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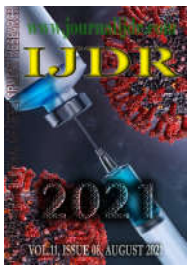

RESEARCH ARTICLE OPEN ACCESS

IMPERATIVE RECONSTRUCTION OF COMPLEX DEFECTS OF THORACIC WALL AFTER NON BREAST CANCER RESECTION

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ABSTRACT

Complex defects of thoracic wall are mainly acquired after cancer resection, whose reconstruction during the same surgical time is imperative. Thoracic reconstruction aims to avoid paradoxical breathing, to protect intrathoracic organs and other noble structures, to obliterate empty spaces and, if possible, to obtain a good aesthetic. This study presents a case series of imperative reconstruction of complex defects of thoracic wall after non breast cancer (NBC) resection. Cases were operated by the plastic surgery teams of Escola Paulista de Medicina and Hospital do Servidor Público Estadual in São Paulo, Brazil, between October 2014 and April 2021. Eight cases were included (mean age = 61,0 years). Due to the complexity of the cases, grafts, flaps, polypropylene mesh and titanium rods were used, being latissimus dorsi muscle flap the most utilized. Mean hospitalization time was 15,5 days. There was a loss of the flap on account of thrombosis in the vascular anastomosis and two deaths. Imperative reconstruction of complex defects of thoracic wall after NBC resection is capable of providing good functional and aesthetic results, mitigating inherent losses by disruption of thoracic wall integrity.

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INTRODUCTION

Chest wall reconstruction after extensive and complex resections is a challenging area of plastic surgery. The first description of thoracic reconstruction using muscle flaps occurred in 1906 by Tansini, an italian surgeon who used a latissimus dorsi musculocutaneous flap to repair a defect resulting from a radical mastectomy (SCHROEDER-FINCKH *et al.,* 2019). The first report on the use of synthetic material dates back to 1909 (KHULLAR and FERNANDEZ, 2017). Since then, new techniques and alternatives have been created to repair deformities acquired in this region. Most complex chest wall defects are the result of resections of malignant tumors (HARATI *et al.,* 2017). These can be divided into primary tumors, that is, derived from soft tissues or the bone framework, and secondary tumors, originating from the lung, mediastinum or even metastatic (HARATI *et al.,* 2017; MERRITT, 2017). Breast neoplasms are the most frequent primary tumors of the chest wall, corresponding to a separate chapter in the literature and, for this reason, they were not addressed in this work.

Primary non-mammary cancers of the chest wall are rare and represent less than 3% of chest tumors (HARATI *et al.,* 2017). Of these, sarcomas arising from bones, cartilage and soft tissue stand out (STILLER *et al.,* 2013). The treatment of these tumors often requires surgical removal "en bloc", that is, resection of the lesion, adjacent soft tissues and costal arches in a single piece, resulting in impairment of respiratory and cardiovascular function that requires imperative reconstruction (D'AMICO *et al.,* 2018; SCHROEDER-FINCKH *et al.,* 2019). The goals of reconstruction at the same surgical time include avoiding paradoxical breathing, protecting intrathoracic organs and other noble structures, filling dead spaces and, if possible, obtaining a good esthetic result (KHULLAR and FERNANDEZ, 2017; D'AMICO *et al.,* 2018). In order to avoid complications and damage to cardiorespiratory function, there is an arsenal of surgical techniques for the reconstruction of such defects, including grafts, flaps and synthetic materials. Generally speaking, defects larger than five centimeters in diameter require some type of reconstruction (THOMAS and SHEN, 2017).

Among the existing options, muscle flaps and synthetic prostheses stand out, such as polypropylene meshes and titanium rods (KHULLAR and FERNANDEZ, 2017; THOMAS and SHEN, 2017; GAO *et al.,* 2018). The decision to choose the flap and synthetic material is usually based on the surgeon's experience and the availability of the institution's resources (CHANG *et al.,* 2004; FRANCO *et al.,* 2015; CROWLEY *et al.,* 2020; CORKUM et al 2020). Due to the complexity of the lesions and reconstructions described, this study aims to contribute to the attempt to overcome the challenging nature of those deformities.

