

A Pilot Study of a Sternal Closure Technique to Prevent Postoperative Pectus Carinatum in Congenital Heart Surgery Pediatric Patients

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Background: Pectus carinatum has the psychological impact of the body image and quality of life of patients. The authors have observed that several pediatric patients with previously normal chest wall contour undergoing open heart surgery developed acquired/iatrogenic postoperative pectus carinatum.

Objective: The aims of the study were (1) to determine the incidence of postoperative pectus carinatum, and (2) to compare the incidence of postoperative pectus carinatum in pediatric patients undergoing open heart surgery using conventional parallel sternal closure (PSC) versus convergent sternal closure (CSC) technique.

Material and Method: The authors prospectively enrolled 52 pediatric patients who underwent open heart surgery. Twelve patients were excluded because of secondary/delay sternal closure ($n = 2$), previous sternotomy ($n = 6$), and prior chest wall deformity ($n = 4$). The 40 patients were randomized into two groups: 20 in PSC and 20 in CSC group. All patients were followed-up at 6 months postoperatively to determine the occurrence of postoperative pectus carinatum.

Results: Of 40 (1.6 ± 1.2 years; 55% were female) patients, post-operative pectus carinatum was present in 11 patients (28%). At 6-month follow-up, post-operative pectus carinatum was more prevalent in patients using PSC technique ($n = 10$) than those using CSC ($n = 1$) technique (50% vs. 5%; RR = 10 [95% CI = 1.41-70.99], $p < 0.001$).

Conclusion: (1) The incidence of postoperative pectus carinatum was about one-fourth (28%) of pediatric patients undergoing open heart surgery. (2) CSC technique reduced postoperative pectus carinatum compared with PSC technique in those patients. (3) The authors suggest using convergent sternal closure technique in pediatric cardiac surgery to prevent the postoperative pectus carinatum.

Keywords: Pectus carinatum after cardiac surgery

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Pectus carinatum is a chest wall deformity characterized by anterior protrusion of the sternum and costal cartilages^(1,2). This deformity has psychological impact of body image, self-esteem, and quality of life in majority of children patients. Furthermore, it may limit some sport or work activities⁽¹⁻⁴⁾. Many children seek cosmetic corrective surgery at late childhood or adolescence^(3,5). Pectus deformities were mostly associated with congenital heart diseases and concomitant skeletal deformities⁽¹⁻⁴⁾. The prevalence of pectus carinatum has been estimated about 0.6-0.97/

1,000 individuals⁽⁶⁾ or up to 2 % assessed by computed tomographic scan^(7,8). In our institution, the authors have observed that several pediatric patients with previously normal chest wall contour undergoing open heart surgery developed acquired/iatrogenic postoperative pectus carinatum. The incidence of acquired/iatrogenic pectus carinatum after open heart surgery in pediatric patients has been unknown. Also, there has been paucity of data regarding sternal closure technique in preventing post-operative pectus complication. Therefore, the aims of this study were to determine the incidence of postoperative pectus carinatum in pediatric patients undergoing open heart surgery and to determine whether the incidence of post-operative pectus deformity was less when applying convergent sternal closure (CSC) technique compared with conventional parallel sternal closure (PSC)

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technique in those patients.

Material and Method

Study patients

After an approval of institutional review board, the authors prospectively identified 52 consecutive children less than 5 years of age who were planned for congenital heart surgery at Siriraj hospital during February 2012 to December 2012. Of 52 children, 10 were excluded because of previous sternotomy ($n = 6$) and chest wall deformity ($n = 4$). Of 42 enrolled patients, 2 were further excluded because of delayed sternal closure (1 in PSC and 1 in CSC group). Forty patients were included for the study. Twenty four hours prior to operation, the patients were randomly assigned in a 1: 1 ratio by mixed block randomization to either PSC or CSC technique. All patients underwent conventional median sternotomy.

Surgical techniques

In all patients, the surgeon performed full median sternotomy as standard approach. Thymus gland was preserved. The pericardium was opened longitudinally to the right of midline to allow for the possible usage of pericardium as a patch. After opening the pericardium, cardiac anatomy was inspected. Cardiopulmonary bypass was established with ascending aortic and bicaval cannulation and then went on with 120-150 ml/kg/min. In a short case such as atrial or ventricular septal defect, mild hypothermia of greater than 32 degree celsius was used. For myocardial protection, the surgeon used the multiple doses antegrade cooled blood cardioplegia with topical cooling. The infusion volume was about 15-20 ml/kg as an initial dose, and 5 ml/kg on subsequent doses.

