Five-year experience with titanium mesh for rigid chest wall reconstruction

Sadia Tasnim, MD, John O. Barron, MD, Siva Raja, MD, PhD, Sudish C. Murthy, MD, PhD, and Daniel P. Raymond, MD

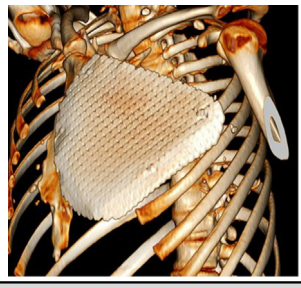
ABSTRACT

Objective: To characterize the performance of titanium mesh (TM) (off-label) for rigid chest wall reconstruction at a single institution over a 5-year period.

Methods: Between January 1, 2019, and May 15, 2023, 22 patients (median age, 61 years) underwent chest wall resection with TM reconstruction at Cleveland Clinic. Indications for resection included sarcoma (n = 15), breast cancer (n = 2), lung cancer (n = 2), chondroblastoma (n = 1), and benign neoplasm (n = 2). Patients were followed every 6 months with computed tomography scans for cancer recurrence. Continuous variables are summarized as median (interquartile range [IQR]); categorical variables, as frequency and percentage. Time to mesh fracture was assessed nonparametrically using Kaplan-Meier analysis.

Results: Among the 22 patients over 21,870 patient-days of TM implantation, 21 (95%) had an R0 resection. The mean area of mesh coverage was 108 cm^2 (IQR, 97-180 cm^2). No patient experienced respiratory complications or mesh failure postoperatively. Of the 3 reoperations (13.6%), 2 were for delayed regional infection (at 7 and 12 months postoperatively), necessitating localized mesh removal, and the third was for local cancer recurrence. Fifteen implants developed visible fractures on imaging at a median time of 9 months after implantation. There were no adverse sequelae, including migration/erosion or clinical decline in respiratory function.

Conclusions: Chest wall resections, particularly those for sarcomas, require large margins for optimal oncologic outcomes. Rigid reconstruction of large defects is desirable, yet options are limited. TM reconstruction provides a promising alternative because of its biocompatibility, rigidity, robust incorporation into surrounding structures, and resistance to infection. (JTCVS Techniques 2024;28:180-90)



Three-dimensional computed tomography scan of chest wall reconstruction using titanium mesh.

CENTRAL MESSAGE

Titanium mesh is a promising option for chest wall reconstruction because of its rigidity, adaptability, biocompatibility, and robust incorporation into surrounding tissue, enhancing infection resistance.

PERSPECTIVE

Chest wall resections, particularly those for sarcomas, require large margins for optimal oncologic outcomes. Rigid reconstruction of such large defects is desirable to assist respiratory mechanics and maintain thoracic integrity, yet options are limited. Identifying a prosthetic material that satisfies these requirements is imperative.

See Discussion on page 191.

To view the AATS Annual Meeting Webcast, see the URL next to the webcast thumbnail.

Chest wall resections, particularly those for sarcomas, require large margins for optimal oncologic outcomes,[1] and thus reconstruction of these large chest wall defects is technically challenging. Most surgeons agree that chest wall defects >4 cm and >3 rib resections merit reconstruction.[2,3] Several aspects must be considered while planning reconstruction, including restoration of chest wall function, prevention of lung herniation and scapular entrapment, and cosmesis.[4] Commonly used modalities include synthetic mesh (polytetrafluoroethylene [PTFE], polypropylene

From the Department of Thoracic and Cardiovascular Surgery, Cleveland Clinic, Cleveland, Ohio.

Read at the 104th Annual Meeting of The American Association for Thoracic Surgery, Toronto, Ontario, Canada, April 27-30, 2024.

Received for publication April 19, 2024; revisions received July 17, 2024; accepted for publication Aug 19, 2024; available ahead of print Sept 3, 2024.

Address for reprints: Daniel P. Raymond, MD, Department of Thoracic and Cardiovascular Surgery, Cleveland Clinic, 9500 Euclid Ave, Cleveland, OH 44195 (E-mail: raymond3@ccf.org).

2666-2507

https://doi.org/10.1016/j.xjtc.2024.08.016

Abbreviations and Acronyms
3D = 3-dimensional
IQR = interquartile range
MMA = methyl methacrylate
PTFE = polytetrafluoroethylene
TM = titanium mesh

[Prolene], polyglactin [Vicryl]), cryopreserved homogenous or allogeneic bone grafts, methyl methacrylate (MMA) "Marlex sandwich," and metal plates and prostheses.

Titanium mesh (TM) has been available for use for roughly 20 years in the United States, in which its primary uses have been in craniofacial applications, including orbital wall[5] and cranial[6] reconstruction. In other countries, TM has been used for chest wall reconstruction.[7-9] To date, few studies have looked at the outcomes of chest wall reconstruction using TM. Here we characterize the outcomes of our chest wall reconstructions with the off-label use of TM.

METHODS

Patients

Between January 1, 2019, and May 15, 2023, 22 patients underwent chest wall reconstruction using TM at Cleveland Clinic. Patient demographics and preoperative, operative, and postoperative details were extracted from the Society of Thoracic Surgeons quality registry and medical records. Type and grade of neoplasms were obtained from either preoperative biopsy or final pathology. Specimen size served as a surrogate for defect size, which was not consistently reported in operative notes. The project and use of data for research were approved by Cleveland Clinic's Institutional Review Board (23-855, on August 23, 2023), with a waiver of individual patient consent.