METHODS

This is a retrospective study of patients undergoing imperative reconstruction of complex chest wall defects secondary to CNM resection. Approval was obtained by the Research Ethics Committee of Universidade Federal de São Paulo (registration number: 0675/2019) and written consent was obtained from all participants, in accordance with the ethical principles of the Declaration of Helsinki and the brazilian requirements of the National Health Council (Resolutions 466/12 and 510/16). We included cases of imperative reconstruction of complex defects of thoracic wall after NBC resection, operated between October 2014 and April 2021, by the plastic surgery teams of Escola Paulista de Medicina and Hospital do Servidor Público Estadual in São Paulo, Brazil, and considered of higher complexity by them. We did not include cases of defects secondary to breast cancer resection, and cases without detailed documentation were excluded. Electronic medical records were accessed to collect preoperative (gender, age and personal medical history), intraoperative (date, surgical technique, flaps, prostheses and time of surgery) and postoperative information (time of hospitalization, histopathological diagnosis, postoperative complications, complementary treatment and follow-up time). Pre- and postoperative images were provided by the Microsurgery Sector of Plastic Surgery Division of Escola Paulista de Medicina - Universidade Federal de São Paulo (EPM-UNIFESP). Excel software (Version 2019; Microsoft Corporation, Redmond, WA, United States of America) was used to build a database and calculate basic statistics (porcentage, average and median) to describe the cases.

RESULTS

Eight cases of imperative reconstruction of complex defects of thoracic wall after NBC resection were selected. Most of the cases were male n = 6 (75%), with mean age of 61.0 years (24.0 to 77.0 years; median = 66.5 years). Demographic data are described in Table 1.

Surgical Aspects: All patients were submitted to surgical treatment for complete tumor excision, with thoracectomy with "en bloc" removal being the most used technique n = 7 (87.5%). Regarding the location, half of the tumors were located in the anterior wall and half in the posterior wall. Five cases (62.5%) required costal arch removal, and the mean number of removed ribs was 4 ribs. In addition to rib removal, three cases (37.5%) required sternectomy, and one case (12.5%) required lung resection. The mean surgery time was 10.3 hours (6 to 16 hours; median = 9.5 hours). Depending on the case, skin grafts, random and axial flaps (fasciocutaneous, musculocutaneous, muscular and based on perforating artery) were performed to cover the defects. The latissimus dorsi muscle was the most used in reconstructions, in three musculocutaneous flaps and in one muscle flap. Regarding prostheses, polypropylene mesh was used in six cases (75%) and titanium rods in two cases (25%) for bone scaffold reconstruction. Table 2 presents the proposed surgeries.

Histopathology and postoperative aspects: The average length of hospital stay was 15.5 days (5 to 30 days; median = 14 days). There was one flap loss due to thrombosis in the vascular anastomosis (12.5%) and two deaths (25%). Sarcoma was the most identified histological type (62.5%), followed by squamous cell carcinoma (25%) and fibromatosis (12.5%).

One case required complementary treatment exclusively with radiotherapy (12.5%) and one case required complementary treatment with radiotherapy associated with chemotherapy (12.5%). Mean postoperative follow-up time was 499.4 days (5 to 2680 days; median = 114.5 days). Table 3 presents postoperative information and histopathological diagnoses.

