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# Endoprosthesis replacement of the sternum handle in $G_1$ chondrosarcoma: clinical case

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***ABSTRACT***

***BACKGROUND:*** Malignant neoplasms with lesions of the chest are quite rare in the sternum and range from 0.5 to 3.1% of the total number of patients with bone tumors of all localizations. In this connection, there are few publications describing the tactics of surgical treatment and methods of prosthetics of the formed defect. The present article describes a clinical case of successful application of an individual prosthesis of the manubrium of the sternum in $G_1$ chondrosarcoma.

***CLINICAL CASE DESCRIPTION:*** to present a clinical observation of the surgical treatment of an 18-year-old patient with $G_1$ chondrosarcoma of the manubrium of the sternum, with individual prosthetics.

***CONCLUSION:*** The use of modern 3D technologies based on the results of CT modeling allows, not only to plan the volume of necessary bone resection, but also to manufacture high-tech prostheses by using 3D printing to replace the defect with planning sufficient support capacity and function.

**Keywords:** chondrosarcoma; sternum prosthesis; chest tumor; 3D printing.

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# Эндопротезирование рукоятки грудины при хондросаркоме $G_1$: клинический случай

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***АННОТАЦИЯ***

***Обоснование.*** Злокачественные новообразования с поражением грудной клетки встречаются достаточно редко и составляют от 0,5 до 3,1% общего числа больных с опухолями костей всех локализаций. В связи с этим имеется достаточно мало публикаций, описывающих тактику хирургического лечения и методов протезирования сформированного дефекта.

***Описание клинического случая.*** В статье представлен случай хирургического лечения пациента в возрасте 18 лет с хондросаркомой $G_1$ рукоятки грудины с успешным проведением её индивидуального протезирования.

***Заключение.*** Использование современных 3D-технологий позволяет по результатам КТ-моделирования осуществлять не только планирование объёма необходимой резекции костной ткани, но и изготавливать высокотехнологичные протезы при помощи 3D-печати для замещения дефекта с планированием достаточной опороспособности и функции.

**Ключевые слова:** хондросаркома; протез грудины; опухоль грудной клетки; 3D-печать.

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ЭКО • ВЕКТОР

# BACKGROUND

Malignant lesions of the flat bones of the chest are usually difficult for surgeons to manage. Although modern imaging techniques enable the selection of the volume of resection according to oncological criteria, the choice of the defect replacement approach makes it necessary to correlate known methods with the task. This difficulty is largely due to the need to consider the high mobility and elasticity of the chest, combined with the need for a large number of fixation sites for the implant in order to create the most complete and most physiological support for the chest. The use of an insufficient number of support points often leads to implant instability.

Primary malignant tumors of the chest wall are relatively rare. Sternum lesions account for 0.5%–3.1% of all bone tumors. The most common bone tumors of the anterior chest wall are chondrosarcomas (27%), followed by osteosarcomas (22%) and fibrosarcomas (22%). Up to 30% of sternum tumors involve cancer metastases from various organs [1–3].

Primary malignant lesions of the sternum in pediatric patients are extremely rare, as are the methods described for the surgical treatment of this disease, which is the reason for our case report on the development and use of an implant.

Radical surgery that strictly complies with the requirements of oncosurgery is crucial in the treatment of most chest sarcomas. Tumors localized to the bones of the anterior chest wall (sternum, clavicle, and ribs) can involve the mediastinal organs, lung parenchyma, great vessels, and nerve plexuses. That is why radical tumor removal should be performed in institutions where there is interaction between thoracic, vascular, traumatological-orthopedic, and oncological surgeons [4–9].

In the preoperative planning of interventions for sternum tumors, it is important to select a method for closing the post-resection defect. If there is impaired integrity in the area of the sternum, it is important to restore the chest skeleton, create an effective support for the ribs and, if possible, preserve the range of motion during breathing. If the manubrium is affected, the integrity of the sternoclavicular articulation, which is important for maintaining shoulder girdle function, will also be impaired. Recent studies describe various attempts to replace chest defects, where reconstruction with the patient's tissues and synthetic implants, usually in the form of plates (often made of titanium nickelide), were used. Among other things, the use of additive technologies in solving this issue was also discussed; however, the presented solutions did not consider the shoulder girdle function [3, 10–13].