Surgical Technique

A double-lumen endotracheal tube is preferred for intubation. Location of the mass and tumor characteristics determine the extent of the incision and the soft tissue defect. Video-assisted thoracoscopy is often used to characterize the internal anatomy and exclude pleural dissemination. After oncologic resection of the primary tumor, specimen margins are assessed with frozen sections as indicated, and defect size is measured. Cryoablation can be performed here for analgesia if planned. A template is created using a sheet of plastic (obtained from the plastic tray in sterile sets) to overlap defect edges by 1 to 2 cm. The template is then used to cut the TM, and sharp ends are trimmed. A portion of suction tubing is incised longitudinally and wrapped around the mesh edge as a gasket to aid mesh placement in the defect. The mesh is then shaped appropriately to the chest wall and transposed appropriately into the defect, and the gasket is removed. TM is secured using screws to the ribs, sternum, and spine based on the location of the defect. Placing the edge of the mesh in proximity to any vascular structure or abdominal contents is avoided, the general rule being not above the second rib, under the scapula, or along the costal margin. Hybrid repairs using a combination of titanium and polypropylene can be used in such circumstances. The number of anchoring screws varies from case to case at the discretion of the surgeon, although our preference is to use as few as possible to ensure the shape and position of the mesh along the chest contour.

Ideally, the rigid reconstruction is covered by a rotational or free muscle flap based on the defect size. It is important to plan such maneuvers carefully with plastic surgery colleagues to ensure appropriate coverage. Previous surgery and interruption of the mammary vessels can significantly impact flap choices. Among the many available options, a latissimus dorsi flap, a pectoralis flap, and the vertical rectus abdominus muscle are the most frequently used.

Statistical Analysis

All analyses were performed using SAS version 9.4 (SAS Institute) and RStudio 4.3.2. Continuous variables are summarized as median (interquartile range [IQR]); categorical variables, as frequency and percentage. Implant time is calculated as the number of days from the day of surgery to the last day of follow-up for all patients. The time to mesh fracture was assessed nonparametrically using Kaplan-Meier analysis and recorded with a 95% confidence interval.

RESULTS

Patient Characteristics

Of the 22 patients, 15 (68%) were female. Most patients (64%) were fully active, with an Eastern Cooperative Oncology Group Performance Status of 0. The most common reason for resection was sarcoma (n = 15; 68%), followed by lung (n = 2; 9%) and breast (n = 2; 9%) cancers (Table 1). Only 3 patients had previous chest wall radiation, and 2 patients had previous chest wall surgery. Patients received preoperative chemotherapy and radiation therapy depending on their type and stage of cancer, as delineated by the multidisciplinary tumor board.

Operative Characteristics

The median operative time was 4.5 hours (IQR, 2-7 hours) (Table 2). Three patients had spine involvement necessitating intervention. One patient underwent resection of the posterior spinal elements from T7-11, along with ligation of T8-10 nerve roots. A second patient underwent resection of 4 transverse processes along with 4 ribs. The third patient underwent resection of posterior spinal elements from T3-9 and ligation of T4-7 nerve roots. Two patients had scapula covering 5% and 15% of the defect. Twenty-one patients (95%) had an R0 resection. Operative details for each patient are provided in Table 3.

Postoperative Analgesia

Most patients had an epidural placed preoperatively (n = 15; 68%). The median time to epidural removal was 4 days. Cryoablation was used in 5 patients (23%). Patients were on multimodal pain control both in the hospital and after discharge.

Mesh Outcomes

There were no "mesh failures," defined as the complete removal of the entire TM or evidence of herniation-related failure. Mesh fracture occurred in 15 patients (68%), at a median of 9 months (IQR, 3-31 months) after surgery (Figure 1). Figure 2, *A* shows an intact mesh fixed

TABLE 1. Preoperative characteristics

Characteristic		Evaluable patients	Value
Age (y)		22	61 (32-70)
Female sex, n (%)		22	15 (68)
Race, n (%)		22	
Caucasian			18 (82)
African American			2 (9)
ECOG score, n (%)		22	
0			14 (64)
1			6 (27)
2			2 (9)
Ever smoker, n (%)		22	11 (50)
Comorbidities, n (%)*		22	
Hypertension			11 (50)
Congestive heart failure			2 (9)
Coronary artery disease			3 (14)
Chronic obstructive pulmonary disease			4 (19)
Pulmonary hypertension			2 (9)
Body mass index, median (IQR)		22	26 (24-29)
Previous thoracic cancer, n (%)		22	
Breast			5 (83)
Liposarcoma			1 (17)
Type of current neoplasm, n (%)	Grade	22	
Breast			2 (9)
	1		1 (4.5)
	3		1 (4.5)
Chondroblastoma	1		1 (4.5)
Giant cell tumor	NA		1 (4.5)
Lung			2 (9)
Adenocarcinoma	NA		1 (4.5)
Pleomorphic/sarcomatoid	3		1 (4.5)
Schwannoma			1 (4.5)
Sarcoma			15 (38)
Chondrosarcoma			3 (14)
	1		1 (4.5)
	2		2 (9)
Ewing sarcoma			2 (9)
	3		1 (4.5)
	NA		1 (4.5)
Osteosarcoma			2 (9)
	3		1 (4.5)
	NA		1 (4.5)
Pleomorphic	3		2 (9)
Spindle cell	3		1 (4.5)
Synovial	3		1 (4.5)
Other			4 (19)
	2		1 (4.5)
	3		1 (4.5)
	NA		2 (9)
Tumor location, n (%)		22	
Anterior (involving sternum)			7 (32)
Lateral (only ribs)			12 (54)
Posterior (involving spine)			3 (14)
Scapula covering defect, n (%)		22	2 (9)
Previous chest wall, n (%)		22	
Radiation			3 (14)
Surgery			2 (10)
Induction		22	
Chemotherapy			6 (27)
Radiotherapy			7 (32)

