How early can we repair pectus excavatum: the earlier the better?†

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Abstract

OBJECTIVES: The optimal age for the repair of pectus excavatum using minimally invasive technique has yet to be determined. We hypothesized that the early repair of pectus excavatum may contribute in preserving chest wall integrity and also in enhancing patients’ growth. The purpose of our present study was to verify a potential advantage of the early repair of pectus excavatum by using a minimally invasive technique.

METHODS: For our study on minimally invasive pectus excavatum repair, 1571 patients from the period 1999 to 2011 were enrolled. Our strategy was to carry out routine repairs in patients older than 3 years of age. To examine the age factor on the results of the repairs the patients were divided into different age groups: Group 1 (<5 years, 618 (39.3%)), Group 2 (6–11 years, 322 (20.5%)), Group 3 (12–20 years, 401 (25.5%)) and Group 4 (>20 years, 230 (14.6%)). A comparative analysis was performed for factors such as complication rates; growth-percentile scores of height, weight and body mass index (BMI); incidence of asymmetry and costal flare score to determine the potential to resume the normal chest wall conformation by earlier repair.

RESULTS: The mean age of the patients was 10.2 years (16 months to 51 years). The incidence of asymmetry was found to be lowest in Group 1 (24.3, 45.5, 58.7, 48.4%, respectively, P < 0.001). The complication rate after repair was also lowest in Group 1 (7.6, 11.5, 16.3, 19.1%, respectively, P < 0.001). The growth of body weight was significant in Groups 1 and 2 (0.53 ± 1.02, P < 0.001). The costal flare score was found to have decreased in Groups 1 and 2 (Group 1: from 1.6 to 0.12, P < 0.001; Group 2: from 1.44 to 0.14, P < 0.001). In Groups 3 and 4, there was no improvement in costal flare after repair.

CONCLUSIONS: Our results suggest that routine early repair of pectus excavatum in patients older than 3 years of age is safe and effective. We would recommend early repair to avoid asymmetry transformation of the deformity and to enhance the patients’ growth potential.

Keywords: Pectus excavatum • Chest wall • Age • Asymmetry

INTRODUCTION

Pectus excavatum is a condition that often causes recurrent upper respiratory infection or pneumonia and growth retardation in patients during their infancy and childhood. Later in the adolescent period, patients suffer from serious emotional disturbances because of their dysmorphic figures [1-3].

The early repair of pectus deformity during early childhood may prevent those problems by relieving cardiopulmonary compression. If the repair is also carried out early, before the patients become aware of the deformities, they will be free from any possible psychic trauma.

We have been using specific approach to repair pectus excavatum early, when repair of the deformity is indicated. We have found that the age of 3 is mature enough for a patient to accept a 9-inch pectus bar and to tolerate the surgical procedure. Keeping this in mind, our strategy to repair pectus excavatum has become a routine repair in patients older than 3 years of age.

There is a report warning of the effects of a too early operation for pectus excavatum repair. In the case reported, an open technique was used with cartilage resection, which caused a serious chest wall constriction [4]. However, with the novel minimally invasive repair technique that preserves cartilage and thoracic wall integrity, the optimal age to repair pectus excavatum has yet to be determined and, moreover, the consequences of repair in earlier childhood are not known. Therefore, the purpose of this study was to verify whether the early repair of pectus excavatum is advantageous or detrimental by assessing the factors in transformation to asymmetry, impact on patients’ growth, complications occurring due to the reparative procedure, relief of lower costal flaring after repair and the durability of repair.

MATERIALS AND METHODS

We analysed the data from 1571 consecutive patients whose pectus was repaired using our minimally invasive technique between 1999 and 2011. The mean age of the patients was...
10.3 years (range: 16 months to 51 years), and the male:female ratio was 4.1 (M: 1263; F: 308). There were 366 adolescent and adult patients (≥15 years, 23.3%). The pectus bar removal was completed in 794 patients as a final step of the repair.

The indications for repair were pectus excavatum with the depression index of ≥1.2 [5] or the presence of psychological symptoms caused by morphologically complex deformities.

