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Three dimensional model for surgical planning in resection of thoracic tumors

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ABSTRACT

INTRODUCTION: The computed tomography scan provides vital information about the relationship of thoracic malignancies to the surrounding structures and aids in surgical planning. However, it can be difficult to visualize the images in a two-dimensional screen to interpret the full extent of the relationship between important structures in the surgical field.
PRESENTATION OF CASE: We report two cases where we used a three-dimensional printed model to aid in the surgical resection of thoracic malignancies.
DISCUSSION: Careful planning is necessary to resect thoracic malignancies. Although two-dimensional images of the thoracic malignancies provide vital information about the tumor and its surrounding structures, the three-dimensional printed model can provide more accurate information about the tumor and assist in surgical planning.
CONCLUSION: Three-dimensional printed model provide better visualization of complex thoracic tumors, aid in counseling the patient about the surgical procedure and assisted in surgical resection of thoracic malignancy.

1. Background

Computed tomography provides excellent information about the relationship between the thoracic malignancy and surrounding structures. The advent of multidetector row computed tomography (MDCT) along with 3D image rendering techniques allow us to create a virtual 3D image of thoracic structures from the 2D image [1,2]. However, the virtual 3D image is still represented in a 2D image on a screen. Although they provide very important structural information, they lack the ease of manipulating the structure that will be encountered at the time of surgery. We have taken the 3D image and created a 3D model using a 3D printer in two cases involving thoracic malignancy.

2. Case presentation

A 51-year-old man presented to the emergency room for evaluation from smoke inhalation as a volunteer fireman and was found to have a right apical mass on the chest X-ray. He had a 45-year history of smoking, chronic obstructive pulmonary disease and Wolff–Parkinson–White syndrome. His chest CT showed a 3.5 cm right upper lobe mass invading the third rib as well as mediastinal lymphadenopathy. The CT-guided biopsy of the lesion showed lung adenocarcinoma. The subsequent positron emission tomography/computed tomography (PET/CT) showed FDG-uptake at the right pancoast tumor with SUV of 59 and uptake at station 4R with SUV of 3.5. The brain magnetic resonance imaging showed no brain metastasis. A mediastinoscopy and biopsy of the 4R lymph node showed no sign of metastatic disease. The patient was diagnosed with T3N0M0 pancoast tumor. He underwent induction chemoradiation therapy with Cisplatin and Etoposide and 50.4 Gy of radiation to the lung cancer. Subsequent chest PET/CT showed the 4.2 cm right upper lobe mass invading the third rib with SUV of 31. The patient also had a spine MRI that showed the tumor had not invaded the spinal canal.

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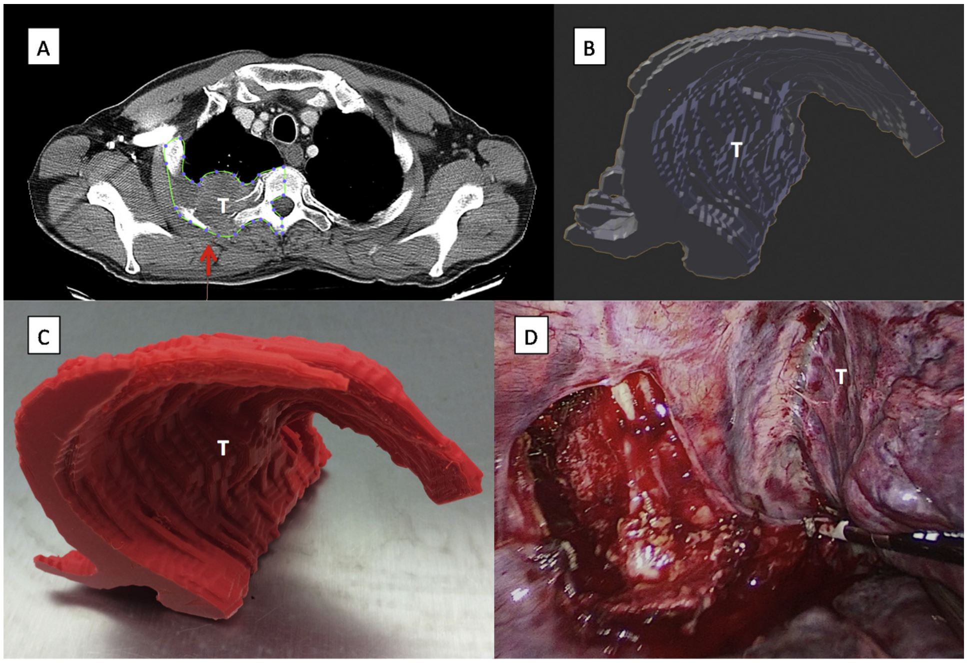

