Sternum Augmentation With Bovine Bone Substitute in the Neonate

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Delayed chest closure may be mandatory after heart surgery to treat a congenital disorder. Sternal closure can be challenging, even when a staged closure procedure has been performed. We present 2 case reports of a sternal augmentation technique in neonates using bovine bone substitute. Staged chest closure was mandatory because of cardiomediastinal disproportion in the first patient, and hemodynamic deterioration followed by an extracorporeal assist device in the second patient. We succeeded in closing the chests in these 2 neonates using this augmentation technique. To the best of our knowledge, these are the first 2 reports of this type of sternum augmentation technique in neonates.

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Primary sternal closure without provoking cardiac compression and subsequent circulatory failure can be challenging in heart surgery to correct congenital disorders. Staged chest closure may be mandatory in such cases. Possible indications for delayed closure are uncontrollable hemorrhage, risk of cyanosis from hemodynamic failure during or shortly after sternal closure, intractable arrhythmias, ventricular assist devices, myocardial edema due to reperfusion, and noncardiogenic pulmonary edema. Herein, we present 2 case reports of neonates in whom we used a sternal augmentation technique with artificial bovine bone to close the sternum completely, without cardiac impairment.

Technique

Case 1

A 3-day-old male neonate weighing 3 kg, with hypoplastic left heart syndrome, underwent a Norwood-type operation for stage-1 palliation. The surgical procedure was complex, and weaning from cardiopulmonary bypass was impossible because of cardiac failure. A ventricular assist device was implanted, and the open chest was covered with a surgical membrane. A small piece of silicone tubing positioned between the 2 sternal edges was used as a placeholder to prevent accidental cardiac compression. The heart recovered, and the ventricular assist device was removed 10 days later. The chest was closed by approximating the sternal edges with stainless steel wire sutures until the hemodynamic parameters led us to suspect cardiac compression. A gap of approximately 1 cm was bridged by interposing 2 blocks of natural bone mineral of bovine origin (Orthoss Block, $1 \times 1 \times 2$ cm; Geistlich Pharma AG, Wolhusen, Switzerland). Because this material can be sliced, we used a scalpel to cut the original bovine bone blocks into the shape required to accommodate the gap depth and length (Fig 1). Once the bridging fragments were brought into position, the ends of the stainless steel wire sutures were twisted in the usual manner (Fig 2). Because of the wire loop position and resulting compression forces, the fragments maintained their position. Ideally, the fragments should bridge at least 1 stainless steel wire to ensure stable sternotomy closure.

Case 2

A 30-day-old male neonate weighing 3.5 kg, with tetralogy of Fallot with absent pulmonary valve, underwent surgical repair at our institution. The ventricular septal defect was closed, both pulmonary artery branches were reconstructed with bovine pericardium, and the absent pulmonary segment was compensated for using a biological conduit. To prevent hemodynamic deterioration due to emphysematous expansion of the left lung and prolonged surgery, the chest was left open. A small piece of silicone tubing was implanted as a place holder, separating the 2 edges of the sternotomy, and the skin was closed with a bovine pericardial patch. The infant did not tolerate routine sternal closure 7 days later. We therefore augmented the sternum artificially as described in Case 1.

Follow-up was 4 days in the first patient, and 7 months in the second. The first infant died during hospitalization, of causes unrelated to sternal closure (pneumonia). The second infant was discharged after 16 days. His postoperative course was uneventful except for a minor subxyphoidal wound dehiscence that was treated successfully in the clinic. Four months later, the child developed a

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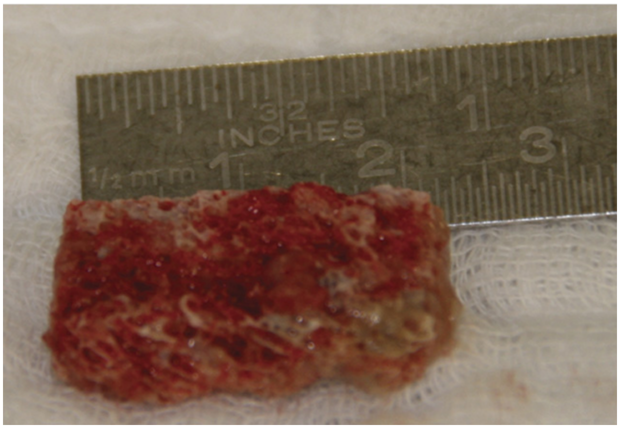

Fig 1. Cube of bovine bone substitute cut into shape.

wound infection and partial sternal instability in the lower segment. We observed a wound dehiscence measuring 5 × 5 mm that was exposing parts of the lower bridging bone segment in the most distal section. The distal bone fragment, not incorporated in the sternal bone tissue, was encapsulated by connective tissue. In contrast, the proximal bone fragment was completely incorporated in the adjacent sternal border edges. Loose parts of the bone fragments were removed, the wound was cleaned, and vacuum therapy was initiated. In addition, antibiotic therapy was administered. The sternum wound was closed 10 days later. Despite the absence of a bridging fragment in the lower portion, the sternum was stable, and no further stabilization measures were necessary (Fig 3).

