Abstract

Objective: The study was undertaken in order to assess the degree of impairment of the cardiovascular system in patients with funnel chest and to investigate any changes caused by surgical correction. Methods: Echocardiographic examinations with systolic, diastolic and ejection volume indices calculation as well as pulmonary function tests were performed before surgery and at medium-term follow-up on 34 patients who were operated on for pectus excavatum between 1987 and 1992. Results: The mean age was 13.4 years. There were 70.6% males. Pulmonary function was found to be restricted preoperatively in 18 patients. Inspiratory vital capacity and forced expiratory volume were increased or did not change at follow-up (5 years) in these patients. In cases with normal or moderately restricted pulmonary function (inspiratory vital capacity, forced expiratory volume more than 75% predicted) the reduction of lung function was noted after surgery. Marked haemodynamic improvement was found with the increase of diastolic and ejection volume of both heart ventricles (mainly right one). The improvement was more evident in patients with severe deformations. Conclusion: Only in case of severe reduction of lung function in a patient with funnel chest can one expect improvement after surgery. Sternocostal elevation improves function of both heart ventricles at rest. © 1998 Elsevier Science B.V. All rights reserved.

Keywords: Funnel chest-surgery; Funnel chest-physiopathology; Funnel chest-ultrasonography; Follow-up studies

1. Introduction

Pectus excavatum, a congenital depressive malformation of the sternum has been described since 1594 (first time by Johannes Schenk) and has successively been the subject of many studies because of its various inherent problems [1].

There is no universally agreed standard for the diagnosis of funnel chest and for surgery [2–5]. The repercussions on respiratory and cardiac dynamics caused by the compression on the mediastinal structures and by the reduction of the respiratory volume have only recently been completely evaluated with the application of the latest techniques [6,7,1,8]. Although postoperatively, cardiorespiratory disorders are often significantly reduced [9], the subjective physical improvement after operation is not always explained by changes in cardiorespiratory function [10].

Many authors are still of the opinion that surgical treatment is indicated in most cases of funnel chest deformity for cosmetic or psychological reasons alone [2,9,11,12].

Non-invasive investigations, such as computed tomography, echocardiography, and stereophotogrammetry, improve functional aspects of the deformity, but so far without directly influencing the decision to operate [2,8].
The study was undertaken in order to assess the degree of impairment of cardiovascular system in patients with funnel chest and to investigate any changes caused by surgical correction.

2. Materials and methods

A total of 34 patients operated on for pectus excavatum between November 1987 and December 1992, participated in the study. Their ages ranged from 4 to 35 years (mean 13.4 years) and there were 24 males (70.6%).

To determine the severity of the deformity one of the ‘pectus indexes’ was employed: the distance from anter- surface of the vertebral body to the sternum at the Louis’s angle/the minimum sternovertebral distance.

To test respiratory function preoperatively and post-operatively, inspiratory vital capacity (IVC), forced expiratory volume in one s (FEV1), and maximal voluntary ventilation (MVV) were measured. Pulmonary function tests were performed with a Pneumoscreen II unit (Jaeger, Germany) with the patients in a seated position. Results were expressed as a percent of predicted normal values (appropriate for gender, age, weight and height) based on the equations generated for the Pneumoscreen II.

During echocardiographic examinations (an Acuson 128 unit) the systolic, diastolic and stroke volume indices of both heart ventricles were calculated. The examinations were performed in the supine position. Right ventricular volume was calculated by subtracting the entire left ventricle (including the left ventricular myocardium) from the entire heart (including the right ventricle and the entire left ventricle). Both the volumes (the entire heart and the entire left ventricle) were calculated as hemiellipsoid by the area-length method with the use of apical four- and two-chamber views. These examinations were standardized. In all cases, five cardiac cycles were estimated by two cardiologists. Each patient was studied at the initial evaluation. At 1 year postsurgery echocardiographic examination was repeated. The pulmonary function measurements were repeated 5 years after surgery. All the patients were examined personally at the outpatients department at the time of follow-up.

