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Original Article

Chest Wall Tumors: A Spectrum of Different Pathologies and Outcomes of Reconstruction Techniques

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Abstract

Background: Chest wall resection and further reconstruction for tumors represent a challenging concept for surgeons. Thanks to the evolving reconstruction techniques, good results were obtained after extensive resection and reconstruction.

Methods: This prospective cohort study was conducted at our University Hospitals throughout 5 years. A total of 43 eligible cases with chest wall tumors were included. All cases were subjected to a multidisciplinary team approach, complete history taking, physical examination, radiological evaluation, and biopsy. The details of surgical techniques, complications, and follow up parameters were included.

Results: The mean age of the included cases was 29.45 years. We included a total of 24 males (55.8%). Fibromatosis was the commonest encountered pathology (27.9%), followed by chondrosarcoma (25.5%), and osteosarcoma (21%). Regarding the method of reconstruction, polypropylene mesh was used in 46.5% of cases, followed by direct closure (30.2%). Ten cases were managed by Methyl Methacrylate within the proline mesh (23.3%), while superimposed muscle flap was performed in only 2 cases (4.6%). Post-operatively, bleeding was encountered in 5 cases collectively (11.6%), while wound infection occurred in 11.6% of cases. Pulmonary complications included pneumonia (2.3%) and atelectasis (11.6%). Furthermore, chest wall instability was present in (11.6%) of cases. On follow up, recurrence was diagnosed in (9.3%) of cases (n = 4).

Conclusion: Surgical intervention is very effective if tailored to every patient as per team plan. A multidisciplinary team approach is extremely important especially if an extensive demolition is required. Indeed, radical wide en-bloc resection can achieve satisfactory results provided that the extent of resection is not influenced by any anticipated reconstruction problems.

KEYWORDS

Chest wall tumors;
Resection;
Reconstruction

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Introduction

The chest wall refers to the structures surrounding and protecting the lungs, enclosed by the spine, and separated from the abdominal cavity by the diaphragm. These structures include multiple tissue types, including cartilage, bone, muscle, fascia, vasculature, lymphatic vessels, fat, and skin [1]. Chest wall tumors could be subdivided into two main categories, primary and secondary. Primary chest wall tumors arise from muscle, fat, blood vessel, nerve sheath, cartilage, or bone of the chest wall. On the other hand, the

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secondary can be from direct invasion of breast or lung cancer or metastases from a distant malignant tumor. Of note, the chest wall can be also involved by primary pleural malignancies [2].

Primary chest wall tumors are rare (0.04% of all body new tumors, and 5% of thoracic neoplasms). About 50 percent of these tumors are malignant [3]. Nowadays, the exact etiology of these tumors is not yet defined. However, genetics, lifestyle, and diet may play a role [4]. Extra-abdominal desmoid tumors can arise at the site of previous thoracotomy [5].

Resection of these tumors could be challenging for either thoracic or reconstructive surgeons, as it can lead to postoperative pulmonary dysfunction. Therefore, it is recommended to use a multidisciplinary approach when managing such lesions to optimized post-surgical outcomes [6, 7].

After tumor excision, it is crucial to establish a functional framework for chest wall reconstruction. After that, it should be covered with healthy well-vascularized tissue. Generally, prosthetic materials along with soft tissue flaps are used for coverage to maintain skeletal stability. Although soft tissue coverage can be performed via rotational skin and muscle flaps, complex reconstructions may be also needed in some cases [8].

Post-surgical outcomes are usually related to the type of tumor excised, and the extent of resection [9, 10]. In this study, we present our experience with chest wall tumor resections in our university hospital. Our referral center covers a great sector of the eastern part of the country.

Patients and Methods:

Study design and setting:

This is a prospective cohort study that was conducted over 5 years (from January 2015 till January 2020) on patients presented with chest wall tumors presented to Mansoura University hospitals. The outpatient clinics of our departments serve patients from 4 neighboring governorates in eastern Egypt (Dakahila, Damietta, Port Said, and Kafr Elsheikh) with an average of 3280 patients per year at the time of the study.

Inclusion and exclusion criteria:

Although there was no age or gender limitation for participating in the current study, refusal to participate, or unfitness for general anesthesia were causes of exclusion. We excluded cases of elastofibromas as they are benign soft-tissue pseudotumor and lipomas which were usually excised with no need for chest wall reconstruction. The invasion of the chest wall by bronchogenic carcinomas was excluded.

