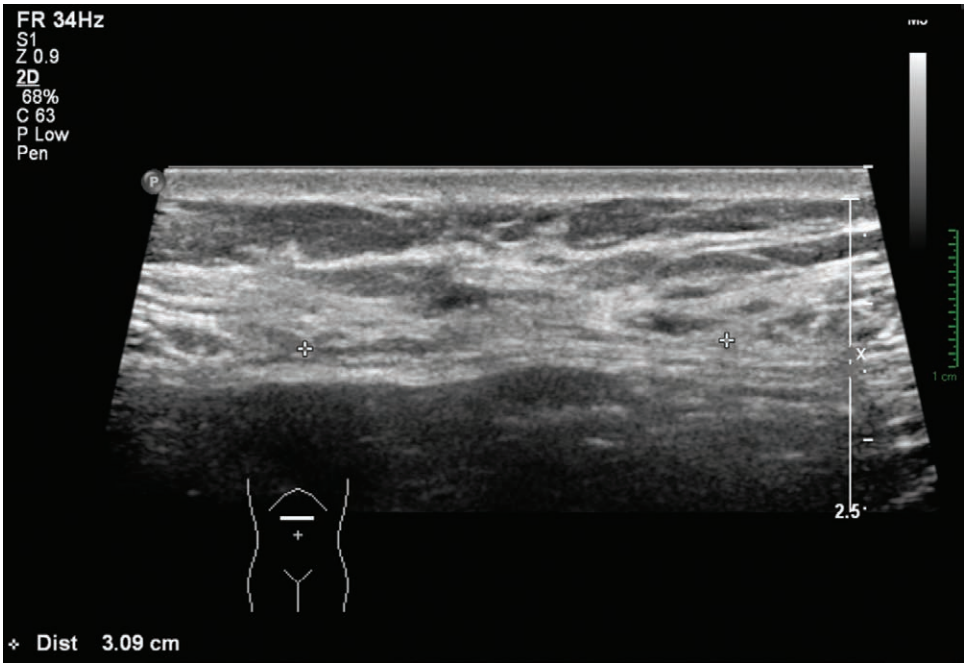

Fig. 2. Ultrasonographic image of the linea alba and the rectus muscles in a man with pectus excavatum, 31 years of age, 23.2 body mass index (patient 3). Transverse scan at the origin at the epigastric area. The + marks show the medial edges of the rectus abdominis muscles. The measured distance between the edges was 3.09 cm.

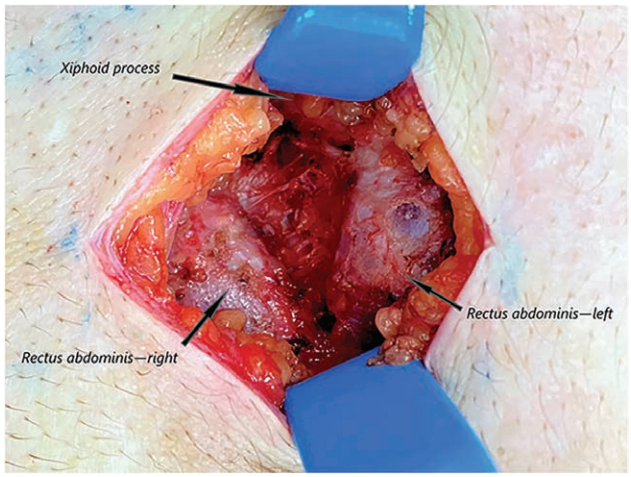

Fig. 3. Aspect of the rectus abdominis muscle at the superior insertion. Note the deviation of the muscle's bundles.

