ORIGINAL ARTICLE

Early Outcomes of the Bird-cage Chest Wall Reconstruction in the Philippine General Hospital

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ABSTRACT

Objective. To describe the treatment outcomes of patients with chest wall tumors undergoing resection and Bird-cage chest wall reconstruction in the local setting.

Methods. Data were obtained from 13 patients who underwent chest wall resection and Bird-cage (methyl-methacrylate neo-rib, mesh, soft tissue, and skin) reconstruction in the Philippine General Hospital from January 2008 to September 2019. Demographics, operative procedures, 30-day operative morbidity, and mortality were evaluated using means and frequencies.

Results. We included 13 (77% female) patients with a mean age of 44.5 years. The most common indication for chest wall resection was recurrent neoplasm (5/13, 38.46%). The most extensive chest wall defect was 600 cm^2. The average length of ICU stay was 5.15 days, and two patients had prolonged intubation (>3 days). The graft infection rate was 38%, pneumonia 23%, and the operative mortality rate was zero.

Conclusion. Bird-cage reconstruction is a safe, reliable, and cheap method of providing rigid chest wall reconstruction for chest wall tumor resection.

Keywords: chest wall tumor, chest wall resection, bird-cage chest wall reconstruction

INTRODUCTION

Chest wall tumors account for <5% of all thoracic neoplasms, and 90% of these chest wall tumors are malignant. They commonly arise primarily from the chest wall's bones, tissues, and cartilage. Sometimes they may be metastatic from a distant primary or a contiguous spread of a malignant neoplasm nearby. Since tumor-free margin is the most important prognostic indicator for oncologic resections of primary chest wall malignancies, radical resections with at least a 2 cm margin are needed.[1] Thus, it is necessary to resect a tremendous amount of normal tissue to prevent recurrence and prolong patient survival. The challenge, however, is how to adequately reconstruct the chest wall to maintain its functions in respiratory mechanics and visceral protection.[2]

All over the world, skeletal stabilization after a significant chest wall resection for the tumor is achieved with different materials: autologous tissue, methyl-methacrylate mesh sandwich reconstruction, Gore-Tex, and titanium plates and screws. Traditionally, chest wall defects larger than 5 cm in maximum diameter should be reconstructed with rigid support to prevent flail chest, paradoxical breathing, and

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respiratory failure.[1] The Bird-cage reconstruction was used in this study. This technique entailed the use of methyl-methacrylate neo rib as the first layer, mesh as the second layer, soft tissue coverage as the third layer, and skin as the fourth layer. It is an easy and inexpensive alternative for reconstruction, especially in a developing country like the Philippines. This paper aimed to describe the outcomes in this single institution using the Bird-cage reconstruction in chest wall tumor resection.

Fornoulis et al. recently published their case series of 20 consecutive patients who underwent massive chest wall resection and reconstruction using a sandwich technique and dual-sided 2mm PTFE mesh. For anterior defects, they used a 1cm synthetic bone cement made of methyl methacrylate, sandwiched between two layers of polypropylene mesh, forming a rigid construction plate that was wired in four corners to the surrounding bony skeleton. For posterior defects, they used the dual-sided 2mm PTFE mesh fixed to the edges of the defect using polypropylene sutures resembling a drum membrane. In this study, the authors noted that poor survival was related to tumor size, histology, and inappropriate initial management by nonthoracic surgeons.[3]

Another technique used in chest wall reconstruction is the titanium rib bridge system, wherein titanium plates are wired to ribs or the sternum.[4] Berthet et al., in their series of 19 patients published in 2011, used a layer of PTFE 2mm thick shaped to match the defect, anchored to the defect using nonabsorbable sutures and fixed to the titanium plate which is inserted on the ribs. They used STRATOS horizontal rib osteosynthesis as rib replacement.[5] Using STRATOS allows a firm reconstruction with easier handling, and its flexibility prevents dead parietal spaces. The material is, however, costly.

