

Repair of Sternal Cleft in Children

Korkut Bostanci¹ · Davor Stamenovic²

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Abstract

Purpose of Review The goal of this paper is to review the surgical techniques for the correction of sternal cleft in children.

Recent Findings Various surgical techniques have been developed for the correction of sternal cleft since 1949, when the first successful repair was reported.

Summary Sternal cleft is an uncommon congenital chest wall deformity. The optimal correction can be achieved by primary repair of the defect in patients younger than 1 year of age, especially during the neonatal period, mostly with an easy technique. In older children, more extensive techniques are applied, using either autologous tissues or synthetic prosthetic materials, with satisfactory functional and aesthetic results.

Keywords Sternal cleft · Sternal fissure · Surgical repair · Chest wall

Introduction

A variety of malformations of the chest wall may be identified in childhood. Sternal cleft—sternal fissure, bifid sternum—is rare when compared to pectus deformities. It

is the least severe form of sternal defects which also include thoracic ectopia cordis, cervical ectopia cordis and thoracoabdominal ectopia cordis. An infant with sternal cleft has a partial or total separation of the sternum, and a normally positioned intrathoracic heart [1–5] (Fig. 1).

The sternum is a mesodermal structure and has a common origin with the pectoral muscles [6]. Lateral mesodermal plates move ventrally during the sixth week of gestation, creating two parallel mesenchymal strips. These strips begin to unite craniocaudally, creating the sternal corpus and partially the manubrium during the seventh week. This union is completed by the end of the tenth week of gestation. The sternum originates as cartilage, then multiple ossification centres develop in a craniocaudal sequence. It is believed that the isolated sternal defect results from the failure of the mesenchymal plate fusion process during the eighth week of gestation [7–9].

Sternal cleft can be classified as complete and incomplete [10]. A complete cleft is the rarest form. Incomplete clefts are either superior or inferior. Inferior clefts may occur as an isolated entity, although it is generally associated with anomalies like ectopia cordis, or thoracoabdominal ectopia cordis—Cantrell's pentalogy. Superior clefts are often an isolated entity [11].

When the sternal cleft is associated with defects of the pericardium, anterior diaphragm and abdominal wall, early surgical repair through a midline thoracoabdominal incision is obligatory [1, 2]. The pericardium is repaired, the diaphragm is attached anteriorly, the sternal bars are approximated and the diastasis recti is corrected. Early repair, when the chest wall is more flexible, is preferred if the infant is healthy enough to tolerate the operation. Although ectopia cordis is generally incompatible with life, thoracoabdominal ectopia cordis has a better prognosis [2].

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✉ Korkut Bostanci
kbostanci@marmara.edu.tr

¹ Department of Thoracic Surgery, Marmara University Faculty of Medicine, Istanbul, Turkey

² Department of Thoracic Surgery, St. Vincentius Kliniken, Karlsruhe, Germany



Fig. 1 Computerized tomography imaging of a superior sternal cleft

When the defect is confined to the sternum and is covered with skin, surgical repair may often be elective [2]. Various techniques to correct sternal defects have been described since 1888 when Lannelongue reported the first limited repair [12–19], yet primary repair has become the treatment of choice in infants [20–22]. Burton described the first true surgical repair of sternal cleft achieved by placing a costal cartilage graft over the defect in 2 cases in 1949 [14]. Again in 1949, Maier performed the first primary closure of sternal cleft on a 6-week-old child, stressing the need for early correction [15]. In 1958, Sabiston described sliding chondrotomies, increasing the length of costal cartilages by oblique incisions [16]. In 1964, Meissner described his technique where he divided the costal cartilages laterally and rotated them medially to cover the sternal defect [17]. Repair with different autologous grafts like costal cartilage or ribs [20–22], and with prosthetic materials like acrylic, silicone, Marlex mesh, or titanium plate have all been reported [19–21, 23].

Surgical Treatment of Sternal Cleft—Various Techniques

Simple Primary Repair

Primary repair of the defect by direct approximation of the sternal bars by simple sutures is the treatment of choice whenever it is possible as it reduces the problems with the prosthetic materials and the troubles in the osteochondral cicatrization that may develop in the chondrocostal division procedures [9, 20, 24]. The age of the patient is the key factor for primary repair as in the neonatal period the chest wall is more flexible and has a lower resistance,

allowing an easy approximation of the sternal bars without any compression on the mediastinal structures, especially on the heart [9, 21, 25]. Primary repair becomes very difficult after the neonatal period and almost impossible after the first year of life, when more extensive techniques should be applied [9].

For a primary repair, a midline vertical incision is made overlying the sternal cleft. Subcutaneous flaps are created, followed by the mobilization of the pectoralis major muscles, then the endothoracic fascia is dissected off the sternal bars and the pericardium is released. The “U” defect at the base of the cleft is turned into a “V” by excising a wedge of cartilage to facilitate the approximation of the sternal bars without any tension (Fig. 2a). Nonabsorbable sutures are placed in interrupted fashion around the bars to reapproximate them [9, 21] (Fig. 2b).