ECOG, Eastern Cooperative Oncology Group; *NA*, not available. *According to the Society for Thoracic Surgeons definition.

with 5 screws at a 4-month follow-up, and Figure 2, *B* shows a fractured mesh that was fixed with 19 screws at a 3-month follow-up. Figure 3, *A* shows the progression of mesh fracture in a patient with an orthotopic heart transplant fixed with 22 screws, and Figure 3, *B* shows the progression of mesh fracture in another patient fixed with only 6 screws. Five patients developed soft tissue infections within proximity of the mesh during the entire study period, including 2 with mesh involvement. Only 1 patient developed an infection within 30 days; the remaining 4 infections occurred after 1 year. The postoperative soft tissue infection rate in our series was 4.5%, with the single case occurring in a patient without flap coverage. Of the 2 patients with mesh infections, 1 patient developed a pectoralis muscle hematoma at 7 months after surgery during adjuvant therapy, necessitating embolization of the bleeding vessel, followed by the development of an abscess. He underwent abscess debridement with trimming of the edge of the TM and complete removal of the polypropylene mesh without further reconstruction. The second patient developed flap necrosis at the distal end necessitating flap debridement at 7 days after surgery. One year later, a draining sinus was detected in the axilla tracking to the cystic cavity at the edge of the TM, which was trimmed by 1 cm along with debridement of the sinus tract and cystic cavity. Both patients recovered without complications and continued to retain their TM implants with sustained chest wall function (Table E1).

Postoperative and Long-Term Outcomes

One patient developed pleural effusion with no significant clinical sequelae. There were no episodes of pneumonia, reintubation, or respiratory failure during this patient's postoperative stay. One patient was readmitted for pneumonia several years later for treatment of cancer metastasis to the lung and subsequently died from

TABLE 2. Operative and postoperative characteristics

Characteristic	Evaluable patients	Value
Operative time, min, median (IQR)	22	270 (156-399)
Number of excised ribs, median (IQR)	22	3 (3-4)
Area of defect (cm^2)	22	108 (97-180)
Margins, n (%)	22	
R0		21 (95)
R1		1 (5)
Grade, n (%)	22	
1		3 (13.5)
2		3 (13.5)
3		9 (41)
X		7 (32)
Epidural placement, n (%)	22	15 (68)
Time to epidural discontinuation, d, median (IQR)	15	4 (2-4)
Intercostal cryotherapy, n (%)	22	5 (23)
Length of stay, d, median (IQR)	22	5 (4-6)
Mesh fracture, n (%)	22	15 (68)
Time to mesh fracture, mo, median (IQR)	15	9 (5.6-13)
Mesh movement, n (%)	22	1 (5)
Soft tissue infection (30 d), n (%)	22	1 (4.5)
Soft tissue infection (total implant time), n (%)	22	5 (23)
Mesh infection (total implant time), n (%)	22	2 (9)
In-hospital respiratory complications, n (%)	22	1 (5)
Pneumonia		0 (0)
Pleural effusion		1 (5)
Respiratory failure		0 (0)
Reintubation		0 (0)
Reoperation, n (%)	22	3 (14)
Chest wall abscess drainage		1 (4.5)
Muscle flap necrosis resection		1 (4.5)
Resection for recurrence		1 (4.5)
Readmission, n (%)	22	6 (27)
Surgical site infection		1 (5)
Muscle flap infection		1 (5)
Reoperation		3 (14)
Pneumonia		1 (5)
Recurrence of cancer, n (%)	22	3 (14)
Follow-up, mo, median (IQR)	22	29 (21-48)
Mortality, n (%)	22	2 (9)

metastatic disease. Another patient died from cancer recurrence several years later. Three patients underwent reoperations, 2 of them for infections as described above. The third patient underwent resection for local cancer recurrence at the edge of the mesh. A small portion of the mesh was excised to obtain an appropriate margin, and most of the prosthesis was preserved.

Follow-up

Patients were followed according to National Comprehensive Cancer Network guidelines for their respective cancers with computed tomography scans to check for cancer recurrence, mesh fracture, migration, and other complications. The median follow-up was 29 months (IQR, 8-65 months). At the time of this report, the cumulative implant time was 21,870 patient-days. Study results are summarized in Figure 4.

DISCUSSION

Principle Findings

Chest wall reconstruction with TM carries a low incidence of mesh infection while maintaining adequate chest wall volume and respiratory mechanics. No mesh failure or organ herniation was noted, but mesh fracture was observed with no adverse sequelae in the short term.

