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CASE REPORT

Virtual reality-assisted localization and three-dimensional printing-enhanced multidisciplinary decision to treat radiologically occult superficial endobronchial lung cancer

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Abstract

Herein, we report the unique case of a 75-year-old male patient who had undergone a left upper lobectomy for lung cancer and developed an incidental superficial endobronchial squamous cell carcinoma in the right upper lobe that was not localizable on modern cross-sectional imaging modalities. The superficial endobronchial squamous cell carcinoma was successfully localized by computed tomography-driven virtual reality endoscopy and was identically matched with a small, whitish, patch lesion on bronchoscopy. The localized lesion was annotated on the corresponding computed tomography images, and illustrated in a fabricated three-dimensional (3D)-printed airway model. Because the exact anatomic location of the lesion and the acute angle of the adjacent bronchial trajectory were visible in the 3D model, enhanced multidisciplinary consultation resulted in the decision to treat the lesion using photodynamic therapy. Photodynamic therapy was successfully performed without complications. A follow-up bronchoscopy two months after treatment confirmed that the superficial endobronchial squamous cell carcinoma had been cured.

Introduction

A multidisciplinary approach is recommended for the optimal management of lung cancer and improves patient survival.[1,2] In this approach, it is essential for all members of the team to understand the precise anatomic localization of the cancer. Herein, we report a case of superficial endobronchial squamous cell carcinoma that was not localizable on modern cross-sectional imaging modalities,[3] but was correctly localized by computed tomography (CT)-driven virtual reality (VR) endoscopy, followed by three-dimensional (3D) printing of a model that was used to make an enhanced multidisciplinary treatment decision.

Case report

A 75-year-old male patient presented with incidental superficial endobronchial lung cancer in the right upper lobe. He had a 40 pack-year smoking history. Four years previously, he underwent a left upper lobectomy followed by adjuvant chemotherapy for squamous cell carcinoma

(pathologic tumor node metastasis stage T3N0M0). A 2 cm pulmonary metastasis was found in the right lower lobe one year after the lobectomy and was treated with stereotactic ablative radiotherapy. The patient underwent bronchoscopy to evaluate a suspected focal inflammatory lesion in the apex of the left lung on follow-up computed tomography (CT) examination. On bronchoscopy, a small, whitish, patched lesion was incidentally found at the proximal portion of the apical bronchus of the right upper lobe (Fig 1a). The result of the bronchoscopic biopsy was squamous cell carcinoma. The forced vital capacity in one second (FEV_1) was 1.67 L, and a lung perfusion scan revealed that 31.8% of lung perfusion was supplied by the right upper lobe, predicting a postoperative FEV_1 of 1.14 L; therefore right upper lobectomy was contraindicated. At the first meeting of a multidisciplinary team to decide the optimal treatment, the considered treatment options included photodynamic therapy, endobronchial brachytherapy, and stereotactic ablative radiotherapy. To localize the lesion on cross-sectional imaging modalities, 1 mm contrast-enhanced standard dose axial chest CT images were meticulously reviewed, and no gross abnormality was observed. On positron emission tomography (PET)-CT, a focal lesion with a maximum standardized uptake value of 5 was shown at the anterior segmental bronchus of the right upper lobe (Fig 1b); this did not agree with the location on bronchoscopy as a result of respiratory misregistration between CT and PET. For localization, 3D VR bronchoscopic images were reconstructed from the CT images using commercially available software (MEDIP, MEDICALIP, Seoul, South Korea), which enabled the direct and straightforward use of a VR device (more specifically, a head-mounted display; HTC Vive; HTC Corporation, Taoyuan, Taiwan). Endobronchial navigation of the right bronchi on VR images showed minute elevation of the bronchial wall in the corresponding area (Fig 1c,d). The location was confirmed by the pulmonologist who had performed the bronchoscopy. We fabricated a 3D-printed airway model using a commercially available 3D printer (MakerBot Replicator 2x, New York, NY, USA) with acrylonitrile butadiene styrene.[4] The fabricated part was used to make an inverted 3D mold. We removed the air from a vacuum chamber, casting with silicone material was performed, and the mold was eventually removed to obtain the airway model. A 100% scale 3D-printed airway model with color-coded anatomical structures was produced (Fig 1e,f). After observing the location of the lesion and the acute angle of the adjacent bronchial trajectory in the 3D model, multidisciplinary team members agreed that the adjacent bronchial trajectory was too acute to stably maintain the catheter during a brachytherapy procedure and critical hilar structures might be at risk during stereotactic ablative radiotherapy. The best treatment option was determined to be photodynamic therapy, which was successfully performed without complications. On follow-up bronchoscopy two months after photodynamic therapy, no residual tumor was observed (Fig 1g) and the result of bronchoscopic biopsy was normal bronchial tissue without residual tumor.

