

## Extended Resection of Chest Wall Tumors with Reconstruction Using Poly Methyl Methacrylate-Mesh Prosthesis

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### ABSTRACT

**Purpose:** This prospective study evaluates the early result of patients with massive chest wall tumors treated by extended resection and reconstruction using Prolene or Marlex mesh-enforced with Poly Methyl Methacrylate Bone Cement (PMMC) prosthesis.

**Material and Methods:** This surgery was performed on 40 patients with a mean age of  $45 \pm 18$  (12-62) at the Department of Surgery, National Cancer Institute, Cairo University between 1998-2001. Primary chest wall tumors were the indications of surgery in 42.5%, while secondary involvement extending from other sites principally breast cancer were the indications for 57.5%. In 85% of patients more than 3 ribs were involved by tumors and lesions were more than 10 cm in the greatest dimension in 50% of cases. Resection involved sternum in 15 (37.5%) cases and in 45% of cases complete extensive rib resections extended between costovertebral junctions and the costochondral junctions were performed. Additional resections of nearby organs were needed in 20 (50%) of cases including partial lung resection in 14 cases, partial vertebral resection in 3 cases and diaphragm resection for 3 cases. Immediate bony reconstruction by inserting Prolene or Marlex mesh-enforced with Poly Methyl Methacrylate Bone Cement (PMMC) prosthesis to the resulting chest wall defect was performed in 36 cases, whereas, 4 cases had delayed reconstruction. Primary simple soft tissue closure was sufficient for 37.5% of patients; whereas 35% were covered by local rotational flap and 27.5% needed myocutaneous flaps.

**Results:** No patient with this immediate reconstruction needed ventilatory support or tracheostomy and flail chest was not noticed. ICU stay was markedly reduced; whereas 85% required less than 7 days. Immediate post operative (40 days) complications were found in 14 patients (35%) and cases with additional lung resection had more complication rate than others (64% vs 19%). Infection occurred in 3 patients and conservative treatment for 3-4 weeks using frequent irrigation and antibiotics was sufficient to keep infection under control. Prostheses were removed without functional respiratory disturbance. Follow-up was carried out for a mean period of 18 months (6-43). Ten patients (27%) suffered relapses including 4 cases (10.8%) with local chest wall recurrence and 6 (16.2%) with distant metastases. Actuarial two year relapse free survival rate

was 65% and survival rate was better for primary chest tumors than secondary tumors (78.5% for primary tumors and 65.2% for chest wall lesions secondary to breast cancer).

**Conclusions:** This type of reconstruction obviated the need for postoperative ventilatory support and/or tracheostomy for such a major chest wall resection. It enabled us to resect large tumors with acceptable morbidity and mortality. Chest wall resection should be attempted aggressively in primary tumors. However, resection for secondary lesions should be selective and limited to palliation mainly.

**Key Words:** Extended chest wall resection - Chest wall reconstruction - Bone cement.

### INTRODUCTION

The goal of surgery when a neoplasm invades the chest wall or arises from it is three folds, first complete tumor resection with clear margins, second in segments of large chest wall resections a replacement must be found to restore the rigid chest wall to prevent physiologic flail and third a healthy soft tissue coverage is essential to seal the pleural space to protect the viscera and great vessels and prevent infection [1].

For small defects less than 5 cm or those located posteriorly under the scapula above the fourth rib (e.g. after resection of pancoast tumors) the skeletal component can be ignored and the defect can be closed with soft tissue alone [2,3].

The principal respiratory derangement after chest wall resection is the result of altered ventilation as wherever there is a defect in the rigid chest wall during respiration there is paradoxical motion of that portion. This rapidly leads to decreased tidal volume, hypoxemia, hypercapnea and increased air way resistance with resulting fatigue and respiratory failure. In this situation, respiratory dependence and tracheostomy are mandatory to save the patient. Immediate chest

wall reconstruction by insertion of rigid prosthesis prevents such condition [3,4,5].

LeRoux and Shama [6] specified the ideal characteristics of a prosthetic material: as rigidity to abolish paradoxical chest motion, inertness to allow in growth of fibrous tissue and decrease the likelihood of infection, malleability so that it can be fashioned to the appropriate shape at the time of operation and radiolucency to allow radiographic follow-up of the underlying problem.