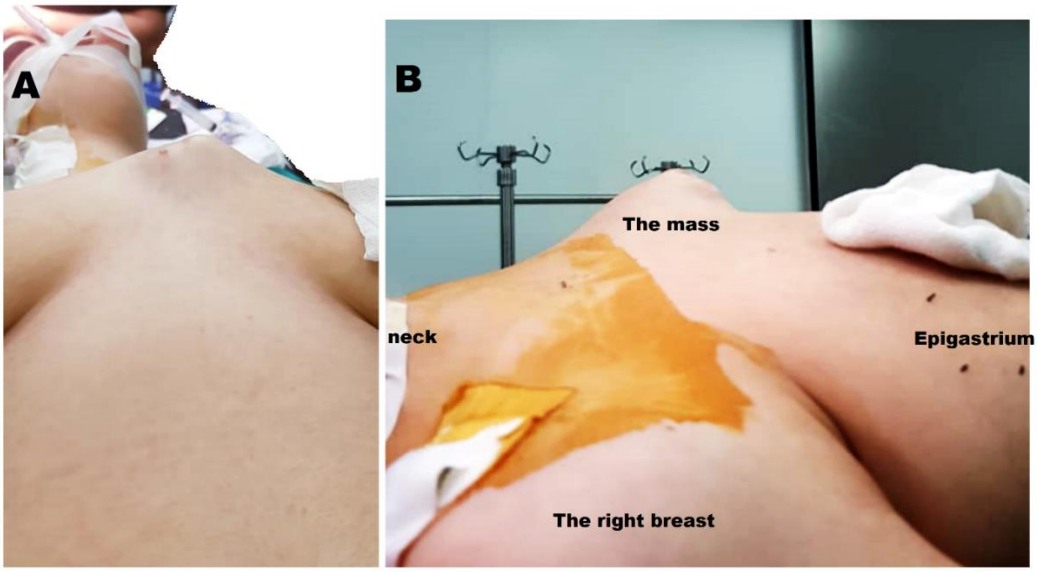

Figure 1: (A) Cranio-caudal view showing a Female patient with a protruding sternal mass. (B) Right side (surgeon's) view of a protruding sternal tumor in a female patient.

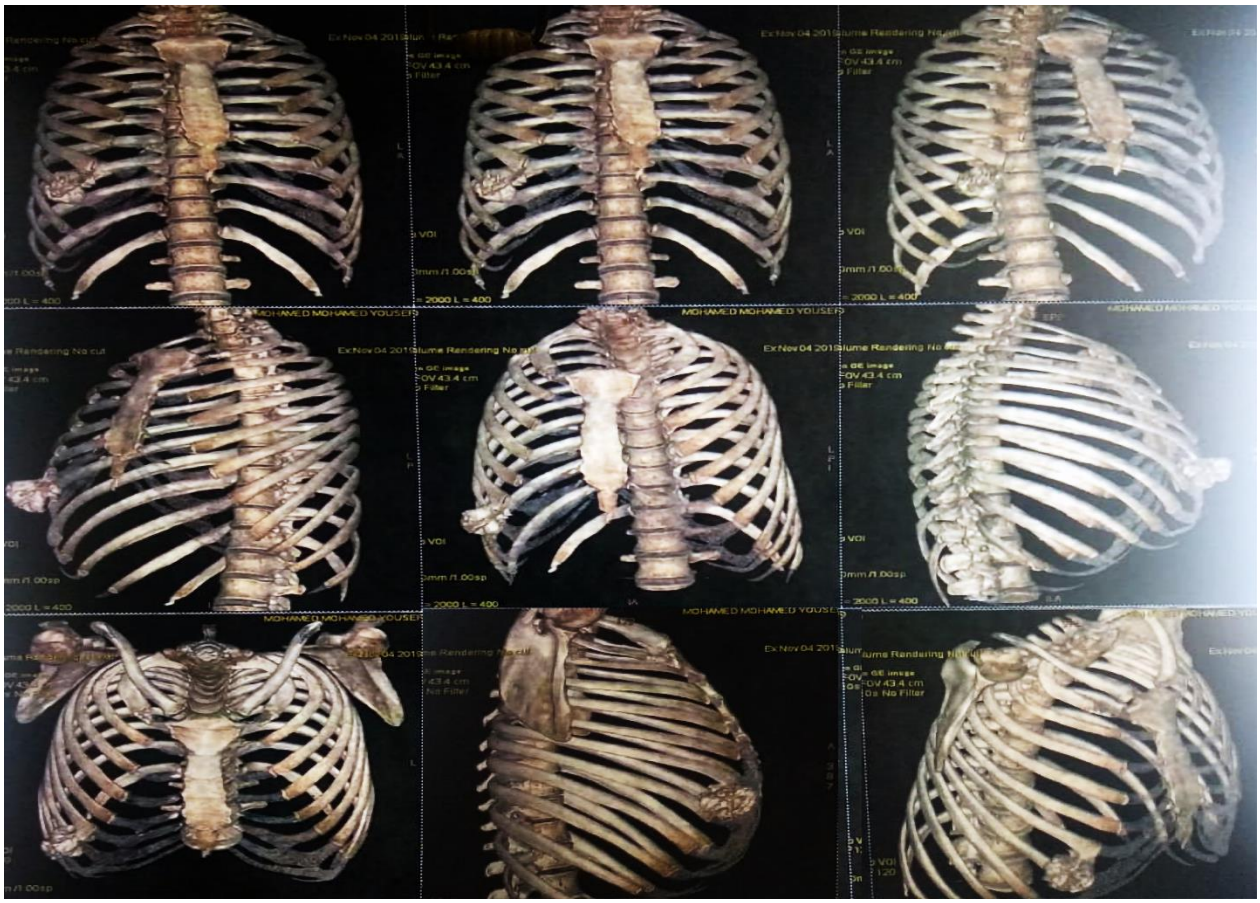

Figure 2: High resolution Computed tomography of the chest wall with three-dimensional reconstruction showing a right-sided chest wall mass occupying the right seventh rib anteriorly.

