Three-dimensional–printed model of surgically resectable angioinvasive pulmonary mucormycosis

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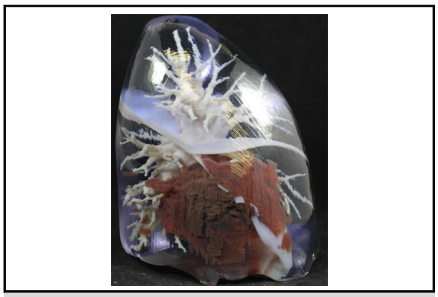

3D-printed model of angioinvasive pulmonary mucormycosis.

CENTRAL MESSAGE

It is important to recognize CT findings of advanced but surgically resectable pulmonary mucormycosis. Customized 3D printing helps to highlight these imaging findings.

Video clip is available online.

Although rare, the incidence of pulmonary mucormycosis is rising.[1] While combined antimicrobial and surgical treatment decreases mortality compared with medical therapy alone,[1] nonspecific presentation often delays definitive diagnosis and therapy.[2] This report presents characteristic computed tomography (CT) findings of pulmonary mucormycosis, enhanced by 3-dimensional (3D)-printed modeling.

Early mucormycosis often forms a "CT halo sign"—a nodule or mass encompassed by ground-glass opacities. This can progress to a "reversed halo sign"—a ground-glass opacity encompassed by denser consolidation. Further progression can produce central tissue destruction with bordering hemorrhage, manifesting as cavitation with surrounding opacities.[3,4] Although contained within one lobe initially, mucormycosis can cross fissures to involve multiple lobes. Patients who undergo surgery—a nonanatomic wedge resection for peripheral disease or lobectomy for central disease—have a survival benefit.[2]

A patient on immunosuppression after bilateral lung transplant presented with pleuritic pain, chills, and a right lower lobe consolidation on chest radiograph. The patient's CT images were representative of pulmonary mucormycosis (Figure 1, *A*, and Video 1) with central necrosis, surrounding consolidation, and ground-glass opacities (the reversed halo sign) centered in the right lower lobe. The CT was used to segment and create 3D computer-generated renderings (Figure 1, *B*), which served as the basis for the 3D-printed model (Figure 1, *C*, and

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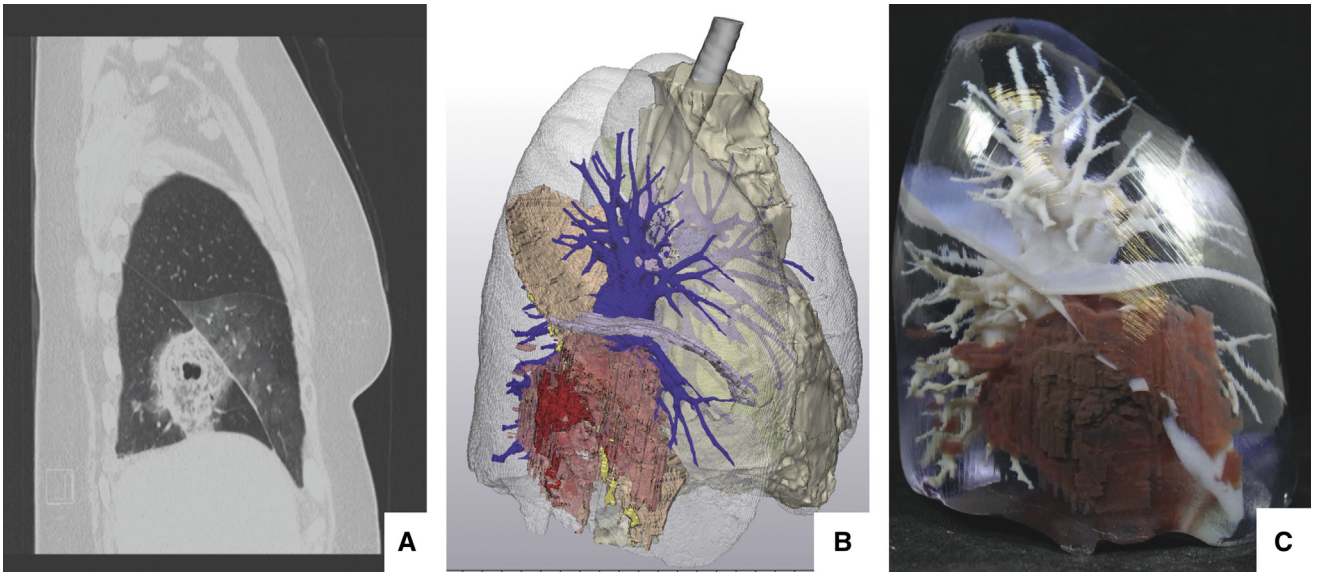
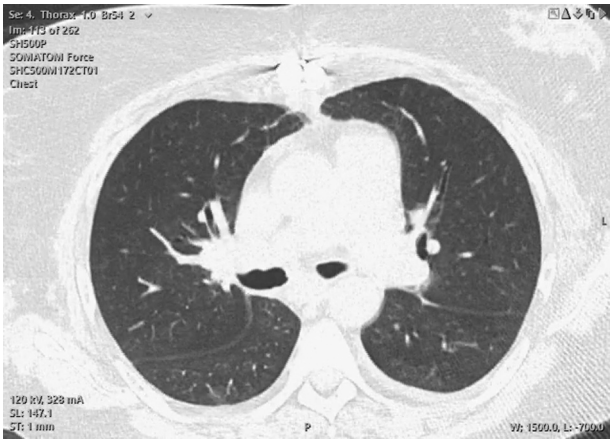