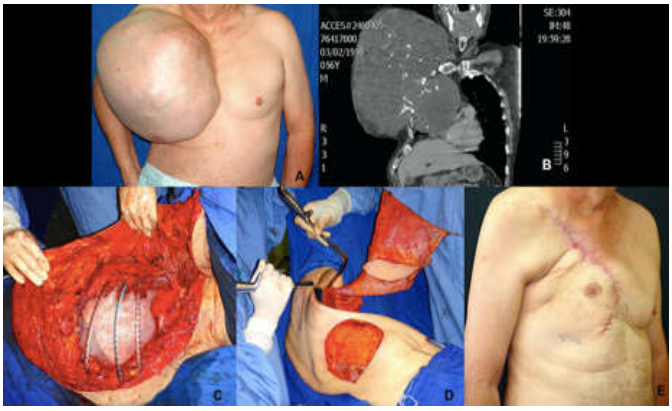

Figure 1 - (A) Case 1, male, 56 years old, with an expansive lesion in the right hemithorax for 20 years, painless, with mild limitation of movement. Presence of a thoracic mass on the right. (B) Chest computed tomography (CT) showing a large mass located on the right chest wall, measuring approximately 32 x 30 x 31 cm, lobulated contours, with sparse calcifications in between, occupying the middle pulmonary field and compressing the right atrium and superior vena cava. There was another lesion with similar characteristics in the right lung apex, measuring 8.4 x 6.3 x 7.5 cm. (C) Right thoracectomy with "en bloc" resection of the lesion, including, including 1st to 5th costal arches, sternum segment, upper and middle lobes of the right lung, T1 nerve root, stellate ganglion, and pectoralis major and minor muscles. (D) Fixation of a double-layer polypropylene mesh, three titanium arches and latissimus dorsi musculocutaneous flap for reconstruction of the pleural cavity, bone framework and soft tissues of the entire hemithorax. (E) Postoperative.

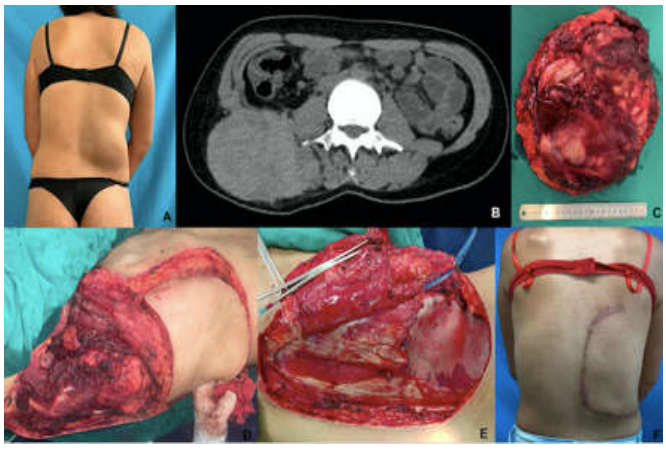

Figure 2 - (A) Case 2, female, 24 years old, with bulging in the thoracodorsal region for four years of progressive growth associated with weight loss. Presence of a hardened mass affecting the right thoracolumbar region, with about 15 cm in diameter, without phlogistic signs and painful on palpation. (B) Chest CT showing a large, heterogeneous expansive solid formation, 11.7 x 8.1 x 9.7 cm, with lobulated contours, located below the thoracolumbar aponeurosis on the right, invading the posterior paravertebral musculature on the right and in contact with the posterior cortex of the costal arches of T11 and T12 without areas of rupture. (C) Surgical piece. (D) Resection of the lesion with removal of parts of the serratus posterior and intercostal muscles, in addition to a costal arch. Caudal rotation of latissimus dorsi musculocutaneous flap with preservation of the thoracodorsal pedicle. (E) Fixation of the thoracolumbar wall with double synthetic polypropylene mesh (F) Postoperative appearance.