Ethical considerations and consent to participate:

Informed written consent was obtained from all cases after the explanation of the details and possible drawbacks of the surgical intervention. Moreover, the study was approved by the Institutional research board (approval number MUIRB-651-15). All patients signed written consent for publishing the medical data without identity disclosure.

Surgical workup and approach:

All cases presented or were referred to our outpatient clinics were subjected to a multidisciplinary team (MDT) approach by performing regular Pulmonology- thoracic surgery – oncology – cardiothoracic anesthesia meetings to determine tailored patient treatment plans and to perform updated briefing on postoperative patient status.

Based on the imaging findings and pathological diagnosis, an MDT decision was taken for all cases. All cases were subjected to complete history taking, thorough physical examination (Figure 1: A, B), and routine preoperative laboratory investigations. Besides, radiological investigations including chest X-ray, Computed tomography (CT), and/or Magnetic resonance imaging (MRI) were ordered to assess the degree of tumor extension (Figure 2). Pulmonary function tests (PFT's) were done for selected patients if there was dyspnea or the expected chest wall resection was extensive. Comparing preoperative and postoperative PFT's was out of the scope of this study. A biopsy was also ordered for most cases to confirm the diagnosis.

In all malignant tumors, a metastatic workup was ordered preoperatively. And all cases were also assessed by the anesthetic team before the procedure. Following tailored surgical planning, all cases underwent surgery with a curative goal after tailored surgical planning. Wide en-bloc radical excision was performed with keeping circumferential radical margins of at least 4–5 cm putting into consideration the nature of the