Following the work of McCormack and his colleagues [7] at the Memorial Sloan-Kettering hospital, poly methyl methacrylate (PMMC)-Marlex mesh sandwich was introduced as a rigid prosthesis to restore the contour and rigidity of the chest wall, thus allowing massive chest wall resection without paradoxical movement and flail chest with rapid recovery and obviation of ventilatory support. Several other materials have been used to support the structural integrity including silicone, Teflon, acrylic materials, metal sheets, autogenous rib grafts and fascia lata but with less results [8].

This study intended to evaluate the PMMC-mesh prosthesis as a rigid element in reconstruction of large chest wall defects and to evaluate this extensive surgery in our patients with chest wall tumors as regards post operative complications and tumor control.

## PATIENTS AND METHODS

During a period of three years extending between March 1998 and June 2001, forty patients with variable neoplasm of the chest wall were admitted to the Department of surgery, National Cancer Institute (NCI), Cairo University. They were 21 females and 19 males with a range of age between 12-62 y and a mean of  $45 \pm 18$  years.

Indications for chest wall resection are summarized in Table (1) where most of them were secondary tumor extensions from nearby organs principally breast cancer (42.5%). Persisting or recurring chest wall involvement with breast carcinoma after mastectomy and radiotherapy required chest wall resection to achieve local control provided the following criteria were present as suggested by Downey and other [3]:

- It was an isolated chest wall recurrence with disease-free interval of more than 2 years.

- It was cosmetically displeasing and painful ulcerated mass.
- Non healing radiation induced ulcer with osteoradionecrosis.

Primary tumors represented 42.5% of cases where most of them were of bony origin and only 3 cases of soft tissue origin.

Most of the cases (87.5%) had their chest wall affection in the anterior and lateral parts as noted in Table (2). Tumors were extensive in size, as 33 (82%) had lesions more than 5 cm in greatest dimension as assessed by clinical and CT scanning and 22 (55%) had lesions infiltrating more than 5 ribs (Table 3).

### *Preoperative preparations:*

All patients had hematological, biochemical and bleeding profiles as a preoperative assessment. Metastatic work up included abdominal ultrasound, thoracic CT scan and MRI if vertebral involvement was suspected. CT was also used to estimate local tumor extensions to intrathoracic structures and overlying soft tissue.

Pulmonary function test was requested in all patients preoperatively to evaluate the lungs in case resection was deemed necessary. Forced expiratory volume in the first second (FEV1) and its ratio to functional vital capacity (FVC) was the most important test to rule out obstructive cases. Anesthetic and medical consultations were needed preoperatively to evaluate the medical condition of the patient and anesthetic risk and to optimize associated morbidity especially respiratory function. In 13 patients (32.5%), medical premorbid conditions were detected including diabetes, hypertension or minor cardiopulmonary problems.

### *Conditions that contraindicated surgery were:*

- Age above 70.
- Severe cardiac disease.
- Poor pulmonary function  $FEV1/FVC < 0.8$ .
- Extensive lesion involving multiple organs or metastatic to extra thoracic organs.
- Associated chest wall infection difficult to encompass with resection.

### *Surgical technique:*

The use of double lumen endotracheal anesthetic tube to deflate the lung at the site of surgery and the proper positioning of the patient depending on the site of the tumor were mandatory

steps. Insertion of epidural catheter and analgesia with diluted morphia was essential with this extensive surgery to decrease pain and allow coughing and restful respiration post operative.

The placement of skin incision varied with the site of the neoplasm. However, in most cases of intrathoracic lesions abutting the chest wall, the standard posterolateral thoracotomy incision was adequate. The skin and soft tissue were incised taking care to select the proper intercostal space for entry into the pleural cavity and this usually was one rib below or above the invaded ribs. Upon entering the pleural cavity, careful digital palpation could confirm the location and extent of the tumor and the incision was then lengthened to the appropriate extent.

For resection of bronchogenic cancer with suspected extension to the chest wall, extrapleural dissection was usually started first and if stopped by resistance, chest wall invasion was then confirmed. Margins of resection were set one rib above and one rib below and (3-5 cm) laterally and medially. Additional frozen section confirmation for the chest wall margins was required after complete resection to confirm their clearance. Chest wall resection was performed first when the extent of involvement was small as it was usually easier to resect ribs first and then perform the lobectomy. However, if chest wall resection required was larger than 10 cm<sup>2</sup>, it was a better policy to perform the lobectomy first to avoid tumor spillage. For other secondary tumors, careful intrapleural palpation was used to determine lung infiltration and partial rib resection was performed first before resecting adherent lung tissue.