Fig. 1. Right upper lobe pancoast tumor. (A) Computed tomography of the tumor (T) with region of interest (green line) around the tumor, ipsilateral side of spine and the chest wall (red arrow). (B) 3D rendering of extracted topology showing tumor (T), spine and chest wall. (C) 3D printed plastic model of the tumor (T), spine and chest wall. (D) Thoracoscopic image of the resection of the chest wall and laminectomy with tumor (T) invading the third rib.

The digital imaging and communications in medicine (DICOM) image of the CT scan, which had 5 mm cuts, was loaded onto OsiriX software (Pixmeo, Bernex, Switzerland). The closed polygon function of region of interest (ROI) was used to outline the tumor along with the ipsilateral half of the spine and the ribs (Fig. 1A). Next, we converted the pixels within the ROI to white and the pixels outside of the ROI to black and used the 3D rendering function in OsiriX to create a binarized 3D volume that was converted to a surface topology with the 3D Surface Rendering Function, then exported from OsiriX as a stereolithography (STL) file. The STL file was imported to Blender software (Stichting Blender Foundation, Amsterdam, Netherlands) and modified with a retopology function (Octree 8 smoothing) to make an object file suitable for 3D printing (Fig. 1B). This process took about 1 h and was performed by the surgeon (MPK) and researcher (JSM). The object file was 3D printed in opaque polylactic acid (PLA) on an M2 printer (MakerGear; Beachwood, Ohio) with computed struts to support overhanging features. After printing, the support struts were removed by hand to reveal the final model (Fig. 1C). The 3D model was shown to the patient to describe the operation. The patient better understood the extent of the surgery compared to looking at the image on the CT scan. The 3D model was taken to the operating room for surgical planning. The thoracic surgeon (MPK) performed right video assisted thoracic surgery (VATS), right upper lobectomy and mediastinal lymph node dissection in the front of the patient while the spine surgeon (RAM) performed T1–T5 decompressive laminectomy for tumor excision