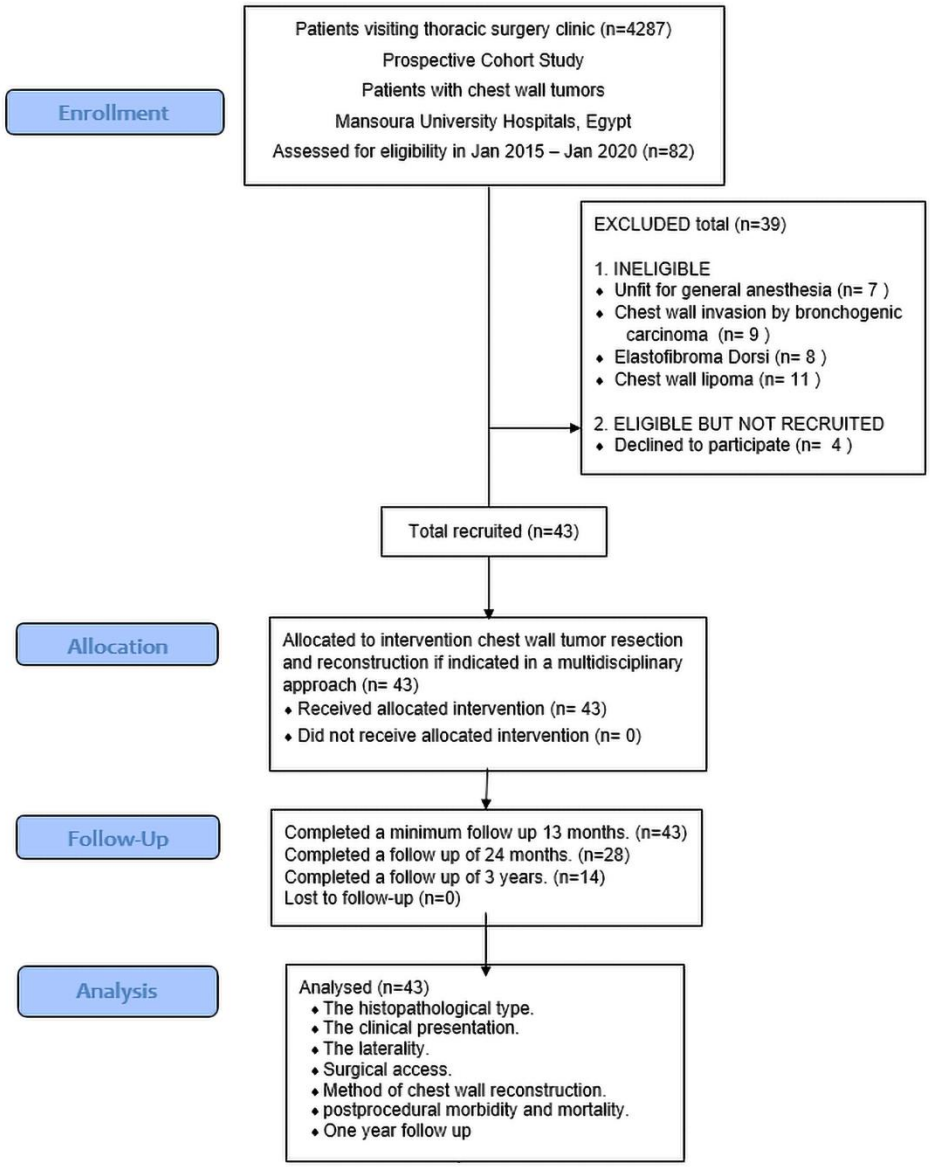

Figure 3: A STROBE flow-chart of the study indicating the recruitment of participants

pathology. Aggressive tumors and those with high recurrence rates; as fibromatosis; required more bony and soft tissue safety margins.

A chest tube was inserted into the thoracic cavity then after reconstruction a wound drain was inserted. As regard anesthesia, a single-lumen endotracheal tube was sufficient, thoracic epidural analgesia was a must as there was predicted severe postoperative pain.

According to the size, pathology of the neoplasm, and nature of the defect, multiple options were available for reconstruction after tumor excision, including polypropylene mesh, Methyl Methacrylate sandwiched between two layers of the mesh or muscle flaps.

The choice of the suitable material and method of chest wall reconstruction was at the discretion of the operating surgeon based on the experience and familiarity with the chosen technique. We considered reconstruction for large defects that required resection of 3 or more ribs.

Small defects and apicoposterior defects do not require reconstruction as the later are protected by the scapula and shoulder girdle. Defects lower than 4th rib posteriorly are at the risk of entrapment of the tip of the scapula.

Postoperative management:

After the operation, the cases were transferred to the intermediate care unit, and then to the ward unless complications were anticipated. Patients who have multiple

comorbidities were transferred to the intensive care unit (ICU). Early ambulation and chest physiotherapy were encouraged. Pain control was achieved using Epidural analgesia in the first 3 days postoperatively. After removal of the epiduaral catheter, NSAIDs and opioids were given accordingly until the patient is discharged.

Postoperative lung function was not tested and this outcome was not tested in this study. All cases were reviewed for the need for postoperative adjuvant therapy. At the regular follow up visits at 1 week, one month, three months, six months, one year, two years, three years following discharge, cases were assessed clinically and radiologically for the outcome of resection. All patients Completed a minimum follow up 13 months and a maximum of three years of some patients. Moreover, if complications were encountered, they were recorded and managed via a MDT approach.

Definitions of study outcomes:

Large defects were defined as defects that need resection of 3 or more ribs.

Significant bleeding was defined as persistent bleeding and large volumes concerning the patients' body surface area (4ml/kg/hour or more) or bleeding that results in a progressive drop in hemodynamics or patients' hemoglobin that may necessitate a blood transfusion.

Insignificant bleeding was defined as the bleeding that had a regressive course, it did not affect hemodynamics and responded to coagulants.

Chest wall instability was defined as an obvious paradoxical movement of the chest wall defect after the repair when upon breathing spontaneously.

Superficial wound infection was defined as surgical wound discharge accompanied by at least one of the local signs and symptoms of infection like pain, tenderness, localized swelling, or redness.

Deep wound infection was defined as wound disruption and systemic signs and symptoms of sepsis.

Milk fistula was defined as a rare condition that occurs when there is an abnormal connection that forms between the skin surface and the duct in the breast of a lactating woman, resulting in spontaneous and often constant drainage of milk from this path of least resistance. It might be a complication that results from a needle biopsy or surgical intervention in a lactating patient.

Study endpoints:

The primary endpoint was the presentation of the histopathological type of the resected specimens in our sample. The secondary endpoints were the clinical presentation of the patients, the laterality, surgical access, method of chest wall reconstruction, and postprocedural morbidity and mortality.

Statistical analysis:

A total of 43 eligible patients were enrolled. The data were tabulated and analyzed using IBM SPSS software version 22.0 (IBM Inc., Chicago, IL, USA). Qualitative data were described using the number and percent. Continuous quantitative variables were assessed for normality; normally distributed variables were reported as mean and standard deviation (SD). Skewed variables were reported as median and interquartile range.

Results

A STROBE flow-chart of participants is presented in (Figure 3), indicating the sequential recruitment of individuals. Eligible were 43 consecutive patients with a mean age of 29.45±4.62 years. We included a total of 24 males (55.8%) as well as 19 females (44.2%). One case had a previous history of trauma (2.3%). Moreover, previous chest surgery was performed in 1 case (2.3%).

