Normalized Cardiopulmonary Exercise Function in Patients With Pectus Excavatum Three Years After Operation

Marie Maagaard, MS, Mariann Tang, MD, PhD, Steffen Ringgaard, MSc, PhD, Hans Henrik M. Nielsen, MD, PhD, Jørgen Frøkiær, MD, PhD, Maj Haubuf, MD, Hans K. Pilegaard, MD, and Vibeke E. Hjortdal, MD, PhD

Department of Cardiothoracic and Vascular Surgery, MR Research Center, and Department of Clinical Physiology and Nuclear Medicine, Aarhus University Hospital, Skejby, Denmark

Background. During exercise cardiac function is often limited in patients with pectus excavatum. Therefore, we hypothesized that cardiopulmonary exercise function would improve after the Nuss procedure.

Methods. Seventy-five teenagers (49 patients, 26 controls) were investigated at rest and during bicycle exercise before surgery, and 1 year and 3 years postoperatively (after pectus-bar removal). Echocardiography and lung spirometry were performed at rest. Cardiac output, heart rate, and aerobic exercise capacity were measured using a photoacoustic gas-rebreathing technique during rest and exercise.

Results. Forty-four patients and 26 controls completed 3 years follow-up. Preoperatively, patients had lower maximum cardiac index, mean ± SD, 6.6 ± 1.2 l/min/m² compared with controls 8.1 ± 1.0 l/min/m² during exercise (p = 0.0001). One year and 3 years postoperatively, patients’ maximum cardiac index had increased significantly and after 3 years there was no difference between patients and controls (8.1 ± 1.2 l/min/m² and 8.3 ± 1.6 l/min/m², respectively [p = 0.572]). The maximum oxygen consumption was unchanged. Left ventricular dimensions increased in patients over 3 years; however, no difference was seen between the 2 groups. Preoperatively, patients had lower forced expiratory volume in the first second of expiration (FEV₁; 86% ± 13%) as compared with controls (94% ± 10%), p = 0.009. Postoperatively, no difference was found in FEV₁ between the 2 groups.

Conclusions. Before operation, FEV₁ and maximum cardiac index were lower in patients compared with healthy, age-matched controls. One year after, both parameters had increased, although only FEV₁ had normalized. After 3 years and bar removal, cardiopulmonary function in patients during exercise had normalized.

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Pectus excavatum is seen in 1 in 400 births, with a male-predominance [1, 2]. During adolescent growth spurt, the chest depression increases in severity, and many patients undergo surgery in their early teens [3].

Patients with pectus excavatum present with symptoms of varying degree, among the most common are dyspnea, fatigue, and decreased exercise stamina [1, 2]. There is no consensus on the impact of pectus excavatum on cardiopulmonary function, and so the indication to operate on the patient remains a hot topic; is it purely a cosmetic operation or does the patient benefit physiologically as well?

At rest, no noticeable impact on cardiopulmonary function has been established [4, 5]. However, during exercise, decreased stamina [6, 7] and improvement after surgery [4, 5, 8–10] have been reported, yet none of the studies referred have considered concurrent growth of teenagers during the investigational period.

In 2 previous papers [11, 12] we found teenagers with pectus excavatum to have lower lung function, measured as forced expiratory capacity during the first second (FEV₁), as well as a lower maximal cardiac index (CI_max) compared with a group of healthy age-matched controls during incremental bicycle exercise. All patients in the study underwent a modified, minimally invasive Nuss procedure [13]. One year after surgery, CI_max was increased during exercise; however, still significantly lower compared with age-matched controls [12].

We continued our investigation of the same study population after pectus bar removal in order to determine whether patients would further increase cardiopulmonary exercise function to a level comparable with the healthy, age-matched controls; in this way continuously taking growth during the investigational period into account.

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Address correspondence to Dr Hjortdal, Department of Cardiothoracic and Vascular Surgery, Aarhus University Hospital, Skejby, Brendstrupgaardvej 100, DK-8200 Aarhus N, Denmark; e-mail: vibehjor@rm.dk.
consideration. With this study we hope to further clarify the impact of surgical correction of the thoracic wall on cardiopulmonary function at rest and during exercise.

We hypothesized that both cardiac index and lung function would increase after surgical correction and removal of the pectus bar compared with preoperative results. Furthermore, we hypothesized that both cardiac index and lung function of the patients after bar-removal would be comparable with healthy, age-matched control subjects.

