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Oncological Outcome of Surgically Resected Sternal Tumors, 16 Years' Experience

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Abstract

BACKGROUND: Tumors of the sternum are rare and can develop from primary bone pathology or through metastatic spread. Sternal resection with immediate reconstruction of the anterior chest wall defect was recommended for both primary and secondary sternal tumors as curative treatment.

AIM: The purpose of our study was to examine the perioperative outcomes, recurrence rate, and OS in patients undergoing partial, subtotal, and total sternectomy.

METHODS: We retrospectively reviewed our experience with sternal resections in 29 patients during a 16-year period. The purpose of our study was to examine the perioperative outcomes, recurrence rate, and overall survival (OS) in patients undergoing partial, subtotal, and total sternectomy.

RESULTS: We found that 5-year OS was 26.0%, Univariate analysis of predictors of survival revealed that, there was a trend toward prolonged 5-year survival at R0 resection (35.5% vs. 0%, $p = 0.058$). Post resection defect size associated with prolonged 5-year OS (42.1% vs. 0%, $p < 0.001$). The absence of post-operative complications associated with prolonged 5-year OS (40.4% vs. 0%, $p = 0.012$), with special attention to absence of post-operative flail chest which was associated with prolonged 5-year OS (36.2% vs. 0%, $p < 0.001$). On multivariable analysis, R0 resection (HR, 3.692 [95% CI, 1.190–11.456], $p = 0.024$) and absence of post-operative flail chest (HR, 52.204 [95% CI, 5.908–461.289], $p < 0.001$) were associated with improved OS.

CONCLUSIONS: We have shown that sternal resection of benign and primary malignant tumors can yield long-term survival. The completeness of resection and absence of postoperative flail chest are the strongest predictors of survival.

Introduction

Tumors of the sternum are rare and can develop from primary bone pathology or through metastatic spread [1]. Chest wall resection for secondary sternal tumor began with Schede in 1866 [2]. Holden first described partial sternectomy for a primary sarcoma in 1878 [3] and the first complete sternectomy was performed by Brodin and Linden in 1959 [4]. Sternal resection with immediate reconstruction of the anterior chest wall defect was recommended for both primary and secondary sternal tumors as curative treatment [5].

Various reconstruction techniques have been described using synthetic, biologic, and metallic materials, but each prosthetic material has its own advantages and disadvantages, and none have proven to be clearly superior. After skeletal stability is established full tissue coverage can be achieved using direct suture, skin graft or local advancement flaps, pedicled myocutaneous flaps, or free flaps [6].

The optimal reconstructive approach is determined by the size, location, and depth of the defect, viability of the surrounding tissue, and prior operative procedures [7]. These reconstructive techniques have relieved complaints, enabled wide resection, avoided flail chest, and achieved good local control and overall survival (OS) [8].

Despite advances in reconstructive surgical techniques, imaging and surgical planning, sternal reconstruction continues to be challenging and lacks consensus on best practice [9]. Apart from a few case series, there are limited large studies of sternal reconstruction outcomes [10].

We retrospectively reviewed our experience with sternal resections in 29 patients during a 16-year period. The purpose of our study was to examine the perioperative outcomes, recurrence rate, and OS in patients undergoing partial, subtotal, and total sternectomy.

Patients and Methods

We retrospectively reviewed. 29 consecutive patients, who underwent resection of either a primary or a secondary sternal tumor between January 2005 and January 2021 at National Cancer Institute, Cairo University, Egypt, this study was approved by our Institutional Review Board.

Resectability of the sternal tumor, based on its location and extent was assessed pre-operatively by computed tomography (CT). Cardiorespiratory fitness was routinely assessed in all surgical candidates. There were no established patient selection criteria for sternal resections. Before the surgery was offered, all patients were presented at the multidisciplinary team, where the treatment options were discussed.