# CLINICAL CASE

## Patient information

Patient G., aged 18 years, was admitted to the Department of Pediatric Bone Pathology and Adolescent Orthopedics of the N.N. Priorov National Medical Research Center of Traumatology and Orthopedics (Moscow) with a large tumor neoplasm that was palpable around the manubrium. The patient revealed that the lesion was noted 1 year previously. A closed biopsy performed in a primary healthcare facility was uninformative; therefore, the patient was referred to a specialized institution.

## Diagnostics

An open biopsy of the pathological focus was performed. Histology revealed a $G_1$ chondrosarcoma of the manubrium. Computed tomography (CT) and magnetic resonance imaging revealed a space-occupying lesion in the manubrium with elements of lytic destruction of bone structures (Fig. 1, 2).

## Treatment

Given the lesion location and the fact is was necessary to totally remove the manubrium, the volume of resection would have notably reduced the amount of chest skeleton and the support ability of the sternoclavicular articulation, and would have affected shoulder girdle function. The solutions proposed by various authors to this problem currently include the use of standard plates that fix the chest or highly specific additive technologies. Regarding the implants proposed, the replacement of a tumor defect in case of a malignant neoplasm was secondarily considered. Thus, to solve this clinical problem, a CT study of the patient was used to reconstruct the bone anatomy of the chest with a tumor based on data of the Digital Imaging and Communications in Medicine archive (the medical industry standard for creating,

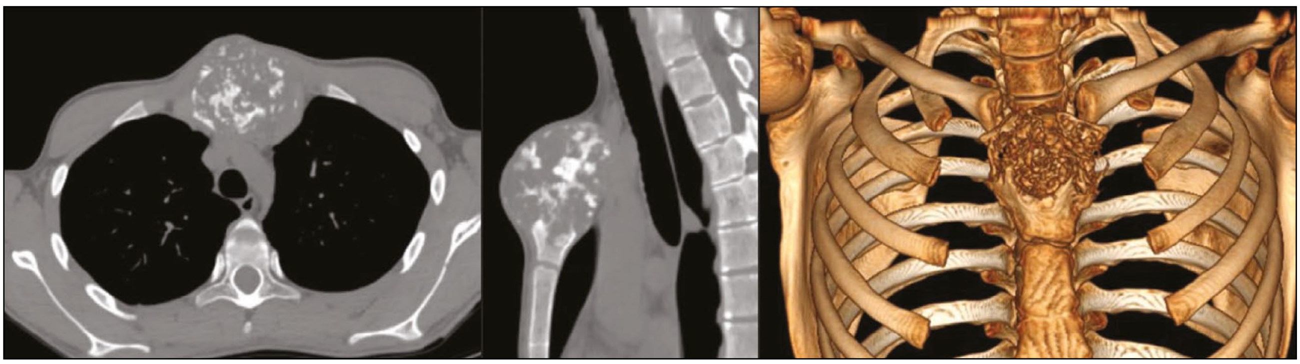

**Fig. 1.** Computed tomography image of the manubrium of the patient G.

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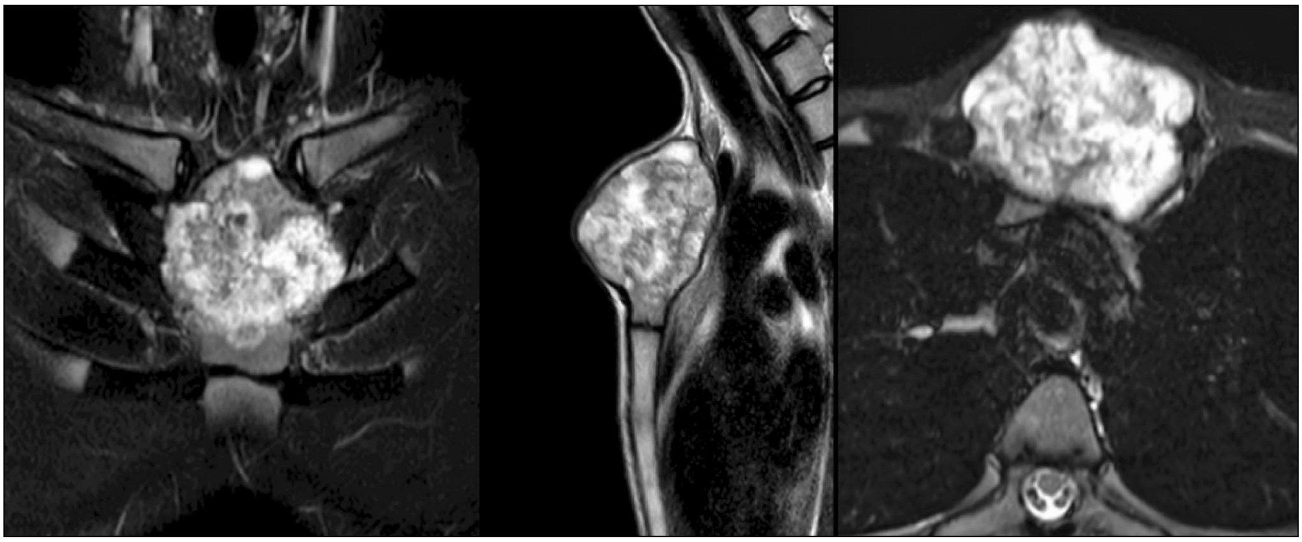