Material and Methods

Participants

This study was a single-center, prospectively controlled study started in 2007. We included 49 patients (10 females, 39 males), all scheduled to undergo the minimally invasive Nuss procedure for pectus excavatum. In the same period, 26 healthy, age-matched controls (10 females, 16 males) were recruited. Criteria for exclusions from both groups were severe lung disease, preexisting heart disease, and lack of Danish language skills. Participants (patients and controls) or their parents gave written consent after oral and written information for a 3-year study period. The study protocol was approved by the local Ethics Committee.

Participants and controls were investigated before patients underwent corrective surgery, 12 months after the inclusion-date, and 3 years after inclusion (for the patients this was after removal of the pectus bar). Participants went through the same examinations and tests throughout the study. Results from baseline and 1-year follow-up have previously been published.

Statistical Considerations

Before launching the study, power calculations were made for volume of oxygen uptake/kg (VO₂) and cardiac index to ensure the amount of participants. With an estimated standard deviation of 5%, a difference between the 2 groups of 20% and a power of 80%, the number needed to investigate was 25 patients and controls. Statistical analyses were performed using StataIC 11.1 (StataCorp LP, College Station, TX). Data were normally distributed as estimated on normal distribution probability plots. The independent t test was used in order to compare results between the patient and control group, while initial and follow-up studies for the same individual were compared with the Student paired t test. Because many tests were conducted, a difference was considered statistically significant if p was less than 0.01. All data are presented as mean ± standard deviation (minimum–maximum).

Questionnaire

Each patient and each control completed a questionnaire examining their smoking habits and exercise habits. Exercise habits were scored from 1 to 4, where 1 was exercise less than once a month and 2 was exercise 1 to 3 times a month. Category 3 was 1 to 2 times per week and 4 being more than 3 times per week. Participants were included in the smoking group if they had been smoking more than 14 cigarettes per week for at least a year. The questionnaires were handed out at all 3 times of examination.

Cardiopulmonary Exercise

In order to assess cardiopulmonary exercise capacity of the participants, we used a noninvasive, photo-acoustic gas-rebreathing technique, combined with a bicycle ergometer fatigue test. As our study subjects were young teenagers who had to participate 3 times each it was critical that the test proved to be easy to apply and that it would not inflict any unnecessary stress on the participant. For that reason we chose the recently validated and noninvasive technique that is based on the golden standard of the Fick principle. A closed system was ensured, with the participant being equipped with a nose clamp and breathing through a mouthpiece connected to a 3-way respiratory valve and a rubber bag, which again was connected to an infrared photoacoustic analyzer-device (Innocor; Innovision A/S, Odense, Denmark). The system used an oxygen-enriched mixture of an inert soluble gas (0.5% nitrous oxide) and an inert insoluble gas (0.1% sulfur hexafluoride) measured by photoacoustic analyzers over 5 breath intervals. From the test we determined minimum-maximum heart rate, CI_{max} and VO₂/kg. The maximum stroke index (SI_{max}) was calculated as CI_{max} divided by maximum heart rate. The CI_{max} and SI_{max} are the body surface area-corrected cardiac output and stroke volume, respectively.

Participants were sitting upright on the bicycle, equipped with a pulse oximeter, in an air-conditioned laboratory. The initial rebreathing test was measured at rest and during exercise. Rebreathing tests were repeated every 3 minutes in order to secure washout of gas particles from the system. After each test, participants would let go of the mouthpiece and breathe in normal, atmospheric air. The participants pedaled at a steady pace of 60 rpm with incremental workload (steps of 30 W) until exhausted and no longer in position to continue despite encouragement from the research team. A sub-maximal exercise effort was achieved with a heart rate of approximately 80% of expected maximum value as well as subjective evidence of fatigue (ie, sweating, hyperpnea). The tests were performed with the same equipment throughout the investigational period.

Echocardiography

Transsthoracic echocardiography (2-dimensional and M-mode) was recorded to exclude potential mitral valve regurgitation and other possible structural abnormalities as well as determining fractional shortening, ejection fraction, left ventricular systolic and diastolic diameter, and right ventricular diastolic diameter. Measurements were obtained with a 4 MS transducer coupled to a VIVID7 ultrasound echo machine (GE Healthcare, UK) and scans were performed and evaluated by the same, experienced echo technician throughout the entire investigational period.
Magnetic Resonance Imaging
Magnetic resonance imaging was performed on the study population at baseline and at 3 years follow-up in order to measure the Haller index (an index for the severity of the deformity calculated as the ratio of the transverse dimension of the chest to the anterior-posterior dimension) from vertebral body to sternum. The scans were carried out at 1.5 Tesla (Philips Achieva, Best, The Netherlands) using a T2-weighted (balanced-steady-state-free-precession), cardiac-triggered sequence. Magnetic resonance imaging was chosen over computed tomography in order to avoid unnecessary exposure to radiation and has recently been validated for measuring Haller index [15].

