Synthetic Versus Biologic Reconstruction of Bony Chest Wall Defects

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Introduction

Chest wall reconstruction is a challenging thoracic operation for even the most seasoned surgeon, particularly when bony defects are present. Iatrogenic defects are typically the result of resection of the chest wall for a number of conditions, including neoplasms, congenital defects, radiation injuries, and complicated infections. Larger defects of the chest wall can lead to skeletal instability, altered respiratory mechanics, and significant cosmetic defects. Reconstruction of these large defects of the chest wall can present an arduous challenge and often require prosthetic materials to fill.

Overall, the objectives of chest wall reconstruction include restoration of skeletal integrity, protection of underlying structures, and providing a good cosmetic result. A variety of materials exist for skeletal reconstruction and are promoted for reconstruction, including rigid versus non-rigid materials, permeable versus non-permeable materials, patches/meshes versus rib/sternal plates/bars, and synthetic versus biologic materials [1]. The ideal prosthetic material would have the following properties: rigid enough to abolish paradoxical chest wall motion; malleable enough to allow for appropriate contouring; physically and chemically inert; allows for tissue in-growth; radiolucent; sterile and resistant to infection; inexpensive. Unfortunately, no material exists that meets all such criteria.

Complications after chest wall reconstruction are frequent, with rates reported as high as 20–60%. Common complications include poor wound healing, seromas, infectious complications, pulmonary complications, and respiratory compromise. Other important postoperative outcomes include chronic pain, quality of life (QOL)

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concerns, and poor cosmetic results. When compared with synthetic materials, biologic reconstruction materials have the theoretical advantage of being more resistant to infectious complications and may require less frequent removal. On the other hand, non-rigid biologic materials are ultimately reabsorbed after some degree of tissue infiltration and regrowth. This may result in less chest wall stability, potentially resulting in greater respiratory compromise and worse cosmetic outcomes. The purpose of this review is to compare outcomes and results from reconstruction with biologic materials versus synthetic materials.

Search Strategy

We examined the literature on chest wall reconstruction for iatrogenic bony chest wall defects comparing reconstruction with biologic material versus synthetic material, with a focus on postoperative complications, mesh removal rates, QOL outcomes, and cosmetic outcomes (Table 60.1). A literature search of English language publications over a 10 year period from 2009 to 2019 was used to identify published data on prosthetic chest wall reconstruction of bony chest wall defects. Database searched included PubMed, Embase, and Cochrane Evidence Based Medicine. Terms used in the search were "prosthetic chest wall reconstruction", "synthetic chest wall reconstruction", and "biologic chest wall reconstruction". No randomized control trials or prospective cohort studies were identified. Five retrospective cohort studies and 19 cases series were included in our analysis. Analysis was limited to studies reporting immediate postoperative outcomes from reconstruction. Case reports were excluded from the analysis. Studies where outcomes related to reconstruction were not reported were also excluded. Results were classified using the GRADE system. As can be ascertained from Table 60.2, the literature in regards to this topic is limited to case series of varying sizes and a few retrospective cohort analyses with limited comparative analyses.

Results

To date, there have been no high-quality randomized clinical trials comparing one prosthetic material to another. As a result, the choice of material used is often based on institutional availability and cost, surgeon preference, and anecdotal evidence (Table 60.2) [2–21, 23–28]. Below, we will review what literature is currently available.

Table 60.1 PICO formatted terms for literature search

P (Patients)	I (Intervention)	C (Comparator)	O (Outcomes)
Pts with iatrogenic chest wall defects	Reconstruction with biological material	Reconstruction with synthetic materials	Complications, quality of life, prosthesis removal