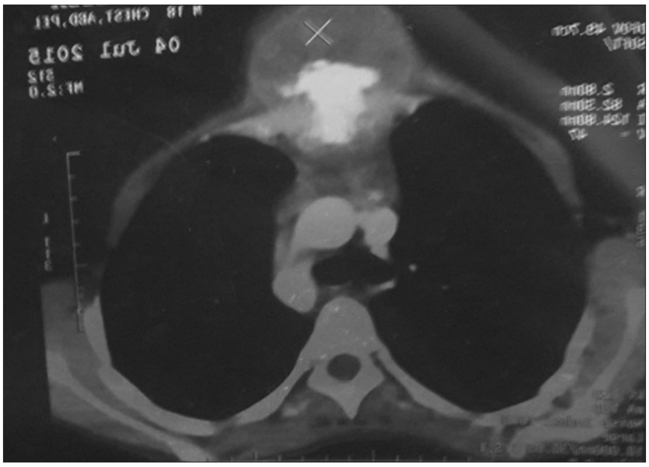

Figure 1: Yalk sac tumor invading sternum

Recurrent breast cancer as a secondary sternal tumor was defined as a tumor involving the primary site of resection, along with sternal invasion. Sternal metastasis was defined as a tumor involving the sternum, without the presence of a disease at the primary tumor site. In most of the patients, the sternum was the only site of disease, and sternal resection was performed with curative intent. It is routine practice at our institutions to discuss such patients and their treatment plans at a multidisciplinary tumor board.

All sternal resections and reconstructions were performed electively, as a single-stage procedure, by the team consisting of thoracic and plastic surgeons. Patient's demographics including age, gender, body mass index, smoking status, previous radiotherapy, and medical comorbidities were collected. Tumor classification was based on the final pathology report and primary or metastatic etiology. Surgical variables such as thoracic defect size, extent and location of defect, type of prosthetic material used for anterior chest wall reconstruction.

Surgical technique

We planned the extent of skeletal resection according to the findings of magnetic resonance imaging and CT scans of the chest (Figure 1), and the method of skeletal and soft-tissue reconstruction was decided by consensus of the thoracic and plastic surgeons.

Skin flaps were raised. Manubrial resection with or without resection of the clavicular head was performed without dividing the sternal body. Peritumoral soft tissue was excised en bloc (Figure 2). Larger tumors involving the sternal body were resected by dividing the cartilaginous portions of the anterior ribs (Figure 3).

Figure 2: Yalk sac tumor invading sternum

Reconstruction was accomplished by myocutaneous flap alone, mesh or with a rigid prosthesis, typically double polypropylene mesh-methyl methacrylate (MMA) "Sandwich" (Figure 4) to minimize the paradoxical chest wall movement. Briefly, a piece of polypropylene mesh, folded in two and cut larger than the skeletal defect, MMA put inside the polypropylene sandwich, then it was sutured to the of the sternum and ribs with 1–0 Vicryl (Figure 5), then coverage pectoralis major myocutaneous flap was done (Figure 6).

If the instability of the chest wall was not anticipated to compromise ventilation, prosthetic material was not used to repair the defect. Patients with wider defects after resection were selected for rigid reconstruction.

Statistical analysis

All statistical calculations were done using the computer program IBM SPSS (Statistical Package for the Social Science; IBM Corp, Armonk, NY, USA) v22 (2013) for Microsoft Windows, Survival analysis was done using the Kaplan-Meier method. Comparison between two survival curves was done using log-rank test. Multivariate analysis was done by Cox regression model to test for independent prognostic effect of statistically significant variables on Univariate level with calculating hazard ratio and its 95% confidence

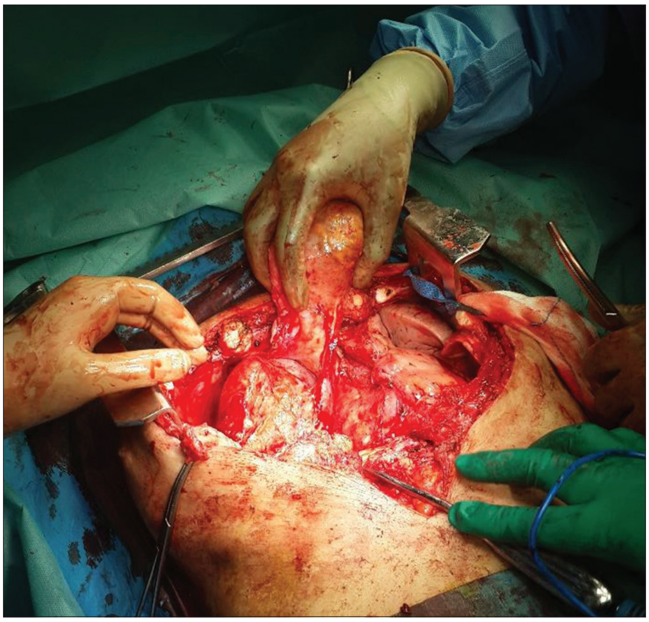

Figure 3: Maximum defect size after sternectomy occurred in yalk sac tumor invading the sternum was 432 cm²

interval. p ≤ 0.05 was considered significant. All tests were two tailed.