Primary chest wall tumors were resected from the costochondral junction to the costovertebral junction to afford clear margins (Fig. 1). Collaboration of spinal surgeons was mandatory for lesions infiltrating vertebrae for the resection and vertebral bone fixation.

When the sternum was involved with tumor, part or the entire sternum was removed with clear margins taking care of the pericardium and the internal mammary artery which was ligated or prepared for microvascular anastomosis if a free flap was intended. Removal of part of the pericardium with the mass should be replaced with prolene mesh to avoid cardiac herniation (Fig. 3).

After completion of enbloc resection, the

ribs were approximated and a chest tube was placed provided the resultant defect was smaller than 5 cm<sup>2</sup> or under the scapula. Larger defects needed solid reconstruction using enforced Methacrylate prolene or marlex mesh, which was fixed to the margins of the defect with strong non absorbable sutures (prolene 1/0). The PMMC was prepared by mixing the powder with sterile water in a fixed proportion. The paste was then spread on the mesh (measured 2 cm larger than the defect all around) leaving 2 cm all around the edges. The other mesh was then spread as a sandwich cover. Contour was fashioned similar to that lost with the resected area by moulding the bone cement before it got hot and rapidly hardened. The prolene-PMMC was used also for sternal replacement especially if ribs and sternum was removed en bloc.

Soft tissue closure followed rib reconstruction and whenever resection included overlying soft tissue. A suitable myocutaneous flap was usually required for closure if the defect was greater than 10 cm<sup>2</sup> otherwise, a rotational flap was enough. Soft tissue replacement by primary closure, rotational flaps or myocutaneous flaps was planned pre-operatively in collaboration with plastic surgeons.

#### *Post-operative care and follow-up:*

Patients were kept in the intensive care unit for a minimum 14 days to stabilize the cardiopulmonary function. Respiratory physiotherapy was essential to reduce the immediate post operative complications. Bronchoscopy, pulmonary toilet and frequent suctioning improved the respiratory condition of the patient if excessive bronchial secretions or atelectasis was found.

Antibiotics (usually third generation cephalosporins) were required for prophylaxis for 15 days as infection of the prosthesis was the most feared complication.

Patients were then discharged to the follow up clinic and were kept on regular chest X-ray radiography 6 monthly and CT scanning yearly or whenever indicated. The marlex-PMMC prosthesis did not obscure the underlying lung for chest X-ray unless Ba impregnated bone cement was used.

Survival was calculated by the Kaplan-Meier methods with exclusion of immediate (40 days) mortality.

## RESULTS

### *Operative technique:*

Twenty six cases (65%) had their primary surgical resection and reconstruction at the NCI; whereas 12 (30%) had incomplete resection in other hospitals and secondary surgery including complete resection and reconstruction were performed in our hospital.

Two patients (5%) with breast cancer had local relapses after chest wall resection were treated again for salvage (tertiary resection) and were further included in the study group.

Thirty six (90%) cases underwent immediate bony reconstruction using bone cement (PMMC) and 4 cases had delayed bone cement insertion. Two cases with lesions in the posterior ribs under covered by scapula were reconstructed by doubled mesh only, but they developed paradoxical respiration necessitating assisted ventilation till reinsertion of bone cement. Similarly, 2 cases with radio-necrotic osteomyelitis in the lower anterior chest wall developed flail chest inspite of reconstruction with myocutaneous flap and double meshes and reoperation with insertion of bone cement were necessary to wean from ventilator.

Resection magnitude in this report was extensive in all cases as seen in Tables (4 & 5). All cases had 3 or more ribs resected, 23 (57.5%) had more than 5 ribs resection, 50% had additional resections of lung, diaphragm or vertebrae and 25/40 (62.5%) had resection of the overlying soft tissue and skin necessitating flap reconstruction.

In 15 cases partial sternectomy associated with partial resection of connected ribs on one or both sides were performed. This subgroup included three cases with primary chondrosarcoma of the sternum and 12 other cases to have clear margins for anterior rib lesions (Fig. 3). Reconstruction required prolene mesh-bone cement combination in addition to soft tissue covering using pedicled flap or the contra lateral breast as rotational flap (Fig. 3).