Regarding the presenting symptoms, the pain was the most common presentation (28 cases – 65.1%). Other presentations and patient characteristics are shown in (Table 1). The most common affected chest wall side was the right one (51.2%), followed by the left side (41.9%), two

Table 1: Demographic data and presenting symptoms of 43 cases with chest wall tumors

		Patients (n= 43) *n* (%)
Age		29.45 ± 18.868
Gender	**Male**	55.8% (24)
	Female	44.2% (19)
Comorbidities		
Smoking		14 (32.6)
Trauma		1 (2.3)
Previous chest operation		1 (2.3)
DM		9 (20.9)
HTN		4 (9.3)
Asthma		3 (7)
Presenting symptoms		
Pain		28 (65.1)
Mass		27 (62.8)
Tenderness		4 (9.3)
Discharging ulcer		1 (2.3)
Dyspnea		5 (11.6)

DM: Diabetes Mellitus; HTN: Hypertension

cases had a sternal tumor (4.65%) and one patient (2.3) had right-sided chondrosarcoma of the 2nd, 3rd, 4th, ribs and the adjoining left hemisternum (Table 2).

Rib destruction was detected in 20.9% of cases, while calcifications were present in 41.9% of patients proved by the multi-slice CT chest reconstruction (Figure 2).

Trucut biopsy was the commonest modality (76.7%), followed by incisional biopsy (16.3%), and lastly excisional biopsy for 3 cases (7%). A fine needle biopsy was not suitable for hard bony tumors.

Strangely Fibromatosis (desmoid tumor) was the commonest pathology (27.9%) in our series (Figure 4), followed by chondrosarcoma (25.6%) and osteosarcoma (21%). Another pathological spectrum is shown in (Table 2).

Video-assisted thoracoscopic surgery (VATS) hybrid approach was used in 2 cases (4.7%). In one patient with a pedicled tumor attached to the 6th rib, it helped to determine the exact site of the tumor. Also, in another young male patient with

Table 2: Radiological findings, type of biopsy and pathological types of the examined lesions.

			Patients (n= 43) *n* (%)
Radiography	**Side**	**Right**	22 (51.2)
		Left	18 (41.9)
		sternum	2 (4.6)
		combined	1 (2.3)
	Effect	**osteolytic**	9 (20.9)
		calcification	18 (41.9)
	Protrusion (mainly)	**Outward**	7 (16.3)
		Inward	16 (37.2)
		Both sides	20 (46.5)
Biopsy		**Excisional**	3 (7)
		Incisional	7 (16.3)
		Trucut	33 (76.7)
Pathology		**Fibromatosis**	12 (27.9)
		Chondroma	4 (9.3)
		Chondrosarcoma	11 (25.5)
		osteosarcoma	9 (21)
		Ewing sarcoma	1 (2.3)
		Fibrous dysplasia	1 (2.3)
		osteoma	2 (4.6)
		Spindle cell tumor	1 (2.3)
		Metastasis	2 (4.6)

huge metastasis from a previously excised left leg osteosarcoma which was occupying the left costomediastinal recess with significant mediastinal shift and doubtful invasion of the diaphragm and pericardium. Preliminary VATS helped us to dissect the tumor and align exactly the tumor borders with adequate safety margins. The resulting defect after tumor excision was large (3 ribs or more) in 74.4% of cases (32 patients) which were evaluated for the suitable method of reconstruction. The average defect span was 3.8±2.5 ribs (ranging from 1 rib to 7 ribs).

Thirty-two cases required skeletal chest wall reconstruction. Prolene mesh was used in 46.5% of cases, while Methyl Methacrylate sandwiched between two layers of polypropylene mesh was used in (23.25%) (Figure 5: A, B, C). Superimposed muscle flaps were used in 2 cases. Thirteen cases (30.2%) needed no construction due to small defects (11 cases) or anatomically protected defects (2 cases).

Table 3: Surgical details and postoperative complications

		All patients (n= 43) *n* (%)
VATS approach		2 (4.7)
Defect size	**small**	11 (25.6)
	Large ≥3 ribs	32 (74.4)
Reconstruction method	**None**	13 (30.2)
	Bone cement & Prolene mesh	10 (23.3)
	Muscle flap	2 (4.6)
	Prolene mesh	20 (46.5)
Complications		
Recurrence		4 (9.3)
Chest wall instability		5 (11.6)
Wound discharge		4 (9.3)
Bleeding and exploration		1 (2.3)
Bleeding no exploration		4 (9.3)
Milk fistula		1 (2.3)
Pneumonia		1 (2.3)
Atelectasis		5 (11.6)
Mortality		0

Postoperative bleeding was encountered in one patient in our series who required re-exploration due to significant bleeding had no chest wall reconstruction and the source was an intercostal artery.