Results

During the study period, 29 patients underwent sternal resections, two patients had benign tumors, the remaining twenty-seven patients had malignant tumors. Primary malignant and non-breast secondary tumors were more common in men. Overall, sarcoma was the most common sternal malignant tumor (n = 14; 51.9%).

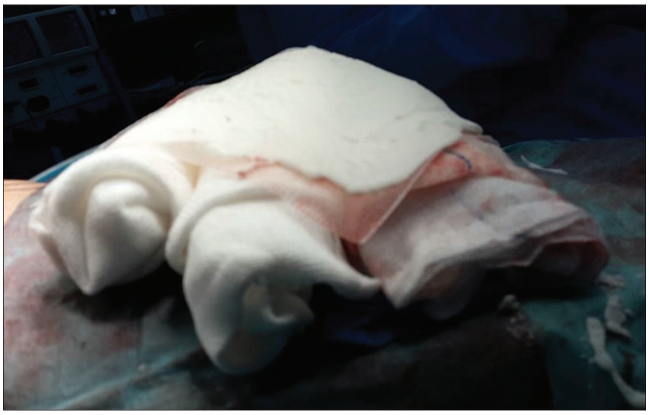

Figure 4: Methyl Methacrylate and double polypropylene mesh processing in the form of "sandwich" prosthesis

After a median follow-up period of 38 months, 18 patients died from the disease, we found that 1 year OS was 88.0%, 2 and 3-year OS, were 55.1% and 50.8%, respectively, and 5-year OS was 26.0% while 1-year DFS was 83.7% as local recurrence occurred in four patients (14.8%), there were no deaths or

Figure 5: Methyl Methacrylate and double polypropylene mesh fixation all around the defect

recurrences in patients with benign tumors. The 5-year OS was 29.9% for patients with primary malignant tumors, The 5-year OS for patients with secondary sternal tumors was 19.4%.

Demographics and preoperative patients' characteristics

The whole cohort was homogeneous in terms of demographics and Preoperative patients' characteristics regarding age, gender, and neoadjuvant chemotherapy (Table 1).

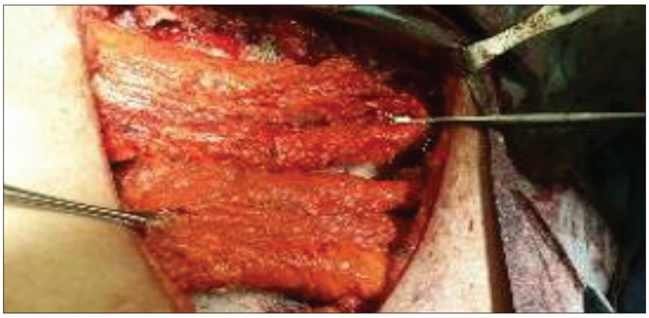

Figure 6: coverage of the MMA and double polypropylene mesh by bilateral pectoralis major muscle flap

Operative and postoperative outcomes

We found prolonged 5-year OS in patients with post resection defect size <100 cm² (42.1% vs. 0%, p < 0.001) (Figure 7) and absence of post-operative complications (40.4% vs. 0%, p = 0.012), especially absence of post-operative flail chest (36.2% vs. 0%, p < 0.001) (Figure 8). Furthermore, we found a statistically significant difference in OS regarding site of the tumor within the sternum whether upper part, lower part, or whole sternum (p ≤ 0.001).

Table 1: Demographics and Preoperative patients' characteristics

Preoperative Characteristics	Number of patients (%)	5-year survival estimate (%)	p-value
Age			
≤40	11 (40.7)	25	0.710
>40	16 (59.3)	25.9	
Gender			
Male	10 (37)	42.9	0.143
Female	17 (63)	16	
Preoperative chemotherapy			
No	17 (63)	22.2	0.906
Yes	10 (37)	40	

There was no statistically significant difference in 5-year OS regarding maximum tumor length whether smaller or larger than 6 cm (p = 0.514), extent of sternal resection whether total, subtotal or partial (p = 0.392), After resection, reconstruction by rigid reconstruction with MMA and double polypropylene mesh in the form of "sandwich" prosthesis was done in 25 patients of the whole cohort, two patients only were reconstructed with polypropylene mesh (Table 2).