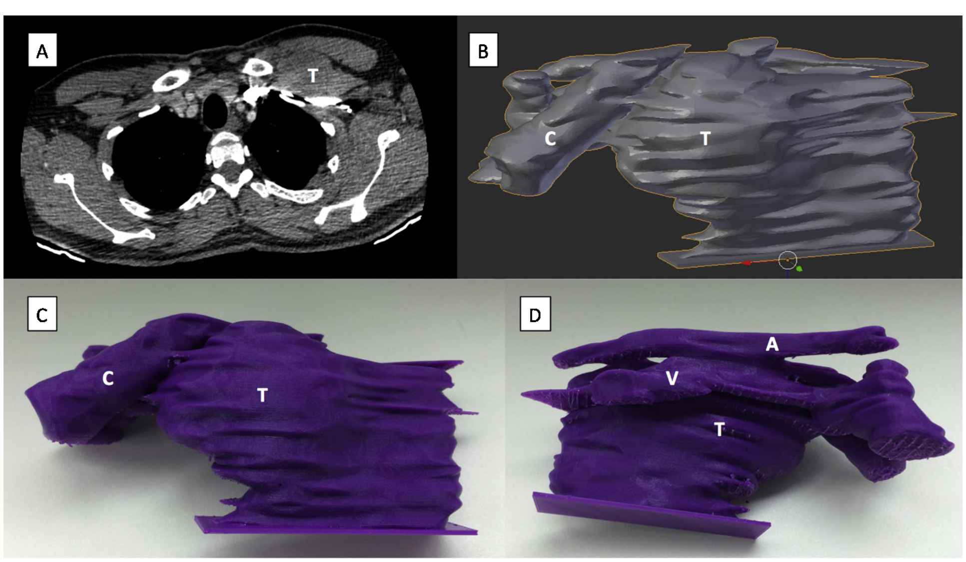

Fig. 2. Chest wall spindle cell neoplasm. (A) Computed tomography of the tumor (T). (B) 3D rendering of extracted topology showing the tumor (T) with clavicle (C). (C) Anterior side of the 3D printed plastic model with tumor (T) and the clavicle (C). (D) Posterior side of the 3D printed plastic model with subclavian artery (A), subclavian vein (V) and tumor (T).

with partial corpectomy at T2–T5 through transpedicular approach with en bloc resection of chest wall (rib 1–5) and right upper lobe through the posterior incision. The 3D model helped in the decision to perform laminectomy and take the first rib to ensure a negative surgical margin. We used the thoracoscope to visualize the tumor's borders during the laminectomy (Fig. 1D). The patient's course was complicated by a prolonged air leak. His final pathology showed a 4.3 cm lung adenocarcinoma invading into the chest wall with very poor response to neoadjuvant therapy without any involvement of the lymph nodes. The patient's final pathology was ypT3N0M0 or stage IIB.

Next, a 35-year-old man presented with an increased swelling of the left chest wall for several months. The patient's chest CT showed a well-defined 5.7 cm non-enhancing homogenous soft tissue lesion arising from left pectoralis minor muscle abutting the clavicle, left subclavian vein and subclavian artery (Fig. 2A). An ultrasound-guided biopsy of the lesion showed a low-grade spindle cell neoplasm. The chest CT with IV contrast with 1 mm cuts was performed to better define the lesion.

The DICOM image of the CT scan was loaded onto Osirix software to create the virtual image as described above (Fig. 2B). We then created the 3D model using the 3D printer as described above (Fig. 2C and D). The 3D model was used to counsel the patient about the extent of surgical resection. The patient underwent en bloc resection of the clavicle, partial pectoralis major muscle, pectoralis minor muscle and the tumor with reconstruction of the space with residual pectoralis major muscle flap. The 3D model helped to determine the extent of the resection of the mass and the relationship of the mass to the surrounding structures. The final pathology was 4.5 cm low grade spindle cell neoplasm with fibrous and myxoid components with negative surgical margin without invasion of the bone or the skeletal muscle. The patient recovered well from the operation without any major event.

3. Discussion

The 3D model has been used in surgical planning for resection of cardiac tumor [3], liver tumor [4], osteochondroma of scapula [5] and renal tumors [6]. In all of these cases along with our experience, the 3D model provides better insight into the patient's tumor with its relationship to surrounding normal tissue. Our experience has shown that the 3D model allows the surgeon to counsel the patient about the exact nature of the operation as well as improves the planning of the surgery to obtain oncologic resection of the tumor. The use of finer cut CT (1 mm vs 5 mm) provides a better representation of the patient's anatomy on the 3D model but it does take longer to create the model. A surgeon can create the 3D virtual image with readily available software and print it using commercially available 3D printers. The 3D model is helpful in surgical planning of complex tumors and it can provide more personalized and precise oncologic resection of thoracic tumors.

Conflict of interest

None.

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Ethical approval

Approved by Houston Methodist Research Institute IRB Board–IRB0407-0155.

Consent

Consent has been waived with IRB approval.

Author contribution

AT, WAE, RAM, PG contributed with data collection and data interpretation.

JM contributed with study concept, data collection, data interpretation.

MPK contributed with study concept, data collection, data interpretation and writing the paper.

Guarantor

Min P. Kim.

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