However, there is no consensus on the preferred material or the best technique to stabilize and cover significant chest wall defects. We present a series of patients who underwent resection and what we like to call the Bird-cage reconstruction of the chest wall using methyl-methacrylate neo-ribs and Prolene mesh, and their short-term outcomes. The objectives of this study were to determine 1). the demographic characteristics of patients who underwent chest wall resection and Bird-cage reconstruction, 2). the indications for resection and reconstruction, 3). the technique of Bird-cage reconstruction, and 4). the reoperation, 30-day operative morbidity, and mortality rates.

MATERIALS AND METHODS

The study was a single-center, retrospective case series. All patients who underwent chest wall resection with Bird-cage reconstruction in the Philippine General Hospital (PGH) from January 2008 to September 2019 (end of data collection) were included.

Surgical Technique

The Bird-cage reconstruction technique entailed four layers of reconstruction.

The first layer was the methyl-methacrylate fashioned into neo-ribs. The neo-ribs were attached to the patient's remaining ribs or sternum (Figure 1).

The second layer was a Prolene mesh placed over the neo-ribs and anchored to the fascia at the borders of the chest wall defect (Figure 2).

The third layer of soft tissue and muscle flap was used to cover the rigid prosthesis (Figure 3).

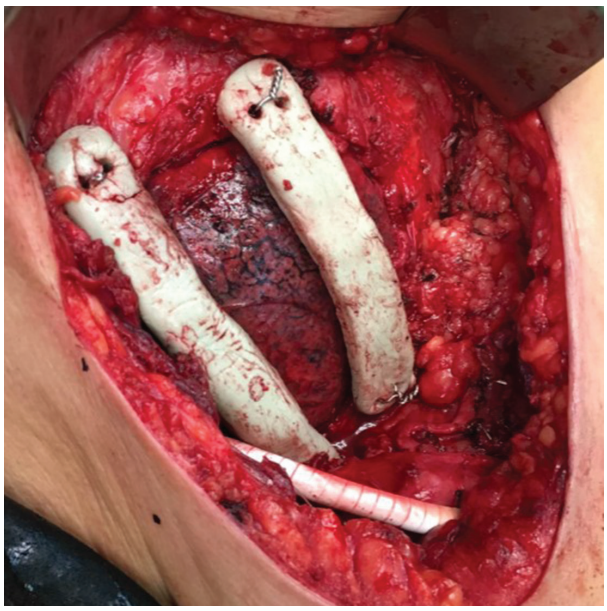

Figure 1. Methyl-methacrylate was fashioned into neo-ribs and wired to the remaining ribs and sternum.

Figure 2. Prolene mesh was placed over the neo-ribs and anchored to the fascia at the borders of the defect.

Figure 3. A muscle flap was mobilized to cover the neo-rib and mesh.

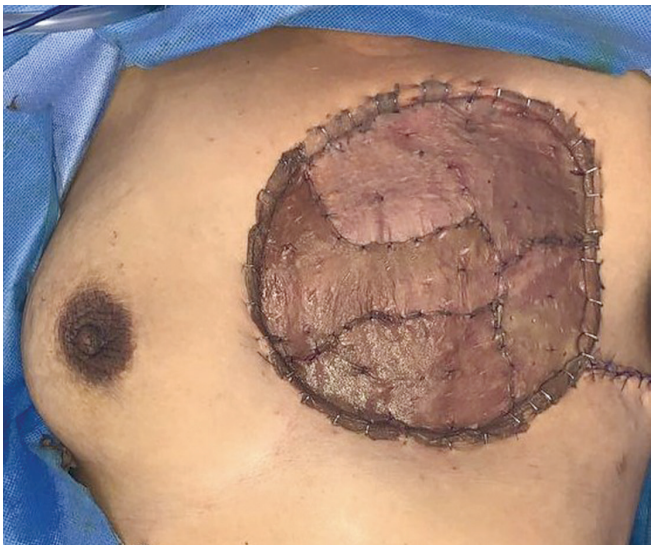

Figure 4. Skin graft was used to cover the muscle flap.