Our strategy was to carry out routine repair of the deformity in patients older than 3 years. All pectus repairs were performed by the primary author (H.J.P) by using our modified minimally invasive repair technique, as described briefly below and elsewhere [6, 7]. None of the patients were excluded from the minimally invasive repair because of morphology or age criteria, and there was no case of open repair (Ravitch or sternal turnover procedure) during this period. Forty-nine patients who underwent a redo procedure to treat the failure of previous repairs in other institutions (35 Ravitch and 14 Nuss procedures) were excluded from the analysis. Timing for the pectus bar removal was after 2 years for patients <12 years old, 2.5 years for patients between 12 and 18 and 3 years for patients over 18 years old.

To analyse the efficacy of repair in different age groups, the patients were divided into four groups: Group 1 (≤5 years, 618 (39.3%)), Group 2 (6–11 years, 322 (20.5%)), Group 3 (12–20 years, 401 (25.5%)) and Group 4 (>20 years, 230 (14.6%)). The variables to be compared between the groups were complication rates; growth-percentile scores of height, weight and body mass index (BMI); incidence of asymmetry and the costal flar score to determine the potential to resume the normal chest wall conformation by earlier repair. Asymmetry is defined when the deepest point of the chest wall depression is located off the centre of the chest wall. Flare is defined as the anterior protrusion of the bilateral lower costal arch. This condition is due to the scaphoid deformation of the lower costal wall in pectus excavatum. The flare score was defined as 0: no flare, 1: mild and 2: moderate to severe.

The postoperative data including body height, weight and BMI were sampled at the time of bar removal, which was generally performed 2 years after the pectus repair.

**Statistical analysis**

Statistical analysis was carried out with the SPSS software package (version 10.0, SPSS, Chicago, IL, USA). Continuous variables were compared by ANOVA or paired t-test, and categorical variables were analysed with a $\chi^2$ test or Fisher’s exact test as appropriate. $P$-values <0.05 were considered to be significant.

**Surgical techniques**

The patient was placed in the supine position and anaesthesia was induced in a standard fashion with a single lumen endotracheal intubation. Standard monitoring consisting of non-invasive blood pressure, oxygen saturation, and electrocardiography. End-tidal carbon dioxide was applied (Intellivue MP70; Philips, Germany). The bispectral index value was monitored using an Aspect A-2000 EEG monitor (Aspect Medical Systems, Newton, USA).

Both arms were allowed to freely hang on overhead slings to avoid arm stretch. An appropriate sized pectus bar (Prime Med, Seoul, South Korea) was selected, and morphology-tailored shaping for each specific patient was performed on the operating table. One centimetre incisions were made on both the midaxillary lines. A specially designed, visually guided introducer (i.e. the pectoscope) or the pectus clamp (employed until 2006, Prime Med) was passed through the mediastinum. A guide (24 Fr, chest tube) was passed through, followed by the bent bar. When the pectus bar was rotated, the convexity of the bar lifted the depressed chest wall. Both ends of the pectus bar were fixed to the adjacent ribs by using the claw fixator (Prime Med) (Fig. 1) or a five-point fixation with a through-the-skin pericostal suture technique (employed until 2007). Hemovac catheters were inserted into the subcutaneous pockets around the pectus bar and/or into the pleural cavities. In the case of adults, teenagers or patients with severe depression, the Crane system was utilized to elevate the sternum before passing the introducer through, to avoid injury to the heart and to make the procedure easier. Since 2009, the hinge plate (Prime Med) has been installed into the hinge points in patients over 12 years of age to prevent stripping of the intercostal muscle (Fig. 2) [8].

Upon completion of the procedure, the patient was extubated and sent to the postanaesthesia care unit. For postoperative pain...
management, an intravenous patient-controlled analgesia (PCA) was applied. The PCA regimen consisted of fentanyl 20 µg/kg and ketorolac 2 mg/kg (total volume including normal saline 100 ml) and was programmed to deliver 1 ml/h as background infusion and 1 ml per demand with an 8-min lockout during a 48 h period.