Sternal closure techniques

The authors closed sternotomy incision in three layers using 3-0, 4-0, and 5-0 Vicryl sutures for deep, middle, and subcuticular layers, respectively, in all study patients. Further, the surgeon used Ti-Cron™ by Covidien, polyester suture which is non-resorbable polyethylene terephthalate, for sternal closure.

Parallel sternal closure (PSC) technique

Suture needle strictly passed the outer table of the sternum approximately 1 cm laterally away from the sternotomy site. The suture needle was then required to run vertically and pass the inner table of the sternum approximately 1 cm laterally away from the sternotomy site (Fig. 1).

Convergent sternal closure (CSC) technique

Suture needle strictly passed the outer table of the sternum approximately 1 cm laterally away from the sternotomy site. The suture needle was then required to run in the convergent fashion towards the medial aspect of the sternum and pass the inner table of the sternum (Fig. 2).

Antibiotic regimen

Intravenous Cefazolin (100 mg/kg/day in 4 divided doses) was given in all patients prior to skin incision and continued for 48 hours postoperatively.

Follow-up

All patients completed followed-up at 6 months postoperatively to determine the occurrence of postoperative pectus carinatum. Pectus carinatum was defined as presence of anterior/convex protrusion of the sternum and adjacent costal cartilages (Fig. 3). The diagnosis of pectus carinatum was determined independently by two experienced observers who were unaware of type of surgical closure technique. If the diagnosis was not in agreement between two observers, the third observer was a judge and Haller index was

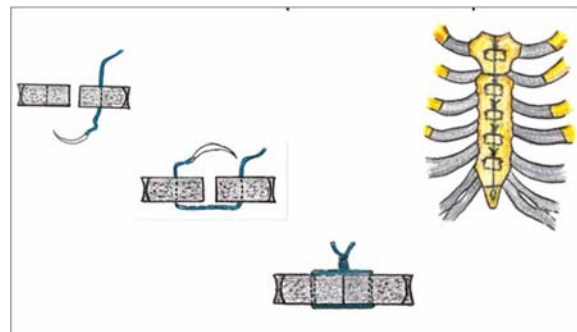


Fig. 1 Sternal closure using conventional parallel technique (PSC).

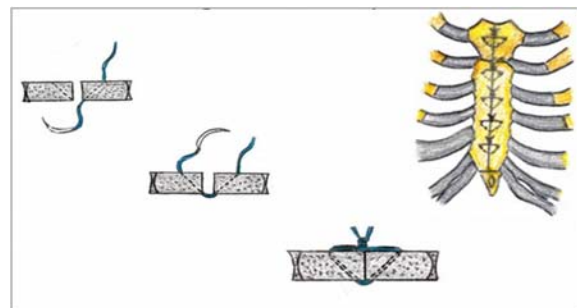


Fig. 2 Sternal closure using convergent technique (CSC).

used to determine pectus deformity.

Statistical analysis

The two patient groups (PSC vs. CSC) were compared using the Chi-square test for categorical variables and the nonparametric Wilcoxon rank-sum test or student's t-test, where appropriate, for continuous variables. Interobserver variability was

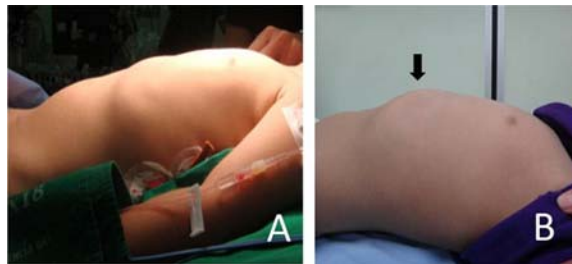


Fig. 3 (A) Preoperative normal sternal contour on lateral view. (B) Post-operative sternal contour of the same patient demonstrated protrusion of anterior chest wall (arrow) consistent with postoperative pectus carinatum.

determined by kappa analysis. Statistical significance was defined as p -value <0.05 .

Interobserver variability

The concordance between two observers in clinical identification of pectus carinatum was very high (kappa = 1.0).

