Chapter 58
Synthetic Versus Biologic Reconstruction of Bony Chest Wall Defects

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Abstract Biologic materials are being increasingly used alone or in combination as material of choice for reconstruction of extensive defects after chest wall resection due to their facilitated incorporation in the host and their resilience to infection. Whether these materials are destined to replace time honored synthetic prostheses is not known, especially since direct comparisons of efficacy in terms of chest wall stability, reduced postoperative infection rates and need for prosthesis removal have not yet been published. Also, biologic materials have elevated costs which may suggest careful use in selected indications.

Keywords Chest wall • Prostheses • Bioengineering • Acellular collagen matrix • Cryopreserved homografts

Introduction

Thoracic surgeons are increasingly faced with the necessity of extended and repeated resections for primary or secondary tumors of the bony chest wall [1, 2]. As a consequence, large defects in the chest wall are created and subsequently reconstructed thanks to the availability of biologic materials recently introduced in the clinical practice [1, 2]. Does this mean that synthetic materials are to be abandoned? Is there substantial evidence in the literature supporting a more liberal use of biologic composites to cover chest wall defects? A major hurdle against the accumulation of reliable evidence in this field is represented by the relative rarity of both

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primary and secondary chest wall tumors. Indeed, the most recent authoritative experiences are based on series counting up to around 200 patients receiving synthetic prostheses [1, 2]. In addition, the use of biologic materials is still limited to a few centers due to their cost [1, 2]. As a result, postoperative outcomes of synthetic and biological materials are usually not analyzed separately and this adds to the uncertainty in the selection of the material for each operative indication.

Search Strategy

In order to compare synthetic vs biologic materials, the search included Medline, the Cochrane controlled trials register and publications between January 1999 and August 2013 that included terms such as: chest wall resection, chest wall reconstruction, chest wall tumors, and chest wall tumors AND [biomaterials OR cryopreserved homografts OR acellular collagen matrix]. The pre-specified primary outcome was postoperative infections of prosthesis and lack of chest wall stabilization. Only publications in English were considered. Case reports and limited (<5 patients) series were excluded from this analysis, and only studies reporting on full thickness chest wall resection and reconstruction were accepted. For their intrinsic biologic features, titanium plate studies were included in the biologic/biomimetic group.

The data were entered in a NCSS version 8 spreadsheet (NCSS, LLC. Kaysville, Utah, USA, www.ncss.com) using studies on synthetic materials as control group due to the lack of clinical studies directly comparing the two reconstructive strategies. In addition, data from studies using synthetic or biologic materials were entered and matched according to decreasing numerosity. Random effect meta-analyses were run for odds ratio in order to estimate effect sizes. Consistency of the meta-analysis was assessed by the effect-equality test for heterogeneity. Heterogeneity refers to the variation across a study that is attributable to statistical heterogeneity rather than chance. As a rule, heterogeneity is established when the Q value divided by N (number of studies) −1 equals >1 and the p value is >0.05.

Results

Neither randomized trials nor comparative studies on the use of synthetic vs biologic composites for chest wall reconstruction in a clinical setting were retrieved from the literature search. Nevertheless, 14 papers [3–16] were selected that included 1,108 and 117 patients in the papers on the use of synthetic (7 studies) and biologic/biomimetic materials (7 studies), respectively. Heterogeneity was ruled out. The results of the meta-analysis showed that 98 (8.8 %) and 12 patients (11.3 %; $p = 0.63$) developed wound infection or prosthesis instability in the synthetic and biologic/biomimetic group, respectively. In addition, although no definitive

