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Evaluation of Thoracic Morphological Changes Using Chest CT in Patients with Congenital Pectus Carinatum Treated by the Modified Abramson Technique

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ABSTRACT

Background: The Pectus carinatum is an outward protrusion deformity of the sternum and adjacent costal cartilages. It is the second most common congenital deformity of the anterior chest wall, commonly occuring in adolescents. **Objective:** The aim of this study was to evaluate thoracic morphological changes using computed tomography (CT) imaging in patients with pectus carinatum treated via the modified Abramson technique at Viet Duc University Hospital from 2020 to 2023. **Methods:** A retrospective cross-sectional study analyzed all cases of congenital pectus carinatum diagnosed, imaged via CT, and surgically treated using the modified Abramson technique at Viet Duc Hospital from January 2020 to December 2023. **Results:** Among 115 patients (mean age: 13.6 ± 2.03 years), the majority presented with symmetrical deformities (70.4%). The average operative duration was 33.3 ± 8.3 minutes, and hospital stays ranged from 4 to 7 days (mean: 5.2 ± 0.90 days). No major postoperative complications were reported. Follow-up ranged from 11 to 48 months. Chest CT Scan reevaluation postoperatively in 69 patients showed significant improvement in thoracic indices: mean pre- and postoperative Haller index (HI) were 2.02 ± 0.20 and 2.46 ± 0.34, respectively. Sternal rotation angle averaged 2.81 ± 3.59, with 68/69 cases showing no or mild torsion. Postoperative asymmetry index (AI) averaged -0.014 ± 0.033. **Conclusion:** The modified Abramson technique provides a minimally invasive and effective treatment for pectus carinatum, achieving significant improvements in thoracic morphology as evidenced by Haller index, asymmetry index, and sternal rotation angles assessed on chest CT.

Keywords: Pectus carinatum, Modified Abramson technique, Computed Tomography.

1. BACKGROUND

The Pectus carinatum is an outward protrusion deformity of the sternum and adjacent costal cartilages. It is the second most common congenital deformity of the anterior chest wall, commonly occuring in adolescents. The minimally invasive Abramson technique, introduced in the early 2000s, has demonstrated effectiveness and safety in correcting the deformity, gaining global adoption (1,2). At Viet Duc Hospital, a modified Abramson technique has been applied since 2016, featuring innovations such as laryngeal mask anesthesia, using a short bar that is the length between the anterior axillary lines on both sides, and fixing both sides with steel thread that access into the pleural cavity. Primary results confirm its safety and clinical efficacy, though prior assessments have been largely qualitative (3). Chest CT imaging offers a robust method for

quantifying anatomical and morphological changes in pectus carinatum, evaluating deformity severity and surgical outcomes.

2. OBJECTIVE

This study aims to objectively assess thoracic improvements using Chest CT imaging before and after the modified Abramson procedure at Viet Duc Hospital between 2020 and 2023.

3. MATERIAL AND METHODS

Study Subjects: All patients diagnosed with pectus carinatum who underwent the modified Abramson procedure, and had chest CT imaging at Viet Duc Hospital between January 2020 and December 2023. The study employed a retrospective and prospective cross-sectional descriptive design. Research Parameters: Collected data included age, sex, clinical classification of pectus carinatum, operative time, hospital stay duration, postoperative complications, Haller index, sternal rotation angle, and asymmetry index (AI) assessed via pre- and postoperative CT.

Asymmetry Index (AI):

Formula: AI = (1- a/b), where "a" is the anteroposterior diameter of the right chest and "b" of the left chest at the highest protrusion.

Normal AI: −0.05-0.05−0.05 to 0.050.050.05.

AI > 0.05: Left chest larger than right.

AI < −0.05: Right chest larger than left.

Patients underwent surgery following a standardized protocol. Data were extracted from medical records and analyzed using SPSS 20.0 software.

4. RESULTS

During the study period from January 2020 to December 2023, 134 patients were diagnosed with pectus carinatum and underwent the modified Abramson technique, of whom 115 patients met the study's inclusion criteria.