TM: Unique Characteristics and Comparison to Other Prosthetics

Chest wall reconstruction requires restoration of chest wall function, but options are limited. Rigidity, malleability, inertness, and radiolucency are desired properties of an ideal prosthetic material.[10] Rigidity allows for stability of the chest wall reconstruction and negative-pressure ventilation. Malleability permits structural adaptation to the anatomic location where it is being placed. Inertness alludes to incorporation or assimilation of the prosthetic material into surrounding structures and infection resistance, and radiolucency allows for radiologic monitoring. Table 4 outlines the characteristics and cost of materials available for reconstruction. We chose TM because of its favorable profile for the repair of large chest wall defects.

Resistance to infection, likely due to rapid and extensive incorporation and liberal use of flap coverage is a promising characteristic of TM. Favorable outcomes have been reported with the use of TM in the chest wall.[7,8] An Italian study of 26 patients reported only 1 infection with preservation of the prosthesis.[8] In our experience, local procedures, such as "wide local excision" by removing all infected material and including a margin of the incorporated mesh, were successful in managing infection. The mesh was exposed using a PlasmaJet (Plasma Surgical) or an argon plasma coagulator and then elevated off the underlying tissue with a Cobb elevator and divided.

Comparison to Synthetic Mesh

The use of Prolene mesh or PTFE mesh in chest wall reconstruction has shown no differences in short- and long-term outcomes. Although these mesh materials are

TABLE 3. Description of patients with titanium mesh reconstruction

Age at surgery, y	Sex	Indication	Location of the defect*	Defect size, cm	Number of ribs resected	Number of screws placed	Any other mesh	Type of muscle flap	Fracture of mesh	Time to fracture, mo	Soft tissue infection	Mesh infection	Mesh removal	Implant time, mo
72	F	BC	1	12.5 × 9	2	4		TRAM	No		Yes	No	No	24
69	F	SC	2	17 × 11.6	5	22	P	LDF	Yes	9	No	No	No	61
45	F	SC	1	18.3 × 15.7	5	9		TRAM	Yes	6	Yes	Yes	Yes	20
29	F	BN	2	12.2 × 5.5	2	5			No		No	No	No	10
61	F	SC	2	19.5 × 14.6	5	5	P	LDF, SAF	No		No	No	No	8
42	F	SC	2	12 × 9.3	3	2			Yes	9	No	No	No	25
64	F	SC	2	10.5 × 9.5	3	5			No		No	No	No	18
71	F	SC	1	15 × 12	3	2		LDF	Yes	9	No	No	No	26
78	M	SC	1	11 × 9.5	3	2	P	PF	Yes	9	No	No	No	25
76	F	BC	1	12.3 × 8	4	3		PF	No		Yes	No	No	24
23	M	BN	2	10 × 7.5	1	2			No		No	No	No	12
70	F	SC	2	17 × 13	3	5	P		No		No	No	No	33
66	F	SC	2	22.5 × 22	6	2	P	LDF, PF, SAF	Yes	4	No	No	No	50
32	F	SC	1	12.8 × 12.2	8	1	P	FF, PF	Yes	14	No	No	No	65
19	M	SC	3	12.5 × 10.5	3	0	P		Yes	12	No	No	No	21
20	M	SC	2	10.5 × 6.5	1	19			Yes	3	No	No	No	59
71	F	SC	3	13 × 10	4	22		LDF, SAF, TF, PSF	Yes	6	No	No	No	37
42	F	LC	2	6 × 2.5	3	6	P		Yes	23	Yes	No	No	40
67	M	LC	2	12 × 8.5	3	4	P		Yes	31	Yes	Yes	Yes	48
26	M	SC	2	12.9 × 7.5	3	5	P		Yes	4	No	No	No	44
37	F	SC	3	8.5 × 8	4	3	P	LDF	Yes	13	No	No	No	38
61	M	SC	1	11.5 × 9	3	5	P	TRAM, PF, LDF	Yes	8	No	No	No	61

BC, Breast cancer; *TRAM*, transverse rectus abdominus muscle; *SC*, sarcoma; *P*, polypropylene mesh; *LDF*, latissimus dorsi flap; *BN*, benign neoplasm (schwannoma, giant cell tumor); *SAF*, serratus anterior flap; *PF*, pectoralis flap; *FF*, free flap; *TF*, trapezius flap; *PSF*, paraspinous flap; *LC*, lung cancer. *1, anterior (sternum involved); 2, lateral (only ribs); 3, posterior (involves spine).