Spirometry
All participants underwent pulmonary function tests preoperatively, 1-year, and 3-years postoperatively. The spirometry was performed in the same laboratory with the same spirometer (Spirotac IV, Vitalograph Ltd., Buckingham, England). Forced vital capacity (FVC), forced expiratory volume during the first second (FEV1), the ratio FEV1/FVC, and the peak expiratory flow (PEF) were recorded. All measured indices were related to size, age, and gender adjusted normal values and were expressed as a percentage of predicted standardized values derived from either Polgar [16] (age range 5 to 17 years) and European Respiratory Society [17] (age range 18–70), depending on the age of the participant.

Results
The missing data on some of the tests were randomly distributed. Number of patients and controls participating in each test are presented in the tables.

Participant Characteristics
Out of the 49 patients and 24 controls that were included at baseline, 45 patients and 24 controls completed the 1-year follow-up investigation. At 3-years follow-up, 44 patients and 26 controls from the baseline study completed the final 3 years follow-up. A total of 42 patients and 24 controls could be followed through all 3 examination dates. Table 1 displays demographics of the study population. There was no significant difference in age or time of test dates between the 2 groups at any point during the test period. Likewise, no significant difference was found between the 2 groups regarding body mass index or gender distribution.

Questionnaires
No difference was observed between patients and controls in level of habitual activity. A nonsignificant tendency toward a decreased level of activity was seen in both groups during the 3 years (Table 1). A predominance of smokers was seen among the patients and with an increasing number throughout the 3 years. However, the group of smokers did not stand out compared with non-smokers regarding lung function test scores or results from bicycle exercising tests (Table 2).

Cardiopulmonary Exercise
Patients and controls increased equally in heart rate and no difference was found between the two groups during the three bicycle tests (Table 3). Before correction, CImax was lower in patients compared with controls during exercise. After bar removal at the 3-year follow-up, CImax had normalized and no significant difference was seen between patients and controls (p = 0.572). Patients increased both from 1-year to 3-year follow-up (p = 0.001) and from baseline to 3-year follow-up (p = 0.0001). Controls experienced neither a change from 1-year to 3-year follow-up (p = 0.461) nor from baseline to 3-year follow-up (p = 0.539). No correlation between the patients’ Haller index and CImax was found either before (R2 = 0.05) or after operation (R2 = 0.2).

The SImax was lower in patients preoperatively, but the difference disappeared after corrective surgery.

Table 1. Demographics and Exercise Habits for Patients and Controls at Baseline, 1-Year, And 3-Year Follow-Up

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline</th>
<th>Unpaired t test, p Value</th>
<th>1-Year Follow-Up</th>
<th>Unpaired t test, p Value</th>
<th>3-Year Follow-Up</th>
<th>Unpaired t test, p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients (n = 49)</td>
<td>Controls (n = 26)</td>
<td></td>
<td>Patients (n = 3)</td>
<td>Controls (n = 24)</td>
<td>Unpaired t test, p Value</td>
<td>Patients (n = 44)</td>
</tr>
<tr>
<td>Age, years</td>
<td>15.5 [1.7]</td>
<td>15.0 [1.9]</td>
<td>0.244</td>
<td></td>
<td>16.4 [1.9]</td>
<td>15.8 [1.8]</td>
</tr>
<tr>
<td>Distribution of</td>
<td>20.4 [0.4]</td>
<td>38.5 [0.5]</td>
<td>0.095</td>
<td></td>
<td>16.3 [0.4]</td>
<td>37.5 [0.5]</td>
</tr>
<tr>
<td>Exercise, %</td>
<td>3.1 [0.9]</td>
<td>3.6 [0.6]</td>
<td>0.026</td>
<td></td>
<td>3.1 [0.9]</td>
<td>3.3 [0.8]</td>
</tr>
</tbody>
</table>

Significant (p < 0.01) difference between patients and controls.