Table 1. Intraoperative Measurements of the Width of the Linea Alba at the Epigastric Zone

Patient (n = 10)	Age (y)	Weight (kg)	Height (cm)	BMI	Width of the Linea Alba 2 cm below the Access Incision (cm)	Width of the Linea Alba at the Costal Arch Insertion (cm)
1	32	50	168	17.7	2.5	4.1
2	17	63	178	19.8	4.1	5.2
3	31	71	175	23.2	3.2	4.3
4	29	68	171	23.0	3.0	4.4
5	19	63	169	22.1	2.3	3.1
6	32	74	168	26.2	2.6	4.3
7	21	62	170	21.5	3.2	4.7
8	31	68	173	22.7	3.0	4.5
9	30	70	177	22.3	2.8	4.3
10	28	71	172	24.0	2.4	4.6
Average	27	65	172.1	22.25	2.9	4.3

separation before the insertion seen in this research is not compatible with what is considered normal anatomy[12,13]

In this study, we only mentioned the DRAM as positive or negative diagnosis with physical examination and image examinations, but we did not insert and compare the intraoperative dimensions found because there is no agreement in the reports about this correlation of the three types of measurements.[14,15]

Descriptions of the physical aspect of the medial PE focus on the depressed position of the sternum and the final costal arches and emphasize a "typical pectus posture"[1] illustrated as a forward-wrapping curvature, a relative prominence of the lower costal arches and a configuration of the depressed abdomen in continuation to the PE, which becomes more and more prominent toward the hypogastrium. It is debated whether it is only a postural position or if it is correlated with true scoliosis, as other bone conditions coexist with PE.[1] The separation of RAMs in continuity with the sternum cavity associated with a patient's posture may highlight the appearance of the depression even more.

The separation of the RAMs may worsen the aesthetic result after surgical correction with the placement of the retrosternal Nuss bars, exposing the xiphoid process, which may become more prominent, especially in patients with a slight anterior prominence. The modification of the molding of the bar has already been described. Being discreetly depressed in its central portion, it avoids hypercorrection and exposure of the xiphoid process until its withdrawal.[3] These modifications introduced in the molding and positioning of the bar (mainly when there is only one) as well as its stabilizers help in improving the aesthetical results. The last surgical step (the resection of the xiphoid process by the anterior route through the skin) has also been described. This resection can be performed when using the open surgical technique of Ravitch and/or combined with Nuss surgery.[16]

In cases where two bars are used, the forces of correction of the deformity, with the upper bar in the intercostal space above the point of greatest deformity and the inferior one in the intercostal space below, are distributed over the structures of the anterior wall more uniformly. This may facilitate the correction and conceals the space left by the RAM diastasis better; however, it must be better evaluated.[3]

The design of the implants for medial PE treatment reported in published articles always include a continuation inferior to the xiphoid process, probably to improve the depressed aspect just below the sternum, and many of the authors noted the possible muscular alterations.[6,17–22] Our findings may indicate the necessity to study the prevalence of DRAM in nontreated patients with all types of PE based on noninvasive physical and image examinations, to define the best protocol to diagnose the presence of DRAM in PE. The muscular separation and the resulting depressed contour below the xyphoid process may indicate the inclusion of the muscular surgical mobilization to improve the aesthetic result.

CONCLUSIONS

The patients with medial PE in this research presented DRAM at the epigastric level and anatomical variations of the RAM insertion at the costal arches. The preoperative examination of patients with PE should include the abdominal wall physical examination and an image examination such as ultrasonography, which does not add any morbidity to our patients and can assist in the surgical planning, both in open surgeries with the implant of moldable silicone or in minimally invasive techniques with the use of Nuss bars.

Jaime Anger, MD, PhD
Av. Brigadeiro Luiz Antonio, 3889
São Paulo 01401-001
Brazil
E-mail: dr.anger@uol.com.br

REFERENCES

1. Morggl B, Kotzot D, Frari BD. Deformities of the anterior thoracic wall. In: Schwabegger AH, ed. *Congenital Thoracic Wall Deformities: Diagnosis, Therapy and Current Developments.* New York, N.Y.: Springer; 2011:3–56.