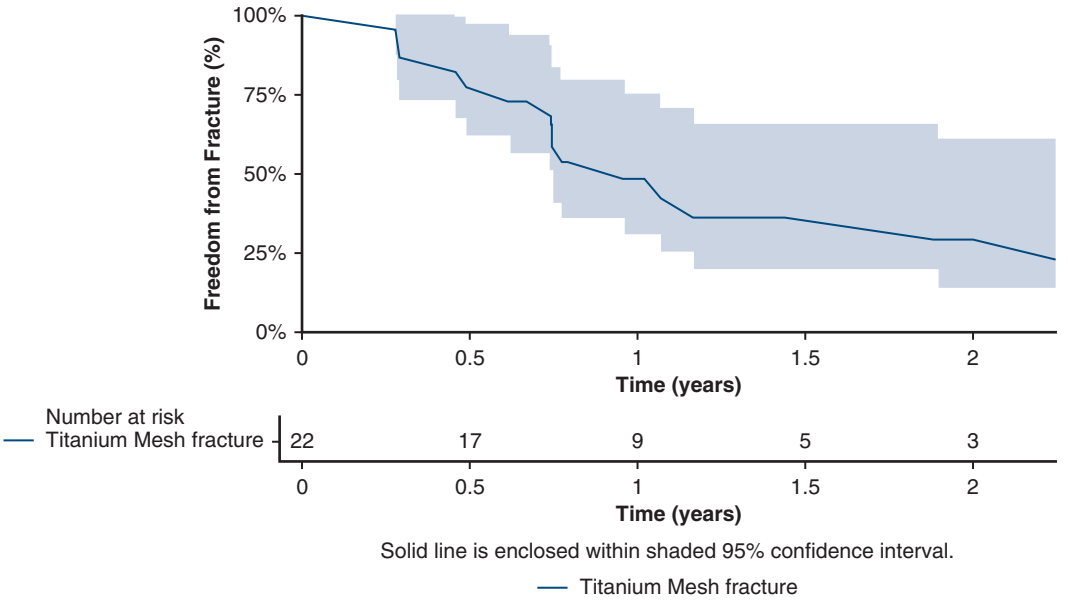


FIGURE 1. Time to mesh fracture. The *solid line* is enclosed within its shaded 95% confidence interval.

easy to place and durable, they are not rigid and cannot effectively recreate the contour of the chest wall. Nonrigid chest wall reconstruction is associated with a high rate of pulmonary complications (36%).[11] This can become challenging when repairing large defects, where a flat closure can lead to volume loss and cardiac compression if the defect is in the left anterior chest. Furthermore, PTFE has poor incorporation into surrounding tissues, resulting in susceptibility to seroma formation and long-standing infection, with an incidence of 10% to 25%, often necessitating complete removal.[2] We have removed infected PTFE at 20+ years after implantation.

Comparison to MMA

MMA, the more commonly used rigid reconstruction modality, has been available since 1980 (off-label application). MMA can be assembled and fixated relatively easily. It is applied between 2 polypropylene mesh layers intraoperatively, molded into the shape of the chest wall, and affixed to the remaining bony structures.[12,13] However, MMA

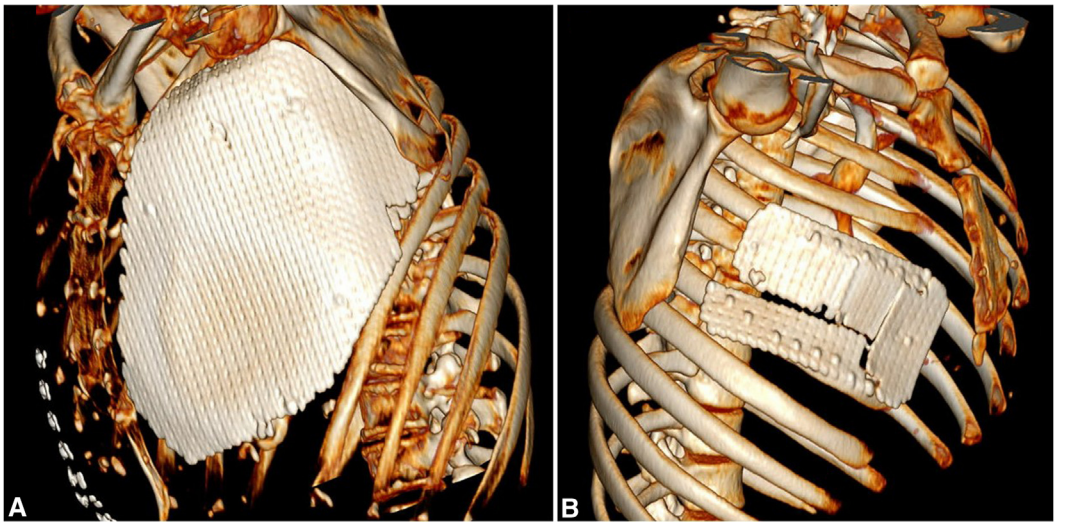


FIGURE 2. Three-dimensional computed tomography scan of chest wall reconstruction using 5 screws, at 4-month follow-up (A) and using 19 screws, at 3-month follow-up (B).