Table 60.2 Summary of published literature for chest wall reconstruction

Author (year)	N[a]	Reconstruction material utilized	Overall complications	Wound infection	Seroma formation	Prosthesis removal	Perioperative mortality	Study design (Quality of evidence)
Synthetic								
Galbis Caravajal et al. (2009) [2]	11	PTFE patch, polypropylene mesh	18%	NR	NR	18%	0%	Case-series (Low)
Daigeler et al. (2009) [3]	62	Polypropylene mesh	42%	15.2%	NR	6.5%	5.4%	Case-series (Low)
Aghajanzadeh et al. (2010) [4]	60	Polypropylene mesh (n = 40), methylmethacrylate/mesh (n = 20)	36%	5%	3%	NR	3.3%	Case-series (Low)
Noble et al. (2010) [5]	17	Methylmethacrylate and polypropylene mesh sandwich	NR	0%	5.9%	0%	0%	Case-series (Low)
Girotti et al. (2011) [6]	101	Synthetic mesh (n = 52), synthetic rigid "shield" (n = 27), synthetic "rib-like" prosthesis (n = 22)	22.7%	12.8%	NR	6.9%	0.9%	Retrospective cohort study (Low)
Fabre et al. (2012) [7]	24	Titanium rib plates with vicryl mesh or PTFE patch	NR	4.2%	8.3%	0%	0%	Case-series (Low)
Berthet et al. (2012) [8]	31	Titanium rib plates with PTFE mesh	16%	9.7%	0%	3.2%	6.4%	Case-series (Low)
Huang et al. (2015)[b] [9]	23	Expanded PTFE patch (n = 18), polypropylene mesh (n = 4), felt (n = 1)	60.9%	8.7% (all with PTFE)	21.7% (all with PTFE)	8.7% (all with PTFE)	0%	Retrospective cohort study (Low)
Aghajanzadeh et al. (2015) [10]	43	Methylmethacrylate and polypropylene mesh sandwich	NR	7%	9.3%	2.3%	2.3%	Case-series (Low)

(continued)

Table 60.2 (continued)

Author (year)	N[a]	Reconstruction material utilized	Overall complications	Wound infection	Seroma formation	Prosthesis removal	Perioperative mortality	Study design (Quality of evidence)
Yang et al. (2015) [11]	27	Titanium mesh	14.8%	0%	7.4%	0%	0%	Case-series (Low)
Khalil et al. (2016) [12]	71	Polypropylene mesh, methyl methacrylate, titanium plates	NR	2.8%	0%	0%	0%	Case-series (Low)
Foroulis et al. (2016) [13]	20	Methylmethacrylate and polypropylene mesh sandwich	20%	0%	0%	0%	0%	Case-series (Low)
Biologic								
Ge et al. (2010) [14]	10	AlloDerm or Flex HD human dermal matrix	40%	10%	30%	0%	0%	Case-series (Low)
Lin et al. (2012) [15]	5	Permacol porcine dermal matrix	40%	0%	20%	0%	0%	Case-series (Low)
Barua et al. (2012) [16]	6[c]	Permacol porcine dermal matrix, Veritas collagen matrix	33.3%	0%	0%	0%	16.7%	Case-series (Low)
Dell'Amore et al. (2012) [17]	4	Sternal allograft	0%	0%	0%	0%	0%	Case-series (Low)
Guillen et al. (2017) [18]	8	L-Lactic acid and glycolic acid copolymer bioabsorbable plates	0%	0%	0%	0%	0%	Case-series (Low)
Schmidt et al. (2016) [19]	6	Permacol porcine dermal matrix	0%	0%	0%	0%	0%	Case-series (Low)
Khalil et al. (2018) [20]	8	Strattice bovine dermal matrix	0%	0%	0%	0%	0%	Case-series (Low)

D'Amico et al. (2018) [21]	11	Protexa porcine dermal matrix	45%	27%	0%	0%	0%	Case-series (Low)
Synthetic and biologic								
Rocco et al. (2014) [22]	46	"New materials" (titanium plates, cryopreserved grafts, and acellular collagen matrices, n = 21) "Conventional materials" (PTFE and methyl methacrylate, n = 21) Combination (n = 4)	16%	8.1%	NR	4.6%	0%	Retrospective cohort study (Low)
George et al. (2014) [23]	21	XCM biologic porcine dermis tissue matrix with (10) or without (11) rib plates	14.3%	14.3% (all with Synthes rib plates)	0%	14.3% (all with Synthes rib plates)	0%	Case-series (Low)
Spicer et al. (2016)[d] [24]	427	Biologic (n = 111) Synthetic (n = 316)	24%[e]	2.8%	NR	0%	1%	Retrospective cohort study (Moderate)
Azoury et al. (2016) [25]	59	Biologic (n = 10) Synthetic (n = 22) Biologic/synthetic combination (n = 27)	24.7%	8.6% (n = 5 in synthetic only, n = 2 combo)	1.2%	0%	6.8% (all in synthetic alone group)	Retrospective cohort study (Moderate)