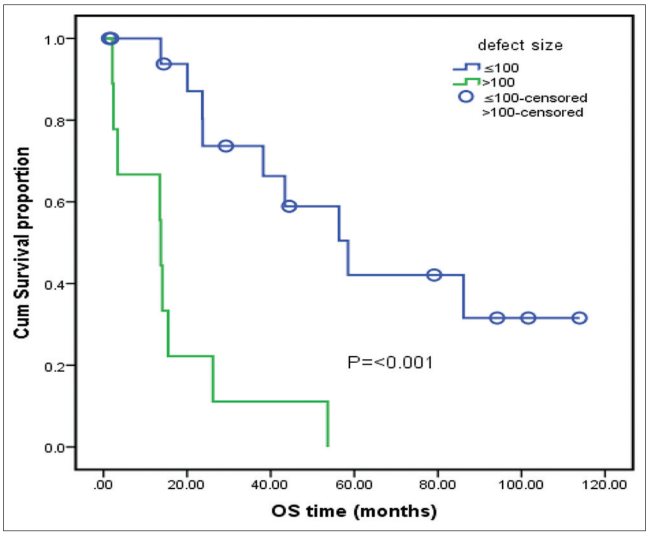

Figure 7: Relation between post resection defect size and overall survival

Pathological outcome

Final pathology report revealed that primary malignant sternal tumors were 14 patients (chondrosarcoma in 12 patients, one patient with osteosarcoma, and the last patient with angiosarcoma) and 13 patients with secondary malignant sternal tumors (6 patients were metastatic or recurrent breast cancer, one patient with metastatic differentiated thyroid cancer, one patient with metastatic transitional cell carcinoma of the bladder, one patient with yolk sac tumor, one patient with metastatic melanoma, one patient with metastatic skin squamous cell carcinoma and another patient with metastatic lung carcinoma).

Table 2: Operative and postoperative outcomes

Operative and Postoperative Outcomes	Number of patients (%)	5-year survival estimate (%)	p-value
Tumor site within the sternum			
Upper half	21 (77.8)	24.1	<0.001*
Lower half	4 (14.8)	7	
Whole sternum	2 (7.4)	0	
Maximum tumor length (cm)			
≤6	14 (51.9)	27.7	0.514
>6	13 (48.1)	24.3	
Extent of resection			
Partial	10 (37)	.47.6	0.392
Subtotal	14 (51.9)	15.4	
Total	3 (11.1)	33.3	
Defect Size (cm²)			
≤100	18 (66.7)	42.1	<0.001*
>100	9 (33.3)	0	
Postoperative complications			
No	17 (63)	40.4	0.012
Yes	10 (37)	0	
Postoperative flail chest			
No	20 (74)	36.2	<0.001*
Yes	7 (26)	0	

*Significant value below 0.05

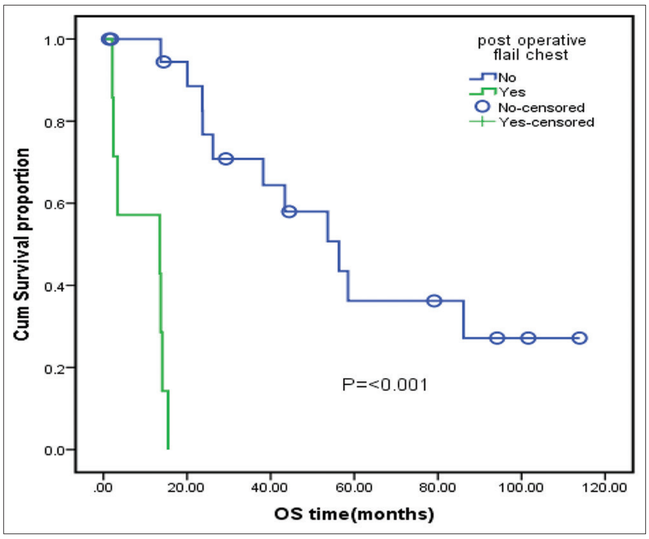

Figure 8: Relation between post-operative flail chest and overall survival

There was a trend towards significance in 5-year OS between negative and positive surgical margin resection (21 [77.8%] vs. 6 [22.2%] patients, p = 0.058], but we found no difference in 5-year OS between primary and secondary sternal malignant tumors (14 [51.9%] vs. 13 [48.1%] patients, p = 0.092), and between low- and high-grade malignant tumors (10 [37%] vs. 17 [63%] patients, p = 0.106) (Table 3).

