



Does an external chest wall measurement correlate with a CT-based measurement in patients with chest wall deformities?☆



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ABSTRACT

Background: Measurements in chest wall deformities are typically conducted using a thorax caliper or a CT scan of the chest wall. This paper focuses on the possible correlation between these two methods to validate the reliability of the thorax caliper, minimize radiation exposure, and limit the usage of expensive imaging techniques.

Methods: We evaluated 95 consecutive patients (77 pectus excavatum (PE), 17 pectus carinatum (PC), 1 mixed deformity) who received surgical correction of the anterior chest wall. The results of the external chest wall measurements and the CT-based measurements were statistically compared.

Results: A significant correlation between the two measurements was observed in PE and PC at the highest point of the deformation. The strongest correlation was noted in PE. We also noted a correlation between the transverse diameter of the external measurement and the inner thoracic diameter of the CT scan but not for the sagittal diameters in the upper parts of the sternum.

Conclusions: Thorax caliper measurements are suitable for determining the sagittal thoracic diameter at the maximum level of the deformity and the transverse diameter with an accuracy comparable to that of CT measurements. Since these values key, the thorax caliper is reliable for monitoring and documenting chest wall malformations.

Level of evidence: Study of diagnostic test. Testing previously developed diagnostic criteria in a consecutive series of patients and a universally “gold” standard—Level I.

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1. Introduction

1.1. Historical background

Pectus excavatum (PE) was first described by Bauhinius [1] in 1594.

In 1882, Ebstein [2] conducted external measurements of PE. His measurements were similar to the measurements performed today. He determined the depth of the malformation, the “sternal line”, the maximal diameter of the right and left thorax and the transverse diameter.

Abbreviations: CT, computed tomography; PC, pectus carinatum; PE, pectus excavatum; Sagittal diameter of the thorax at the level of, T1: the upper edge of the manubrium, T2: the Angulus Ludovici, T3: the maximum level of the malformation; CT-measurements: a the retrosternal distance, S the anterior-posterior thorax diameter, b the inner transverse thoracic diameter, b' the thoracic diameter (including the surrounding soft tissue).

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1.2. Epidemiology

PE is the most common malformation of the anterior chest wall and comprises 87–90% of malformations [3]. Data about the incidence of PE differ from 1:300 or 1:400 [4,5] to 1:1000 or even 1:8000 [6].

The second most common malformation of the anterior chest wall is pectus carinatum (PC), which comprises 5–7% of malformations. PC occurs in between 1:1000 and 1:10,000 cases [7]. The reported ratios of affected males and females differ in pectus excavatum patients between 3:1 [6] and 9:1 [8]; in pectus carinatum patients the reported ratio is 4:1 [3].

1.3. Physical examination

There are many different methods used to classify and examine PE (Table 1). The simplest way to document the disease is using photography. Schwabegger [9] recommended taking pictures from seven different angles: frontal, 90° and 45° laterally from the left and right sides, and from the top and bottom.

Another simple method uses a flexible ruler to obtain measurements. This device is adapted to the thorax shape and then transferred onto paper. A profile of the anterior chest wall is accordingly obtained,

Table 1
Methods and indices.

Author	Method of measurement	Point of measurement	Metrics	Index	Conclusion
Schwabegger [9]	Photo documentation	–	–	–	
Rebeis et al. [10]	External measurement	Lower third of the sternum	B = depth of the deformity A = anteroposterior distance	Anthropometric index (AI) $AI = B/A$	Cut point: $AI = 0.12$; $> =$ pectus excavatum
Hecker et al. [11]	Thorax-caliper	Many different points along the sternum, parasternal left/right, medio clavicular left/right	Anterior–posterior diameter	–	Development of a thorax profile (sagittal and horizontal), to compare preoperative and postoperative findings
Hümmer [12]	Thorax-caliper	T1: upper edge of the manubrium T2: Angulus Ludovici T3: deepest point of the funnel chest	Anterior–posterior diameter	Pectus excavatum severity index (T.I.): $(T3/T1) * 100$ (%)	Normal: T.I. 100–150 Pectus excavatum: T.I. < 110 Pectus carinatum: T.I. > 140
Colombani [13]	Thorax-caliper	Maximum severity of the deformity	Anterior–posterior diameter Distance between spinous and medio-clavicular line		Difference > 2.5 cm: significant for a moderately severe or severe pectus excavatum
Haller et al. [16]	CT	Maximum severity of the deformity	A = transversal diameter B = anterior–posterior diameter	Haller-Index: $HI = A/B$	$HI > 3.25$ = pectus excavatum
Mueller et al. [14], Khanna et al. [15]	X-ray	Maximum severity of the deformity		Haller-Index	Significant correlation between Haller-Index calculated by CT- and X-ray based measurements
Lo Piccolo et al. [17]	MRI	Maximum severity of the deformity		Haller-Index	Significant correlation between Haller-Index calculated by CT- and MRI-based measurements