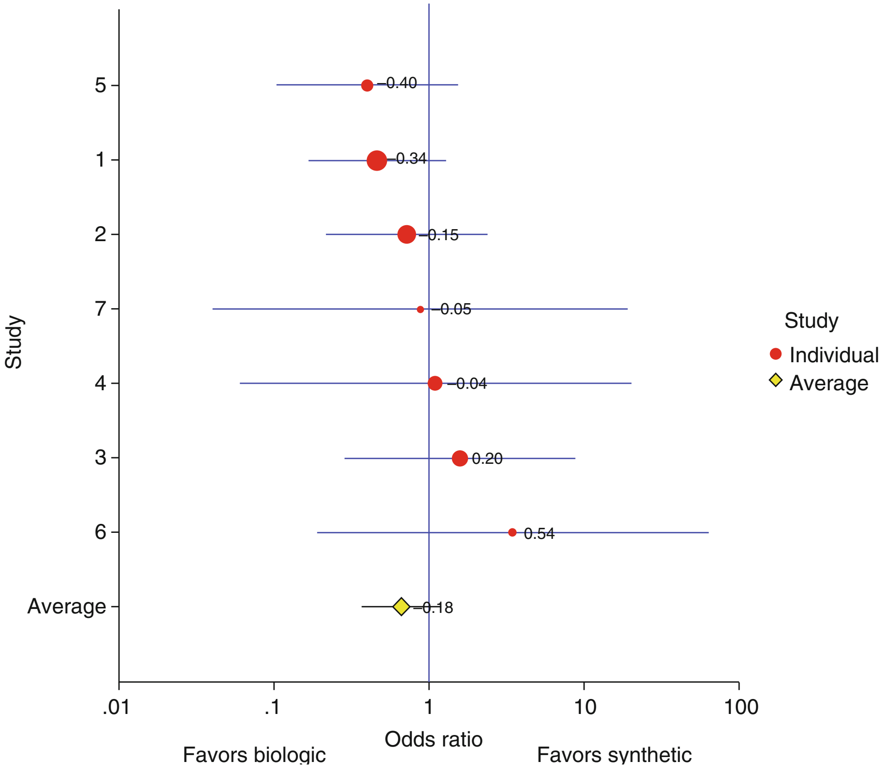

Fig. 58.1 Random effect meta-analysis of 14 papers on chest wall resection and reconstruction using biologic/biomimetic or synthetic materials

conclusions could be drawn, it appeared that the use of recently introduced biologic/biomimetic materials may be associated with a trend towards reduction of prosthetic suppurative complications compared to synthetic materials (Fig. 58.1 and Tables 58.1 and 58.2).

Biomimesis as Preservation of Structure and Function

Biomimetic reconstruction of the chest wall relies on a few fundamental principles, such as respect of the anatomy, preservation of function, selection of adequate reconstructive materials, and integration of multidisciplinary efforts [2]. For relatively limited chest wall defects, the pursuit of biomimesis is usually not a problem. Conversely, the issue of covering extensive defects while restoring osteomuscular continuity and protecting inner viscera becomes a challenging one, especially in the event of multiple reoperations and infected or previously irradiated surgical sites

Table 58.1 Dataset from 14 papers on materials used for chest wall reconstruction (7 synthetic and 7 biologic)

Studies	Total synthetic	Events synthetic	Total biologic	Events biologic
Weyant et al. [13]	262	20	32	5
Puviani et al. [3]				
Lans et al. [9]	229	22	25	3
Miller et al. [5]				
Mansour et al. [10]	200	19	24	1
Fabre et al. [15]				
Deschamps et al. [6]	197	9	11	0
Berthet et al. [12]				
Girotti et al. [14]	101	13	10	3
Ge et al. [7]				
Koppert et al. [8]	68	12	9	0
Wiegmann et al. [11]				
Kachroo et al. [16]	51	3	6	0
Barua et al. [4]				

Table 58.2 Effect-equality (heterogeneity) test for synthetic and biological materials data. The heterogeneity test is added to verify reliability of meta-analysis. Heterogeneity is established when the Q value divided by N (number of studies) −1 equals >1 and the p value is >0.05

Outcome	Cochran's Q	DF	Probability level
Odds ratio	3.4612	6	0.7491
Risk ratio	4.8987	6	0.5569
Risk difference	5.0390	6	0.5388

[2]. Ideally, appropriate reconstructive materials need to adapt to the chest wall geometry while conferring structural stability and be easily incorporated by the host [2]. Although not all defects need to be covered, it is advisable to always avoid lung herniation and scapular impingement [2].

Reconstructive Strategy

Besides the size of the chest wall defect and the condition of the area to be resected, the reconstructive options can also be dictated by its location and the contemplated use of synthetic and biologic materials alone or in combination [1, 2]. For lateral defects, titanium plates or polypropylene/polytetrafluoroethylene (PTFE) meshes are used when only one rib is removed and local anatomy mandates reconstruction; for larger defects, polytetrafluoroethylene (PTFE) patches or titanium plates can be used [12]. In the event of reoperations or in infected or heavily irradiated areas, the utilization of patches of acellular collagen matrix (ACM) may be preferred due to the characteristics of this material facilitating incorporation and resilience to infection [17]. If titanium plates are used, these need to be separated from the overlying myocutaneous layers with a rebsorbable (i.e., polyglactin) mesh to avoid friction [18]. For posterior chest wall defects, coverage may not be needed. However, patients may perceive the development of seroma as a sign of chest wall instability and an indication of an unsatisfactory postoperative outcome. This minor complication can be easily prevented by use a synthetic mesh to close the defect. For larger defects, the choice of the reconstructive material should include consideration of non-rigid, rather laminar coverage in consideration of the pressure that occurs in this region when the patient is in a recumbent position [4, 19]. A special clinical scenario is encountered when concurrent vertebral resections are required. In this context, ACM patches, due to the intrinsic biologic characteristics, confer the necessary stability and protect the exposed spine against wound infection [19].