**Fig. 2.** Magnetic resonance image of the manubrium of the patient G.

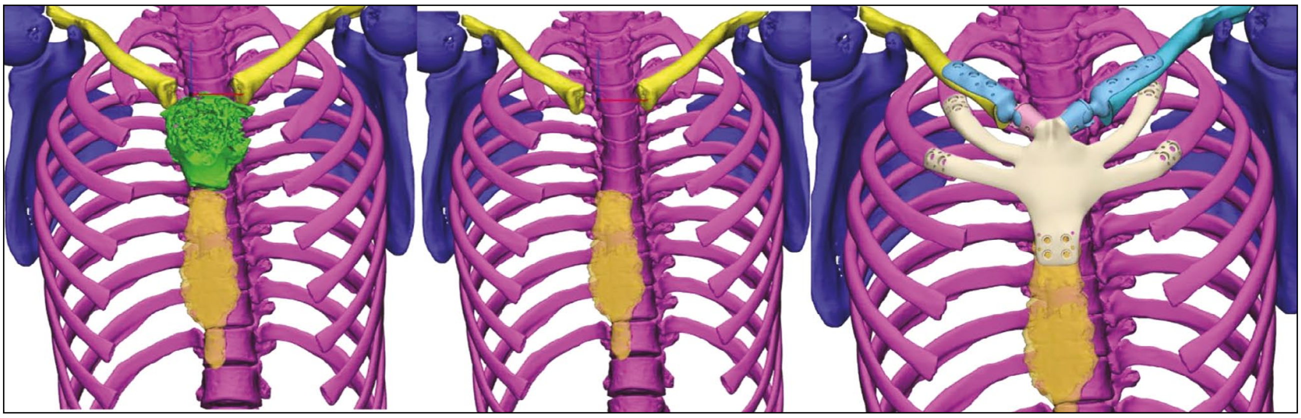

**Fig. 3.** Modeling of the surgical intervention according to the CT of the patient G.

storing, transmitting, and visualizing digital medical images and documents of examined patients). Based on the 3D model, the volume of the manubrium for resection was reconstructed for the preoperative planning of the implant (Fig. 3).

Considering the formed defect, existing anatomical structures of the patient, and terms of reference, an implant design was formulated, which included the following requirements:

- fixation of ribs 1 and 2 and the sternum body to bone structures;
- fixation points would be prepared with 3.5-mm cortical screws and cerclages in the form of pre-modeled holes;
- fixation to the clavicles using plates, with the formation of a platform for the area of resection regarding the sternoclavicular articulation;
- design of a hinge structure in the sternoclavicular articulation to maintain mobility in the upper shoulder girdle;
- product materials would comprise titanium and polyethylene.

In cooperation with NPK Sintel (Russia), we designed a prosthesis for the manubrium with movable elements for sternoclavicular articulation (Fig. 4).

Contrast-enhanced CT was performed during the preoperative preparation (Fig. 5). Firm adherence of the tumor to the left and right internal thoracic arteries and the aorta was noted. Considering the expected extent of intervention and possible intraoperative risks, the surgical team included an orthopedic traumatologist, an oncologist, and a thoracovascular surgeon.