which provides information about the funnel depth, the opening angle and the respiratory mobility of the chest wall.

Rebeis et al. [10] developed the Anthropometric-Index (PEX-AI). With the patient in a supine position, the anterior–posterior diameter and the funnel depth are determined using a special measuring apparatus. The ratio of these measurements is the PEX-AI.

In 1981, Hecker et al. [11] described the use of a thoracic caliper to externally measure the chest wall. These authors wanted to determine an objective parameter that would enable a comparison between preoperative and postoperative findings.

Hümmer [12] measured the anterior–posterior diameter at three different places: at the upper edge of the manubrium (T1), at the Angulus Ludovici (T2), and at the deepest point of the funnel (T3). The ratio of the values T1 and $T3 \times 100\%$ determines the pectus severity index.

According to Colombani [13], a thorax caliper should be used as part of each preoperative assessment. Here, the anterior–posterior diameter is to be measured at the deepest point of the funnel.

A chest X-ray can also be used to evaluate PE. Mueller et al. [14] determined the Haller Index from X-rays. They were able to demonstrate a significant correlation between the Haller Index from X-rays and from CT data ($0.984, p < 0.01$). In a similar study, Khanna et al. [15] demonstrated a significant correlation between the Haller Index measured in X-rays and CT images.

Haller et al. [16] were one of the first researchers who used CT to describe PE. He determined the transverse diameter and retrosternal distance at the lowest point of the deformity. The ratio of these two quantities formed the Haller Index, which describes the severity of the deformation.

Lo Piccolo et al. [17] verified the consistency of the results from CT- and MRI-based measurements with respect to the Haller Index and the Asymmetry Index.

1.4. Theory

Since significant correlation between measurements based on different imaging procedures could be shown yet the relationship between them and external measurements of the chest wall needs to be investigated. The clinical question, if an external chest wall measurement

correlates with a CT-based measurement in patients with chest wall deformities should be answered by this study.

2. Materials and methods

2.1. Patients

In this study, we included all consecutive patients who had undergone a surgical correction of the anterior chest wall between January 2009 and September 2012. We additionally required that a preoperative thorax caliper measurement and a thorax CT be available. Patients younger than 15 years were excluded from the study.

Ninety-five patients fulfilled these criteria (77 PE patients, 17 PC patients, and 1 patient with a mixed deformity). The average age of the patients at the time of surgery was 23.1 ± 8.6 years (range: 15.0–63.5 years).

2.2. Study design

The measurements were collected preoperatively in all of the included cases. The thorax caliper measurements were documented in a standardized medical history form. Furthermore, the preoperative CT scans were analyzed using Magic Web (Version VA60C-0212, Siemens, Munich, Germany). All of the CT scans were performed using a standardized protocol (CT: SOMATOM Definition Flash, Siemens, 2 detectors 2×128 slices, rotation time: 0.28 s, temporal resolution: 75 ms).

All of the data were documented using Excel (Version 2010, Microsoft, United States) in a tabular form of a register. The analysis was performed using Excel and SPSS (Version 21, IBM Statistics, United States).

2.3. Thorax caliper measurements

We performed the external measurements of the anterior chest wall using a thorax caliper at the T1 point (i.e., at the upper edge of the manubrium), the T2 point (Angulus Ludovici), and the T3 point (i.e., the point of maximum severity of the deformity) (Fig. 1A, B), as described by Hümmer [12]. In addition, we measured the transverse diameter

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