Gender distribution: 115 patients included 112 males and 3 females. The mean age was 13.6 ± 2.03, of which 109/115 (94.8%) patients were aged 10-18 years old, 5 patients were under 10 years old, and the oldest patient was 23 years old (Figure 1).

The clinical classification of pectus carinatum: 83/115 patients (72.2%) had symmetrical pectus carinatum, 32/115 patients (27.8%) had asymmetrical pectus carinatum. In the asymmetric group, the majority were right-sided with 29/32 cases. Only 3 cases of left-sided were assessed by clinical examination (Figure 2).

All the patients (n=115) underwent preoperative chest CT scan with an average Haller index (HI) of 2.03 ± 0.22 in. The average sternal rotation angle was 7.3 ± 5.5, with 19 cases without torsion (0°), 86 with mild torsion (<15°), 10 with moderate torsion (15–30°), and no case of severe torsion with a rotation angle > 30 degrees. The mean preoperative AI was -0.03 ± 0.07.

All patients underwent the modified Abramson procedure, involving small 2 cm incisions on both sides of the anterior chest wall. A single compression bar was placed externally to correct the protrusion, restoring the chest to a normal clinical shape. The bar length was determined by the distance between the anterior axillary lines passing over the most prominent area. It was secured bilaterally to the ribs with double steel wires, with pleural cavity access. The average surgical time was 33.3 ± 8.3 minutes. There were no intraoperative complications. The average hospital stay was 5.2 ± 0.9 days.

A total of 69 out of 115 patients underwent postoperative chest CT scans for re-evaluation. The mean postoperative HI was 2.46 ± 0.34, the postoperative mean value approached the normal range at 2.56; Sternal Rotation: Mean 2.81 ± 3.59°, the sternal rotation

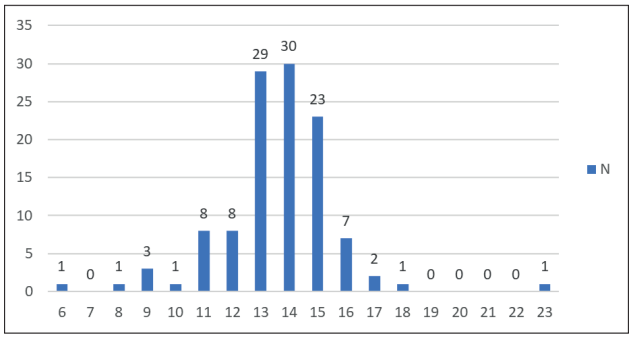

Figure 1. Age distribution in the study

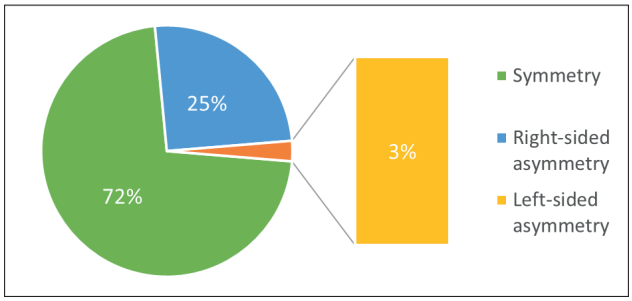

Figure 2. Classification of pectus carinatum through clinical examination

Clinical Morphology (n=115)	AI on chest CT Scan			Total	p Chi square
	AI > 0,05	0,05 ≥ AI ≥ -0,05	AI < -0,05		
Left-sided asymmetry	2	1	0	3	<0,001
Symmetry	1	68	14	83	
Right-sided asymmetry	0	10	19	29	
Total	3	79	33	115	

Table 1: Correlation between AI (Asymmetry Index) and clinical morphology.

Clinical Morphology	Sternal torsion		Total	p Fisher
	<15°	15–30°		
Symmetry	80	3	83	0,005
Asymmetry	25	7	32	
Total	105	10	115	

Table 2: Correlation between sternal rotation angle and clinical morphology of pectus carinatum, assessed using Fisher's exact test.