NR not reported, *PTFE* polytetrafluoroethylene. AlloDerm: Allergan, Madisan, NJ; Flex HD: Ethicon, Bridgewater, NJ; Permacol: Covidien, Mansfield, MA; Veritas: Synovis, St Paul, MN; XCM: Depuy Synthes, Oberdorf, Switzerland; Protexa: Teconss, Giaveno, Italy; Synthes Titanium System: Depuy Synthes, Oberdorf, Switzerland

[a]Number of patients reconstructed with synthetic or biologic prosthesis. Patients treated without reconstruction or with autologous tissue flaps only not included

[b]14 patients in this study were reconstructed with autologous tissue and are not included here

[c]Number of chest wall reconstructions, total sample size of case series was 44 including soft tissue reconstructions

[d]A variety of reconstruction materials were used including biologic, synthetic, flexible, and rigid

[e]Only pulmonary complications were reported

Woven meshes and patches such as polypropylene and polytetrafluoroethylene are easy to use, non-absorbable, and provide uniform tensile strength. However, as they are synthetic they may be more prone to infection, which typically requires removal of the prosthesis. More recent case series report infection rates ranging from 5% to 15%, with similar rates of prosthesis removal [2–4, 6, 9, 22]. Similarly, seroma rates were between 3% and 22%, however this was highly dependent on perioperative technique and typically did not require removal of the prosthetic if infection was absent.

Recent studies of newer titanium plates have shown promising results, however in the majority of cases these are used along as a rigid scaffold along with a biologic or synthetic mesh with similar infection rates to more traditional synthetic materials alone [7, 8, 12, 22]. Interestingly, Yang et al. published a series of 27 patients reconstructed with a titanium mesh, and reported no wound infections or chest wall instability [11]. While these results are promising, this was a small retrospective series and additional study of this mesh is needed.

Biologic meshes are typically made from allograft or homograft tissue that has been decellularized, leaving only a collagen matrix. These meshes promote new collagen deposition and tissue ingrowth, as opposed to scarring which is seen with synthetic meshes. Anecdotally they are often utilized in infected fields. The majority of studies examining the use of biologic materials are limited to small case series. Infection rates ranged from 0% to 27% [14–21]. Despite this, however, most of these series reported that the prosthesis could be salvaged without removal.

For example, Schmidt et al., in a series of 6 patients reconstructed with a porcine decellularized dermis matrix, reported no infectious complications and good to excellent chest wall stability measured by the surgeon's impression and evidence of structural changes on CT scan [19]. D'Amico et al., in a series of 11 patients with chest wall resection for sarcoma, reported a wound complication rate (hematoma and infection) of 27%, though none required implant removal [21]. Similar to the Schmidt series, they found good long-term chest wall stability and integrity on CT scan at 2 years after surgery.

Quality of life after chest wall reconstruction with either synthetic or biologic materials has been studied only by a few authors and the endpoints have not been standardized. Compared to patients undergoing lung resection without the need for chest wall resection, those who underwent lung resection combined with chest wall resection and reconstruction experienced similar quality of life (pain, fatigue, dyspnea) and overall lung function [26]. Long-term outcomes appear to be more strongly related to preoperative status than the extent of chest wall resection required for treating lung cancer and the type of reconstruction necessary [27]. Treatment of chest wall tumors with resection and reconstruction results in long-term quality of life results similar to that in the general population [28].

