Three-dimensional (3D) lung segmentation for diagnosis of COVID-19 and the communication of disease impact to the public

Emma R Schachner [1], Bradley Spieler [2]

[1]Department of Cell Biology and Anatomy, Louisiana State University Health Sciences Center New Orleans, New Orleans, Louisiana, USA
[2]Department of Radiology, Louisiana State University Health Sciences Center New Orleans, New Orleans, Louisiana, USA

Correspondence to
Dr Bradley Spieler; bspie1@lsuhsc.edu
Dr Emma R Schachner; eschachner@gmail.com

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DESCRIPTION

Three individuals were admitted to the hospital (ages 46–56; two men and one woman) with a multiday history of symptoms associated with the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and underwent contrast-enhanced thoracic CT due to worsening symptomatology. Three-dimensional (3D) digital models were created to visualise the extent of the disease within the respiratory system (figures 1 and 2) from the thin section (1 mm) data sets. All patients presented emergently with variable pulmonary symptoms ranging from mild to severe, including shortness of breath and all were febrile. Two of the patients

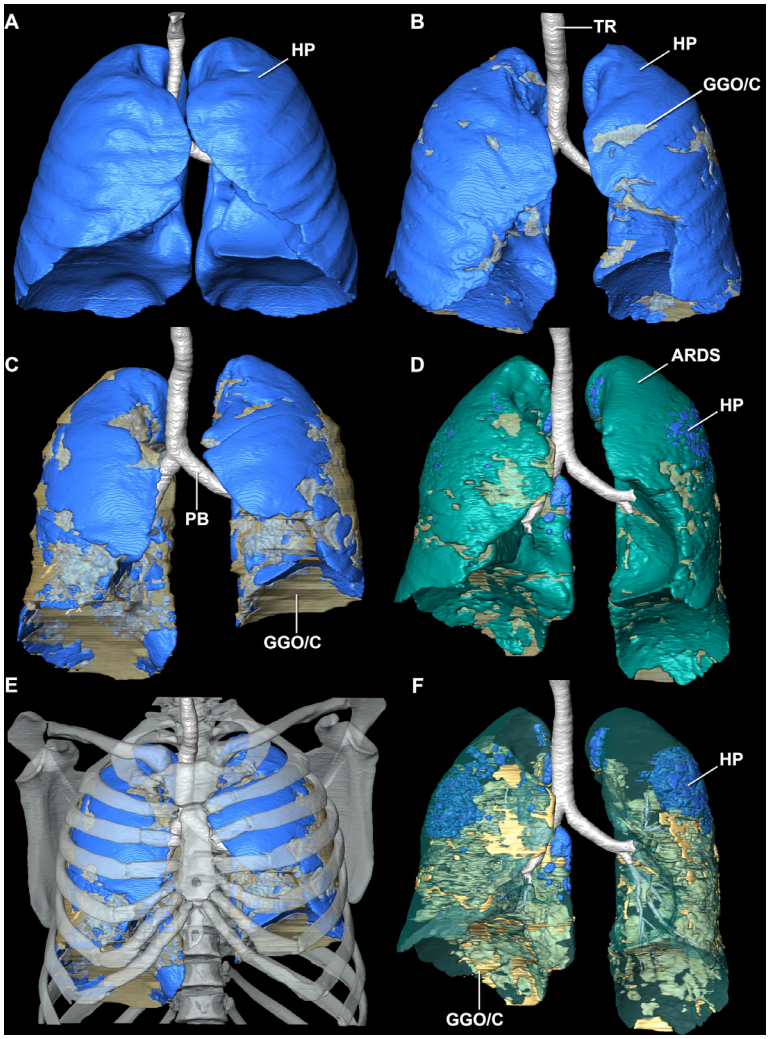

Figure 1 Three-dimensional segmented surface models of normal, COVID-19 and suspected COVID-19 lungs in anterior view. (A) Healthy lung model of a 50-year-old man. (B) Lung model of a COVID-19-positive 46-year-old man with mild respiratory symptoms. (C) Lung model of a COVID-19-negative 56-year-old man with clinical suspicion for COVID-19. (D) Lung model of a COVID-19-positive 55-year-old woman with severe respiratory symptoms and ARDS. (E) C with a skeleton. (F) D but with the ARDS tissue made translucent to demonstrate the full extent of the ground glass opacities and consolidation throughout the parenchyma. ARDS, acute respiratory distress syndrome; C, consolidated infection; GGO, ground-glass opacities; HP, healthy parenchyma; PB, primary bronchus; TR, trachea. Colour key: blue, healthy tissue; yellow, consolidation and ground glass opacities; green, ARDS.