The indications for surgery were based on two principles:
1. we operated any time we had recognized the significant deformity,
2. we were very reluctant to operate on a patient who did not ask for the operation.

The operation was performed under general anaesthesia. During the surgery, costal cartilages in the parasternal region were excised subperichondrially and bilaterally, the sternum was cut transversally above the deformity and longitudinally across it. After that, the anterior thoracic wall was stabilized in the proper position with Kirschner’s wires.

The parametric Student’s t-test was used to compare the values before and after surgery in the particular patients. Probability values (P values) less than 0.05 were considered significant.

3. Results

Before surgery, decreased exercise tolerance was observed in 14 (42%) of the patients. After surgical correction the diminution of exercise tolerance persisted in six patients (17.6%).

There were 22 patients (group I) who demonstrated mild or moderate deformity: pectus index less than 1.3. The average value of the index was 1.24 ± 0.5. In 12 patients (group II) the deformity was considered severe. The index was 1.3 or more (average value: 1.43 ± 1.3). After surgery the index was 0.96 ± 0.6 in patients from group I, and 1.03 ± 0.5 in patients from group II. The results before and after surgery in particular patients were statistically different (PI = 0.031, PII = 0.022).

3.1. Echocardiographic evaluation

The average values of the diastolic, systolic and stroke volume indices before and after surgery are presented in Table 1.

The results of left ventricle diastolic volume index (LVEDVI) before and after surgery were similar. The value after surgery increased in 13 patients from group I and in 10 patients from group II, but the changes were not statistically significant. Statistical analysis of left ventricle systolic volume index (LVESVI) showed that the operation did not change the index as well. Both increase and decrease of these values were noticed. 12 patients from group I and six patients from group II demonstrated an increase of LVESVI after surgery. Stroke volume index of left ventricle (SVI I v) increased after surgery in 14 patients from group I and in 11 patients from group II. The results after surgery were significantly different in patients from group II (P = 0.035).

Right ventricle diastolic volume index (RVEDVI) increased after surgery in all the patients on average about 50% in group I and about 100% in group II. The results were significantly different after surgery in the patients from both groups (PI = 0.027, PII = 0.006). The right ventricle systolic volume index (RVESVI) changed significantly after surgery in the patients from group II (P = 0.031). In the patients with moderate or mild deformity the operation did not have significant influence on these values. Statistically significant increase of stroke volume index of the right ventricle (SVI
rv) after surgery was noted in all patients from both groups (P1 = 0.0002, PII = 0.0001).

3.2. Pulmonary function tests

The results of pulmonary function tests are presented in Table 2.

Both preoperative and postoperative values were given as percentages of predicted. Before surgery the average value of inspiratory vital capacity (IVC) in patients from group I was 84.7 ± 16.1% and in patients from group II 70.9 ± 18.4%. At 5 years after surgery the average value of IVC was 88.4 ± 20.1% in I group and 76.4 ± 17.9% in II group. There were no statistically significant differences between the results before and after surgery in patients from both groups (P1 = 0.137, PII = 0.096).

The average value of IVC before surgery was found less than 75% predicted in 18 patients (64.1 ± 10.7%). After surgery the average value was 78.9 ± 12.1%. The results after surgery in these patients were statistically different (P = 0.026).

The average value of forced expiratory volume in 1 s (FEV1) before surgery in patients from I group was 78.4 ± 17.1% and in patients from group II 64.8 ± 16.3%; 5 years after surgery the average values were 82.7 ± 23.2% in patients from I group and 68.7 ± 15.3% in patients from II group. The results after surgery were not significantly different (P1 = 0.082, PII = 0.069).

The value of FEV1 before surgery was less than 75% predicted in 22 patients (average 60.8 ± 12.1%). The results after surgery were 72.4 ± 14.2%. In these particular patients the values of FEV1 were significantly different after surgery (P = 0.034).