Results displayed as standard mean with ± standard deviation. Results from baseline and 1-year follow-up are previously published [11, 12].

n = number of participants.
Cardiopulmonary Function and Nuss Procedure

Table 2. Smoking Habits for Patients and Controls at Baseline, 1-Year, and 3-Year Follow-Up

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline</th>
<th>Unpaired t Test, p Value</th>
<th>1-Year Follow-Up</th>
<th>Unpaired t Test, p Value</th>
<th>3-Year Follow-Up</th>
<th>Unpaired t Test, p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Smokers (n = 1)</td>
<td>Non-smokers (n = 55)</td>
<td></td>
<td>Smokers (n = 4)</td>
<td>Non-smokers (n = 61)</td>
<td></td>
</tr>
<tr>
<td>Total of smokers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients</td>
<td>1</td>
<td>31</td>
<td>4</td>
<td>37</td>
<td>9</td>
<td>35</td>
</tr>
<tr>
<td>Controls</td>
<td>0</td>
<td>24</td>
<td>0</td>
<td>24</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>Clmax, mL/kg/m²</td>
<td>6.7 [-]</td>
<td>7.2 [1.7]</td>
<td>7.9 [0.5]</td>
<td>7.7 [1.5]</td>
<td>7.6 [0.7]</td>
<td>8.2 [1.4]</td>
</tr>
</tbody>
</table>

Results displayed as standard mean with ± standard deviation. Results from baseline and 1-year follow-up are previously published [11, 12].

Furthermore, patients significantly increased Slmax over the study period (baseline to 3-year test, \( P = 0.0002 \)), which was not the case for the control subjects (\( P = 0.299 \)). Maximum oxygen uptake was significantly lower in patients 1 year after operation compared with controls. At 3-year follow-up, the difference had disappeared between the 2 groups.

Echocardiography

No difference was seen in ejection fraction and fractional shortening between patients and controls (Table 4). Diastolic dimensions of the left ventricle increased in patients during the 3 years (\( P = 0.0002 \)) as well as left systolic dimensions (\( P = 0.0001 \)); however, these remained unchanged in controls (\( P = 0.233, \ P = 0.082 \), respectively). Yet, no difference was detected between the 2 groups during the study period. Right ventricular diastolic diameter increased in controls from baseline during the 3 years (\( P = 0.001 \)), but no difference was seen between patients and controls, and patients remained unchanged during the 3 years (\( P = 0.013 \)). All measurements were within normal limits.

Magnetic Resonance Imaging

Before operation, patients had a significantly higher Haller index of 4.9 ± 1.4 as opposed to that of the controls of 2.6 ± 0.3 (\( P = 0.0001 \)). After bar removal, no difference was found between Haller indices of patients (2.8 ± 0.4) and controls (2.6 ± 0.3), \( P = 0.052 \).

Spirometry

Dynamic pulmonary function tests from baseline, 1-year and three-years postoperatively are outlined in Table 5. Preoperatively, patients’ FEV1 was lower compared with healthy controls. At 1-year and 3-year follow-ups, patients improved FEV1 compared with baseline (\( P = 0.001, P = 0.0001 \), respectively) and were no longer different from controls. Forced expiratory volumes did not change during the 3 years and both groups scored within normal ranges of their predicted values.

Comment

In 2 previous studies on preoperative status and early outcome of this cohort, we found that patients with pectus excavatum had a significantly lower Clmax compared with healthy age-matched controls during exercise [11, 12]. With this prospective study we wanted to further investigate the effects of bar removal on patients’ cardiac function compared with the control group. After bar removal, 3-years post implantation, normalization of Clmax was seen in patients when comparing them with the same control group. This normalization of cardiac output during exercise may be due to the larger thoracic

Table 3. Cardiac Function Testing During Bicycle Exercise in Patients and Controls at Baseline, 1-Year, and 3-Year Follow-Up

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline</th>
<th>Unpaired t Test, p Value</th>
<th>1-Year Follow-Up</th>
<th>Unpaired t Test, p Value</th>
<th>3-Years Follow-Up</th>
<th>Unpaired t Test, p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum heart rate, beat/minute</td>
<td>Patients (n = 47)</td>
<td>Controls (n = 26)</td>
<td></td>
<td>Patients (n = 40)</td>
<td>Controls (n = 24)</td>
<td></td>
</tr>
<tr>
<td>Maximum heart rate, beat/minute</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum cardiac index, mL/min/m²</td>
<td>6.6* [1.2]</td>
<td>8.0 [1.7]</td>
<td>7.3* [1.1]</td>
<td>8.5 [1.6]</td>
<td>0.001</td>
<td></td>
</tr>
</tbody>
</table>

* Significant (\( p < 0.01 \)) difference between patients and controls.