Wide local excision and complete rib resection from costochondral to costovertebral junctions was done in 18 patients. In 11 patients, the lesions were primary chest wall tumors (2 chondrosarcomas, 3 osteosarcomas, 3 giant cell tu-

mours, 2 large fibromatosis and a case of round cell tumour) and in 2 of them the first and second ribs were resected in the specimen. The other 7 cases included 3 cases with pancoast tumors, 2 cases with peripheral squamous cell lung cancer invading ribs, one case with local recurrent breast cancer and one case with a large metastatic adenocarcinoma who had a past history of ovarian cancer treated 4 years before with no evidence of recurrence other than the chest wall lesion.

In 3 patients with giant cell tumors, additional partial vertebrectomy and internal vertebral body fixation using both bone graft and prosthesis were performed and patients had smooth post-operative period. Diaphragm was resected in 3 cases with lesions in the lower chest wall including the case of ovarian metastasis and 2 cases with fibromatosis invading it. For all of them, reconstruction with prolene mesh fixed to the edge of resection all around was sufficient to prevent respiratory paradoxical movement and abdominal visceral herniation especially on left side (one case).

Bilobectomy (upper and middle) was performed with adding complete 4 ribs resection in two cases with right sided lung cancer (peripheral bronchogenic cancer in upper part of middle lobe and one case with pancoast tumor), while three upper lobectomy resections were done for the other lung cancer lesions. The other 4 lobectomy and 5 segmentectomy resections were performed to help resection of 6 primary chest wall tumors (2 chondrosarcomas, 2 giant cell tumours, one round cell tumour and one fibromatosis) in addition to three recurrent breast cancer.

Wide local excision and incomplete rib resection was performed mainly for the lesions secondary to recurrent breast cancer in 9 cases (Fig. 2), tumor extensions to ribs in 3 breast cancer cases and three case with radionecrosis. Three cases with relatively benign primary tumours including two chondromas and a ganglioneuroma were resected with partial rib resection.

Resection of the 1<sup>st</sup> and 2<sup>nd</sup> ribs was performed in 5 cases including three pancoast tumours and two primary chest wall tumors.

Soft tissue reconstruction (Table 5) was accomplished with primary closure in 15 cases, while local rotation skin flap was needed in 10

cases and breast flap in 4 patients (Fig. 3). Reversed pectoralis major myocutaneous flap based on internal mammary perforators was used in 2 cases, latissimus dorsi myocutaneous flap in 4 cases and TRAM flap was used in 5 cases.

Operative time was 5 hours on average and ranged between 2 to 8 hours. The average blood transfusion was 4 units per case ranging between 2 for relatively small resections for radio necrosis and 8 units for cases that needed vertebral bone resection.

#### *Post operative period:*

Stay in the intensive care unit was less than 7 days for 34 (85%) patients; whereas 6 patients needed more than 7 days including 4 patients with delayed PMMC insertion and 2 patients with bilobectomy lung resection.

We had 14 cases (35%) with postoperative complications and two postoperative mortalities (Table 5). In 9 patients complications were multiple. Complications were more frequent in cases where lung resections were added 9/14 (64%) than other cases without lung resection 5/26 (19%) and in patients with preoperative irradiation 8/17 (47%) than non irradiated group 6/23 (26%).

Two immediate postoperative mortalities occurred. First was a 57 years old male with pancoast tumour and preoperative chemotherapy. He developed bronchopneumonia on the 4<sup>th</sup> postoperative day and respiratory failure one day after. Patient was connected to ventilator but he failed to respond to aggressive antibiotic therapy and developed multiple organ failure. He died on the 17<sup>th</sup> post operative day.

The other was a 58 years old female with chest wall radio necrosis. She developed sudden chest pain on the 3<sup>rd</sup> post operative day and died after one day due to massive anterior myocardial infraction and ventricular fibrillation.

Three patients suffered from wound sepsis that reached the mesh prostheses. They had anterior chest wall resections (an osteosarcoma on left upper side and two breast recurrence resections with preoperative irradiation). One of these cases developed ipsilateral empyema in addition to wound sepsis. Under water seal tube drainage for 16 days together with antibiotics helped dryness of pleural space. Frequent wound irrigation for 8 weeks were adequate to

control infection and after this period prosthesis was removed. The underlying fibrous tissue was rigid enough to avoid flail chest problem and complete aseptic wound healing was noticed. The other two patients were managed similarly with frequent daily wound irrigation for 8 and 9 weeks followed by prosthesis removal and adequate functional results were achieved in both patients.

Two patients developed hydro-pneumothorax and another two had prolonged pneumothorax due to air leak. Prolonged under water seal tube drainage (12-17 days) was sufficient to control the condition.

