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.

Surgical options include mobilizing the osteo-cartilaginous tissues to place them in the desired position or filling the existing cavity, with silicone being the most frequently used material. The minimally invasive bone mobilization surgery described by Nuss is the most used procedure. 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. 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 the linea 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.

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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 xiphoid. 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.
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. 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. 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. Most reports involving DRAM and its abnormalities involve the areas around the umbilical scar. However, in 2009, Beer 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...
separation before the insertion seen in this research is not compatible with what is considered normal anatomy. 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.

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” 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. 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. 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 aesthetic 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.

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.

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. 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 xiphoid 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.

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