Customized 3-dimensional printed rib plating in chest wall reconstruction

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Chest wall reconstruction with customized 3D printed rib implants.

CENTRAL MESSAGE

Chest wall reconstruction with customized 3D printed rib implants offers an individualized approach for each patient and is likely to shape the future of thoracic surgery.

See Commentary on page 216.

Video clip is available online.

Chest wall reconstruction with customized 3-dimensional (3D) printed rib implants is a novel surgical technique. Here, we present our initial experience with utilizing this technique in 2 patients who underwent oncological resections and chest wall reconstructions with 3D printed rib implants during June and September 2019, respectively. The patients' informed consents were obtained for publication of the study data.

CASE 1

A 27-year-old woman presented with an enlarging, painless right chest wall lump. Computed tomography (CT) thorax demonstrated a well-circumscribed mass, measuring 6.2 × 6.2 × 5.3 cm, arising from the costochondral junction of the right sixth anterior rib. She underwent excision of the right anterior chest wall mass en bloc with the right sixth and seventh ribs guided by a preoperatively 3D printed cutting guide and implant positioning template (Figure 1), followed by reconstruction of the chest wall defect and ribs using a StarPore implant (Anatomics, Melbourne, Australia). Intraoperative blood loss was minimal. Intravenous broad-spectrum antibiotics were given on induction and continued for 48 hours. She had an uneventful recovery: her chest tube was removed on the first postoperative day and she was discharged on the fourth postoperative day without early complications. Final histopathology in keeping with the preoperative biopsy was high-grade chondrosarcoma, final stage was pT1 N0 M0. Per multidisciplinary meeting recommendations, she completed adjuvant consolidative radiotherapy uneventfully.

CASE 2

A 72-year-old man, with previous surgical resection of a left anterior chest wall benign enchondroma in 2016, now presented with a new left chest wall mass for 5 months. High resolution CT thorax with 3D reconstruction demonstrated a 3.0 × 3.3 × 2.2 cm soft tissue lesion arising from the anterior aspect of the left sixth costal cartilage. He underwent a left anterior thoracotomy, wide resection of the tumor, and chest wall reconstruction. Similarly, a StarPore implant was used (Figure 2). Intravenous broad-spectrum antibiotics were given on induction and continued for 48 hours. Intraoperative blood loss was minimal. He remained stable, his chest tube was removed on the first

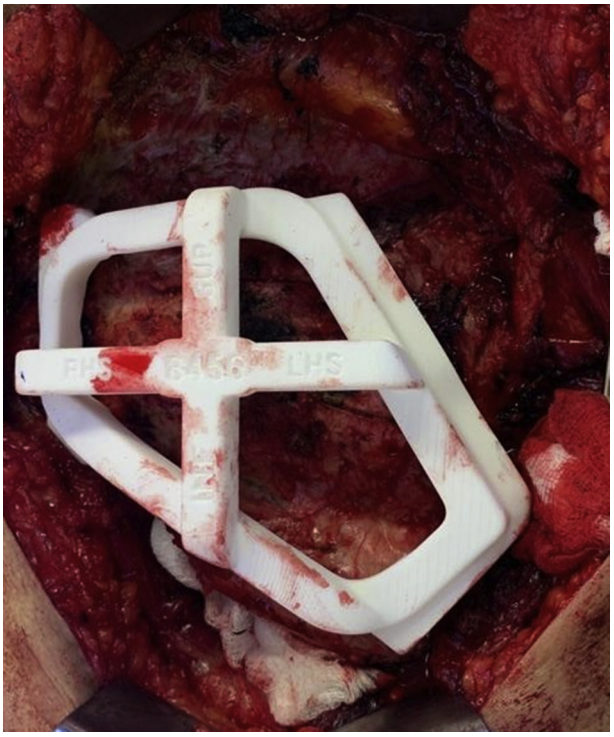


FIGURE 1. Intraoperative photograph from Case 1 showing the preoperative 3-dimensional printed cutting guide and implant positioning template being used after excision of the right anterior chest wall mass en bloc with the right sixth and seventh ribs.

FIGURE 2. Intraoperative photograph from Case 2 showing the 3-dimensional printed customized implant used for chest wall reconstruction with bicortical screw fixation after wide resection of the soft tissue tumor originating from the left sixth costal cartilage.

postoperative day, and he was discharged on the fourth postoperative day without early complications. Final histopathology was high-grade chondrosarcoma, consistent with the preoperative biopsy, with a final stage of pT1 N0 M0. He underwent adjuvant radiotherapy uneventfully, in accordance with the consensus at the multidisciplinary meeting.