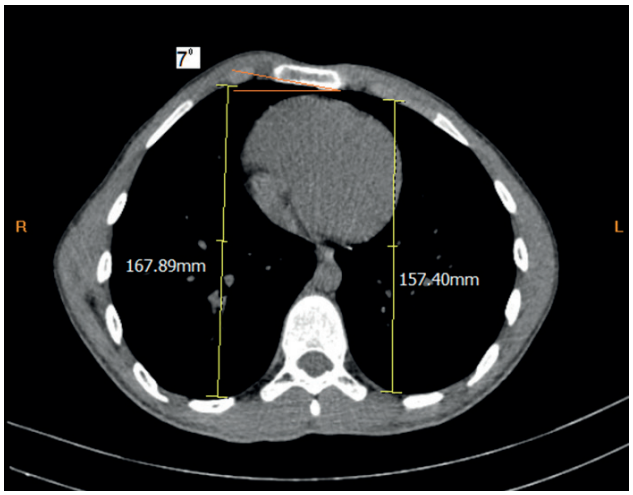

Figure 3. Measurement of the asymmetry index (AI) (-0.06) and the sternal rotation angle (7°) on chest CT imaging (Source: Author).

Haller index	Our study (n=115)	Park HJ 2016[10] (n=16)	Lei Wang 2021[11] (n=53)	Xuefeng Zhang 2022[7] (n=112)
Preoperative	2,03 ± 0,22	2,04 ± 0,34	2,07 ± 0,21	1,96 ± 0,22
Postoperative	2,46 ± 0,34	2,54 ± 0,29	2,78 ± 0,33	2,78 ± 0,35

Table 3: Comparison of Haller index from other studies

angle showed good improvement included 32 cases with 0°, 36 with mild torsion (<15°), 01 with moderate torsion (15–30°). The mean postoperative AI was -0.014 ± 0.033; Additionally, the postoperative AI value moved closer to zero, reflecting a well-corrected preoperative asymmetry and a more balanced thoracic morphology.

5. DISCUSSION

The Abramson procedure was introduced in the 2000s and first published in 2005 by Argentine surgeon Horacio Abramson (1). This technique involves placing a metal bar externally over the most prominent part of the sternum and securing it to the ribs bilaterally to restore normal chest morphology. Widely adopted and refined over time like improvements in bar design and stabilizer, it has shown promising outcomes in pectus carinatum correction. However, it is not suitable for all types of pectus carinatum, such as cases with overly rigid chest walls and cartilages or pigeon chest deformities, where standard chest compression strategies are ineffective. For symmetrical and asymmetrical pectus carinatum, the Abramson technique has demonstrated safety, efficacy, and cosmetic benefits (2). At Viet Duc Hospital, modifications were made to optimize its application in Vietnam, reducing costs, surgical duration, and postoperative complications. These modifications include using a shorter bar, with its length measured as the distance between the anterior axillary lines on both sides, passing through the most prominent point of the chest wall, laryngeal mask ventilation, and securing the bar to the ribs with double steel wires with pleural cavity access (3).

From January 2020 to December 2023, 134 patients underwent the modified Abramson procedure, with 115 evaluated preoperatively via CT scan. Follow-up was performed in 97 cases, including 69 patients undergoing postoperative chest CT scans. One critical factor determining surgical success in pectus carinatum correction is the flexibility of the chest wall, which inversely correlates with patient age. Therefore, age is a key consideration for surgical indication. Yuksel suggests an optimal age range of 11–20 years (4). In 2018, Yuksel et al. reported excellent outcomes in 93.8% of 172 patients aged over 10 years (5). In our study, 95.5% of patients were aged 10–18 years, with an average age of 13.6 ± 2.03 years, similar to Apaydin's study (mean age: 14.4 ± 7.8 years) (6).