Reoperation was performed for 10 (25%) of patients. Four patients needed reoperation to enforce the mesh reconstruction with PMMC as mentioned before and 3 cases needed removal of whole prosthesis to control sepsis. Three other patients required surgery to evacuate a hematoma collected under the free TRAM flap in one patient and another two cases needed debridement of peripheral flap necrosis and closure of wound dehiscence.

#### *Oncologic results:*

Surgical margins were adequate and free of tumor in 37 patients (92.5%); whereas 3 cases had involved margins on thorough examination of paraffin sections (a case of bronchogenic cancer, osteosarcoma and giant cell tumor).

Twenty six patients (65%) were subjected to adjuvant radiotherapy in their treatment course. Preoperative high-dose conventionally fractionated radiation therapy to the primary (45-55 Gy) was given to 5 lung cancer cases and 12 patients with lesions secondary to breast cancer had chest wall irradiation as adjuvant treatment after mastectomy. Postoperative irradiation was given to 9 cases. Three patients with close margins and 6 other cases with massive lesions (5 primary tumors and one metastatic ovarian cancer) had average irradiation dose of 47 Gy (40-56 Gy), given as 1.8 Gy/day. Preoperative chemotherapy was given to 4 patients having osteosarcoma and lung cancers and two patients were given postoperative chemotherapy (round cell tumor and ovarian metastatic cancer).

Follow up period had a mean of 18 months and a range of 6 to 43 months three cases were excluded including two postoperative mortalities and a patient with ovarian metastasis. Ten patients

(27%) developed relapses during the period of observation (Table 7). Two cases of primary chest wall tumors (osteosarcoma and chondrosarcoma) developed pulmonary metastases 11 and 20 months postoperatively, while two patients with breast cancer developed multiple bone and lung metastases 4 and 6 months post resection. Local recurrence was detected in two patients with breast cancer, one patient with bronchogenic tumor and a case of giant cell tumor in the vertebral bones. Two patients with pancoast tumors developed cervical and mediastinal nodal relapse. All relapses were detected in the first two years of follow up and a 2-year relapse free survival of 65% was found for cases having complete two years follow-up. This survival rate was highest for primary chest wall tumors and lowest for lung cancer tumors. In this study only one patient out of 4 cases with lung cancer who passed the surgical procedure lived without recurrence for 25 months. The other 3 cases developed relapses and died 8, 13, 14 months post surgery.

Table (1): Indications for chest wall resection for 40 patients.

Primary chest wall tumors	No.	%	Extension from other sites	No.	%
Chondroma	2	(5)	Lung cancer	2	(5)
Ganglion neuroma	1	(2.5)	Pancoast tumor	3	(7.5)
Fibromatosis	2	(5)	Breast cancer	9	(22.5)
Giant cell tumor of ribs	3	(7.5)	(local recurrence) (tumor extension)	3	(7.5)
Chondrosarcoma	5	(12.5)	(radio necrosis)	5	(12.5)
Osteosarcoma	3	(7.5)	Metastatic ovarian cancer	1	(2.5)
Round cell tumor	1	(2.5)			
<b>Total</b>	<b>17</b>	<b>(42.5)</b>	<b>Total</b>	<b>23</b>	<b>(57.5)</b>

Table (2): Sites of chest wall involvement in 40 patients.

Site	No.	(%)
Primary sternal	3	(7.5)
Superior involving (1 <sup>st</sup> & 2 <sup>nd</sup> ) ribs	5	(12.5)
Anterior ribs extending to sternum	12	(30)
Antrolateral	8	(20)
Lateral	7	(17.5)
Posterolateral	2	(5)
Posterior involving vertebrae	3	(7.5)

Table (3): Frequency distribution of lesions by greatest dimension and number of infiltrated ribs.

Size of tumor	No.	(%)	Number of invaded ribs	No.	(%)
Less than 3 cm	0		Less than 3 ribs	6	(15)
3 to 5 cm	7	(17.5)	3 to 5 ribs	12	(30)
5 to 10 cm	13	(32.5)	More than 5 ribs	22	(55)
More than 10 cm	20	(50)			

Table (4): Extent of resection and additional resected structures.