Four cases had higher bloody drainage in the first postoperative day which was controlled medically. Another 4 cases showed superficial wound infection. Proper antibiotics and frequent dressing were sufficient. In a female patient 24 years old with excised right 3rd and 4th ribs anteriorly due to chondrosarcoma was proved to have a milk fistula that managed medically well. The medical management included broad-spectrum antibiotic treatment till modified by a culture result and cabergoline (prolactin antagonist) without breast pumping was prescribed by a general surgeon to slow milk production and drainage, and thus promote wound healing. Simple local wound care with Vaseline gauze was used to help with healing.

Five patients who received large polypropylene mesh, chest wall paradoxical movement was evident while spontaneous breathing during weaning of anesthesia. Heavy dressing with a wide adhesive bandage for few days was enough to stabilize the chest.

Most patients had epidural analgesia for the first postoperative day. NSAID and opioids were given latter according to the degrees of pain. All postoperative complications are illustrated in (Table 3).

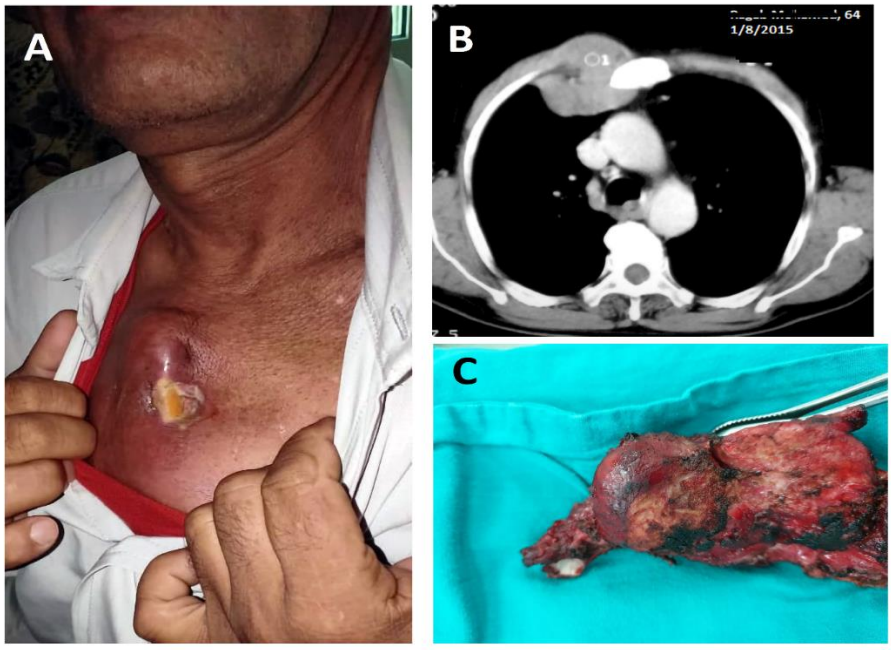

Figure 4: Desmoid tumor invading the anterior chest wall of a 64 years old male patient. A. Inspection of the anterior chest wall mass B. Computed tomography of the chest showing the mass. C. the specimen after wide local excision.