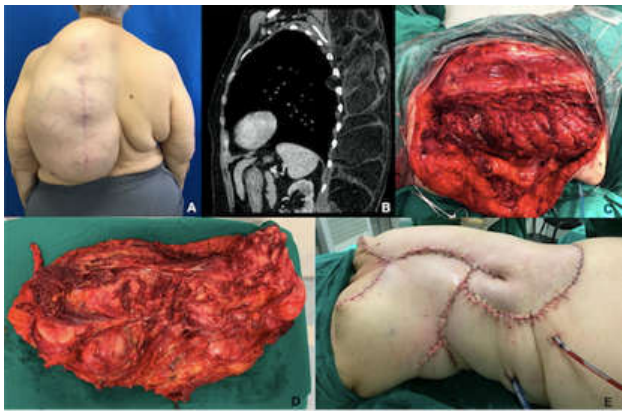

Figure 3 - (A) Case 3, female, 73 years old, with a left dorsal tumor for two years of progressive growth. Presence of a voluminous and hardened mass in the entire dorsal region on the left. (B) Chest CT showing a large expansive formation on the left dorsum, with heterogeneous content, predominantly adipose, with invasion of the pleural space and restrictive atelectasis by compression. (C) Thoracectomy with "en bloc" removal of the lesion with four costal arches. (D) Surgical piece. (E) Rotation of the right latissimus dorsi muscle flap to close the bone framework defect and local random fasciocutaneous flaps to cover the defect in the thoracic region.

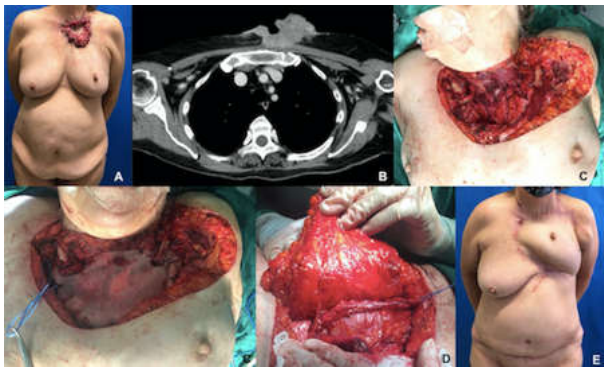

Figure 4 - (A) Case 4, female, 65 years old, with an ulcerated lesion on the anterior chest wall for seven years of progressive growth. Ulcerated lesion with raised edges in the left parasternal region, approximately 15 cm in diameter, friable. (B) Chest CT showing vegetative formation, with irregular contours, in the anterior region of the chest, measuring 9.7 x 10.9 cm, extending to the pectoralis major muscle, without contact with the cortical bone of the sternum. (C) Resection of one third of the sternum, bilateral clavicular joints, the left pectoralis major muscle and part of the right one with placement of a polypropylene mesh during the first approach with a perforator flap of the deep inferior epigastric artery. (D) Closure with a rhomboid fasciocutaneous flap based on the lateral thoracic artery in reconstructive salvage surgery after previous flap loss due to anastomotic thrombosis caused by hemodynamic instability. (E) Postoperative appearance.

Figure 5 - (A) Case 5, male, 68 years old, with a necrotic tumor in the anterior thoracic region for six months. A vegetating, necrotic, friable lesion in the anterior thoracic region, approximately 45 cm in diameter. (B) Resection of the tumor. (C) Reconstruction with a vertical rectus abdominis musculocutaneous flap and placement of a polypropylene mesh. (D) Immediate postoperative appearance.

Figure 6 - (A) Case 6, male, 75 years old, with a painful tumor on the right back for two months, fast growing, associated with a weight loss of 2 kg and mobility restriction of the ipsilateral upper limb. Presence of a voluminous and indurated mass in the dorsal region on the right, with increased vascularization, and painful palpation. (B) Chest CT showing a solid, heterogeneous mass with a neoplastic aspect, centered on the dorsal region to the right, measuring 20.7 x 17.4 x 14.7 cm, in close contact with the adjacent muscle planes. (C) Resection of the tumor followed by rotation of the latissimus dorsi flap to the left, encompassing skin on the right flank, and removal of a partial skin graft from the right lower limb to cover the lesion. (D) Postoperative appearance.