Access to the tumor and sternum was through a skin incision in the form of a three-pointed star. The pectoral muscles were mobilized and dissected (Fig. 6). The anterior sections of the tumor, the body of the sternum, clavicle, and the pairs of ribs 1 and 2 were separated. Above rib 3 on the left and right, the pleura was bluntly dissected. A sternotome was inserted through the formed channel, and the sternum was transected. Segmental resection of the cartilaginous part of the pairs of ribs 1 and 2 was performed, and the sternoclavicular articulations were transected on the left and right. The sternocleidomastoid muscle was dissected away on the left and right.

Next, the manubrium (with the tumor) was mobilized from the pleura; the fragment with the tumor was brought out ventrally and the soft tissues were also mobilized. The manubrium was removed as a single block. During the mobilization, no defect of the internal thoracic arteries or the aortic wall was noted. In preparation for the prosthetics, a 1-cm resection of the medial part of the clavicles was performed. Before implantation, the support zones were sutured with cerclages (Fig. 7).

Using cortical screws and cerclage sutures, the implant was fixed to the bone structures. The functional test revealed the rigid and stable fixation of the lower pole of the implant and preservation of movements in the sternoclavicular articulation during functional tests. The implant was gradually covered with the pectoral muscles. The sternocleidomastoid muscles were sutured to the implant and soft tissues of the pectoral muscles adjacent to the implant. The blood loss was 240 mL, and the surgery lasted for 3 h 35 min. The patient stayed in the resuscitation and anesthesia department for 1 day and was transferred to the hospital. No respiratory problems were noted in the postoperative period. A 40-mL hematoma was noted in the projection of the pectoral muscle on the right and was completely evacuated with double puncture. According to CT control data, the implant position was stable (Fig. 8).