2. Nuss D, Kelly RE Jr, Croitoru DP, et al. A 10-year review of a minimally invasive technique for the correction of pectus excavatum. *J Pediatr Surg*. 1998;33:545–552.
3. de Campos JR, Tedde ML. Management of deep pectus excavatum (DPE). *Ann Cardiothorac Surg*. 2016;5:476–484.
4. Horch RE, Stoelben E, Carbon R, et al. Pectus excavatum breast and chest deformity: indications for aesthetic plastic surgery versus thoracic surgery in a multicenter experience. *Aesthetic Plast Surg*. 2006;30:403–411.
5. Anger J, Alcalde RF, de Campos JR. The use of soft silicone solid implant molded intraoperatively for pectus excavatum surgical repair. *Einstein (Sao Paulo)*. 2014;12:186–190.
6. Chavoin JP, Grolleau JL, Moreno B, et al. Correction of pectus excavatum by custom-made silicone implants: contribution of computer-aided design reconstruction. A 20-year experience and 401 cases. *Plast Reconstr Surg*. 2016;137:860e-871e.
7. Snel BJ, Spronk CA, Werker PM, et al. Pectus excavatum reconstruction with silicone implants: long-term results and a review of the English-language literature. *Ann Plast Surg*. 2009;62:205–209.
8. Johnson WR, Fedor D, Singhal S. Systematic review of surgical treatment techniques for adult and pediatric patients with pectus excavatum. *J Cardiothorac Surg*. 2014;9:25.
9. Reinpold W, Köckerling F, Bittner R, et al. Classification of rectus diastasis—a proposal by the German Hernia Society (DHG) and the International Endohernia Society (IEHS). *Front Surg*. 2019;6:1.
10. Muysoms FE, Miserez M, Berrevoet F, et al. Classification of primary and incisional abdominal wall hernias. *Hernia*. 2009;13:407–414.
11. Beer GM, Schuster A, Seifert B, et al. The normal width of the linea alba in nulliparous women. *Clin Anat*. 2009;22:706–711.
12. Testut L. *Tratado de Anatomia Humana*. 8th ed. Barcelona: Salvat Editores; 1944;956–1004.
13. Rath AM, Attali P, Dumas JL, et al. The abdominal linea alba: an anatomo-radiologic and biomechanical study. *Surg Radiol Anat*. 1996;18:281–288.
14. Emanuelsson P, Dahlstrand U, Strömsten U, et al. Analysis of the abdominal musculo-aponeurotic anatomy in rectus diastasis: comparison of CT scanning and preoperative clinical assessment with direct measurement intraoperatively. *Hernia*. 2014;18:465–471.
15. van de Water AT, Benjamin DR. Measurement methods to assess diastasis of the rectus abdominis muscle (DRAM): a systematic review of their measurement properties and meta-analytic reliability generalization. *Man Ther*. 2016;41-53.
16. Tedde ML, de Campos JR, Wihlm JM, et al. The Nuss procedure made safer: an effective and simple sternal elevation manoeuvre. *Eur J Cardiothorac Surg*. 2012;42:890–891.
17. Masson JK, Payne WS, Gonzalez JB. Pectus excavatum: use of preformed prosthesis for correction in the adult. Case report. *Plast Reconstr Surg*. 1970;46:399–402.
18. Marks MW, Argenta LC, Lee DC. Silicone implant correction of pectus excavatum: indications and refinement in technique. *Plast Reconstr Surg*. 1984;74:52–58.
19. Grappolini S, Fanzio PM, D'Addetta PG, et al. Aesthetic treatment of pectus excavatum: a new endoscopic technique using a porous polyethylene implant. *Aesthetic Plast Surg*. 2008;32:105–110.
20. Chavoin JP, Grolleau JL, Moreno B, et al. Correction of pectus excavatum by custom-made silicone implants: contribution of computer-aided design reconstruction. A 20-year experience and 401 cases. *Plast Reconstr Surg*. 2016;137:860e–871e.
21. Chavoin JP, Grolleau JL, Chaput B, et al. [The pectus excavatum: secondary surgery with implants]. *Ann Chir Plast Esthet*. 2019;64:620–633.
22. Wechselberger G, Ohlbauer M, Haslinger J, et al. Silicone implant correction of pectus excavatum. *Ann Plast Surg*. 2001;47:489–493.