Figure 7 - (A) Case 7, male, 50 years old, with a slow-growing lesion on the anterior chest wall for two years, associated with local pain and clear discharge. Presence of tumor measuring about 15 x 10 cm in extension, ulcerated, with irregular edges and a background with granulation tissue and fibrin areas. (B) Chest CT showing an infiltrative expansive lesion measuring approximately 12.0 x 6.0 x 7.0 cm, centered on the midline of the anterior chest wall, affecting the

skin, muscle-adipose planes and sternum, extending to the anterior mediastinum, and suspicious lymph nodes in the left axillary chain. (C) Thoracectomy with "en bloc" removal of the lesion, including manubrium, sternal body, 1-6th costal cartilages bilaterally and thymus, followed by placement of a polypropylene mesh posteriorly to the costal arch and two 12 cm titanium rods anchored on the 3rd and on the 5th costal arches. (D) Creation of a transverse microsurgical flap of the rectus abdominis muscle, with anastomosis in the internal mammary artery.

Figure 8 - (A) Case 8, male, 77 years old, with bulging in the right posterior hemithorax for one year, with progressive growth. (B) Presence of solid tumor located in the right posterior costal grating, measuring about 15 x 15 cm, mobile, with local hyperemia and heat, without floating point, painful to touch and with the presence of serosanguineous secretion drained by central ulceration. (C) Chest CT showing a mass with soft tissue density, heterogeneous, well circumscribed, posterolateral to the right hemithorax, without involvement of the ribs and pleura. (D) Posterolateral thoracectomy on the right with "en bloc" removal of the lesion with four costal arches. (E) Reconstruction with stretched polypropylene mesh. (F) Reconstruction with rhomboid fasciocutaneous flap from the lower abdomen and rhomboid skin flap from the right pectoral region and closure of the residual defect with a z-plasty flap of the dorsum.

DISCUSSION

Breaking the integrity of the chest wall during cancer resection implies higher rates of postoperative complications, dependence on mechanical ventilation and prolonged hospital stay, especially in elderly patients and in large lesions (BATISTA et al 2014; GAO *et al.,* 2018; CORKUM *et al.,* 2020). In this sense, there is a need for reconstruction with stable coverage at the same surgical time for a better prognosis (CHANG *et al.,* 2004; LOSKEN *et al.,* 2004). There is no standardized approach for selecting technique or materials to be utilized, and several attempts at protocol approaches have been proposed (FRANCO *et al.,* 2015; CORKUM *et al.,* 2020). Thus, the surgical team should, based on their experience and on the characteristics and expectations peculiar to the patient, choose the approach that brings them the best functional and aesthetic result under the principle of scaling up reconstruction techniques (NETSCHER and BAUMHOLTZ, 2009; JANIS *et al.,* 2011). The latissimus dorsi muscle flap stands out for its versatility and is one of the most utilized in reconstructive surgery of the chest wall. It is used to reconstruct full-thickness defects due to its large volume. Based on the thoracodorsal and posterior intercostal arteries, it has a wide arc of rotation and it can cover almost the entire ipsilateral chest wall. However, for its use, the patient is commonly positioned in lateral decubitus during the surgical procedure, causing additional technical difficulties. In addition, it has seroma risk and can cause shoulder dysfunction in some patients, which was not observed in this study (SKORACKI and CHANG, 2006; SAUERBIER *et al.,* 2011). It was the most used flap (cases 1, 2, 3 and 6), especially for cases with greater depth of resection, which reached the thoracic bone framework. Under the same proposal, Brito et al (2020) reported reconstruction after resection of a giant chondrosarcoma that reached the mediastinum, obtaining good functional results and hospital discharge within 13 days, similar to case 1.