The fourth layer was with a split-thickness skin graft or primary skin closure (Figure 4).

A total of 13 patients were included in this study. The patient list was generated from the Department of Surgery database, Integrated Surgical Information System (ISIS). The following search terms were used: "chest wall resection," "rib resection," "sternectomy," "manubriectomy," and "rib reconstruction." The identified patients' hospital records were reviewed. The patients' demographic data profile, pre-operative and reconstructive factors, intraoperative records, and immediate postoperative course were detailed from their hospital charts.

Extubation time, length of ICU and hospital stay, and the duration of ventilator use were recorded. Reoperations, complications, and mortalities, and the corresponding causes, were also noted. After discharge, patients were asked to follow up with the cardiothoracic surgeon at least four weeks after the operation. The occurrence of major adverse cardiovascular or respiratory events at 30 days postoperatively was noted. From the data gathered, frequencies were noted. Operative morbidity, mortality, and reoperation rates were determined. Mean hospital stay, length of intubation time, and ICU stay in days were also computed.

The study protocol was approved by the University of the Philippines Manila Research Ethics Board.

RESULTS

Demographic profile and preoperative factors

Patients' demographic profiles and preoperative factors are shown in Table 1. A total of 13 patients underwent chest wall resection with Bird-cage reconstruction at the time of data collection. The mean age at the time of operation was 44.5 years. Of the thirteen patients, 10 (77%) were females.

Table 1. Demographic Profile and Preoperative Factors

Variable	Frequency	Percentage (%)
Age at operation		
≤40 years	4	30.8
>40 years but ≤65 years	9	69.2
>65 years	0	0.0
Sex		
Male	3	23.0
Female	10	77.0
Poor mobility		
Yes	3	23.1
No	10	76.9
Co-morbidities		
With		
Hypertension	1	7.6
Diabetes mellitus	1	7.6
COPD	0	0.0
Others	0	0.0
Without	12	92.3
Cardiac Function		
EF >55%	10	76.9
EF ≤55%	0	0.0
Not done	3	N/A
Post-radiation therapy		
Yes	4	30.7
No	9	69.2
Indications for chest wall resection *(N=13)*		
Primary neoplasm	3/13	23.08
Metastatic neoplasm	2/13	15.38
Direct extension	3/13	23.08
Recurrent neoplasm	5/13	38.46
Infection	0	0.0
Trauma	0	0.0

Table 2. Histopathology and Indication for Resection

Histopathology	Indication for resection
1. Ewing sarcoma	metastatic
2. Recurrent Synovial Sarcoma	recurrent
3. Soft tissue sarcoma	primary
4. Malignant Phyllodes tumor	direct chest wall extension
5. Malignant Phyllodes tumor	recurrent
6. Recurrent breast cancer	recurrent
7. Metastatic papillary thyroid carcinoma	metastatic
8. Chest wall sarcoma	primary
9. Chondrosarcoma	primary
10. Malignant Phyllodes tumor	direct chest wall extension
11. Borderline Phyllodes tumor	direct chest wall extension
12. Rhabdomyosarcoma	recurrent
13. Pleomorphic sarcoma	recurrent

Table 3. Reconstructive Factors

	Frequency	Percentage (%)
Condition of tumor		
Intact Skin	6	46.2
Infected	3	23.1
Ulcerated	4	30.7
Biggest size of mass *(widest diameter)*		
<10 cm	4	30.8
10-20 cm	8	61.5
>20 cm	1	7.7
Size of chest wall defect *(widest diameter)*		
<10 cm	3	23.0
10-20 cm	9	69.2
>20 cm	1	7.7
Number of ribs reconstructed with methyl-methacrylate		
One	4	30.8
Two	8	61.5
Three	1	7.7
Soft tissue coverage		
Primary closure	5	38.5
STSG (split thickness skin graft)	8	61.5
Muscle flap	13	100.0
Delayed reconstruction		
Yes	0	0.0
No	13	100.0