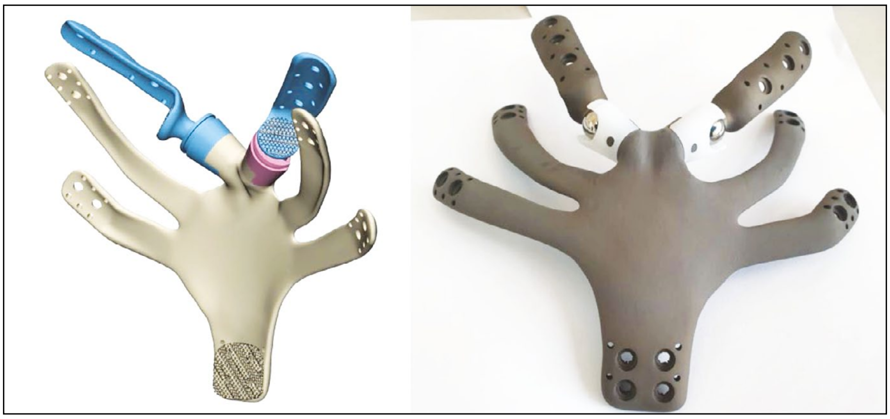

**Fig. 4.** A 3D model prototype and the finished product.

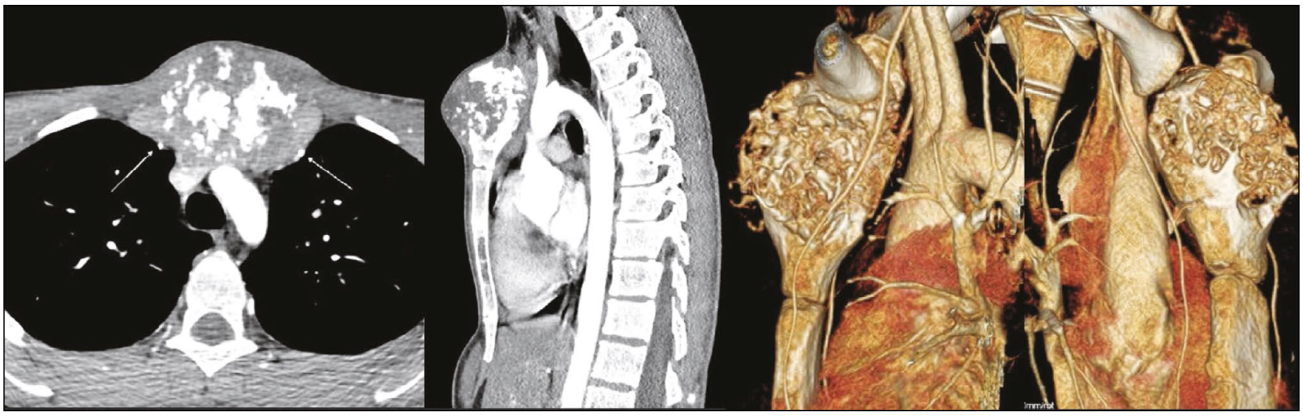

**Fig. 5.** CT arteriography with contrast enhancement of the aorta and internal thoracic artery.

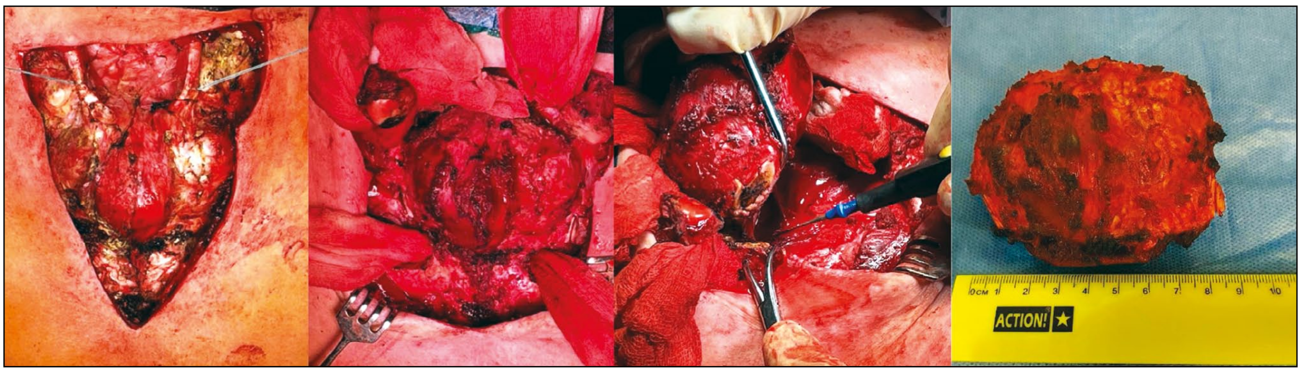

**Fig. 6.** Stages of tumor isolation in the patient G.

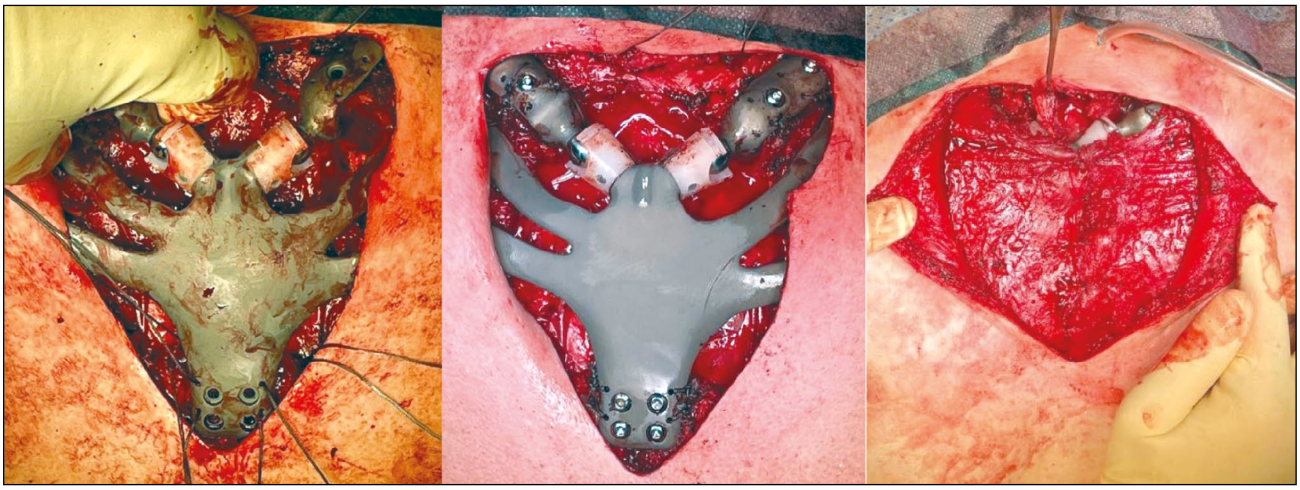

**Fig. 7.** Implantation stages.

**Fig. 8.** Radiograph, CT reconstruction, and appearance of the patient after surgery.

## Dynamics and outcomes

The patient was placed on Delbe rings on day 5 to stabilize the shoulder girdle. On day 14, he was discharged for outpatient follow-up to the primary healthcare facility. Posture correction of the thoracic spine was scheduled 3 months after surgery. Development of movements in the upper shoulder girdle was monitored by a rehabilitation specialist 2 months after the surgery. Images after 12 months showed no signs of recurrence or implant instability. Full function was recorded during movements of the shoulder girdle. Signs of implant instability were not detected by CT, and the patient has not complained of pain or discomfort (Fig. 9).