In contrast, in a retrospective review with 59 patients from the MD Anderson Cancer Center in the United States, the latissimus dorsi was the third most used type of muscle flap, behind the rectus abdominis and serratus anterior muscles (CORKUM et al 2020). The second most utilized muscle in this case series was the rectus abdominis. In cases 5 and 7, it was used to cover anterior chest wall defects in their different configurations. Widely used, its flap is based on the superior deep epigastric arteries, when pedicled, and the inferior ones, when microsurgical. It is used to cover the anterior and lateral regions of the chest. This flap can be oriented vertically (VRAM) or transversely (TRAM). Although both allow coverage of the chest wall, they cause a defect in the rectus abdominis and its anterior sheath, favoring herniations and eventrations (SKORACKI and CHANG, 2006; SAUERBIER *et al.,* 2011). Warbrick-Smith et al. (2013) used this flap in the VRAM configuration, as in case 5, to cover the defect after resection of a giant basal cell carcinoma, also located in the anterior thoracic region. However, performing a much deeper resection, an association with an omentum flap was necessary.. In its turn, the deep inferior epigastric artery perforator flap is obtained by careful dissection of the perforating branches along their path inside the rectus abdominis muscle, being used in case 4 of this study. Anastomosis is most commonly performed with branches of the internal mammary, circumflex scapular or thoracodorsal artery. Because it preserves the abdominal muscles and innervation, it has a lower risk of herniation and better postoperative recovery compared to abdominal muscle flaps (O'MALLEY *et al.,* 2016). Futter et al (2000), comparing the residual muscle strength after reconstruction in breast context, found a significantly lower impact in the use of DIEP compared to TRAM. Since case 4 presented loss of the microsurgical flap due to thrombosis of the anterior vascular anastomosis because of postoperative hemodynamic instability, it is not possible to attribute any complications exclusively to DIEP. Despite this, no herniation or eventration was observed in the 481 days of follow-up.

Synthetic prostheses are necessary when the removal of the neoplastic lesion involves the resection of ribs in order to preserve the stability of the rib cage and restore lung expansion (SCHROEDER-FINCKH *et al.,* 2019). Polypropylene meshes are flexible materials that allow uniform distribution of tension (KHULLAR and FERNANDEZ, 2017). These were the prostheses used in this series, being applied in three cases with resection of ribs in numbers of four, six and five (cases 8, 7 and 1, respectively), one case with bilateral resection of the sternum and clavicular joints (case 4), one with wide depth of resection, reaching the bone framework (case 2), and another with wide extension of resection (case 5). In general, the removal of less than five ribs or the sternum alone could be repaired only with a polypropylene mesh, whereas when five or more ribs were resected, the polypropylene mesh was used in association with titanium rods. Chang et al (2004) obtained a similar result in their study with 113 patients who underwent reconstruction of oncological chest defects, in which the combination of synthetic materials (methylmethacrylate between two layers of polypropylene) was necessary when four or more ribs and/or sternum were removed. Titanium rods are rigid materials that enable the reconstruction of the rib cage framework, maintaining local stability and avoiding paradoxical breathing. Titanium is the metal of choice for its great tensile strength, biological compatibility and low risk of infection (KHULLAR and FERNANDEZ, 2017; THOMAS and SHEN, 2017; GAO *et al.,* 2018). They were used in cases 1 and 7. In both cases, extensive resection of the bone framework was necessary (five and six ribs removed, respectively) and infection was not observed. Berthet et al (2015) retrospectively studied the complications of titanium implants for thoracic reconstruction and found that the anterior location and the presence of three or more prostheses was a significant risk factor for implant failure. The anterior thoracic region was the insertion site of three prostheses in both cases and no implant failure was observed in the 2680 days of follow-up of case 1. Case 7 died on the fifth postoperative day. In this case series, the patients were mostly elderly (median = 66,5 years) and had large lesions in prime thoracic areas. The important repercussion of surgical trauma is evidenced by the postoperative hospital stay (median = 14 days) and severity of complications, present in more debilitated patients due to underlying

Table 1. Preoperative information.

Case number	Sex	Age (years)	Personal medical history
1	Male	56	Ex-smoker
2	Male	24	Abdominopelvic fibromatosis (2019)
3	Female	73	Lipoma (2008), fibrolipoma (2013) and well differentiated liposarcoma (2018) at the same site of 2020's lesion
4	Female	65	Thoracic basocellular carcinoma resected with compromised margins and complemented with radiotherapy (2008)
5	Male	68	Kidney transplant
6	Male	75	Medullary aplasia (2016), diabetes mellitus, hypothyroidism, benign prostatic hyperplasia, gastroesophageal reflux disease and ex-smoker
7	Male	50	Active smoker
8	Male	77	None

Table 2. Intraoperative information.