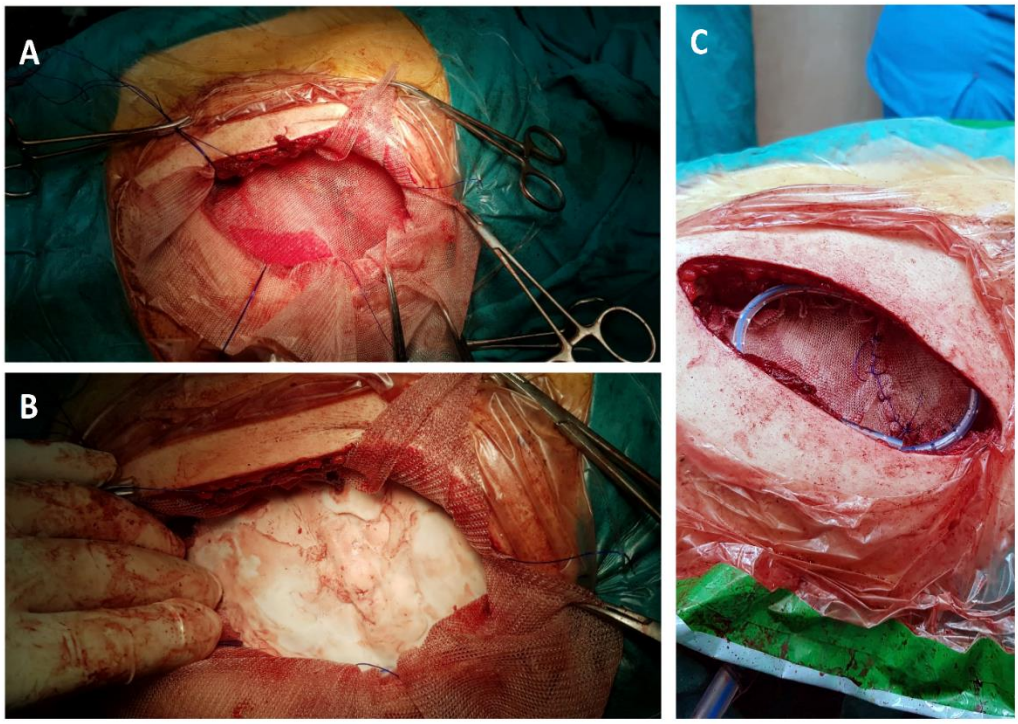

Figure 5: A. The first step in constricting chest wall by bone cement sandwich. Closing the defect by 1st layer proline mesh from 3 sides leaving one for helping protection of the underlying structures. B. Applying the Methyl Methacrylate film over the proline mesh. C. final view of the bone cement sandwich and drain in situ

Discussion

This study was conducted at our cardiothoracic surgery department in a university hospital aiming to present our experience in chest wall tumor resection and reconstruction.

The mean age of our series was 29.45 years ranging from 6 to 65 years old. According to the previous literature, there is a great variation in the age of presentation almost like our series. Nevertheless, younger patients have smaller and more benign tumors, whereas older patients tend to have larger and more aggressive tumors [11].

In our study, we have a total of 24 males in addition to 19 females. And this result copes with other researches who showed the frequency of chest wall tumors is more common in males [12]. The presentation in our study including pain (65.1%), mass (62.8%), tenderness (9.3), dyspnea (14%), and discharging ulcer (2.3%). While chest wall neoplasms can be asymptomatic and 20% of them detected incidentally on chest X-ray [13, 14].

In the current study, our cases were evaluated initially by chest X-ray, and CT or MRI was subsequently ordered. Although the chest X-ray can detect cortical bone destruction or confirm the tumor of bony origin; CT is more sensitive in evaluating all the mentioned parameters and also evaluating the lung and the pleural invasion by the tumor [15]. Moreover, MRI can help to differentiate neoplastic lesions from other mimicking disorders like inflammation or infection, it can demonstrate the various internal components of complex lesions and also the neurological and vascular invasion of the tumor [16].

In our study, a biopsy was ordered nearly for all cases. Trucut biopsy was the gold standard technique (76.7%) being safe and sufficient, followed by incisional one (16.3%) and lastly the excisional one (7%). Other biopsy types included fine needle looks inappropriate.

It is usually recommended to take a biopsy from such lesions as the radiological diagnosis is usually inadequate for definitive diagnosis. It is recommended to take an excisional biopsy for lesions less than 5 cm in size. For larger lesions, incisional biopsy or true cut needle biopsy can be performed [14].

After the biopsy, the delay is not permitted, and the surgery must be done rapidly taking into consideration the excision of the biopsy track together with skin ellipse. Regarding tumor types encountered in the current study, fibromatosis was the commonest encountered pathology (27.9%), followed by chondrosarcoma (25.5%), and osteochondroma (21%).

Desmoid tumors (also called aggressive fibromatosis) are benign myofibroblastic neoplasms. They are rare tumors. In 8–10% of cases, their location is in the chest wall. When chest involvement is present, these are known to be locally aggressive with a high recurrence rate [17].

A previous study has also published that chondrosarcoma is the commonest chest wall malignancy, as it accounts for 30% of the primary malignancies [18].

There is no explanation of why the prevalence of fibromatosis was high in the last few years. In our study, it affects mainly middle-aged females and has a high degree of recurrence.

Chest wall surgery is the best option for the primary tumors and also for selected cases of secondary tumors which may be a curative option [7, 19]. Wide tumor excision with negative margins is a critical predictor of local recurrence rates. It is also imperative that following resection, there is a chest wall stabilization to avoid a negative impact on respiratory function [20, 21].

Rigid reconstructive techniques depending on autologous rib grafts or semirigid fascial grafts are less commonly used since the introduction of synthetic mesh as in our study. The ideal synthetic mesh should be rigid enough to minimize paradoxical chest wall movement, porous enough to allow tissue ingrowth, malleable, radiolucent (i.e. to see any radiographic evidence of tumor relapse), and inert (i.e. not inflammatory, or eliciting an immune response) [22].

A variety of muscle flaps are generally readily available for rotation to cover most chest wall defects (including pectoralis, latissimus dorsi, and rectus abdominis flap). The choice of flap coverage is chosen based upon the location and size of the defect, the availability and condition of adjacent muscles, prior or possibly future radiation, and the overall condition of the patient [23].

We used muscle flaps in 2 cases; one was rotational pectoral muscle flab after excision and mesh reconstruction of large upper left chest wall fibromatosis. The other one was a female patient who had large right chest wall osteosarcoma repaired by proline mesh and reinforced by latissimus dorsi muscle flap.