Regarding the classification of pectus carinatum, clinical examination was primarily used for assessment. Symmetrical pectus carinatum was observed in 72.2% (83/115) of patients, while asymmetrical cases accounted for 27.8%. These findings align with those reported by Xuefeng Zhang (2022), where 83% were symmetrical and 17% asymmetrical (7). Among CT imaging parameters evaluating severity, the Haller Index (HI) remains the most recognized and prioritized. However, HI alone does not comprehensively represent the extent or asymmetry of chest wall deformities. Thus, assessing the sternal rotation angle and asymmetry index (AI) is crucial for determining deformity severity, complexity, as well as contributing to the prognosis and evaluation of treatment effectiveness. Few studies have examined changes in the sternal rotation angle and asymmetry index (AI) before and after intervention. Notably, Marcelo Martinez-Ferro (2016) and Sergio B. Sesia (2019) emphasized the importance of additional CT-derived parameters for assessing the severity and complexity of chest wall deformities. These parameters not only enhance the evaluation of deformity characteristics but also contribute to better understanding the out-

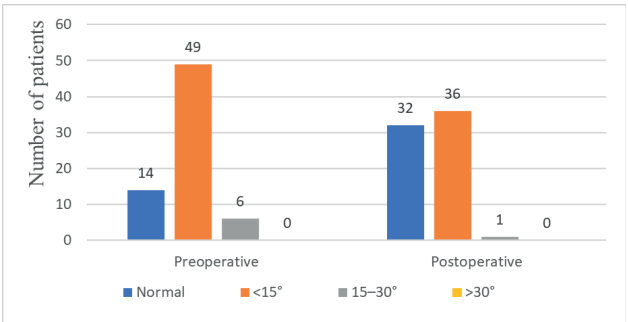

Figure 4: Pre- and Postoperative Sternal Rotation (n=69)

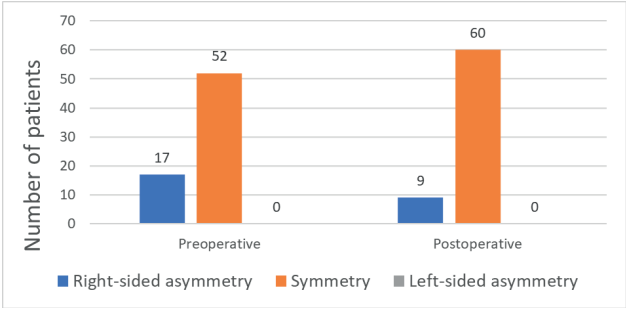

Figure 5: Pre- and Postoperative Asymmetry index (n=69)

comes of treatment interventions (8, 9).

In our study, all patients undergoing chest CT were assessed using the Haller index (HI), asymmetry index (AI), and sternal rotation angle (Figure 3). Both the AI and sternal rotation angle were considered relevant to the clinical morphology of pectus carinatum. To evaluate concordance between clinical and radiological findings, we analyzed the relationship between clinical examination results (symmetrical vs. asymmetrical morphology) and the AI values derived from CT imaging (Table 1). Chi-square testing revealed a strong correlation between clinical morphology and AI, with statistical significance at 99% confidence ($p < 0.001$).

Similarly, increased sternal torsion was associated with more asymmetrical chest deformities. The mean sternal rotation angle in our study was 7.3° (n = 115), with 91.3% of cases exhibiting no or mild torsion (<15°), 8.7% moderate torsion (15–30°), and none with severe torsion. Further comparison of asymmetrical morphology with sternal torsion demonstrated a significant correlation: greater torsion corresponded to more asymmetrical deformities (Table 2).

The Haller Index (HI) is calculated differently for pectus carinatum and pectus excavatum to reflect their unique deformities. For pectus carinatum, HI is the ratio of the widest transverse diameter to the anteroposterior distance, measured from the anterior vertebral surface to the posterior sternal surface at the most protruding point. A lower HI indicates greater severity, with HI < 2.2 typically indicating diagnostic and HI < 1.8 severe deformity.8 In our study, the mean HI was 2.03 ± 0.22. Among participants, 14.8% had HI < 1.8, and 63.5% fell within 1.8–2.2. These findings are consistent with prior studies by Park HJ (2016) (10) and Lei Wang (2021) (11), (1 but slightly higher than results reported by Xuefeng Zhang (2022) (7), with no significant differences (Table 3). Ziyin Shang recommends surgical intervention for pectus carinatum or excavatum in patients with clinically evident deformities, cosmetic or psychological concerns, or an HI < 2.3 (12). Furthermore, Shang's study indicates that the failure rate of non-surgical bracing treatment increases with age, with a significant 85% failure rate in patients aged 12–15 years in a cohort of 767 individuals (12).