RESULTS

In morphological analysis, 636 (40.5%) patients were found to possess asymmetric morphology. Within the asymmetric type, 375 were of the eccentric type (58.9%), 166 were of the unbalanced type (26.1%), and 95 were of the combined type (14.9%). Upon comparison between different age groups, the incidence of asymmetry was lowest in Group 1 among other groups (24.3, 45.5, 58.7, 48.4%, respectively, P < 0.001) (Fig. 3).

The complication rate after repair was lowest in Group 1 (7.6, 11.5, 16.3, 19.1%, respectively, P < 0.001). The incidence of pneumothorax was lowest in Group 1 (0.3, 4.2, 5.7, 6.6%, respectively, P < 0.001). There were no variations in the bar dislocation rate (1.2, 2.0, 2.1, 3.8%, respectively, P = 0.161) and wound seroma (3.0, 3.2, 3.9, 3.8%, respectively, P = 0.895) between the groups (Fig. 4). There were no differences in reoperation rates (1.2, 3.2, 3.2, 3.8%, respectively, P = 0.078) (Fig. 4) and recurrence of pectus excavatum after the bar removal (Group 1: 1, Group 2: 2, Group 3: 0 and Group 4: 0, P = 0.743), among the different groups.

The growth by increase in percentile of body weight was significant in Groups 1 and 2 (Groups 1–2: 0.53 ± 1.02, P < 0.001, Groups 3–4: 0.02 ± 0.99, P = 0.88). There was no difference in growth by height between the different groups and increased BMI was observed in all the groups (Fig. 5).

A decrease in the costal flare score was observed in Groups 1 and 2 (Group 1: from 1.8 ± 0.45 to 0.00 ± 0.00, P = 0.001; Group 2: from 1.57 ± 0.79 to 1.43 ± 0.00, P = 0.003). There was no improvement in costal flare after repair in Groups 3 and 4 (Fig. 6).

Outcomes of repair in all groups were not different. The satisfaction score in each age group was excellent or good (98.9, 97.7, 99.4 and 98.3%, respectively, P = 0.446).

DISCUSSION

The open techniques for pectus excavatum repair that mainly involve a radical resection of costal cartilages have been prevailing over the past 50 years [9]. One of the crucial problems with the open repair techniques is the weakening of the chest wall due to the deficiency of costal cartilages, which eventually leads to growth failure of the chest cage. Haller [4] indicated that there was a risk of chest wall constriction after too extensive and too early operations for pectus excavatum.

A new concept of pectus excavatum repair was introduced by Nuss in 1997 [10]. The technique was principally designed to lift the depressed chest wall by the action of the lever system by using a pectus bar. The technique preserved the integrity of the chest wall without resection of any part of the cartilages, ribs or sternal osteotomy. Therefore, minimally invasive repair maintains normal chest wall function and is aesthetically superior in terms

![Figure 3](https://example.com/figure3.png)

**Figure 3:** The difference in asymmetry transformation of the deformity in age groups. (Age G: age group): Age G1 vs all other Age G: P < 0.001; Age G3 vs Age G4: P = 0.005.

![Figure 4](https://example.com/figure4.png)

**Figure 4:** The complications and reoperation in different age groups. Age G: age group.

![Figure 5](https://example.com/figure5.png)

**Figure 5:** The growth of the patients after repair of pectus excavatum. (A) Age groups 1–2 and (B) Age groups 3–4; P: percentile.
of avoiding the anterior skin incision. Since 1999, we have adopted the minimally invasive technique for pectus excavatum repair as a principal technique. This new technique has successfully been applied with satisfactory results to a wide range of patients, from paediatric to adult patients [7, 11], but there have been no investigations to determine the ideal age for repair of pectus deformities using the minimally invasive technique.

