Three-dimensional printing titanium ribs for complex reconstruction after extensive posterolateral chest wall resection in lung cancer

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Large chest wall resection is essential for T3 non-small cell lung cancer with invasion of the chest wall. Skeletal reconstruction using moldable titanium plates, bars, and meshes is the common option to prevent the frequent complications associated with this procedure.¹ Three-dimensional printing (3DP) titanium implants have offered a valid option with perfect anatomic fitting and an almost infinite variety of designs.² Herein, we present a case of chest wall reconstruction using the 3DP technique.

Three-dimensional printing titanium ribs implanted into a chest wall.

Central Message

Five 3-dimensional printing titanium ribs were implanted into the patient's chest wall after a resection of the lung and chest wall.

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CLINICAL SUMMARY

A 60-year-old male patient was referred to our department for treatment of lung cancer. The chest computed tomography (CT) scan showed a 13 × 12 cm

FIGURE 1. The chest computed tomography scans using (A) coronal and (B) horizontal scanning. C, 3-dimensional printing thoracic model and (D) the en bloc excised tumor specimen. The black arrow points out the tumor invasion with the ribs. E and F, The 3-dimensional computed tomography scan after the reconstruction using titanium ribs. G, The titanium ribs were fixed on the thoracic model before surgery. H, The 5 titanium ribs.

FIGURE 2. A, The tumor had invaded the chest wall, from the sixth to 10th ribs (black arrow). B, A radical complete (R0) en bloc resection of the inferior lobe of the right lung to a 15×15 cm section of the posterior chest wall, from the sixth to 10th ribs, was performed. C, The 3-dimensional printing titanium ribs were implanted into the chest wall and bound with the residue ribs via steel wiring. D, The 3-dimensional printing titanium ribs were anchored to the thoracic vertebra by using angle-stable, self-locking nails.

mass on the right inferior lobe of the lung, with invasion of posterior chest wall, from the sixth to 10th ribs (Figure 1, A and B). The whole body positron emission tomography CT and bone scintigraphic imaging presented a localized disease without any distant metastasis in other organs. A high-accuracy 3-dimensional (3D) CT scan with a slice thickness of 1.25 mm was performed to obtain preoperative images of the thorax, and then the images were exported in DI-COM format to 3D-DOCTOR imaging software (Able Software Corp, Lexington, Mass). Polylactic acid materials were used to create the 3DP thoracic model (Figure 1, C) on which the resection margin was estimated at a minimum distance of 2 cm beyond the cancer (Figure 1, D). The length of each 3DP titanium rib was beyond the prospective resection margin of 3 to 4 cm, which made enough room for unpredictable situations (Figure 1, E and F). An EOS M280 3DP machine (EOS GmbH, Krailling, Germany) subsequently produced these implants from surgical-grade titanium alloy with a whole weight of 275 g (Figure 1, G and H). The 3DP process cost about \$300 for the thoracic model and \$13,800 for the titanium ribs. Two weeks were spent on this procedure, including 1 week of designing and

evaluating, 26 hours of printing, and 4 days of postsurgical grade processing.

The patient underwent a radical complete en bloc resection of the inferior lobe of the right lung to a 15×15 cm section of the posterior chest wall, from the sixth to 10th ribs (Figure 2, A and B). The disease-free resection margins were established during operation on the basis of frozen tissue section analysis. An additional resection would be adopted if a positive margin was found. The titanium ribs were bound with the residue ribs via steel wires, and the other ends were anchored into the thoracic vertebra using angle-stable, self-locking nails (Figure 2, C and D). The 2 self-locking nails could simultaneously anchor the titanium ribs to the thoracic vertebra at a certain angle, and this structure ensures the stability of implants to the greatest extent. A dual mesh patch and latissimus dorsi myocutaneous pedicled flap were fixed on the inner and outer surface of the titanium ribs, respectively. Histopathology showed a grade II squamous cell carcinoma, and the TNM stage was classified as T3 N1 M0 (stage IIB). The patient was discharged home 15 days after surgery and the chest CT scan showed a stable reconstruction, with

preservation of thoracic morphology and excellent cosmetic results.

COMMENT

Biomimetic reconstructions are expected to offer better function and cosmetic results after extensive chest wall resection.³ Especially for the posterolateral chest wall, no skeletal autograft implant can be used for reconstruction of this region.⁴ The 3DP technique allows users to rapidly convert digital 3D models into a perfect titanium implant. Some competitive advantages include that 3D computer-assisted design eliminates the need to shape, cut, or contour the implant and this procedure may produce a perfect anatomic fit.² Moreover, the 3DP technique can provide an almost infinite variety of designs of implants according to the individual demands of each patient, including rare or uncommon cases.⁵

The cost and production time of 3DP titanium prostheses are considerable and notable. The production time was relative for cancer progression or metastasis; thus, this technique should be restrained to highly aggressive cancers. Furthermore, it must be considered in advance so that the resection extent may be expand beyond the operation plan, which may result in inconformity

between the 3DP prosthesis and the chest wall defect. A segmental link device can be added to the prosthesis to easily adjust the length of the implant. Traditional implants, such as titanium plates, bars, and meshes, should be prepared as an alternative. With 3DP implants being accepted on a larger scale, it is important to establish a thorough regulatory practice and avenue for this technique that involves the materials, physicochemical property, biocompatibility, processing methods, and other aspects.

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