Table 3: final pathological outcome

Pathologic Outcome	Number of patients (%)	5-year survival estimate (%)	p-value
Pathological type			
Sarcoma	14 (51.9)	29.9	0.092
Breast and others	13 (48.1)	19.4	
Grade			
Low	10 (37)	33.3	0.106
High	17 (63)	26	
Surgical margin			
Negative	21 (77.8)	35.5	0.058*
Positive	6 (22.2)	0	

*Significant value below 0.05

Predictors of survival

Univariate analysis of predictors of survival revealed that, there was a trend towards prolonged

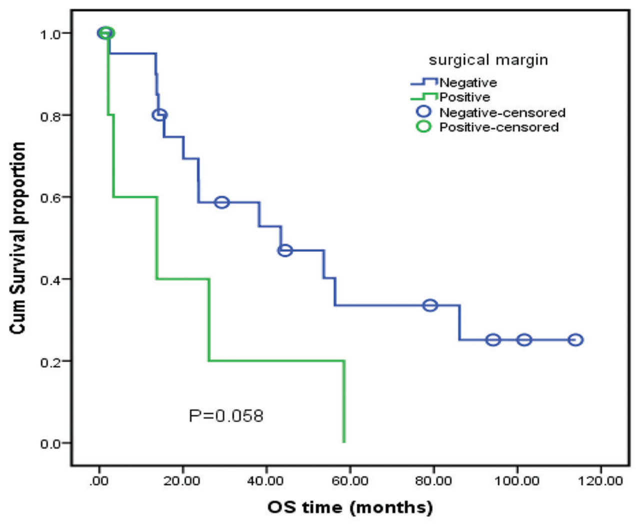

Figure 9: Relation between R0 resection and overall survival

5-year survival at R0 resection (35.5% vs. 0%, p = 0.058) (Figure 9). Post resection defect size associated with prolonged 5-year OS (42.1% vs. 0%, p < 0.001) (Figure 7). The absence of post-operative complications associated with prolonged 5-year OS (40.4% vs. 0%, p = 0.012), with special attention to absence of post-operative flail chest which was associated with prolonged 5-year OS (36.2% vs. 0%, p < 0.001) (Figure 8). On multivariable analysis, R0 resection (HR, 3.692 [95% CI, 1.190–11.456], p = 0.024) and absence of post-operative flail chest (HR, 52.204 [95% CI, 5.908–461.289], p < 0.001) were associated with improved OS.

Discussion

We found that sternotomy can be performed with low morbidity and mortality. Malignant sternal tumors had better OS after R0 resection, and patient mortality rate is significantly improved in the absence of postoperative flail chest, No difference in OS between primary and secondary or high and low grade malignant sternal tumors.

Sternectomy is the treatment of choice for sternal tumors because these tumors are often chemo- and radio-insensitive such as chondrosarcomas, sternotomy is indicated with curative or palliative intent (control of pain, removal of ulcerating lesion, and debulking) [11]. Sternal resection and reconstructions consist in an adequate radical resection associated with the maintenance of chest stability, lung function, and an acceptable cosmetic result [12].

The use of induction therapies remains controversial for low-grade primary sternal tumors, but different chemo or chemo radio-regimens are available for osteosarcomas, Ewing sarcomas, and high-grade soft tissue sarcomas with the improvement of OS [13], [14]. However, our study did not find a difference in OS between those who received chemotherapy or not, whether neoadjuvant or adjuvant.

The patients with isolated local recurrence after sternal tumors resection are considered candidate for surgery, and they should underwent re-resection rather than adjuvant radiotherapy; the use of adjuvant radiation did not seem to have a clear association to decrease local recurrence rate [5], which is similar to our results as local recurrence occurred in four patients who were managed with re-resection rather than radiotherapy.