Primary Repair with Chondrotomies

The use of multiple bilateral oblique—or sliding—chondrotomies reduces the internal organ compression in older patients [16]. These chondrotomies increase the chest wall dimensions and flexibility. The technique is useful in older infants and children with a less flexible chest and a widening defect [1]. As a modification, the cartilages can also be divided laterally and swung medially to cover the sternal defect [1, 17].

For a repair with chondrotomies, the sternal bars are prepared as in the simple primary repair. A sliding oblique chondrotomy is performed bilaterally on the first three to five costal cartilages, then the sternal bars are advanced from both sides to meet in the midline [26] (Fig. 3). If the attempts to approximate the sternal bars are unsuccessful due to the unyielding sternoclavicular joints, the clavicles can be fractured at the junction of the medial and lateral two-thirds and then the sternal bars are approximated [27]. As an alternative, a partial resection of the first three costal cartilages can be performed bilaterally, followed by the disruption of the sternoclavicular junction on both sides [9]. In these patients, the repair is performed with transsternal steel wires. The detached major pectoral muscles are sutured back on the area of costal slide to close the dead space—if any—on the costal cartilages on both side. A mediastinal and a subcutaneous drain are placed, followed by wound closure [26, 27].

Autologous Repair

Autologous repair techniques are suitable for older children who are not suitable for primary repair. It should be preferred as it avoids problems related to the implanting of prosthetic materials.

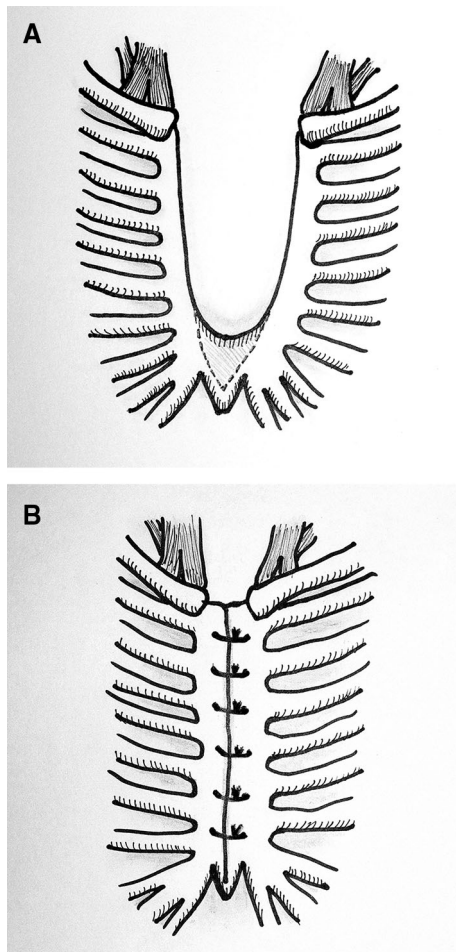


Fig. 2 **a** The “U” cleft at the base is turned into a “V” by excising a wedge of cartilage to facilitate approximation of the sternal halves without undue tension. **b** View after primary closure of the sternal cleft

de Campos described his autologous repair technique in 1998 [11]. In this technique, a posterior sternal wall is created with periosteal flaps from the sternal bars. The periosteum of each bar is incised on its lateral border and elevated from its anterior and medial surfaces (Fig. 4a). Both flaps are then turned inside out and sutured together in the midline with absorbable sutures, providing a stable posterior sternal wall. Two or three chondral grafts are resected subperichondrially, and the gap between the two sternal bars is filled with these grafts. Then the cartilaginous bridge at the distal end of the cleft is resected to facilitate the approximation of the sternal bars (Fig. 4b). Approximation, also the stabilization of the chondral grafts is provided by steel wires [11, 28]. Servical muscle-sparing is mostly not needed with this technique. Pectoral muscles are sutured in the median plane.

Primary approximation and the use of autogenous tissue rather than synthetic materials are the two main advantages of this technique. Cardiac compression is less likely to

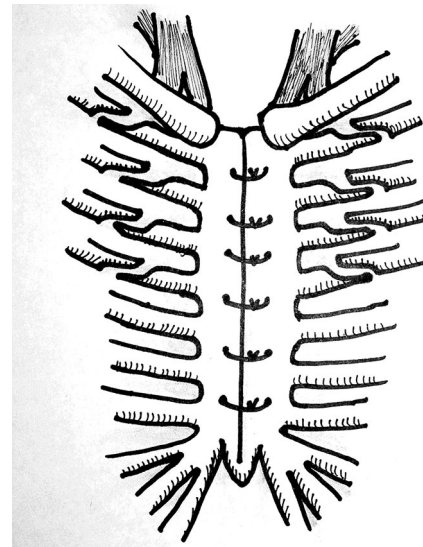


Fig. 3 A sliding cartilage flap is created between the second and fourth costal cartilages, and the sternal bars from both sides are advanced to meet in the midline

develop with this procedure as periosteal flaps enlarge the thoracic perimeter. Moreover, periosteal flaps bridge confers an anatomical substract for osteogenesis, allowing a neosternum remodelling. This technique allows normal growth of the chest wall and provides sufficient strength and rigidity in the neosternum [28].