As of September 2024, 97 out of 115 patients returned for follow-up at Viet Duc Friendship Hospital, with 69 of them undergoing repeat chest CT scans for evaluation. For objective assessment of chest morphology changes, we compared pre- and post-surgical CT scans in these 69 patients.

The average Haller Index (HI) demonstrated significant improvement, with pre-surgical HI of 2.02 ± 0.2 and post-surgical HI of 2.46 ± 0.34, approaching the normal value of 2.56. Paired comparison of pre- and post-surgical HI revealed a statistically significant difference ($p < 0.001$). These findings are consistent with those of Suh JW (2016)13 and Lei Wang (2021) (11), who reported preoperative and postoperative HI values of 2.01 ± 0.19 and 2.22 ± 0.19, and 2.07 ± 0.21 and 2.78 ± 0.33, respectively. Xuefeng Zhang also showed significant changes, with HI before and after surgery of 1.96 ± 0.22 and 2.78 ± 0.35 (Table 3) (7). These findings corroborate the success of the Abramson method in achieving normal thoracic anatomy and positive clinical outcomes.

The sternal rotation angle also showed significant improvement, with a pre-surgical value of 7.13 ± 5.9 and post-surgical value of 2.81 ± 3.59. Notably, the number of patients with a normal rotation angle increased, while those with low and medium rotation angles decreased sharply (Figure 4). Paired comparison analysis revealed a mean difference of 4.32, indicating a statistically significant reduction in the sternal rotation angle ($p < 0.001$), further confirming the effectiveness of the surgical intervention.

Simultaneously, the paired samples correlation test showed a proportional relationship between pre- and post-surgical rotation angles. The higher the preoperative rotation angle, the more difficult it was to return to normal values after surgery. Conversely, a smaller preoperative angle was easier to correct, with a significant p-value of 0.003.

Another notable change was observed in the Asymmetry Index (AI), with pre- and post-surgical values of -0.028 ± 0.037 and -0.014 ± 0.033, respectively. The postoperative AI increased and approached 0, indicating significant correction of preoperative asymmetry, which became more balanced. This result was statistically significant with a paired test ($p = 0.002$). Specifically, the number of patients achieving symmetry increased, while those with asymmetry decreased sharply (Figure 5).

Further comparison between the asymmetry index and sternal rotation angle revealed a strong correlation through Pearson's test between these two quantitative variables, with a correlation coefficient of $|r| = 0.872$ (≥ 0.5), indicating a statistically significant relationship ($p < 0.001$). Evaluating both the sternal rotation angle and AI is crucial in predicting the severity of chest wall deformity and assessing treatment outcomes. While there are limited studies addressing changes in the sternal rotation angle and asymmetry index before and after surgery for pectus carinatum, our study demonstrated significant positive changes in these parameters. Specifically, we observed notable improvements in the Haller index (HI), asymmetry index (AI), and sternal rotation angle before and after surgery, emphasizing their critical role in assessing the severity of pectus carinatum deformity and the effectiveness of treatment.

6. CONCLUSION

Since its implementation in 2016, the modified Abramson method for treating pectus carinatum at Viet Duc Friendship Hospital has demonstrated favorable outcomes in managing pectus carinatum. This study provides strong evidence of morphological changes, as assessed by the Haller index (HI), asymmetry index (AI), and sternal rotation angle on chest

CT scans before and after surgery, thereby validating the effectiveness of the modified Abramson technique.

- **Author's contribution:** Each author was included in all phases of preparation of this article.
- **Conflict of interest:** The authors declare that they have no competing interests.
- **Financial support and sponsorship:** Nil.

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