Results displayed as standard mean with ± standard deviation. Results from baseline and 1-year follow-up are previously published [11, 12].

n = number of participants; VO2 = volume of oxygen uptake.
Table 4. Echocardiographic Parameters in Patients and Controls at Baseline, 1-Year, and 3-Year Follow-Up

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline</th>
<th>1-Year Follow-Up</th>
<th>3-Year Follow-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Patients (n = 42) Controls (n = 20) Unpaired t Test, p Value</td>
<td>Patients (n = 45) Controls (n = 24) Unpaired t Test, p Value</td>
<td>Patients (n = 44) Controls (n = 25) Unpaired t Test, p Value</td>
</tr>
<tr>
<td>Ejection fraction, %</td>
<td>0.65 [0.06] 0.66 [0.06] 0.438</td>
<td>0.64 [0.05] 0.64 [0.05] 0.668</td>
<td>0.62 [0.05] 0.62 [0.04] 0.857</td>
</tr>
<tr>
<td>Fractional shortening, %</td>
<td>34 [4.0] 35 [3.0] 0.672</td>
<td>35 [3.7] 34 [3.4] 0.330</td>
<td>33 [3.3] 33 [2.9] 0.907</td>
</tr>
<tr>
<td>Left ventricular diastolic diameter, cm</td>
<td>4.6 [0.4] 4.8 [0.5] 0.220</td>
<td>4.8 [0.4] 4.7 [0.5] 0.617</td>
<td>4.9 [0.4] 4.8 [0.5] 0.670</td>
</tr>
<tr>
<td>Right ventricular diastolic diameter, cm</td>
<td>3.0 [0.3] 3.1 [0.4] 0.329</td>
<td>3.1 [0.3] 3.1 [0.3] 0.981</td>
<td>3.3 [0.3] 3.2 [0.3] 0.453</td>
</tr>
<tr>
<td></td>
<td>2.1 [0.3] 2.1 [0.3] 0.661</td>
<td>2.2 [0.3] 2.2 [0.4] 0.970</td>
<td>2.3 [0.3] 2.4 [0.3] 0.120</td>
</tr>
</tbody>
</table>

Results displayed as standard mean with ± standard deviation. Results from baseline and 1-year follow-up are previously published [11, 12].

Our results on SImax during exercise support the abovementioned theory further. Preoperatively, patients had lower SImax than controls but bettered this postoperatively, demonstrating significant improvement when comparing post bar results with baseline and 1-year follow-up results. Furthermore, no difference existed in maximum heart rate during the 3 exercise tests between patients and controls, which further accentuates the association between postoperative improved function and an increase in cardiac (stroke) volume during exercise, much in synchronization with results from Beiser and colleagues [5].

A change in physical activity could influence the exercise capacity examined during a study period. Several studies [1, 2, 19, 20] report of improved body image in pectus excavatum patients postoperatively and often a correspondingly greater desire to participate in sports. Our study considered this by examining participants’ sports activities during the 3 years. No difference was observed between the groups regarding weekly amount of exercise either before or after operation. Other studies [6, 7, 21], which also examined patients’ exercise habits preoperatively, found cardiovascular impairment during exercise that could not be explained by physical deconditioning. And accordingly, the improved Clmax and SImax in our study could not be directly linked to differences in physical activity pattern postoperatively or primarily associated to growth during the study period.

Echocardiography at rest revealed significant increase in left ventricular diastolic and systolic diameters in patients during the 3 years, although no difference was observed between patients and controls. This increase points at a potential physiological gain and normalization from the changed anatomy; a theory supported by others [22]. Increased right ventricular diastolic diameter was observed in controls during the study period. This could

Table 5. Dynamic Lung Function Parameters in Patients and Controls at Baseline, One-Year, and Three-Year Follow-Up

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline</th>
<th>1-Year Follow-Up</th>
<th>3-Year Follow-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Patients (n = 48) Controls (n = 25) Unpaired t test, p value</td>
<td>Patients (n = 41) Controls (n = 24) Unpaired t test, p value</td>
<td>Patients (n = 44) Controls (n = 26) Unpaired t test, p value</td>
</tr>
</tbody>
</table>

* Significant (p < 0.01) difference between patients and controls.

Results displayed as standard mean with ± standard deviation. Results from baseline and 1-year follow-up are previously published [11, 12].

FEV1 = forced expiratory volume in the first second of expiration; FVC = forced vital capacity; n = number of participants; PEF = peak expiratory flow.
suggest that a complete normalization of the right ventricle is not yet reached in the patients 3 years postoperatively. However, another aspect to consider is the complexity in reproducing the preoperative right ventricular measurements in patients with changed chest wall geometry.

