Recent and Future Developments in Chest Wall Reconstruction

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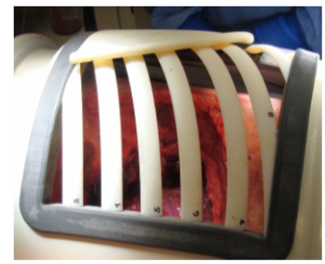
Reconstruction following major chest wall resection can be challenging. Conventional methods of using mesh with or without incorporation of methyl methacrylate are slowly being replaced by chest wall reconstruction prosthetic systems that use titanium plates or bars. The most popular systems in use are the titanium STRATOS bars and MatrixRIB plates, which have different systems for securing to the chest wall. In general, these new approaches are user friendly, are more ergonomic, and may avoid certain complications associated with the more conventional methods of reconstruction. However, the successful implantation of these titanium prosthetic systems requires the operator to be familiar with the limitations and potential pitfalls of the process. Follow-up data are only just emerging on the risk factors for implant failure of these prosthetic systems, as well as certain device-specific complications, with fracture failure being increasingly recognized as a significant problem. In the future, emerging intraoperative real-time imaging and 3-dimensional printing technology, as well as development in biomaterials, will allow chest wall reconstruction to become increasingly personalized.



Implantation of prosthesis into patient.

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INTRODUCTION

Chest wall tumors usually require radical surgery with adequate surgical resection margins that can result in large defects. Complex reconstruction is sometimes required to maintain chest wall integrity and cosmesis, as well as to prevent paradoxical chest wall movement that may lead to respiratory compromise. The reconstruction should also aim to avoid defects that allow organ herniation, counteract significant chest retraction leading to thoracoplasty-like effect, and be capable of affording some protection to underlying mediastinal organs against external impact. Conventional chest wall reconstruction, particularly for large defects, may be associated with high rates of complications.[1] For many decades, methyl methacrylate has been the popular choice to reconstruct parts of the sternum, ribs, and chest wall.[2] However, recent advances in rib fixation devices may simplify the reconstruction process, in particular the DePuy Synthes MatrixRIB precontoured plate and the STRATOS (Strasbourg Thoracic Osteosynthesis System; MedXpert GmbH, Heitersheim, Germany) titanium systems.[3-5] The implantation of new devices when executed correctly can be more user friendly, ergonomic, and may avoid certain problems associated with traditional reconstruction methods. Often, the successful implantation of a prosthetic rib requires knowledge of certain tips and tricks, which are discussed. In addition, specific complications relating to these systems are highlighted. Lastly, there are exciting future developments in a more personalized approach to prosthetic chest wall reconstruction on the horizon.

CONVENTIONAL APPROACHES

A whole multitude of materials are available for chest wall reconstruction; however, traditionally, the most commonly used were synthetic meshes and bone substitutes, such as methyl methacrylate. The meshes and patches are easy to manipulate and handle and can be easily sutured to the ribs and surrounding connective tissue. The flexibility of the meshes usually allows a uniform distribution of tension at the defect edges, and their relative porosity can limit adjacent seroma formation. Despite being used as a double layer in most situations, the meshes tend to lack rigidity, which when

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covering large chest wall defects, are unable to maintain the natural chest wall curvature. This has important implications not only for cosmesis but also for postoperative pulmonary function. Methyl methacrylate is widely used for reconstructing the rigid structures of the chest wall, and it may be applied as a sandwich between 2 layers of a mesh. However, the material can be difficult to use in inexperienced hands. Despite technical modifications introduced by Lardinois et al[6] on the methacrylate mixture and application methodology, which allow better configuration of the prosthesis, problems with anchorage and dislocation remain. Other potential problems that are encountered, albeit uncommonly, include methyl methacrylate toxicity, poor anchorage and fixation difficulties of the material, fracture of the methacrylate and associated chronic pain, as well as prosthesis infection.[1] The transition and recognition for the need of reconstructing the chest wall with “neo-ribs” that is more akin to the anatomy and perhaps physiology of the native chest wall was recognized and presented by Dahan et al.[7] They describe the technique of using Kirschner wires that are inserted into the cut rib ends as the framework for holding the silicon molds, into which the viscous methyl methacrylate is injected and allowed to harden, before the molds are eventually split and removed. When compared with the nonporous large plate of methyl methacrylate, this modification allows some tissue ingrowth and better fluid drainage.

DEVELOPMENT AND USE OF TITANIUM PROSTHESES

Usage of metal prostheses for chest wall reconstruction may have been reported as far back as 1909 by a French surgeon Gangolphe for management of a large sternal notch enchondroma.[8] Titanium implants have been more widely used since the mid-1950s, with the eventual development of the Austin Moore and Thompson orthopedic prostheses. The strength, corrosion resistance, and biocompatibility of titanium make it ideal for implants. However, problems with early prostheses fracture led to modification from using “pure” titanium to the stronger titanium alloys in these devices. The first alloy used for biomedical implants was Ti-6Al-4V containing 6% aluminum and 4% vanadium, which is the same material used for construction of the National Aeronautics and Space Administration (NASA) Space Shuttles. Unfortunately, it was found that the vanadium from Ti-6Al-4V prostheses slowly seeped out and became toxic to humans. Hence, the titanium alloy Ti-6Al-7Nb containing 6% aluminum and 7% niobium became the standard for prostheses, which is the same stronger alloy currently used in hip implants of today, as well as in some of the titanium rib prostheses system, such as the DePuy Synthes MatrixRIBs.

There are numerous materials and rib prostheses systems that exist. Perhaps one of the oldest dedicated systems is the Borrelly steel staple-splints system (Medicalex, Bagneux, France), which was popularized in the 1990s. Currently, the most favored prostheses are the STRATOS system and MatrixRIB precontoured plate system.[4,9] The STRATOS titanium system may be considered an evolution of the Borrelly system by working through a similar mechanism of securing to the rib ends using clips that resemble claws at the 2 ends of the bar. On the contrary, the MatrixRIB precontoured plate system is secured by fastening the plate to the rib with locking screws through predrilled holes. In general, most thoracic surgeons are less familiar with bone drilling and use of plates and screws than colleagues in other surgical specialties are. Therefore, it is even more important to gain knowledge of certain tips and tricks to avoid some of the pitfalls during implantation of the MatrixRIB precontoured plate system.

CONSIDERATIONS DURING MATRIXRIB PLATE IMPLANTATION

Achieving good pneumostasis and hemostasis is important, as returning to the pleural space often means having to take down the chest wall reconstruction. A chest tube of generous size should be placed through a separate port incision toward the apex. The neopleura is reconstructed with either a doubled-up polypropylene mesh or a Gortex mesh based on surgeon preference. In certain cases, the defect may be so large that several pieces of Gortex mesh are required, and a rapid and secure method to unite the pieces is by using the Covidien TA 90-mm stapler.[9] The mesh should be trimmed to 2 cm larger than the defect in all directions to allow some “give” avoiding too much tension, while maintaining the general conformation. Interrupted horizontal mattress ETHIBOND 2-0 sutures are placed circumferentially 3 cm apart on the mesh and then sutured to the chest wall fascia internally. Such suture distribution should provide good security and may reduce interstitial fluid accumulating in the chest wall and seroma formation by allowing drainage into the pleural space. Our practice of placing the mesh deep to the artificial ribs prevents lung herniation between implanted plates. Before tying all the sutures and “closing off” the pleural space with the mesh, the