Results

Patient characteristics are shown in Table 1. Of 40 patients, the mean age was 1.6 ± 1.2 years; 55% were female. The baseline characteristics between two groups were not significantly different. None of patients had concomitant scoliosis, other back deformities, Marfan syndrome, Noonan syndrome, or family history of chest wall deformities. Of 40 study patients, 7 (18%) were diagnosed as having Down's syndrome (3 and 4 in PSC and CSC, respectively).

Incidence of postoperative pectus carinatum

Among 40 patients who underwent congenital heart surgery, postoperative pectus carinatum was present in 11 patients (28%) at 6-month follow-up. All

Table 1. Baseline characteristics of patients

| | Overall (n = 40) | Parallel sternal closure (PSC) (n = 20) | Convergent sternal closure (CSC) (n = 20) | p -value* |
|---------------------------------------|---------------------|-----------------------------------------------|-------------------------------------------------|-------------|
| Age (years) | 1.5±1.1 | 1.2±1.0 | 1.8±1.4 | 0.11 |
| Female (n, %) | 22 (55) | 12 (60) | 10 (50) | 0.53 |
| Weight (kgs) | 8.99±3.69 | 8.13±3.39 | 9.85±3.87 | 0.14 |
| Operations | | | | |
| VSD closure (n, %) | 13 (32.5) | 7 (35) | 6 (30) | 0.88 |
| TOF repair (n, %) | 11 (27.5) | 7 (35) | 4 (20) | |
| BDGs(n, %) | 4 (10) | 1 (5) | 3 (15) | |
| AVSD repair (n, %) | 3 (7.5) | 1 (5) | 2 (10) | |
| ASD closure (n, %) | 2 (5) | 1 (5) | 1 (5) | |
| Central shunt (n, %) | 2 (5) | 1 (5) | 1 (5) | |
| Others(n, %) | 5 (12.5) | 2 (10) | 3 (15) | |
| Down syndrome (n, %) | 7 (17.5) | 3 (15) | 4 (20) | 0.99 |
| Pediatric cardiac surgeons | | | | |
| A (n, %) | 4 (10) | 1 (5) | 3 (15) | 0.08 |
| B (n, %) | 15 (37.5) | 5 (25) | 10 (50) | |
| C (n, %) | 13 (32.5) | 10 (50) | 3 (15) | |
| D (n, %) | 8 (20) | 4 (20) | 4 (20) | |
| Preoperative chest circumference (cm) | 45.9±6.6 | 44.5±5.9 | 47.4±7.1 | 0.17 |
| Preoperative chest's AP diameter (cm) | 9.6±2.0 | 9.3±1.8 | 9.8±2.2 | 0.46 |

* The p -value comparing between PSC and CSC techniques

VSD = ventricular septal defect; TOF = Tetralogy of Fallot; BDGs = bidirectional Glenn shunt; AVSD = atrioventricular septal defect; ASD = atrial septal defect

of 11 patients who had pectus carinatum after cardiac surgery had inferior prominence (chondrogladiolar type) of pectus deformity.

Comparison of postoperative pectus carinatum between both groups

At 6-month follow-up, postoperative pectus carinatum was more prevalent in patients using PSC technique (n = 10) than those using CSC (n = 1) technique (50% vs. 5%; RR = 10 [95% CI = 1.41-70.99], $p < 0.001$), Fig. 4.

Sternal wound infection

Of 40 patients, none of those had postoperative sternal wound infection.

Discussion

The major findings of the authors' study are (1) postoperative pectus carinatum was present in about 28% at 6 months post-operation, and (2) patients in the parallel sternal closure group had more postoperative pectus carinatum, compared with the convergent sternal closure group.

Pectus carinatum is a chest wall deformity characterized by anterior protrusion of the sternum and costal cartilages^(1-4,7). This deformity is commonly associated with congenital heart diseases and congenital anomalies^(9,10). Acquired type of pectus carinatum has been reported after open heart surgery known as iatrogenic pectus carinatum^(3,11). The iatrogenic deformity after sternotomy is almost always inferior/lower or chondrogladiolar type^(3,11). In accordance with previous reports, all of our patients who developed postoperative pectus carinatum had chondrogladiolar deformities.