Other non-available options in our center were bovine pericardial patch, titanium meshes, and titanium bars. Regarding complications encountered in the current study, bleeding was encountered in 5 cases (11.6%) with only one case of re-exploration, while superficial wound infection occurred in 9.3% of cases. Pulmonary complications included pneumonia (2.3%) and atelectasis (11.6%). Furthermore, chest wall instability was present in 11.6% of cases. Surgical mortality was not encountered in our cases.

Any thoracic surgeon must put in mind that postoperative bleeding will be a dilemma after chest wall reconstruction. Hence perfect hemostasis is a must.

The reported chest wall reconstruction-related complications range from 24 to 46 percent in large reviews [24-26]. Multiple studies have reported that mortality following chest wall reconstruction is most commonly related to pulmonary complications and sepsis with rates ranging from zero to 17% [27-31].

In another study [30] which included 7 cases, two early complications, and one late complication (asymptomatic bone allograft fracture on the site of the bar implant) were encountered.

A recent retrospective single-center study performed by Osman and his colleagues published in this journal [31] that concluded all patients who underwent chest wall reconstruction for a variety of defects resulting from resection of tumors,

trauma due to primarily firearms or motor car accidents, resection of radio necrotic tissues, infection and dehiscence of median sternotomy wounds after cardiac surgery. The study was conducted in a university hospital in the southern part of our country.

Their study comprised 30 patients (70% males) in 3 and half years duration, with a median age of 43 ± 16.3 years, resection and reconstruction were performed in 23 cases (15 neoplastic,5 infective and 3 firearm cases) while reconstruction alone was performed in 7 (traumatic flail chest) cases. Eighteen patients, underwent rib resection with an average of 4.18 ± 2.2 ribs (range 2-6). Associated lung resection was performed in 5 patients (27.8 %): diaphragmatic resection was done in 2 cases also total sternal resection was performed in 5 cases.

Only 15 patients were operated for chest wall neoplasms. Reported pathologies were 7 Chondrosarcomas, 2 osteogenic sarcomas, 2 round cell malignancies, 2 sternal liposarcomas, 1 rhabdomyosarcoma, and 1 mesothelioma invading the chest wall.

Unlike our study, the number of cases was less than half the number of our presented study, the distribution of the pathologies was different. Our age group was significantly younger than that in their study population. Recurrence was reported in one case of round cell tumors due to non-compliance with chemo-radiotherapy.

Osman and his colleagues [31] commonly used prolene mesh (43%), methyl methacrylate (13.3%), Muscle flaps (10%), Omental patches (10%), plates and screws (13.3%), and stainless-steel wires for chest wall reconstruction. Yet, no specific detail was brought as regards the reconstructing the defects for chest wall neoplasm cases. Gonfiotti, et al. [6] reported a local recurrence for a desmoid tumor and a high-grade sarcoma 15 and 26 months postoperative respectively.

On our follow up, recurrence was diagnosed in 9.3% of cases (n = 4), two of them had fibromatosis and responded well to adjuvant therapy (one of them had a positive resection margin and recurred 9 months later and the other was 12 months postoperative). The other two recurrences were chondrosarcoma 6 months postoperative (had a negative margin) and recurrent metastatic chest wall mass secondary to a cancer breast that was operated 10 months before. No postoperative deaths were registered during our minimum of 13-month follow up period. No further events were recorded in cases followed up to three years postoperatively (Figure 3).

It has been previously reported that recurrence rates vary as per the tumor pathology as well as response to chemothoereapy [14]. Bony malignant chest wall tumors account for 55% of all chest wall masses and have an average 5-year survival of 60%. In chondrosarcomas, 10% of patients with negative margins will have local recurrence; whereas 75% of those with positive margins will have local recurrence. Malignant fibrous histiocytomas (MFHs) have a reported local recurrence rates of higher than 30%. Liposarcoma have high recurrence rates due to little response to chemo-radiotherapy [14].

Study limitations

This study is a single-center study prospective performed in a high-volume center for 5 years. Data from multiple centers with a larger number of cases and a wider variety of pathologies can be included in a larger study. More extensive use of video-assisted thoracoscopic surgery for excision of chest wall tumors should be used in our center. Titanium plates and other materials for chest wall reconstruction were not used in this study. The study did not compare the mid-term outcomes of different reconstruction techniques for all cases. Postoperative lung function was not tested and was not compared to preoperative LFT as this outcome was out of the scope of this particular study. The study lacks mid-term and long term follow up results for some of the study participants. A long-term follow-up is required in cases with malignant chest wall neoplasm and Desmoid tumors due to high recurrence rates.

Conclusion

Surgical intervention is very effective if tailored to every patient. A spectrum of

reconstructive techniques for larger defects exists with comparable outcomes and costs. A multidisciplinary team approach is usually preferred especially if an extensive demolition is required. Indeed, radical wide en-bloc resection can achieve satisfactory results provided that the extent of resection is not influenced by any anticipated reconstruction problems. Reconstruction materials are either autologous or synthetic. Prolene mesh and methyl methacrylate sandwich technique remain reasonable and relatively cheap synthetic options

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