Extent of resection	No.	(%)	Additional resection	No.	(%)
Partial sternectomy ± rib resection	15	(37.5)	- Lung Segmentectomy	14	(35)
- Complete rib resection	18	(45)	Lobectomy	5	
3-5 ribs	6		Bilobectomy	7	
More than 5 ribs	12		Pneumonectomy	2	
- Partial rib resection	17	(42.5)	- Diaphragm	0	
3-5 ribs	6		- Vertebrae (partial)	3	(7.5)
More than 5 ribs	11			3	(7.5)
			<b>Total</b>	<b>20</b>	<b>(50)</b>

Table (5): Skin and soft tissue reconstruction.

Technique applied	No.	%
Primary closure	15	37.5
Rotational flap	14	35
Skin flap	10	
Breast flap	4	
Myocutaneous flap	11	27.5
Pedicled pectoralis	2	
Pedicled latissimus	4	
Pedicled TRAM	3	
Free TRAM	2	

Table (6): Post-operative morbidity and mortality in 14 (35%) patients including surgical, medical and flap complications.

Surgical complications	No.	%	Flap complications	No.	%
Hydro-pneumothorax	2		Total sloughing	0	
Air leak	2		Edges necrosis	5	
Surgical emphysema	2		Dehiscence	3	
Empyema	1		Haematoma	1	
Atelectasis	1		Seroma	0	
Mesh infection	3		Total	5/25	(20)
Minor wound infection	1		Medical morbidity	4	(10)
Mortality	2	(5)	Acute renal failure	1	
Respiratory failure	1		Pneumonia	2	
Myocardial infarction	1		Ventricular extrasystole	1	

Table (7): Pattern of recurrence and 2-year free survival (actuarial).

Tumor origin	Local recurrence	Systemic metastasis	Total relapse	2 year survival
Primary chest wall tumor	1	2	3/17 (17.6%)	78.5%
Breast cancer	2	2	4/16 (25%)	65.2%
Lung cancer	1	2	3/4 (75%)	25%
<b>Total (37 patients)</b>	<b>4 (10.8%)</b>	<b>6 (16.2%)</b>	<b>10 (27%)</b>	<b>65%</b>

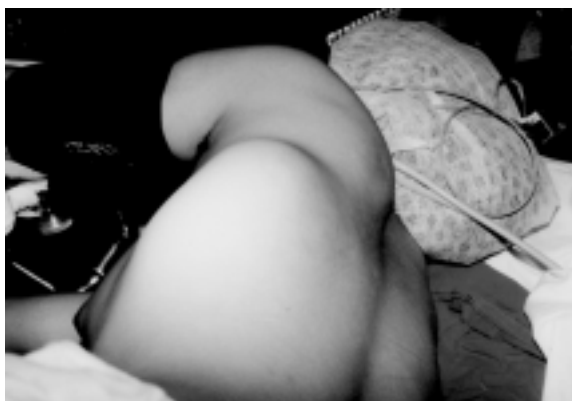


Fig. (1,A): A 34 years old lady with chondrosarcoma of lateral chest wall extending between 4<sup>th</sup> and 8<sup>th</sup> ribs. She is in the classic lateral thoracotomy position.

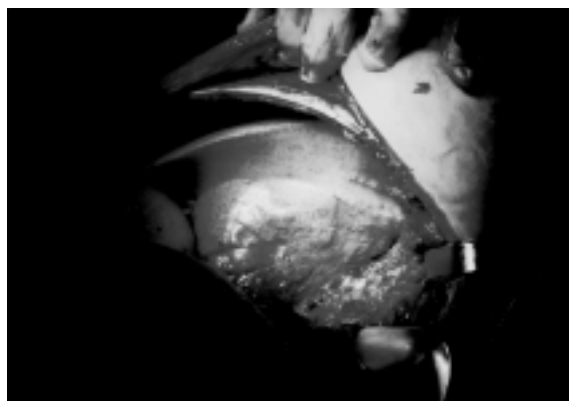


Fig. (1,B): Chest wall defect after resection of 6 ribs (3<sup>rd</sup> to 9<sup>th</sup>) from the costochondral to the cost vertebral junction in addition to segmental lung resection for adherent part.



Fig. (1,C): Methacrylate double mesh sandwich is inserted in the defect after moulding to shape the curvature of the lateral chest wall. Primary soft tissue closure was possible in this case.



Fig. (1,D): 10 days post operative with complete recovery.