Before surgery the average values of maximal voluntary ventilation (MVV) were 107.3 ± 35.2% in patients from I group and 96.5 ± 29.8% in patients from II group. After surgery the values were 98.8 ± 23.5% in patients from group I and 92.2 ± 19.2% in patients from group II. The changes after surgery were not statistically significant (P1 = 0.124, PII = 0.155).

MVV before surgery was found 75% predicted or more in 27 patients (the average value 112.3 ± 30.2%). The results after surgery decreased significantly in these patients (average value 100.3 ± 20.1%, P = 0.021).

4. Discussion

Despite a number of studies, the pathophysiologic effect of pectus excavatum and the results of corrective surgery remain controversial [8]. It is difficult to compare various studies because of differences in surgical techniques, study protocol, the relatively small number of patients and various follow-up intervals [13]. It has frequently been stated that this deformity is purely a cosmetic problem [13], the patients have normal pulmonary function at rest, and normal working capacity, oxygen transport and cardiac output in response to exercise [8].

According to other authors, however, [10,14] preoperatively, total lung capacity and inspiratory vital capacity were significantly smaller than predicted and further decreased after operation. The reduction in lung function at follow-up was most pronounced in patients who have the least functional impairment: TLC more than 75% predicted [13].

The ventilatory restriction worsens after corrective surgery despite the improvement of radiological indices of the pectus deformity and is not related to the age or time elapsed after operation [15].

In the group of patients with preoperative ventilatory limitations (IVC, FEV1 less than 75% predicted) we noticed statistically significant improvement after surgery. On the contrary, in patients with normal or higher than predicted maximal voluntary ventilation, the values of MVV were significantly lower after surgery. This may suggest that only in patients with severe ventilatory limitation is improvement after surgery possible. In cases with normal or moderately restricted pulmonary function the reduction of lung...
function is noted after surgery or the pulmonary function does not change.

Points of view about cardiac function in patients with funnel chest and about the influence of surgery on it are often contradictory [10,16,17]. Many authors are of the opinion that surgery has no significant effect on cardiac function and cardiorespiratory response to exercise [8,13,18]. Other authors proved that more than 98% of patients have improvements in exercise tolerance, endurance, cardiac and respiratory symptoms after surgery [19], but the subjective improvement after operation is not explained by changes in cardiorespiratory function [13,17].

The pectus patients before operation are usually not significantly different from normal subjects with respect to: cardiac index, left ventricular ejection fraction, left ventricular end-diastolic volume index, end-systolic volume index, stroke volume index at rest or during exercise [17]. However, the inability to develop an appropriate cardiac output and stroke volume to exercise increases with age [4,20]. No relation could be found between right ventricular emptying fraction and the severity of the chest deformity [21].

The operation performed in our department on patients with funnel chest has a positive influence on haemodynamic function. The results before surgery were not compared with the results in healthy people. However, the significant increase of diastolic and stroke volumes of the right ventricle in all the patients and stroke volume of the left ventricle in patients with severe deformations was noted after surgery.

Quigley et al. [8] suggest that the most likely explanation for the increased duration of exercise in their patients with funnel chest after surgery is the improved cardiac function after relief of cardiac compression. This suggestion corresponds with our data.

The authors are aware of the limitations of the echocardiographic subtraction method employed in the study. Usually, larger right ventricular volumes are more often underestimated than smaller volumes [22]. This is because generally it appears to be technically more difficult to record the maximum area of the larger end-diastolic heart than that of the smaller end-systolic heart [7,22]. This method does not take into account the outflow tract volume, although it appears to be larger in diastole than in systole [22].

5. Conclusions

(1) Surgical repair of funnel chest causes significant increase of right ventricular diastolic and stroke volume indexes.

(2) Only in case of severe reduction of lung function in a patient with funnel chest, is improvement in pulmonary function tests after surgery possible.

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