In pectus excavatum deformity, the direction of the costal cartilages contributes to progressive deepening of the chest wall depression, which makes the cartilage grow towards the back. The growing of the costal cartilages in the wrong direction supports the phenomenon that the excavatum is aggravated as the patient gets older. In contrast to the open techniques in which defects are caused in chest wall, the minimally invasive technique preserves chest wall integrity. Thus, we hypothesized that the early repair of pectus deformity can facilitate normal chest wall growth based on the theory that remodelling, in contrast to repair by using the pectus bar, the sternum and the rib cage can be remodelled by lifting and splinting the excavated chest wall. This process absolutely preserves the integrity of the growth centre of the bony thorax and vascular supply to the repaired chest wall.

There have been concerns about complications occurring from the reparative procedure of pectus excavatum in very young patients. However, as revealed in our study, the youngest group of patients, between 3 and 5 years of age, was least morbid due to the operative procedure or the pectus bar as well as the rigid fixation system, when compared with older age groups. Based on this result, we support the notion that pectus excavatum repair can be carried out without additional morbidity in patients older than 3 years of age or even younger. Younger patients have more malleable chest walls, which can be plausible to remodel and thus, the procedure is easier to perform and is less traumatic to the patients. Consequently, younger patients might have earlier recovery without any troublesome postoperative pain [16].

One of the common symptoms, caused by pectus excavatum, is frequent upper respiratory tract infection. The majority of young patients suffered from recurrent upper respiratory tract infection, and, in even worse cases, they were repeatedly hospitalized due to pneumonia. The early repair of the deformity would be an approach to resolve this problem and to enhance the patients’ growth and development. We observed a phenomenon that frequent upper respiratory tract infection was reduced significantly in the majority of pectus excavatum patients repaired before the age of 5 years.

There has been a unique feature of the pectus excavatum called ‘lower costal flare’ [17]. This term arises from the morphological characteristics of the chest wall excavation, which forms scaphoid dysmorphology of the anterior chest wall. Costal flaring becomes conspicuous after pectus repair because the chest wall depression disappears but the lower costal deformity still remains. This is only a cosmetic problem, but difficult to resolve. We assumed that early correction of the deformity, when the cartilage was malleable and before the bones became ossified, would play a key role in prevention of permanent costal flaring. Our results demonstrated that younger patients under the age of 12 years could achieve close to normal chest configuration without undesirable lower costal flaring.

Kelly et al. [18] suggested that pectus excavatum can recur during the pubertal growth spurt after being repaired early in childhood. For that reason, reports in the literature recommend delaying the repair of pectus deformity until after puberty to obtain more definitive and long-lasting repair [19]. However, our results after the bar removal with a follow-up of 10 years at the longest, demonstrated the durability of the repair in all age groups. In our study series, with 1571 pectus repair and 794 pectus bar removal cases, we had only three cases of recurrence (0.4%) and two cases of reoperation among them [7]. We did not
observe any differences in the youngest group, in terms of durability of repair, when compared with other age groups. We propose that the cause of the recurrence might be inadequate lifting of the chest wall depression or missing the target at the initial repair, which remains a residual depression of the chest wall. As a result, the growth of the costal cartilages may direct towards the wrong direction during the pubertal growth spurt and causes recurrence of the chest wall depression.

In conclusion, our results suggest that routine early repair of pectus excavatum in patients older than 3 years of age is safe and effective. Furthermore, we did not observe any detrimental effects related to the repair procedure due to the reason that the recipients were too young. Instead, we could obtain numerous beneficial effects with our approach of early repair of pectus deformity under the age of 5 years. First, in the youngest group, the operative procedure was associated with the lowest complication rates and, thus, was less morbid during postoperative recovery when compared with all other age groups. Secondly, early repair contributed considerably in avoiding asymmetry transformation of the deformity including the sternal rotation. Thirdly, the real virtue of early repair was enhancement of the patients’ growth potential and prevention of repeated upper respiratory tract infection by relief of the cardiac compression. Fourthly, in contrast to the open repair techniques that may cause chest wall constriction, this minimally invasive approach advocated normal chest wall growth since early childhood by preserving the integrity of the chest wall structure. Finally, repairing the deformity before the age of 5 allowed patients to have completed all the surgical procedures including the pectus bar removal, prior to the school age. With our approach, the ‘early repair of pectus excavatum’, we are hopeful of possible physical and psychological advantage for the patients by resolving cardiac compression and unsightly deformities in early childhood.