Table 4. Outcomes

	Frequency	Percentage (%)
Overall length of stay		
<7 days	1	7.7
7-14 days	5	38.5
>14 days	7	53.8
Postoperative length of stay		
<7 days	2	15.4
7-14 days	7	53.8
>14 days	4	30.8
ICU stay		
<3 days	4	30.8
3-7 days	7	53.8
>7 days	2	15.4
Length of ventilator use		
Zero	6	46.2
1-3 days	5	38.5
>3 days	2	15.3
Reoperation		
Yes	5	38.5
No	8	61.5
Complications		
Pneumonia	3	23.1
ARDS	0	0.0
Flap loss	3	23.1
Infection	5	38.46
Hematoma/Bleeding	0	0.0
Atrial fibrillation	0	0.0
Others	0	0.0
Mortality *(30 day)*		
Yes	0	0.0
No	13	100.0

Only one patient had comorbidities, namely: hypertension and diabetes mellitus. Ten patients underwent preoperative echocardiography; all ten had preserved systolic function, with an ejection fraction of >55%. Three patients had a history of poor mobility. Four patients had previous radiotherapy at the site of resection.

All 13 patients underwent preoperative biopsy. Table 2 shows the histopathology and indications for resection of the chest wall tumors. The most common indication for resection was recurrent neoplasm (5/13, 38.46%%). Three patients underwent resection for direct extension from other malignancies; three had primary chest wall tumors, while two had metastatic chest wall tumors.

Tumor Resection and Reconstruction

The reconstructive factors are listed in Table 3.

Six patients had tumors with the intact overlying skin, four had ulcerations, and three were grossly infected. The most extensive chest wall defect was 30 cm x 20 cm (600 cm^2). The same patient had the most number of ribs resected (n = 6) and the most reconstructed ribs (n = 3). The mean area of the chest wall defect was 164.53 cm^2. The most frequent number of ribs resected was 2 (n=8, 61.5%). All patients had R0 resection, confirmed by the final histopathologic report.

All patients underwent chest wall reconstruction for rigid, soft tissue, and skin coverage. In all rigid reconstructions, the Bird-cage technique was used.

The majority of patients had split-thickness skin grafting over the muscle flap (8/13, 61.5%), while the rest had primary skin closure (5/13, 38.5%). Only one patient had the sandwich (2-layer mesh and methyl-methacrylate neo-rib in between) technique for rigid reconstruction. The rest of the

12 patients had the one-layer Prolene mesh on top of the methyl-methacrylate neo-rib.

Outcomes

The treatment outcomes for the 13 patients enrolled in the study are summarized in Table 4.

Most (7/13) of the patients had a prolonged (more than 14 days) overall length of hospital stay. The average postoperative length of stay was 17.62 days. Most (7/13) had postoperative stays lasting between 7 and 14 days. Six (46.1%) patients were extubated in the operating room, while five were extubated the following day. Two patients remained intubated for more than three days, and these two patients had prolonged stays in the Intensive Care Unit (ICU), lasting more than seven days. They were treated for hospital-acquired pneumonia. The average length of stay in the ICU was 5.15 days. 30.8% (4/13) had a short stay in the ICU, while 53.8% (7/13) had 3-7 days stay. Most patients remained in the ICU to closely monitor the soft-tissue coverage. No 30-day operative mortality was reported among the patients in this study. The general morbidity rate of graft infection was 38.46% (5/13).

Five patients underwent reoperation for reconstruction site infection. Three of these patients had associated small graft or flap loss with exposed mesh, needing minor debridement and partial removal of the exposed mesh. The small raw areas post-debridement were left to granulate. Organisms isolated from all five patients were mixed gram-positive methicillin-resistant *Staphyloccocus aureus*, diphtheroids, and gram-negative *Pseudomonas aeruginosa* and *Klebsiella* pneumonia. In a subgroup analysis, four patients with infection or graft loss had preoperative tumors with ulceration and infection. Only 1 out of 4 preoperative radiotherapy patients had subsequent graft loss postoperatively in another subgroup analysis. Three (23.1%) patients were also treated for hospital-acquired pneumonia. Two of these patients had prolonged preoperative length of stay (more than seven days).