To our knowledge, our study is the first to describe the incidence of pectus carinatum after sternotomy. The authors demonstrated that, with conventional median sternotomy technique, postoperative pectus carinatum was not uncommon in pediatric patients. About one-third (28%) of study patients developed this deformity. The etiopathogenesis of pectus carinatum is unknown. The well accepted theories of the causes of pectus carinatum include lesions in cartilaginous growth plate between the sternal bone segments⁽¹²⁾, hypoplasia of inferior segments⁽³⁾, the anteriorly exaggerated growth of the sternum^(2,13), and sternal fusion due to lesions in the center of sternal ossification⁽²⁾. In present study, the authors found that postoperative pectus carinatum was significantly more prevalent in patients using the PSC

technique compared with the CSC technique. The authors hypothesized that the CSC technique created more force compressing the sternum in the invert direction (Fig. 5) therefore it may prevent protrusion of the sternum (hence, postoperative pectus carinatum).

Study limitations

The authors did not study bone density of patients in each group. The authors were unable to control the strength, rigidity, and exact direction of sternal suture and bone approximation, created by various surgeons, in a similar degree in each case. Furthermore, the present study assessed pectus deformity at 6 months postoperatively; the late

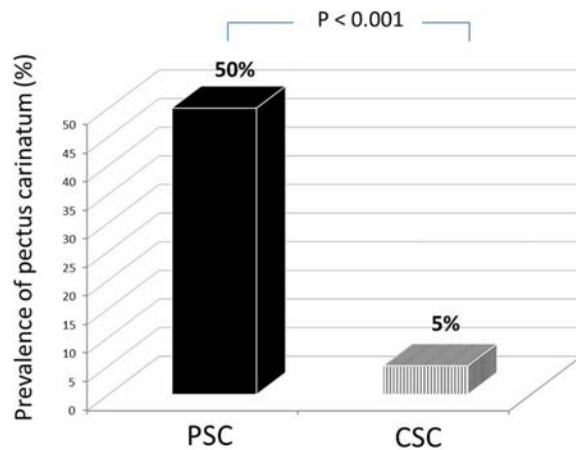


Fig. 4 The incidence of postoperative pectus carinatum in patients using conventional parallel sternal closure technique/PSC, (black bar) and convergent sternal closure technique/CSC (grey/strip bar).

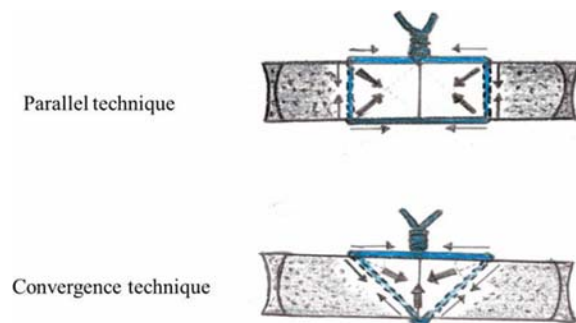


Fig. 5 Vectors of forces between two techniques. The vectors of forces in the parallel technique distributed all the way from the outer to the inner table of the sternum. The vectors of forces in the convergent technique maximally compressed at the middle of the sternotomy site which can protect sternal inversion.

occurrence of pectus carinatum after 6 months was unknown.

Conclusion

The authors demonstrated that the incidence of postoperative pectus carinatum was about one-fourth (28%) of pediatric patients undergoing open heart surgery. Convergent sternal closure technique significantly reduced postoperative pectus carinatum compared with conventional parallel sternal closure technique. The authors suggest using convergent sternal closure technique in pediatric cardiac surgery to prevent postoperative pectus carinatum complication.

What is already known on this topic?

Pectus carinatum is a chest wall deformity characterized by anterior protrusion of the sternum and costal cartilages. And several pediatric patients with previously normal chest wall contour undergoing open heart surgery developed acquired/iatrogenic postoperative pectus carinatum.

What this study adds?

The authors demonstrated that the incidence of postoperative pectus carinatum was about one-fourth (28%) of pediatric patients undergoing open heart surgery. Convergent sternal closure technique significantly reduced postoperative pectus carinatum compared with conventional parallel sternal closure technique.

Potential conflicts of interest

None.