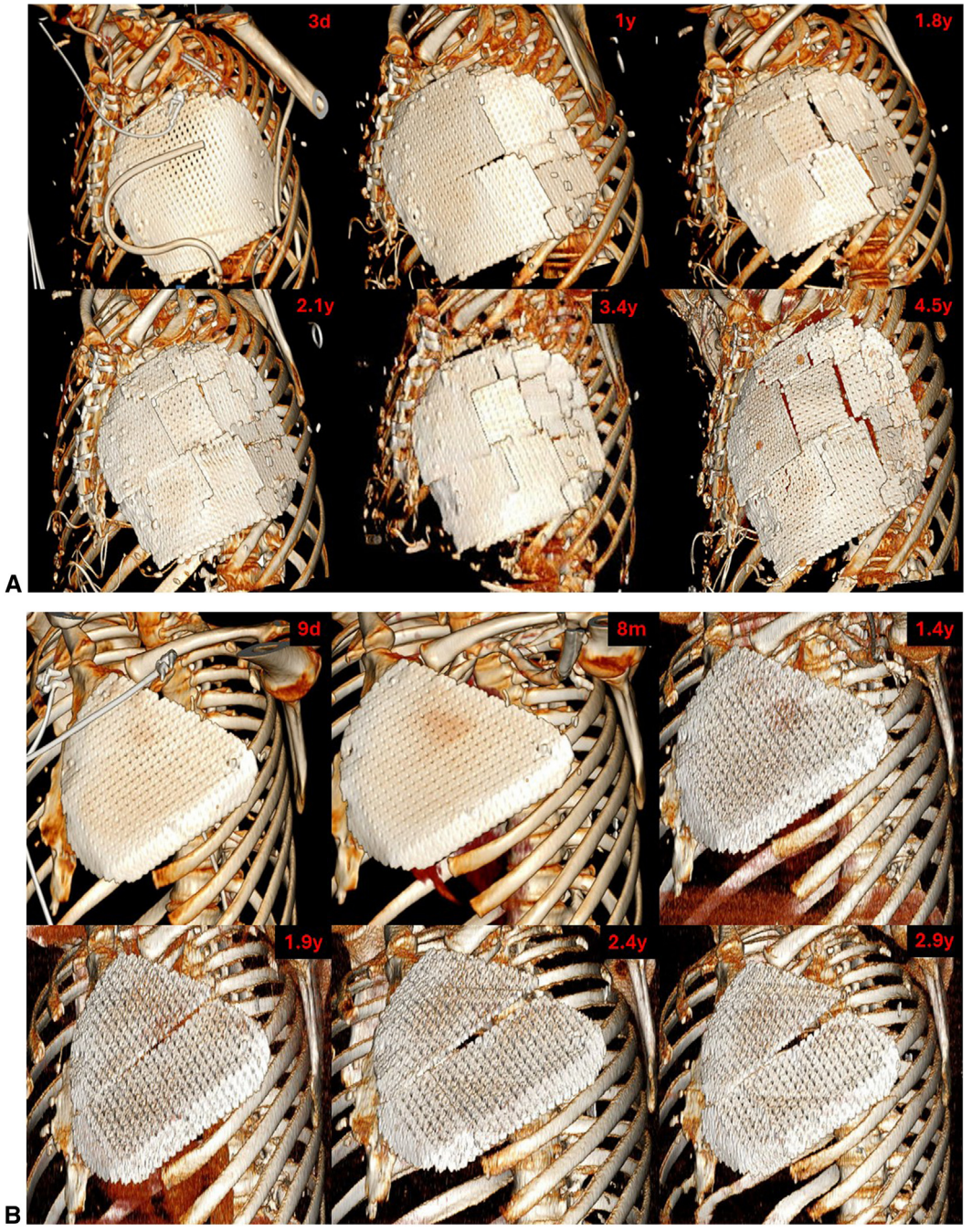


FIGURE 3. Evolution of mesh incorporation. A, Orthotopic heart transplant patient, fixed using 22 screws. B, Another patient, fixed using 6 screws.

is not permeable to fluids and does not incorporate well into surrounding tissue, thus predisposing to seroma formation, which can become a nidus for infection. The incidence of infection incidence with MMA can be up to 80%, with almost all cases necessitating complete removal.[2,14,15] MMA also is associated with an 8% rate of respiratory complications.[15] Notably, cracking rarely occurs with MMA constructs. We still prefer TM over MMA, as the robust incorporation and relative infection resistance prevent complete loss of the prosthesis, which can be debilitating with large defects.

Comparison to 3-Dimensional Printed Prostheses or Bone Grafts

Three-dimensional (3D)-printed prostheses are an additional option for rigid reconstruction. Cryopreserved homogenous or allogeneic bone grafts are other options for rigid reconstruction. Both are relatively early