Discussion

To our knowledge, this is the first report of successful localization of radiologically occult superficial endobronchial lung cancer using advanced VR endoscopy, followed by the fabrication of 3D-printed model. Photodynamic therapy,[5] endobronchial brachytherapy,[6] and stereotactic ablative radiotherapy[7] can be considered to treat early-stage endobronchial non-small-cell lung cancer in patients in which surgical resection is difficult. A certain portion of early-stage

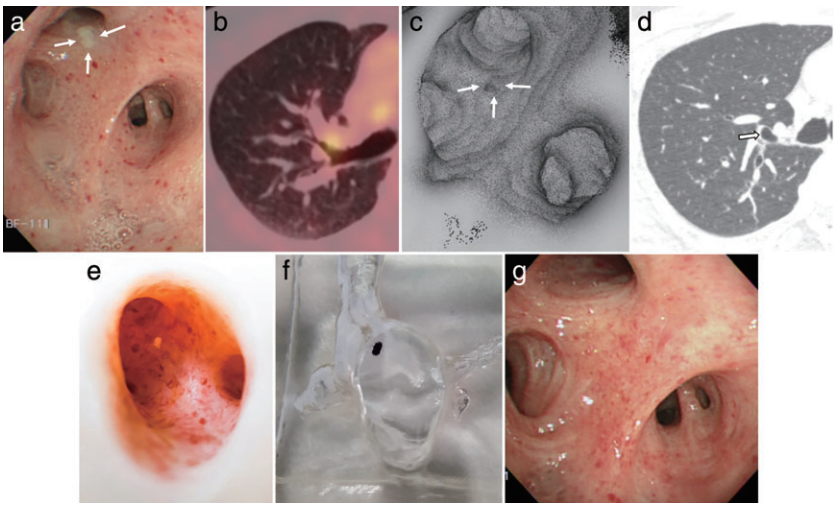

Figure 1 Representative images of: (**a**) bronchoscopy, (**b**) fused positron emission tomography-computed tomography (CT), (**c**) virtual reality endoscopy, (**d**) CT with the invisible lesion annotated by an arrow, (**e,f**) opaque and transparent three-dimensional printed models, and (**g**) follow-up bronchoscopy two months after photodynamic therapy.

superficial endobronchial squamous cell carcinoma does not display any radiologic abnormality on CT scan.[3] Our case could not be visualized on modern multi-detector contrast-enhanced thin-section CT images and was misregistered on fused PET-CT images. The multidisciplinary team had difficulty assessing the technical feasibility of the potential treatment options and determining the best treatment as the precise location of lung cancer on the cross-sectional imaging modalities was unknown. By reviewing the annotated lesion on CT images and the 3D model, the team could determine the anatomy of lung cancer and adjacent bronchial trees, leading to a decision to apply photodynamic therapy, which cured our patient without complications.

In summary, new imaging techniques including advanced VR images and 3D printing enhanced multidisciplinary discussion to make the optimal treatment decision for early lung cancer that was difficult to locate because of radiological invisibility on conventional cross-sectional imaging modalities.

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Disclosure

No authors report any conflict of interest.

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