The effect of pectus excavatum on lung function still remains inconclusive. Many studies report of slightly lower lung function preoperatively [4, 7, 23, 24]. Our patient group also scored less through all 3 years, but only FEV₁ was lower preoperatively compared with our healthy controls. Postoperatively, FEV₁ normalized in patients and no difference was found between patients and controls.

The importance of a comparable control group was clearly underlined throughout the study. Taking the growth of these young people into consideration it was frequently noted that patients increased parameters during our study, whereas the controls remained unaltered. Undeniably, the correction of pectus excavatum has an independent impact on patients’ increasing parameters.

Limitations
We compared patients with controls at 3 different points in time, with a substantial risk of committing a type 1 error. In order to avoid this, we chose a lower level of significance (p < 0.01). Another limitation is that we only examined healthy adolescents and therefore our findings cannot be extrapolated to other age groups or illuminate the cardiopulmonary exercise function of unoperated pectus patients. Furthermore, the termination of each exercise test was based on subjective parameters; however, both groups were judged by the same observers and on the same parameters throughout the study period.

Conclusions
Preoperatively, maximum cardiac index during exercise was lower in patients with pectus excavatum compared with healthy, age-matched controls. One year after, this had increased in patients and 3 years postoperatively cardiac index had normalized. Forced expiratory volume was significantly lower in patients preoperatively and subsequently normalized to age-predicted values postoperatively. Cardiopulmonary exercise function in patients normalizes after surgical correction of their pectus excavatum. With these final 3-year results, this study supports those in favor of surgical correction for pectus excavatum not only being of cosmetic nature, but also of physiological importance.

Study nurse Vibeke Laursen, research secretary Jette Breiner, and echo technician Bente Mortensen are warmly acknowledged for their highly valuable contribution. The study was made possible by a donation from the Danish Agency for Science, Technology and Innovation, Director Kurt Bennelycke and his wife Grethe Bennelycke’s Foundation, Grosserer L.F. Fogh’s Foundation, Helga and Peter Korning’s Foundation, and Aase and Ejnar Danielsen’s Foundation.

References
INVITED COMMENTARY

Surgical intervention for pectus excavatum (PE) remains controversial. There is no consensus on the effect of PE on cardiopulmonary function, and many physicians consider the Nuss procedure a purely cosmetic operation. A number of studies have investigated cardiopulmonary function during rest, where there is no noticeable effect. Several reports have shown decreased cardiopulmonary function during exercise that improves after surgical repair, but none have considered the concurrent physiologic changes that occur because of growth compared with a control group of teenagers during the same observation period.

This is exactly what the authors did in the present study [1], which may be considered the third in a series of studies on the same groups of teenagers who underwent minimally invasive repair for PE. In the first study, the authors reported that patients had lower cardiac index compared with healthy age-matched controls during exercise [2]. In the second study, the authors compared healthy controls and the same PE patients 1 year after the operation and found that cardiac index had increased during exercise but was still significantly lower compared with controls [3].

In the present study [1], the authors carefully studied the same 42 PE patients and 24 controls 3 years postoperatively and after their metal bars had been removed. They found that cardiopulmonary function, as measured by echocardiography, maximum cardiac index, spirometry, and maximal oxygen uptake, in PE patients during exercise had normalized, with no difference between patients and controls. It would have been interesting to learn about the natural course of cardiopulmonary function if their control group had been PE patients who had not been operated on, but such a study would be considered unethical. Nevertheless, these findings are new and important information for thoracic surgeons who see and guide teenaged PE patients (and their parents) and clearly suggest that surgical intervention for PE is not just a cosmetic procedure.

That said, it is still relevant to discuss if improvements in cardiopulmonary function should be the only legitimate indication for a surgical correction for PE. It is not unlikely that improvements in cardiopulmonary function are related to severity of PE, an issue that should be addressed in future studies, and without doubt, a vast number of PE patients have little if any physiologic limitations because of their PE. However, they desperately seek advice for surgical correction during adolescence because of major concerns with their body image leading to poor psychosocial functioning and withdrawal from many social activities, including sports. Surgical correction of PE in such patients has been shown to significantly improve their self-esteem and social functioning and consequently leads to a better quality of life [4, 5].

Peter B. Licht, MD, PhD
Department of Cardiothoracic Surgery
Odense University Hospital
Sdr. Blvd 29
Odense DK-5000, Denmark
e-mail: peter.licht@rsyd.dk

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