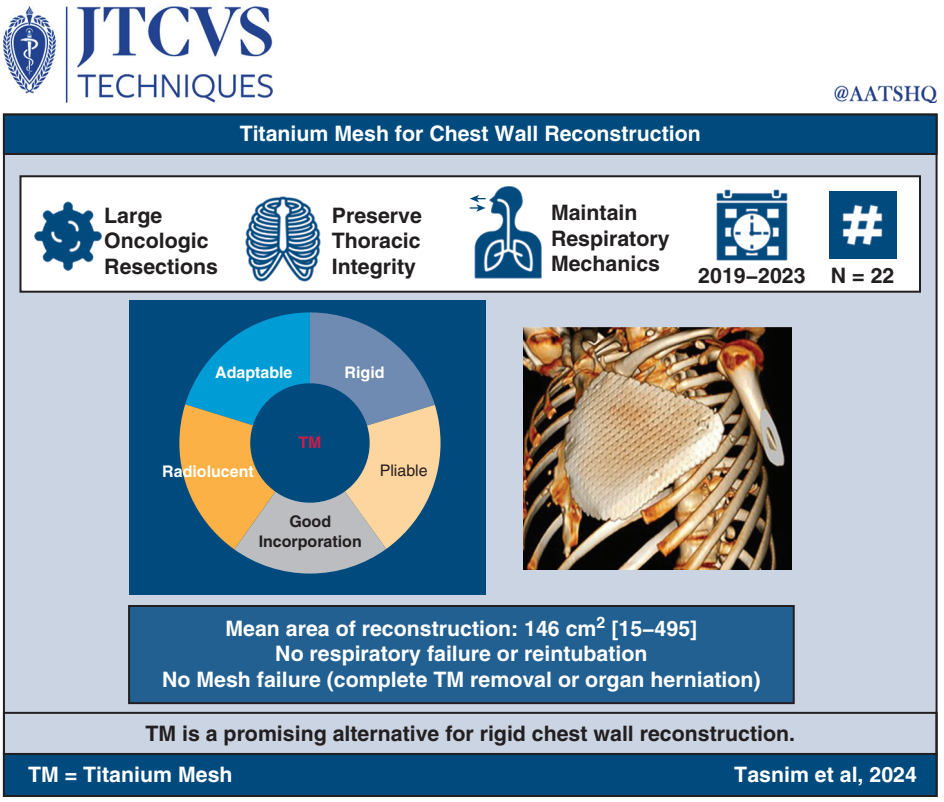


FIGURE 4. Titanium mesh is an effective and promising material for rigid chest wall reconstruction.

technologies that are used only rarely for various reasons, including technical challenges, cost, availability, need for extensive preplanning, inability to modify the prosthesis during the operation, and need to be printed or ordered ahead of time. An additional challenge is the creation of a durable prosthesis-to-rib interface. Little is known about the long-term durability and incorporation of 3D-printed prostheses.

Mesh Fractures

Mesh fracture was an unexpected finding during cancer surveillance. It occurred in 68% of patients, at a median of 9 months after reconstruction. The patients generally were not aware that it had occurred. There were occasional reports of positional crepitus. This had not led to any reinterventions or adjunctive therapies in 20,000+ patient-days of mesh implantation. We attribute this to rapid incorporation of the mesh into the chest wall to fix it in place. A high number of fixation points to the dynamic chest wall may speed this process. Capitalizing on rapid incorporation, we tried to minimize the number of anchoring points to allow the mesh some mobility in the dynamic chest wall. Figure 2 compares mesh fracture using a high number and a low number of fixation points. Figure 3 shows that a small mesh repair fixed with multiple screws can fracture earlier than a larger mesh fixed with fewer fixation points. In addition, once the mesh is placed into the soft tissue defect and the surrounding gasket is removed, the prosthesis becomes very difficult to manipulate because the edges catch the soft tissue. This further reinforces the importance of the ability to minimize the number of fixation points.

A single case effectively demonstrates the benefits of the TM prosthesis. A 69-year-old female (Table 3; patient 2) with a history of breast conservation therapy underwent

TABLE 4. Characteristics of different reconstruction materials

Material	Rigidity	Fixation	Durability	Incorporation	Cost
Polypropylene	+	+++	+++	+++	$
Polytetrafluoroethylene	+	+++	+++	+	$$
Methyl methacrylate	+++	++	+++	+	$
3D-printed prosthesis	+++	+	?	?	$$$
Titanium	++	++	++	+++	$$

3D, 3-dimensional.

an orthotopic heart transplant to treat ischemic cardiomyopathy. Her postoperative course was complicated by bilateral diaphragm dysfunction necessitating 2 L of oxygen supplementation on exertion (Eastern Cooperative Oncology Group Performance Status 2). Several years after her transplant, she underwent a completion mastectomy for recurrent breast cancer. She then developed a 7 cm radiation-induced left chest wall leiomyosarcoma and was treated with induction radiation before undergoing chest wall resection (17 cm × 11.6 cm) with 5 ribs. Her reconstruction included TM with a small additional area of polypropylene mesh. The prosthesis was covered with a rotational latissimus dorsi flap. She had an uncomplicated post-operative course and is now cured of her cancer (63 months disease-free). Her mesh fractured in 9 months with no serious complications such as mesh migration. Figure 3, *A* shows the progression of mesh fracture. In this case, rigid reconstruction was necessary due to defect size and location. The ability to shape the prosthesis permitted placement overlying the transplanted heart without compression while maintaining a rigid chest wall structure. Moreover, this was a lengthy and challenging procedure, and the patient was at a high risk for infection because of her immunosuppression and extensive radiation history. In this circumstance, infection resistance of the prosthesis was imperative and a significant reason for selecting TM, as she could not have tolerated prosthesis failure due to her lung function and defect size.

Limitations

Our sample size of 22 makes it difficult to draw any definitive conclusion about this novel technology. We could not perform any predictive or comparative statistical analysis. The retrospective nature of this study limits the generalizability of our findings. Our median follow-up of approximately 2.4 years and maximum follow-up of 5.4 years allowed us to make inferences only about short-term outcomes of TM reconstructions.

CONCLUSIONS AND FUTURE DIRECTIONS

TM is an effective but presently off-label material for rigid reconstruction of chest wall. Its favorable characteristics include rigidity, malleability, biologic compatibility, and dense incorporation. Metal fatigue leading to fracture of the mesh is a disadvantage of this material, which in our experience has not led to clinically significant sequelae, but rather suggests an opportunity for future prosthesis development.