FIGURE 1. Creation of 3-dimensional (3D) printed model of the reversed halo sign of late pulmonary mucormycosis. A, Sagittal view from computed tomography (CT) scan of the chest; B, computer-generated 3D visualization recreated from CT images; and C, 3D-printed model shows a cavitary lesion in the right lower lobe with surrounding areas of consolidation and extensions of ground-glass opacities peripherally that invade into the right middle lobe. The 3D-printed model shows the necrosis in *brown*, consolidation in *dark maroon*, ground-glass in *light maroon*, fissures *in white*, and pulmonary vessels and airways in *tan colors*; this model serves as an educational tool at our institution for mucormycosis pathogenesis.



VIDEO 1. Computed tomography images of late stage pulmonary mucormycosis (1 mm slices in lung window) used to create the 3D-printed model (image numbers in *upper left*). Central necrosis is apparent from image 163 through 174; consolidation produced by the angioinvasive fungal mass extends from image 151 to 199; and ground-glass opacities extend from image 130 to 216. Video available at: https://www.jtcvs.org/article/S2666-2507(22)00245-0/fulltext.

VIDEO 2. 3D-printed model of late pulmonary mucormycosis. The 3D-printed model shows a cavitary lesion in the right lower lobe with surrounding areas of consolidation and extensions of ground-glass opacities peripherally which invade into the right middle lobe. The angioinvasive fungal ball is present in *maroon*, with the central necrosis pictured in *brown*. The fungal mass crosses the white fissure separating the right lower lobe from the right middle lobe. The other uninvolved lung, clear mediastinum, and *tan–yellow* tracheobronchial structures are also visible. Video available at: https://www.jtcvs.org/article/S2666-2507(22)00245-0/fulltext.

Video 2) using multimaterial PolyJet technology (Stratasys).

Mucormycosis infection was printed in brown/dark maroon for areas of necrosis and consolidation, and light maroon for surrounding ground-glass opacities that extend into the right middle lobe. The cavitary mass was resected by right lower lobectomy, with intercostal muscle flap over the bronchial stump. To maximize remaining parenchyma, the right middle lobe was preserved, and residual infection treated medically. The patient remains well 2 years later. This model serves as an institutional educational tool for diagnosis and treatment of pulmonary mucormycosis.

This report contains no patient identifiable information, so the Stanford institutional review board did not review this study and patient consent for publication was not received.

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