Anterior chest wall defects mandate a reconstructive strategy primarily aimed at avoiding flail chest physiology and lung herniation. As a result, rigid materials are advocated [13, 14]. For defects resulting from the removal of one anterolateral rib segment, a non-absorbable mesh or a single titanium plate usually suffices [2]. By contrast, larger defects may require biomimetic reconstruction by restoring the intercostal space structure. To this end, the combination of titanium plates (ratio 1:2 with the removed ribs) and ACM or PTFE patches has been described, also in reoperations [12, 15, 20, 21].

When a sternal resection becomes also necessary, reconstruction with biologic materials is gaining increasing favor among surgeons [21–23]. In this setting, cryopreserved homograft material can serve as sternal replacement alone or in combination with synthetic composites [20]. In addition, titanium plates to bridge the defect and ACM or omentum to protect the mediastinum represent a reasonable alternative to PTFE or methylmethacrylate (MMM) sandwiches especially for reoperations [12, 13, 15, 23, 24].

Evidence Supporting the Use of Synthetic Materials

Synthetic materials include a wide range of time-honored composites that have been utilized for chest wall reconstruction for decades [2]. Polypropylene or polyglactin meshes and methylmethacrylate sandwich along with PTFE patches represent materials which maintain their integrity either alone or in combination with biologic prostheses [2, 10, 22, 24]. Following reconstruction with synthetic meshes, postoperative morbidity rates in terms of infection of the surgical site range between 4.6 and 23 % [1]. Local wound complications mandate removal of the reconstructive material in between 1.6 and 13 %, with an average around 7 % [1]. Lans and colleagues reported their experience with synthetic reconstruction of the chest wall yielding suppurative complications in 50 patients out of 75 developing moderate to severe complications [9]. As to residual pulmonary function, no differences between preoperative and postoperative FEV1 (forced expiratory volume at 1 s) irrespective of the associated lung resection, were noted after using MMM for reconstruction [24].

Evidence Supporting the Use of Biologic Materials

Biologic materials include mainly cryopreserved homografts and acellular collagen matrix patches [1, 2]. The main features of biologic materials include remarkable strength and user friendliness, along with easy incorporation into the host irrespective of the primary condition of the resected area (e.g., infection) [1, 2].

In spite of being synthetic, titanium plates behave as biologic composites due to the resistance to infection and the possibility to be utilized in heavily irradiated fields alone or as a support for biological or synthetic meshes [1, 2] . Cryopreserved homografts have been used by pediatric and plastic surgeons especially as sternal replacements [20]. Cadaveric sternum, iliac crest, ribs, and fascia lata have all been described to typically cover anterolateral chest wall defects [1–3, 18]. After harvesting, the bony segments undergo cryopreservation at −70 °C for at least 3 months to reduce antigenicity [18]. Implantation can be done directly or accompanied by the provision of a vascularized bed (i.e., omental flap) which revascularizes the graft, thus facilitating incorporation into the host [18]. Postoperatively, neither immunosuppressors nor steroids are used [18].

Acellular collagen matrix (ACM) patches are either human, bovine or porcine derivatives which have been implanted to cover chest wall defects originated by costovertebral, sternocostal and simple rib resections [25, 26]. These tissue patches are ready to use, do not complicate major intraoperative handling and they behave as autologous materials. A major limitation in the use of ACM patches is still represented by their cost, ranging from $ 1,750 to $ 15,000 for the largest size patches [1].

Conclusions

The intuitive concept of added usefulness of biologic compared to synthetic materials for chest wall reconstruction may be further substantiated by future studies and the availability of mature results from ongoing surgical experiences. The use of acellular collagen matrix patches alone or in combination with cryopreserved homografts and titanium plates represent today a valid theoretical alternative to time honored synthetic materials for chest wall reconstructions for previously irradiated and/or infected areas. However, refinement of indications is imperative, especially in light of the significant costs related to the use of such biologic/biomimetic composites.

Recommendations

In summary, biologic/biomimetic materials are preferred to synthetic materials due to their easy incorporation into the host and resilience to infection. Hence, these materials should be the first reconstructive choice when the resected area is infected or has been heavily irradiated.

A Personal View of the Data

Between January 2005 and May 2013, 111 procedures were done at the Division of Thoracic Surgery of the National Cancer Institute in Naples to remove chest wall tumors. In 31 % of the cases, chest wall reconstruction was accomplished through biomaterials recently introduced in the clinical practice used alone or in combination also with time-honored composites. We used titanium plates, acellular collagen matrices and cryopreserved homografts to cover extensive defects during redo operations or after heavy irradiation or localized infection. In our opinion, cost effectiveness of biomaterials is particularly advantageous for these indications to bail thoracic surgeons out of at times extremely challenging clinical scenarios.

Recommendation

- Biological materials are preferred to synthetic materials for chest wall construction, especially in patients in whom the target area is infected or has been irradiated. (Evidence quality very low; weak recommendation)

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