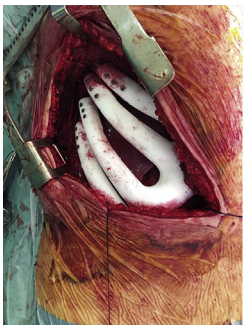
DISCUSSION

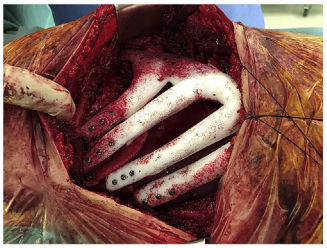
The complex anatomy of the thorax and each unique defect renders chest wall reconstruction extremely challenging.[1] It is crucially important that chest wall reconstruction achieves adequacy of resection, structural stability, and a favorable cosmetic outcome[2] while avoiding major complications.[1] Modern chest wall reconstructive surgery increasingly emphasizes an individualized approach, and patient-specific implants designed based on accurate 3D imaging can be an effective solution.[1,3]

3D printing involves additive manufacturing techniques to build structures from the ground up.[3,4] High resolution initial image data such as from CT and magnetic resonance imaging is imperative[1,5]—it is then reconstructed into a 3D volumetric dataset,[1,4,5] converted to a stereolithography file, and subjected to segmentation and surface preparation before printing by a 3D printer.[4] Recently, the use of polymers as a viable biomaterial for 3D printing is being explored.[1]

Whereas the preoperative CT imaging was performed in our institution for both patients, the 3D printing of the implants was done externally by a third-party medical device company (Anatomics). The primary operating surgeon planned safe resection margins preoperatively. The implants utilized in our patients were made of surgical grade solid silicone, and segmentation was automated by software. The implants were sterilized by ethylene oxide sterilization and we received them in a presterilized packing that was only opened onto the sterile surgical field. Both patients underwent their surgeries within 2 weeks of 3D printing of the implants, and we did not encounter inaccurate margins intraoperatively or the need for resizing of our implants. We used bicortical screw fixation with DePuy Synthes (Johnson & Johnson Medical Devices Companies, Franklin Lakes, NJ) in both cases. Muscle and fascia can be attached to the prosthesis with suturing because the material is both porous and able to retain its tensile strength simultaneously. 1 chest tube was placed at the end of each surgery. The implants cost approximately $11,000 and were paid for by the patients. Further details on the procedure through which the prostheses we used in our patients were fabricated have been explained in the accompanying video (Video 1).

Chest wall reconstruction is an important application of 3D printed implants.[5] Studies have shown that the error of cross-sectional data of 3D printed ribs was <0.2 mm, allowing its accuracy to meet clinical requirements.[2,3,5] Notably,





VIDEO 1. Video describing the concept of 3-dimensional printed implants in chest wall reconstruction and surgical techniques utilized in our patients. Video available at: https://www.jtcvs.org/article/S2666-2507(21)00308-4/fulltext.

operative time is shortened, exposure to anaesthesia is less, blood loss is lower, and postoperative restoration of function is optimal.[2-4] This translation to improved surgical outcomes for patients is truly invaluable.[4,5]

3D printed models are also useful visual aids that enable surgeons to better inform patients preoperatively about complex surgeries, facilitating improved communication and decision making.[2] Furthermore, the cost of 3D printing is decreasing, making it more affordable for institutions and patients.[4]

At the same time, it is important to acknowledge some of the challenges inherent to 3D printed implants. There is a lack of diversity of biomaterials, in addition to existing design-induced and process-induced limitations. Despite of the use of biomaterials, implants are still foreign bodies that can trigger inflammatory reactions and are prone to infection.[3] Sterilization of printed models is also a common concern.[4]

Both of our patients have been followed in the outpatient setting by the surgical team as well as the oncology team. They are 16 and 13 months, respectively, postoperation at present, and have no evidence of functional limitations or disease recurrence.

CONCLUSIONS

3D printing is a rapidly evolving field and is likely to shape the future of thoracic surgery. At this juncture, it is essential to identify suitable indications for the use of 3D printed patient-specific implants, develop practical workflows to facilitate smooth implementation into clinical practice and ensure easier accessibility of this technology and surgical technique to patients. At the same time, patients who have already undergone reconstructive surgery with 3D printed implants should be followed-up to study at least the short- and medium-term outcomes in the near future.

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