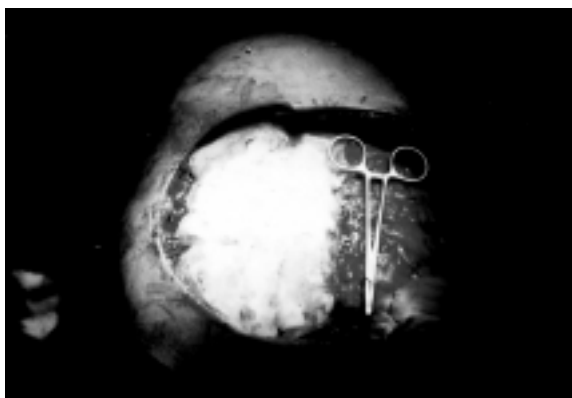


Fig. (2): A 51 years old lady with breast cancer local recurrence in the lateral chest wall. Incomplete rib resection of 5 ribs was performed together with overlying soft tissue and the defect was reconstructed with bone cement and pedicled TRAM flap.



Fig. (3): A 61 years old lady with radionecrosis of the sternum and nearby left 4 ribs, 20 days post resection and reconstruction. Partial lower sternectomy together with left 4<sup>th</sup> to 8<sup>th</sup> ribs partial resection was performed and defect was reconstructed by bone cement and breast flap.

## DISCUSSION

Resection of a massive chest wall tumor is inherently a grave procedure with much morbidity and mortality. However, the advent of mechanical positive pressure ventilation, antibiotics, thoracic suction drainage, blood products, one lung anaesthesia and modern reconstructive techniques have made it feasible to resect extensive chest wall tumors with reasonable mortality and morbidity [4]. To avoid the flail segment which result after such resections and the subsequent paradoxical movements and respiratory compromise, double or triple layers mesh prosthesis as rigid support was used but, results were not satisfactory and 65% of patients had a degree of paradoxical motions that compromised respiratory function [8].

The Memorial Sloan-Kettering group introduced the marlex-PMMC as a prosthetic support to restore the rigidity of the chest wall and obviate the need for respirator and tracheostomy [7]. Malleability of the Methacrylate paste before it hardens was quite sufficient to reform in addition a contour similar to that of the chest for lateral chest wall resections [1,9].

Most of our cases had large lesions, more than 5 cm in size (82.5%) and involved more than 3 ribs (85%), indicating the need for rigid reconstruction (Table 3). Using this prosthesis, we extended resection safely up to 8 ribs completely and resected the first and second ribs in 5 cases with little morbidity or prolonged ICU stay. This reconstruction enabled resections for all locations in the chest (upper or lower and anterior or posterior) (Table 2) without external shape deformity and patients were satisfied with its rigidity with no difference in comparison to the normal side (Fig. 1d).

Additional resection of lung, diaphragm and sometimes large thoracic vessels (SVC, innominate vein or subclavian vessels) were reported in the literature as safe procedures in addition to wall resection [10-12]. In this report, additional lung, diaphragm and vertebrae resections were carried out in almost half of the cases without intra operative mortality but, with more postoperative complications (64%).

Operative blood loss averaged 4 units of blood due to the extensive exposure and additional resection of vertebral bone and partial lung resection [2,9,10,13-15].

ICU stay period was markedly reduced as evidenced by the fact that about 85% of our patients had ICU stay less than one week. Graeber in 1999 [8] recorded 84% ICU stay with an average of  $5\pm 9$  days (range 1 to 83) in a series of patients with chest wall resection for variable indications.

Collaboration with plastic surgeons is essential to the success of this surgery as in 62.5% of our cases there was loss of soft tissue and skin covering that required flap designs to cover the prosthesis. In this report, rotational flaps including breast flap were used in 14 patients (35%), while pedicled and free TRAM flaps were used in 3 and 2 cases, respectively. Pedicled latissimus dorsi flap was utilized in 4 cases and pectoralis major myocutaneous flap in 2 cases. Complications related to flaps vascularity was noticed in 20% with no major flap loss.

We had a total complication rate of 35% and a high percentage of complications occurred in those patients who had additional lung resection compared to those who did not (64% vs 19%) and in patients with history of radiation before surgery. Deschamps and his colleagues [4] reported the Mayo Clinic experience of chest wall resection and prosthetic reconstruction (1977-1992). For 197 patients treated by chest wall resection, 46% complication rate was noticed including 4.6% wound infection that led to removal of prosthesis and 4% operative mortality rate. High complication rates for combined chest wall and lung resection particularly after preoperative lung cancer irradiation were reported in several other centers ranging between 34 and 65% [2,12,14,16]. Intraoperative injury to large thoracic veins or vessels in the thoracic inlet is grave and fatal in many studies [2,10,14]. Meticulous, slow and thorough dissection was needed for upper rib resections and for pancoast tumor resections to avoid vascular injury and we did not have such complication in our series.