Conflict of interest: none declared.

REFERENCES


APPENDIX: CONFERENCE DISCUSSION

Dr M. Yuksel (Istanbul, Turkey): I have two questions. First of all, which criteria did you use to differentiate between the pectus deformity and other childhood diseases, like flared lower costal bones or rickets?

Dr Park: You have a variety of different diseases in the pectus deformity group, but, fortunately or unfortunately, I didn’t see many other types of disease. Actually, in my experience I have never seen rickets deformity. I really can’t answer your question. But I would like to mention the costal flare. The problem with the flare is due to the fact that we have a very scaphoid chest wall deformity with pectus excavatum, and we can fix the depression by lifting the chest wall with a pectus bar, but we cannot touch the lower costal area with the pectus bar. It’s very hard to resolve this problem. There is not any physiological problem with the flare, but we cannot solve that problem at all. But we have found that the remodelling process may contribute to resolving the flare and the chest wall conformation in a later period.

Dr Yuksel: Second question, how reasonable is it to compare the results of a group of little children with teenagers or adults? For example, it would be better to compare the results of a group of children between 1 to 5 years old undergoing the correction operation, with children between the same ages but not undergoing the correction operation.

Dr Park: In this study we were trying to demonstrate what happens when we repair the very young patients. I mentioned in my background that there are some reports, probably from Dr Nuss’s group, which claimed that there can be some recurrence when we repair in the very early period. They had some patients with recurrence in pubertal growth. We tried to answer that, so we divided the patients into the different age groups. Your idea might be a very good item to study the next time, but for this study we were trying to compare the results of the repair in different age groups.

Dr M. Dusmet (London, UK): You have been doing this for 12 years now on very small children, so what has happened to that early cohort of patients who were 5, 6, 7 years old when they had their Nuss procedure? How many of them have had a recurrence of the pectus excavatum now that we’re 10–12 years out and these patients are now about 15–20 years old?

Dr Park: Actually, we have only three cases of recurrence out of 800 pectus bar removals. So it’s a very, very low number. We just can’t compare the differences. The thing I know is that we don’t have much recurrence with age.

Dr Dusmet: At what time after the pectus bar removal?
Minimally invasive or maximally intrusive

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The article by Park et al. ‘How early can we repair pectus excavatum: the earlier the better?’ [1] is a question within a question which confronts the practitioner like a Russian nesting-doll. Is the repair of pectus excavatum appropriate in young children? Has the procedure, identified as ‘minimally invasive’ [2], become today’s method of choice for the repair of pectus excavatum? Should it be used in the very young?

The issue of timing of the correction of pectus excavatum generated quite a flurry in the professional literature in the 1990s. Milovic, Olić [3] and Haller et al. [4] called attention to a group of patients who, after the surgical correction of their pectus excavatum anomaly in their early childhood, prior to becoming adolescents, developed restrictive thoracic dystrophy, a condition characterized by a narrow torso, a small immobile and ‘peaked’ anterior chest wall, horizontal ribs and breathing difficulties of various degrees. They postulated that the development of this condition, also referred to as ‘acquired Jeune disease’, was due to the fact that these patients were operated on before the age of 4 years [3, 4] and recommended that the repair of pectus excavatum should be delayed until they became teenagers. In our view, the problem with these patients was not that they were operated on too early, but that the surgical technique was faulty, i.e. a too radical resection of the costal cartilages and extirpation of the growth plates, both which interfered with the future growth of the thoracic cage. We have proven in our clinical material that with an appropriate surgical technique, which includes conservative cartilaginous resection and the preservation of the growth centres, the correction of pectus excavatum may be safely performed even in the very young [5].

The present question is whether experiences gained in open pectus excavatum repair be applied also to the Nuss operation? While the Nuss procedure does not involve the resection of the cartilages, the transfixion of the anterior chest wall with rigid