Case number	Proposed surgery	Date(s)	Depth of resection	Number of resected ribs	Flap(s)	Graft	Prosthesis	Surgical time (hours)
1	Right thoracectomy with en bloc removal of the lesion	10/01/2014	Until right lung and mediastinum	5	1 musculocutaneous	None	Polypropylene mesh and 3 titanium rods	11
2	Right dorsal fibromatosis resection	10/14/2020	Until rib cage	1	1 musculocutaneous	None	Polypropylene mesh	8
3	Left thoracectomy with en bloc removal of the lesion	8/28/2020	Until rib cage	4	1 muscle-only and randoms local fasciocutaneous	None	None	8
4	Anterior thoracectomy with en bloc removal of the lesion and partial esternectomy. After, re-exploration of microsurgical pediculus with flap removal	10/31/2019 and 01/11/2020	Until rib cage	0	1 perforator-based. After, 1 fasciocutaneous based on lateral thoracic artery	None	Polypropylene mesh	13
5	Anterior thoracectomy with en bloc removal of the lesion	4/24/2021	Until intercostal muscles	0	1 musculocutaneous	None	Polypropylene mesh	12
6	Right thoracectomy with en bloc removal of the lesion	11/25/2020	Until mediastinum	0	1 musculocutaneous	1 partial skin	None	8
7	Anterior thoracectomy with en bloc removal of the lesion	8/26/2018	Until mediastinum	6	1 microsurgical musculocutaneous	None	Polypropylene mesh and 2 titanium rods	16
8	Right thoracectomy with en bloc removal of the lesion	1/27/2021	Until mediastinum	4	1 fasciocutaneous, 1 cutaneous and 1 z-plasty	None	Polypropylene mesh	6

Table 3. Postoperative information and histopathological diagnosis.

Case number	Hospitalization time (days)	Histopathological diagnosis	Complementary treatment	Postoperative complications	Postoperative follow-up time (days)
1	14	Chondrosarcoma	None	Wound dehiscence and mild motor deficit in the right upper limb	2680
2	4	Deep fibromatosis with infiltration of striated muscle, adipose and bone tissue	None	None	448
3	19	Grade III liposarcoma	Radiotherapy	Wound dehiscence and epidermolysis	221
4	26	Primary cutaneous carcinosarcoma with a predominance of the epithelioid component	None	Hemodynamic instability with flap loss due to thrombosis in the vascular anastomosis. After re-exploration, there was wound dehiscence and hypertrophic scar	481
5	12	Moderately differentiated squamous cell carcinoma	None	Epidermolysis	68
6	30	High-grade rhabdomyosarcoma	None	Aplastic anemia refractoriness with the need for progressive transfusional support in addition to graft infection, culminating in death	30
7	5	Moderately differentiated squamous cell carcinoma	None	Intraoperative hemodynamic instability, culminating in death	5
8	14	High-grade pleomorphic sarcoma	Radiotherapy and chemotherapy	None	62

disease and/or more invasive neoplasms. Similarly, Chang et al (2004) had a mean length of stay of 11.5 days and disease-related mortality in advanced stages, not being directly attributed to the reconstructive procedure. The first death occurred in a 75-year-old man (case 6), with medullary aplasia under treatment, who was affected by high-grade rhabdomyosarcoma and had an important complaint of pain. In order to provide dignity and quality of life, a surgical approach was chosen despite the clinical severity of the patient, who had only 20,000 platelets/mm^3. The surgery was performed with an argon scalpel after transfusion of platelet concentrate, increasing values to 50,000 platelets/mm^3. The second death occurred in a 50-year-old man (case 7) with a high smoking burden and who was affected by moderately differentiated squamous cell carcinoma, suffering from postoperative hemodynamic instability. Imperative reconstruction of complex defects of thoracic wall after NBC resection is capable of providing good functional and aesthetic results, mitigating inherent losses by disruption of thoracic wall integrity.

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