As a wide resection of the anterior chest wall often threatens stability, reconstruction plays a crucial role in determining postoperative morbidity and mortality [15], [16]. Rigidity and protection of the viscera can be achieved using rigid prosthetic materials, while non-rigid materials are useful for sealing the dead space. Several reports suggest that stabilizing the anterior chest wall with rigid material could decrease the risk of developing an acute restrictive disease, avoiding deformities and restoring an acceptable thorax volume, and this leads to a reduced incidence of post-operative complication and mortality [17], [18].

In our experience, in the case of partial sternectomy, soft reconstruction was needed in the form of polypropylene mesh and muscle flap in only two patients which were diagnosed with benign nature. MMA sandwich for rigid reconstruction was performed in the remaining 27 patients. Pectoralis major myocutaneos flap was the most frequently selected muscle flap used for coverage (14 patients), skin advancement was used for coverage in 7 patients, a pedicled LD flap was used in five patients, Omentual flap was used for coverage in only one patient.

Our study showed a relatively high rate of overall complications (11/29, 38%), and respiratory complications in the form of flail chest (7/29, 24%) Respiratory complications are the main cause of in-hospital mortality in chest wall resections [8], based on an impaired rib cage mechanical function, causing atelectasis, pneumonia and subsequent respiratory failure and sepsis. It is unclear whether surgical procedure and type of reconstruction could minimize the possibility of development of pulmonary complications; however, our results demonstrated that an effective rigid reconstruction, an early extubation, and mobilization with an aggressive physiotherapy may decrease the incidence of respiratory impairment and related conditions [5].

Our complication rate is higher than previously published, where the other studies showed that the use of the newly developed methods of reconstruction in the form of titanium device may be the cause of this difference in post-operative complication rate especially flail chest [5], [19], we used the cheaper MMA double sandwich technique in all cases who needed rigid reconstruction.

We found no difference in 5-year OS between primary and secondary sternal malignant tumors (14 [51.9%] vs. 13 [48.1%] patients, p = 0.092), after multivariate analysis, but we found that R0 resection (HR, 3.692 [95% CI, 1.190–11.456], p = 0.024) was associated with improved OS in both groups. These results were contradictory to MSKCC study published in 2015, which concluded that only primary malignant sternal tumors had favorable OS and RFP after R0 resection [1].

Our study has some limitations: (I) Small sample size; (II) a single-institution series, retrospectively analyzed between 2005 and 2021 (III) heterogenicity of sternal tumors (IV) lack of a structured follow-up about cosmetic outcome, daily activity level and quality of life and (V) using single method for rigid reconstruction which is MMA double sandwich technique.

It would be desirable to perform multi-institutional study that could clarify the role of neoadjuvant and adjuvant therapies with introduction of newly developed custom-made titanium device.

In conclusion, we have shown that sternal resection of benign and primary malignant tumors can yield long-term survival. The completeness of resection and absence of postoperative flail chest are the strongest predictors of survival.