We identified three retrospective cohort studies which directly compare biologic and synthetic prosthetics, and are summarized in Table 60.3 [22, 24, 25]. One such study from Spicer et al., compared outcomes after reconstruction with absorbable (Vicryl and biologic, n = 111) and non-absorbable (synthetic, n = 316) meshes [24]. On multivariable analysis, they found no difference in pulmonary complications

Table 60.3 Studies comparing synthetic and biologic prosthetic chest wall reconstruction materials

Author (year)	Conclusions
Rocco et al. (2014) [22]	Combined use of synthetic and biologic materials associated with increased risk of local wound complications (p = 0.032; OR not reported). No difference identified between synthetic alone versus biologic alone
Spicer et al. (2016) [24]	No difference identified in infection rates between biologic and synthetic mesh (p = 0.477, OR not reported), or pulmonary complications (OR = 1.47, 95% CI 0.86–2.53, p = 0.155)
Azoury et al. (2016) [25]	No difference identified in incidence of chest wall/wound complications between synthetic, biologic or combination biologic inlay with synthetic onlay mesh groups (31.8%, 10%, 22.2% respectively, p = 0.47)

(OR = 1.47, 95% confidence interval 0.86–2.53, p = 0.155) or wound infection rates (p = 0.477, OR not reported). It should be noted that in their study, they found a remarkably low overall wound infection rate of 2.8% (n = 12), and had no explants due to infected mesh, regardless of material used.

Azoury et al. reported similar results and found no difference in incidence of chest wall/wound complications between synthetic, biologic or combination biologic inlay with synthetic onlay mesh groups (31.8%, 10%, 22.2% respectively, p = 0.47) [25]. They concluded that combined use of both materials provides the dual advantages of tissue ingrowth and revascularization from the acellular dermal matrix along with the structural durability of a synthetic mesh, although they acknowledged that larger sample sizes were needed to make definitive conclusions.

Rocco et al. in 2014 reported a case series examining the use of vacuum assisted closure as well as comparing what they refer to as "new materials" (titanium plates, cryopreserved grafts, and acellular collagen matrices} with conventional materials (polytetrafluoroethylene and methyl methacrylate) [22]. Twenty-one patients were treated with new materials, 21 with conventional materials, and 4 with both. Interestingly, the authors found no difference in local wound complications between these two cohorts when only a single material was used. However, in a multivariable regression, the use of both materials together was associated with higher rates of wound complications (OR not reported, p = 0.032). These results are difficult to interpret given only 4 patients in the combined materials cohort.

There is no comparative QOL data between biologic and synthetic materials. Future study will require prospective comparative studies including well-validated QOL endpoints, in addition to measuring clinical outcomes.

Conclusions and Recommendations

In summary, the current literature in regards to utilization of synthetic vs. biologic prosthesis for reconstruction of bony chest wall defects is limited to single institution retrospective cases series, and a few retrospective cohort studies. Only three studies directly compare postoperative outcomes between synthetic and biologic

prostheses, specifically in regards to infectious wound complications. These few retrospective series are limited by selection bias given the study design, there does not appear to be a significant difference in regards to wound complications or rates of prosthesis removal. There may be increased risk of local wound complications when a combination of synthetic and prosthetic materials is used, however the data is limited and conclusive statements cannot be made. There is little data in regards to QOL or cosmesis.

Based on this review of the literature, many surgeons will prefer to use a biologic prosthesis in a contaminated field. In the absence of an infected, contaminated field, a synthetic prosthesis should be used with likely equivalent rates of infectious complications and rates of prosthesis removal, and lower costs. Recommendations regarding postoperative QOL and cosmesis cannot be made at this time.

Recommendations

- A synthetic prosthesis is recommended as the best overall choice for chest wall reconstruction (evidence quality low, weak recommendation).
- A biologic prosthesis is recommended for chest wall reconstruction in a contaminated field (evidence quality low, weak recommendation).

A Personal View of the Data

Reconstruction of iatrogenic bony chest wall defects is a difficult challenge for even the most seasoned surgeon. If a prosthetic material is needed for reconstruction, our preference is to utilize synthetic mesh material in most situations. The available case series show that infectious rates with synthetic materials are relatively low, with low rates of mesh removal. The added advantage of structural integrity and lower cost make synthetic materials, such as PTFE, our preference in the absence of an infected field. When a rigid prosthetic is needed our typical practice is to use methyl methacrylate “sandwiched” in Vicryl mesh, however newer titanium materials show considerable promise and warrant further study. In the presence of an infected field, our preference is to utilize a biologic prosthesis. Further recommendations and future study will require prospective, randomized trials with clearly defined endpoints for complications, cosmesis, and quality of life.

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