# DISCUSSION

Analyzing the surgical technique and type of implant used in the literature is usually difficult because additive prostheses with replacement elements for the manubrium are described in only a few reports, and none of the described implants had movable sternoclavicular articulations [11, 14, 15]. In our opinion, maintaining the support ability and biomechanics of the upper shoulder girdle is important and was implemented in our case. Among other things, the hybrid type of attachment to the bone elements allows strong contact with the implant and reduces the risk of prosthesis instability, which is crucial for the maturation of cicatrical tissue in the early postoperative period.

Sternum tumors are rare, and there is no unified implant that applies to every patient; therefore the use of additive technologies for such tumors is important [2–4]. Moreover, a prosthesis of the entire sternum or its segments in surgical practice is extremely rare; thus, data regarding the use of individual implants and long-term follow-up details are

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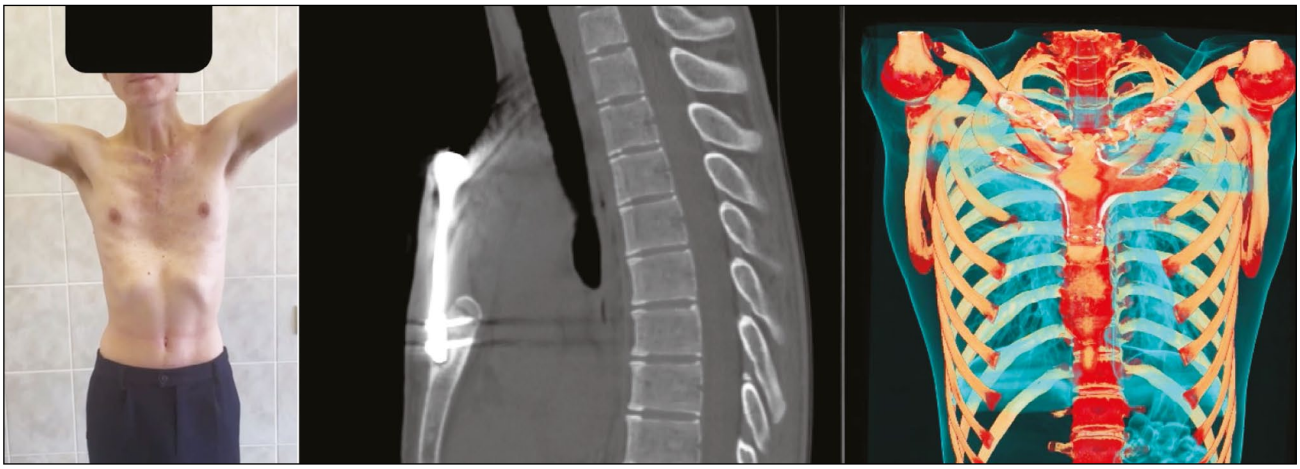

**Fig. 9.** CT reconstruction of the prosthesis position and the function of the shoulder girdle 1 year after the surgery.

scarce. Our study seems relevant as it provides important information regarding possible management considerations for sternum tumors.

## CONCLUSION

Individual prosthetics for tumor lesions of the sternum seem mandatory for many surgical cases because of the different chest shapes of patients and different lesion volumes. When designing individual implants, many factors should be considered, such as the biomechanics of breathing and the support ability of the upper shoulder girdle, including the sternoclavicular articulation. As with all individual products, the possibility of errors in their manufacture cannot be ruled out; therefore, it is necessary to strictly observe the positioning of patients during CT and accurately determine the volume of the selected bone tissue for resection before installing an individual implant.

## ADDITIONAL INFO

**Author contribution.** Thereby, all authors made a substantial contribution to the conception of the work, drafting and revising the work, final approval of the version to be published and agree to be accountable for all aspects of the work.

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**Competing interests.** The authors declare that they have no competing interests.

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