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เทคนิคการเย็บปิดกระดูกอกแบบ *Convergent* เพื่อป้องกันภาวะ *Pectuscarinatum* หลังผ่าตัดในผู้ป่วยเด็กที่รับการผ่าตัดหัวใจแบบเปิด

ธีรวุฒิ จันทวรรณ, สมชาย ศรียชาติ, อวรร ทรัพย์ทวีสิน, ปุณณฤกษ์ ทองเจริญ, พันธุ์ศักดิ์ ลักษณะบุญสูง, เกรียงไกร ดันตวิงศ์โกสีย์

ภูมิหลัง: ภาวะ *Pectuscarinatum* ส่งผลกระทบต่อลักษณะทางกายภาพและคุณภาพชีวิตของผู้ป่วย ผู้นิพนธ์ได้ทำการสังเกตพบว่ามีผู้ป่วยเด็กหลายรายที่ก่อนผ่าตัดมีลักษณะกระดูกอกปกติ แต่ภายหลังการผ่าตัดหัวใจแบบเปิดเกิดภาวะ *Pectuscarinatum* ขึ้นมา

วัตถุประสงค์: มีเป้าหมาย 2 ประการ คือ 1) เพื่อศึกษาอัตราการเกิดขึ้นใหม่ของภาวะ *Pectuscarinatum* หลังการผ่าตัด และ 2) เพื่อเปรียบเทียบอัตราการเกิดขึ้นใหม่ของภาวะ *Pectuscarinatum* หลังการผ่าตัดหัวใจแบบเปิดในผู้ป่วยเด็กที่ได้รับการเย็บปิดกระดูกอกแบบเทคนิค *Parallel* เดิมเทียบกับเทคนิค *Convergent*

วัสดุและวิธีการ: ผู้นิพนธ์ได้คัดเลือกผู้ป่วยเด็กที่ได้รับการผ่าตัดหัวใจแบบเปิดจำนวน 52 ราย โดย 12 ราย ถูกคัดออกจากการศึกษา เนื่องจากเย็บปิดกระดูกอกได้ซ้ำจำนวน 2 ราย, เคยถูกผ่าตัดเปิดกระดูกอกมาก่อน 6 ราย และมีความผิดปกติของกระดูกอกก่อนผ่าตัดอยู่แล้ว 4 ราย จากนั้นผู้ป่วย 40 ราย ได้ถูกสุ่มแยกออกเป็น 2 กลุ่ม คือ กลุ่มและกลุ่มที่เย็บปิดด้วยเทคนิค *Convergent* กลุ่มละ 20 รายเท่ากัน ผู้ป่วยทั้งหมดได้รับการติดตามการรักษาเป็นเวลา 6 เดือน เพื่อดูการเกิดภาวะ *Pectuscarinatum* หลังการผ่าตัด

ผลการศึกษา: จากผู้ป่วย 40 ราย มีอายุเฉลี่ยที่ 1.6 ปี เป็นเพศหญิงร้อยละ 55 มีผู้ป่วยเกิดภาวะ *Pectuscarinatum* หลังการผ่าตัดจำนวน 11 ราย คิดเป็นร้อยละ 28 โดยจากการติดตามการรักษาเป็นเวลา 6 เดือน มีผู้ป่วยที่เกิดภาวะ *Pectuscarinatum* หลังการผ่าตัด ในกลุ่มที่เย็บปิดด้วยเทคนิค *Parallel* เดิม จำนวน 10 ราย คิดเป็นร้อยละ 50 ซึ่งมากกว่ากลุ่มที่เย็บปิดด้วยเทคนิค *Convergent* ซึ่งมีเพียง 1 รายคิดเป็นร้อยละ 5 เท่านั้น เมื่อคำนวณค่า RR จะได้เท่ากับ 10 มีค่า 95% CI เท่ากับ 1.41-70.99 และค่า *p-value* น้อยกว่า 0.001

สรุป: 1) อัตราการเกิดขึ้นใหม่ของภาวะ *Pectuscarinatum* หลังการผ่าตัด คือร้อยละ 28 ในผู้ป่วยเด็กที่ผ่าตัดหัวใจแบบเปิด 2) การเย็บปิดกระดูกอกด้วยเทคนิค *Convergent* ลดอัตราการเกิดภาวะ *Pectuscarinatum* หลังการผ่าตัดได้ เมื่อเทียบกับกลุ่มที่เย็บปิดด้วยเทคนิค *Parallel* เดิม และ 3) ผู้นิพนธ์แนะนำให้ใช้การเย็บปิดกระดูกอกด้วยเทคนิค *Convergent* เพื่อลดอัตราการเกิดภาวะ *Pectuscarinatum* หลังการผ่าตัดในผู้ป่วยเด็กที่ได้รับการผ่าตัดหัวใจแบบเปิด