Prognosis following chest wall resection in this study varied with the type of tumor, whether, primary or secondary. The value of resection for lung cancer invading ribs is controversial and some authors use hilar node involvement as a guide to resect or to consider the lesion inoperable. Tarstek et al. [16] concluded that, if the mediastinal lymph nodes are not involved, an en bloc resection is warranted, as the 5-year mortality is more associated with the extent of

the pulmonary cancer than with the extent of chest wall resection. In contrast, Magdeleinat and colleagues [17] did not consider N2 disease a contraindication to en bloc resection and reported an actuarial 5-year survival of 25% in T3N0 patients, 20% in T3N1 and 21% in T3N2.

The value of radiation therapy in chest wall invasion with bronchogenic non small cell cancer is controversial. Piehler et al. [18] reported an improved 5 year survival with preoperative radiation as 56 versus 38% and similarly Carrel et al. [14] had 5-year survival advantages with preoperative irradiation. In our patients, the number of this subgroup was small to conclude a benefit for the extended resection or the preoperative radiation given; only one patient survived more than 2 years.

Chest wall lesions secondary to breast cancer treatment was the second most common indication of resection in this series as in other studies [3,4,8]. Breast cancer is the most common female malignancy and chest wall recurrence invading bone was found to be 1-2% for stage I and 10-12% for stage II [19]. The effectiveness of chest wall resection for locally recurrent breast cancer remains poorly defined, possibly because of the general impression that it harbors a rapidly progressive metastatic disease and that extensive resection is inappropriate [3]. On the contrary to this view, the use of surgical resection offers good palliation for osteo radionecrosis and accompanying pain and infection to the degree that McKenna and his colleagues [20] extended the indication to resect metastatic cancer provided there is no brain metastasis, bone marrow involvement or bulky metastatic disease to two organs. We think that resection gives a rapid relief of the distressing symptoms of local chest wall recurrence over other lines of therapy and should be attempted as long as there is expected relatively long survival. For these patients with chest wall invasion, we had 65.2% 2-year survival after resection signifying good palliation at least. Downey and colleagues [3] reported on the experience of the Memorial Solan-Kettering cancer centre in this particular group of patients. They retrospectively reviewed the results of 38 women treated between 1987 and 1997 and found an overall survival at 1, 3 and 5 years after chest wall resection as 74%, 41% and 18%, respectively and the proportion of patients free of local recurrence at the same follow up period

were 59%, 42% and 13%, respectively. They reached a conclusion that in spite of low operative mortality and good palliation, chest wall resection is unlikely to improve survival.

Primary chest wall tumors should be resected aggressively whatever the pathology is and even in benign diseases because it is sometimes difficult to differentiate radiologically and histologically between chondroma and chondrosarcoma, in addition to the liability of recurrence in both tumors [13]. These tumors have better prognosis than secondary tumors. Sabanthan et al. [15] reporting on a series of 49 patients with primary chest wall tumors recorded a 5 & 10 overall survival of 68% indicating that all relapses appeared in the first 5 years of observation. They, had 67% 10-years survival for chondrosarcomas and 43% for Ewing's sarcoma. Burt and his coworkers [13] reviewed 40 years experience of the Memorial hospital for chondrosarcomas (88 patients) and osteosarcomas (38 patients) of the chest wall and noticed a 5 year overall survival of 64% and 15%, respectively indicating a more favorable prognosis for cartilaginous tumors over osteogenic sarcomas. Another study from the Memorial Cancer Center reported 66% overall 5-year survival for 149 patients with primary soft tissue sarcomas of the chest wall and 27% local recurrence after resection. Disease free survival was higher for low grade sarcomas than high grade (90% and 49% respectively) and tumor size was not an independent prognostic factor as in limb soft tissue tumors [21].

*In conclusion:* Chest wall resection should be attempted in all primary chest wall tumors, except those amenable to respond to chemoradiation as plasmacytoma, due to the high survival rate of these tumors after adequate surgery. Chest wall resection for secondary tumors should be limited to the best palliation possibility as survival gain by this surgery is limited. Reconstruction is no longer an obstacle to major curative resection because of versatility of methods of bony and soft tissue reconstruction.

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