Comment

In heart surgery to correct congenital disorders, staged chest closure may be necessary and ultimately lifesaving. Factors that may lead to the decision for delayed sternal closure include uncontrollable hemorrhage, increased risk of cyanosis as a result of hemodynamic impairment during or shortly after sternal closure, intractable arrhythmias, ventricular assist devices, myocardial edema due to reperfusion, noncardiogenic pulmonary edema, and cardiac enlargement due to application of biological or synthetic material. The increasing number of procedures performed in infants younger than 2 years highlights the problem of retrosternal space deficiency. Ziemer et al [1] reported that temporary chest wall plastic surgery may lower mortality, emphasizing the significance of staged chest closure in pediatric cardiac surgery in certain cases despite the risk of mediastinal infection. To lower the risk of infection, the skin above the sternum is closed primarily or using a surgical membrane. These immediate measures enable the heart to recover from low cardiac output and myocardial edema, and they circumvent the risk of hemorrhagic or atypical tamponade while facilitating access to the mediastinum when necessary. Despite the time saved by staged chest closure, the surgeon's intention is efficient primary closure as early as possible to prevent mediastinal infection or ankylosis of the rib cage. There is a good likelihood that the chest wall will approximate, and delayed chest closure will be feasible if the cause of cardiomediastinal disproportion can be corrected (ie, edema associated with cardiac or pulmonary enlargement, initially uncontrollable hemorrhage, or a removable ventricular assist device). However, conditions such as shunt-dependent circulation, noncardiogenic pulmonary edema, and cardiomediastinal disproportion due to additional biological or synthetic materials often prohibit immediate sternal closure without provoking cardiac compression with subsequent circulatory failure. We are unaware of any proved solution for bridging the sternal gap via mechanical osteosynthesis. Knox et al [2] described the bridging of sternal bone deficiency in patients with sternal clefts.

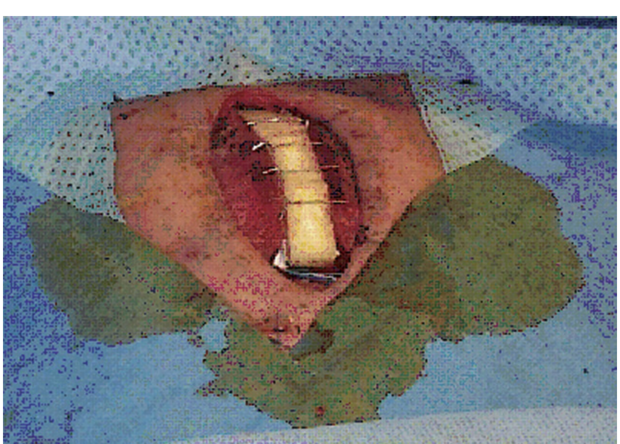

Fig 2. Bovine bone substitute brought into position.

Fig 3. Result 1 month after wound closure. Despite the missing bridging bovine bone cube in the very distal portion, the sternum is stable.

Their group reconstructed partially existent sternal bone with harvested ribs embedded in a prepared "bed" of periosteum and pectoralis fascia. However, this method is invasive and time-consuming, and is primarily used to treat sternal clefts. In the 1970s, Hulbert et al [3] demonstrated the ability of porous material, which makes the pore size–dependent ingrowth of cells possible. In the early 1990s, Baumgart et al [4] adopted this principle and described the primary closure of a median sternotomy using hydroxyapatite blocks as connecting pieces for sternal gap augmentation. We present the next generation of porous material of mammalian origin, consisting of cancellous bovine bone (Orthoss), which mimics the natural character of sternal bone better than hydroxyapatite mineral does. Because the material can be cut, it is easy to shape. Two to 3 longitudinally shaped blocks (each $1 \times 1 \times 2$ cm) usually suffice to bridge the sternal gap. The porous structure facilitates the formation and ingrowth of new bone. Because the material is of bovine origin, its pore size corresponds to the original conditions of human sternum cancellous bone. In contrast to slowly resorbed hydroxyapatite blocks, no biodegradation takes place in the bovine mineral. We observed the ingrowth of new bone in a surgical wound debridement due to a sternal wound infection in one of our patients. The upper, entirely covered portion of the wound revealed a fair amount of substitute bone ingrowth, and that part of the sternum was thus stable. The lower bovine block, partially uncovered because of wound dehiscence, was encapsulated by connective tissue and revealed no mineralized-bone ingrowth. We assume that infection of the nonvital material anticipated normal osteoid formation.

Despite cardiomediastinal disproportion, we easily managed primary closure of a median sternotomy using natural bone mineral of bovine origin (Orthoss). Use of this augmentation technique led to a highly functional and cosmetic result, without risking cardiac compression and subsequent circulatory failure. We believe that this augmentation technique using natural bone mineral of bovine origin offers a valuable option in surgery to correct congenital disorders in the presence of cardiomediastinal disproportion, and risks provoking an atypical cardiac tamponade.

We acknowledge that our case number was small. In case 1, follow-up was very short, and we mention it only to demonstrate the feasibility of this technique. We suggest this augmentation technique be included in the surgeon's armamentarium because it may be helpful in a difficult situation. Repeat surgical procedures may be even more challenging; thus we believe it advisable to reserve this technique for use in rare cases.

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