References

1. Ahmad U, Yang H, Sima C, Buitrago DH, Ripley RT, Suzuki K, *et al*. Resection of primary and secondary tumors of the sternum: an analysis of prognostic variables. Ann Thorac Surg. 2015;100(1):215-22. https://doi.org/10.1016/j.athoracsur.2015.03.013
   PMid:26002443
2. Donegan W. Cancer of the breast. Local and regional recurrence. In: Major Problems in Clinical Surgery. Berlin, Germany: ResearchGate; 1979. p. 484-503. https://doi.org/10.1016/0003-4975(95)00641-w
3. Soysal O, Walsh GL, Nesbitt JC, McMurtrey MJ, Roth JA, Putnam JB Jr., *et al*. Resection of sternal tumors: Extent, reconstruction, and survival. Ann Thorac Surg. 1995;60(5):1353-9.
   PMid:8526626
4. Richardson W. Enchondroma of the manubrium sterni successfully removed by operation. Br Med J. 1913;1(2732):985-6. https://doi.org/10.1136/bmj.1.2732.985
   PMid:20766631
5. Bongiolatti S, Voltolini L, Borgianni S, Borrelli R, Innocenti M, Menichini G, *et al*. Short and long-term results of sternectomy for sternal tumours. J Thorac Dis. 2017;9(11):4336. https://doi.org/10.21037/jtd.2017.10.94
   PMid:29268502
6. Geissen NM, Medairos R, Davila E, Basu S, Warren WH, Chmielewski GW, *et al*. Number of ribs resected is associated with respiratory complications following lobectomy with en bloc chest wall resection. Lung. 2016;194(4):619-24. https://doi.org/10.1007/s00408-016-9882-3
   PMid:27107874
7. Ferraro P, Cugno S, Liberman M, Danino MA, Harris PG. Principles of chest wall resection and reconstruction. Thoracic Surg Clin. 2010;20(4):465-73. https://doi.org/10.1016/j.thorsurg.2010.07.008
   PMid:20974430
8. Chapelier AR, Missana MC, Couturaud B, Fadel E, Fabre D, Mussot S, *et al*. Sternal resection and reconstruction for primary malignant tumors. Ann Thorac Surg. 2004;77(3):1001-7. https://doi.org/10.1016/j.athoracsur.2003.08.053
   PMid:14992915
9. Sharaf B, Sabbagh MD, Vijayasekaran A, Allen M, Matsumoto J. Virtual surgical planning and three-dimensional printing in multidisciplinary oncologic chest wall resection and reconstruction: A case report. Int J Surg Case Rep. 2018;47:52-6. https://doi.org/10.1016/j.ijscr.2018.04.022
   PMid:29729609
10. Butterworth JA, Garvey PB, Baumann DP, Zhang H, Rice DC, Butler CE. Optimizing reconstruction of oncologic sternectomy defects based on surgical outcomes. J Am Coll Surg. 2013;217(2):306-16.
    PMid:23619320
11. Incarbone M, Nava M, Lequaglie C, Ravasi G, Pastorino U. Sternal resection for primary or secondary tumors. J Thorac Cardiovasc Surg. 1997;114(1):93-9. https://doi.org/10.1016/s0022-5223(97)70121-1
    PMid:9240298
12. Walsh GL, Davis BM, Swisher SG, Vaporciyan AA, Smythe WR, Willis-Merriman K, *et al*. A single-institutional, multidisciplinary approach to primary sarcomas involving the chest wall requiring full-thickness resections. J Thorac Cardiovasc Surg. 2001;121(1):48-60. https://doi.org/10.1067/mtc.2001.111381
    PMid:11135159
13. Martini N, Huvos AG, Burt ME, Heelan RT, Bains MS, McCormack PM, *et al*. Predictors of survival in malignant tumors of the sternum. J Thorac Cardiovasc Surg. 1996;111(1):96-106. https://doi.org/10.1016/s0022-5223(96)70405-1
    PMid:8551793
14. van Geel AN, Wouters MW, Lans TE, Schmitz PI, Verhoef C. Chest wall resection for adult soft tissue sarcomas and chondrosarcomas: Analysis of prognostic factors. World J Surg. 2011;35(1):63-9. https://doi.org/10.1007/s00268-010-0804-x
    PMid:20857106
15. Weyant MJ, Bains MS, Venkatraman E, Downey RJ, Park BJ, Flores RM, *et al*. Results of chest wall resection and reconstruction with and without rigid prosthesis. Ann Thorac Surg. 2006;81(1):279-85. https://doi.org/10.1016/j.athoracsur.2005.07.001
    PMid:16368380
16. Mansour KA, Thourani VH, Losken A, Reeves JG, Miller JI Jr., Carlson GW, *et al*. Chest wall resections and reconstruction: A 25-year experience. Ann Thorac Surg. 2002;73(6):1720-6. https://doi.org/10.1016/s0003-4975(02)03527-0
    PMid:12078759
17. Berthet JP, Canaud L, D'Annoville T, Alric P, Marty-Ane CH. Titanium plates and Dualmesh: A modern combination for reconstructing very large chest wall defects. Ann Thorac Surg. 2011;91(6):1709-16. https://doi.org/10.1016/j.athoracsur.2011.02.014
    PMid:21531380
18. Fabre D, El Batti S, Singhal S, Mercier O, Mussot S, Fadel E, *et al*. A paradigm shift for sternal reconstruction using a novel titanium rib bridge system following oncological resections. Eur J Cardiothorac Surg. 2012;42(6):965-70. https://doi.org/10.1093/ejcts/ezs211
    PMid:22551966
19. Marulli G, Duranti L, Cardillo G, Luzzi L, Carbone L, Gotti G, *et al*. Primary chest wall chondrosarcomas: Results of surgical resection and analysis of prognostic factors. Eur J Cardiothorac Surg. 2014;45(6):e194-201. https://doi.org/10.1093/ejcts/ezu095
    PMid:24616390