Long-term follow-up is needed to assess the durability of this construct. Future study is required to determine whether alterations in technique—specifically, reducing the number of hard fixation points—may mitigate this process. Investigation into alternative means of fixation and alternative rigid materials that are more appropriate for a dynamic chest wall may bear fruit. Comparison to other studies is challenging, as patient populations are unique to each study based on the variable types being treated. Ideally, such comparison studies should be limited to one or similar types of cancer rather than a spectrum of cancer including indolent lesions and metastatic lesions. Creation of a consortium of high-volume centers performing chest wall resections may be the best means of studying chest wall reconstruction effectively.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://www.aats.org/resources/five-year-experience-with-tita-7116.

Conflict of Interest Statement

Dr Raymond is a development partner and invited speaker for KLS Martin and has an equity interest in Zimmer. All other authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

References

1. Abdel Rahman ARM, Rahouma M, Gaafar R, et al. Contributing factors to the outcome of primary malignant chest wall tumors. *J Thorac Dis*. 2017;9(12):5184-5193. https://doi.org/10.21037/jtd.2017.11.61
2. Sanna S, Brandolini J, Pardolesi A, et al. Materials and techniques in chest wall reconstruction: a review. *J Vis Surg*. 2017;3:95. https://doi.org/10.21037/jovs.2017.06.10
3. Seder CW, Rocco G. Chest wall reconstruction after extended resection. *J Thorac Dis*. 2016;8(suppl 11):S863-S871. https://doi.org/10.21037/jtd.2016.11.07
4. Suzuki K, Park BJ, Adusumilli PS, et al. Chest wall reconstruction using a methyl methacrylate neo-rib and mesh. *Ann Thorac Surg*. 2015;100(2):744-747. https://doi.org/10.1016/j.athoracsur.2015.02.127
5. He Q, Rao P, Wang L, Li Y, Fu G, Xiao J. Reconstruction of orbital wall fractures with superior orbital fissure syndrome using individualized preformed titanium mesh: a pilot study. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2023;135(1):24-32. https://doi.org/10.1016/j.oooo.2022.05.004
6. Yao S, Zhang Q, Mai Y, et al. Outcome and risk factors of complications after cranioplasty with polyetheretherketone and titanium mesh: a single-center retrospective study. *Front Neurol*. 2022;13:926436. https://doi.org/10.3389/fneur.2022.926436
7. Nedumaran B, Krishnasamy A, Mahalingam S, Ramasamy M, Kaliaperumal N. Primary intrathoracic synovial cell sarcoma requiring radical resection of the chest wall and diaphragm with reconstruction using titanium mesh. *Indian J Thorac Cardiovasc Surg*. 2022;38(6):644-647. https://doi.org/10.1007/s12055-022-01378-3
8. Tamburini N, Grossi W, Sanna S, et al. Chest wall reconstruction using a new titanium mesh: a multicenters experience. *J Thorac Dis*. 2019;11(8):3459-3466. https://doi.org/10.21037/jtd.2019.07.74
9. Garach NR, Kammar PS. Rare tumour of sternum: resection and reconstruction. *Indian J Med Res*. 2020;152(Suppl 1):S125. https://doi.org/10.4103/ijmr.IJMR_2205_19

10. le Roux BT, Shama DM. Resection of tumors of the chest wall. *Curr Probl Surg*. 1983;20(6):345-386. https://doi.org/10.1016/s0011-3840(83)80007-0
11. Corkum JP, Garvey PB, Baumann DP, et al. Reconstruction of massive chest wall defects: a 20-year experience. *J Plast Reconstr Aesthetic Surg*. 2020;73(6): 1091-1098. https://doi.org/10.1016/j.bjps.2020.02.010
12. Kużdżał J, Warmus J, Grochowski Z, Gądek A. Reconstruction of the sternal manubrium. *J Thorac Cardiovasc Surg*. 2014;147(6):1986-1988. https://doi.org/10.1016/j.jtcvs.2014.01.040
13. McCormack P, Bains MS, Beattie EJ Jr, Martini N. New trends in skeletal reconstruction after resection of chest wall tumors. *Ann Thorac Surg*. 1981;31(1): 45-52. https://doi.org/10.1016/s0003-4975(10)61315-x
14. Petrella F, Casiraghi M, Mariolo AV, Diotti C, Spaggiari L. Rigid prosthesis removal following chest wall resection and reconstruction for cancer. *Shanghai Chest*. 2018;2:64. https://doi.org/10.21037/shc.2018.08.02
15. Weyant MJ, Bains MS, Venkatraman E, et al. Results of chest wall resection and reconstruction with and without rigid prosthesis. *Ann Thorac Surg*. 2006;81(1): 279-285. https://doi.org/10.1016/j.athoracsur.2005.07.001

Key Words: chest wall reconstruction, titanium mesh, synthetic mesh

TABLE E1. Clavien-Dindo classification of complications (total implant time)

Complications	Clavien-Dindo grade	N (%)
Soft tissue infection (treated with antibiotics)	II	3 (13.6)
Soft tissue infection (needing surgical intervention)	III	2 (9)
Mesh infection	III	2 (9)
Pneumonia	II	0 (0)
Pleural effusion	I	1 (4.5)
Respiratory failure	IV	0