Similar to this periosteal flaps procedure, other autologous repair techniques such as “bilateral sternal bar turnover flaps,” “double osteochondroplasty flap,” or “reversed sternal plate flaps” techniques can be performed for the correction of sternal clefts [29–31]. Reversed sternal flaps are a good option for older patients. Autologous split rib grafts can also be an alternative for this purpose [32].

Repair Using Synthetic Materials

Although the use of synthetic materials such as Marlex, stainless steel mesh, silicone, acrylic, Teflon, Prolene mesh, absorbable polyglactin plate, and porous polyethylene implant are reported to be associated with tissue reactions and increased risk of infection, they appear to provide a much more rigid frame when compared to autologous tissues [33–36]. Besides, the therapy can be affected by the limited availability of autologous tissues in infants.

Advantages of titanium plates include higher strength and stiffness, light weight, plasticity, resistance to infection, good histocompatibility, and low interference with magnetic resonance imaging and computed tomography [34]. Displacement, migration, erosion into vital structures or infection are the potential complications as with other prosthetic materials.

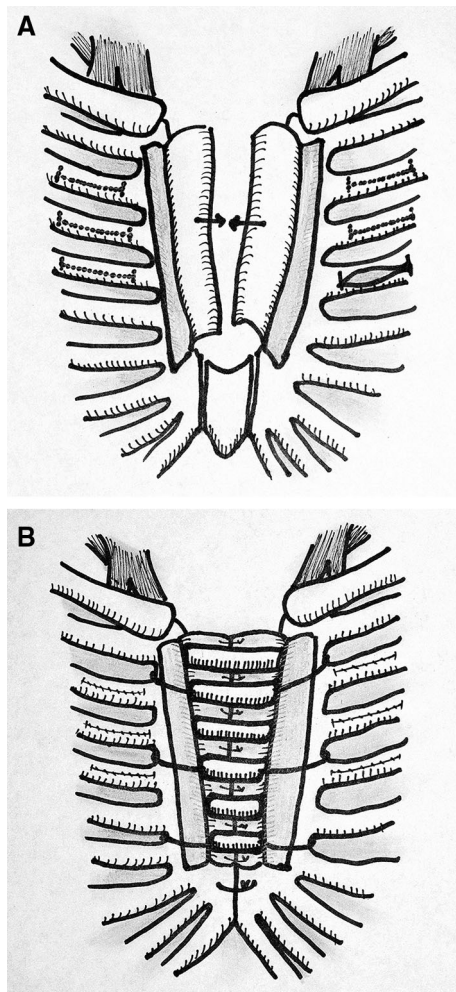


Fig. 4 **a** The periosteum of each bar is incised on its lateral border and elevated from its anterior and medial surfaces. Then the cartilaginous bridge at the distal end of the cleft is resected to facilitate the approximation of the sternal bars. **b** Both flaps are then turned inside out and sutured together in the midline with absorbable sutures, providing a stable posterior sternal wall. Two or three chondral grafts are resected subperichondrially, and the gap between the two sternal bars is filled with these grafts. Approximation, also the stabilization of the chondral grafts is provided by steel wires

In some older children and teenagers, a rib homograft can be harvested to place into the defect, and the defect can then be covered by a prosthetic mesh. The cervical muscles inserting into the separated sternal bars are mobilized and then reinserted in the midline [9].

Since the synthetic prosthetic materials will not grow with the child, another surgical intervention may be necessary in the future. Depending on the child's age and availability of autologous tissues, either another synthetic material can be inserted or an attempt can be made to perform a primary closure using autologous tissues [34•]. To overcome this problem, an alternative solution can be using absorbable mesh plates as a prosthetic material [35•]. The use of an absorbable polyglactin plate allows to

maintain any osseous or cartilage autografts, to leave a sufficient volume for the rib cage, and to avoid synthetic materials that may hamper growth.

Repair Using Muscle Flaps

Muscle or musculocutaneous flaps, such as pectoralis major muscle or rectus abdominis musculocutaneous flaps, can also be used for the repair of sternal cleft, either on their own or together with autologous or synthetic materials [36–38].

For a repair with pectoralis major muscle flaps, the parasternal origins of both pectoralis major muscles are released and the muscles are elevated on their thoracoacromial circulation. Each pectoralis major muscle is advanced to the midline and approximated over the pericardium. In case of a complete sternal cleft, the upper abdominal closure can be performed by direct approximation of the rectus abdominis muscles. Drains should be placed above and below the pectoralis muscle flaps and the overlying fasciocutaneous flaps are advanced to achieve skin closure. For inferior or total clefts bilateral contiguous pectoralis major and rectus abdominis muscle flaps can also be used [38].

Conclusions

Sternal cleft is an uncommon congenital chest wall deformity. The optimal correction can be achieved by primary repair of the defect in patients younger than 1 year of age, especially during the neonatal period, mostly with an easy technique. In older children, more extensive techniques are applied, using either autologous tissues or synthetic prosthetic materials, with satisfactory functional and aesthetic results.

Compliance with Ethical Guidelines

Conflict of interest Korkut Bostanci and Davor Stamenovic declare that they have no conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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