DISCUSSION

Extensive chest wall resection and reconstruction are challenging procedures requiring a multidisciplinary approach. Maintaining the integrity and stability of the chest wall is an important consideration when doing the reconstructive process. Without rigid support during chest wall reconstruction, a flail chest may occur, resulting in pulmonary complications like prolonged ventilatory support and pneumonia. The materials used for rigid reconstruction are titanium mesh, PTFE, and methyl-methacrylate. The use of titanium mesh as synthetic material for rigid reconstruction has been a reasonably new introduction. Most studies narrating their experience with the titanium mesh showed no reported infection and less than a 5% fracture rate.[6]

Yang et al. reported 27 patients who underwent titanium mesh to reconstruct massive chest wall defects following oncologic resection. There was no infection or chest wall instability noted in his series, and the operative mortality was zero.[7]

However, as an institution catering to patients of low socioeconomic status, the affordability of titanium mesh can be challenging. The material cost for two ribs using the Bird-cage reconstruction (methyl-methacrylate with Prolene mesh) is about PhP 10,000.00 pesos. Methyl-methacrylate has been associated with infection, and various studies around the world reported a 10-20% infection rate.[6,8,9] It is also the most common indication for prosthetic graft removal.[10] Most infections were related to the sandwich technique of reconstruction, where a methyl-methacrylate plate is sandwiched between two mesh and used for rigid support.

Although there is much concern about whether to do delayed reconstruction versus outright rigid reconstruction among these patients with known infected tumors, most surgeons in our institution agree that respiratory complications are much worse than the fear of postoperative complications like infection in the reconstruction site. In a study by Bautista and Mata on chest wall resection and reconstruction for chest wall tumors at the PGH, delayed extubation was significantly related to mortality and morbidity among patients who underwent chest wall resection without rigid reconstruction.[11] In our study, only two patients had prolonged intubation (>3 days), and the majority were extubated within 24 hours postoperatively. Most of these patients also had a prolonged preoperative length of stay. Five patients had reoperation for debridement or partial removal of prosthetic graft material due to wound infection. The small post-debridement raw areas were left to granulate in all patients. Four of the five patients had an infected or ulcerated tumor preoperatively. This series showed that extensive antibiotic coverage was required to prevent further complications. None of these patients suffered significant respiratory complications requiring mechanical ventilatory support due to reoperation. Preoperative radiotherapy has minimal significance in the chance of having wound complications postoperatively. All patients in this study had informed consent regarding the planned oncologic resection and Bird-cage chest wall reconstruction.

This study was limited in its small sample size and lack of patient follow-up beyond 30 days. A long-term follow-up would have been good for examining the recurrence rates, long-term survival, and long-term wound complications. Unfortunately, patients in this study were lost to follow-up. In a study done by Scarnecchia E et al., patients with chest wall malignancies who underwent R0 resection and reconstruction had a 5-year survival rate of 67%. Those who underwent R1 resection had a 59% recurrence rate and a 15% 5-year survival rate.[12] Complete surgical resection is still the most important prognostic factor for survival among patients. The ability to reconstruct the chest wall allows oncologic surgeons to proceed with an R0 chest wall resection without fear of respiratory complications associated with a flail chest.

The Bird-cage reconstruction provides a safe, cheap, and accessible alternative to titanium mesh to reconstruct the chest wall.

CONCLUSION

Bird-cage reconstruction provides a cheap alternative to rigid reconstruction for chest walls following extensive chest wall resection to achieve adequate margins. It allows for shorter mechanical ventilatory support following surgery and, subsequently, shorter ICU stay.

Statement of Authorship

ERB contributed in the conceptualization of work, acquisition and analysis of data, drafting and revising of manuscript, and final approval of the version to be published. JKDZ contributed in the acquisition and analysis of data, drafting and revising of manuscript, and final approval of the version to be published.

Author Disclosure

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