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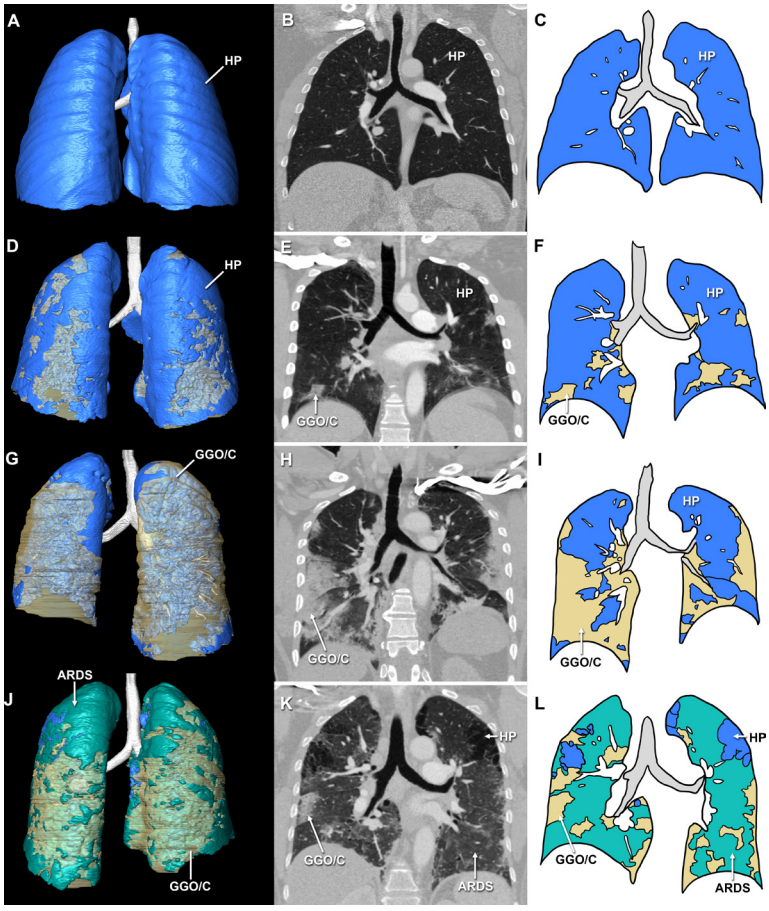

Figure 2 Three-dimensional (3D) segmented surface models of normal, COVID-19 and suspected COVID-19 lungs in posterior view (left) and coronal views with accompanying simplified diagrammatic illustrations of the coronal CTs demonstrating the infection sites. Healthy lungs of a 50-year-old man as a segmented 3D model in posterior view (A), a coronal contrast enhanced CT slice (B) and a diagrammatic illustration of B (C). COVID-19-positive 46-year-old man (mild respiratory symptoms) as a segmented 3D model in posterior view (D), a coronal contrast enhanced CT slice (E) and a diagrammatic illustration of E (F). Lungs of a COVID-19-negative 56-year-old man with clinical suspicion for COVID-19 as a segmented 3D model in posterior view (G), a coronal contrast-enhanced CT slice (H) and a diagrammatic illustration of H (I). Lungs of a COVID-19-positive 55-year-old woman with ARDS as a segmented 3D model in posterior view (J), a coronal contrast enhanced CT slice (K) and a diagrammatic illustration of K (L). Models demonstrate the relationship, distribution and full extent of the disease in 3D versus the single CT slice which only provides information on the localised position of the infection. ARDS, acute respiratory distress syndrome; C, consolidated infection; GGO, ground-glass opacities; HP, healthy parenchyma. Colour key: blue, healthy tissue; yellow, consolidation and ground glass opacities; green, ARDS. Images not to (relative) scale.

were reverse transcription polymerase chain reaction (RT-PCR) positive for SARS-CoV-2 (figure 1B,D,F; figure 2C,D,G,H). The third patient was RT-PCR negative for SARS-CoV-2, but this was presumed to be a false-negative result given compelling clinical and imaging features indicative of COVID-19 (figures 1C,E and 2E,F). A fourth patient who presented to the emergency department and was suspected of having COVID-19 also underwent CT to assess for the possibility of pulmonary embolus (figures 1A and 2A,B). This individual tested negative for SARS-CoV-2, and the lungs were normal. All CT examinations were obtained using a Philips iCT 256 or iQon Spectral CT systems. Data were acquired using a 128×0.625 mm or 64×0.625 mm detector configuration with dual sampling, rotation time of 0.33 s (120 kVp 72 mAs).

The full effect of COVID-19 on the respiratory system remains unknown;[1] however, the use of 3D digital segmented models from CT data provides the opportunity to evaluate the extent and distribution of the disease in one encapsulated view for clinicians, particularly in the case where RT-PCR for SARS-CoV-2 is negative but there is strong clinical suspicion for COVID-19. The 3D digital surface models (figures 1, 2A,C,E,G) were segmented by hand in the scientific visualisation programme Avizo V.7.1 (Thermo Fisher Scientific) following established methods for lungs in non-model organisms.[2–4] The utility of CT in the diagnosis of COVID-19 pneumonia has been a focus of recent radiologic literature with specific CT patterns of findings being well documented, including patchy and/or confluent, bandlike ground glass opacity or consolidation in a peripheral and mid-to-lower lung zone distribution.[5–12] Given diagnostic challenges with respect to false-negative results by RT-PCR, the gold standard for COVID-19 diagnostic screening, CT can be helpful in establishing this diagnosis.[13] Importantly, these CT features can range in morphology and appear to correlate temporally with disease progression.[13 14] This allows for 3D segmentation of the data in which lung tissue can be volumetrically quantified,[4] or airflow patterns could be modelled.[15] Moreover, these models provide for a holistic view of the extent of pulmonary disease that can be appreciated by a wide-range medical imaging viewership.[16 17] Unlike simple volume rendered images, these models can be 3D printed, and thus have a much broader functional application that allows for the collaboration between basic and clinical scientists, which is particularly important given the critical nature of COVID-19.[2 18–20]

Learning points

- Three-dimensional segmented digital models provide a dramatically clearer method for visually evaluating the impact of COVID-19 on the lungs than straight radiographs, CT data or reverse transcription polymerase chain reaction alone.
- These printable digital models are additionally very powerful for communicating the impact of COVID-19 on the respiratory system to the general public.

Correction notice This article has been corrected since published online. The text has been corrected from "to men" to "two men" in the first sentence.

Twitter Emma R Schachner @paleofox

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ORCID iDs
Emma R Schachner http://orcid.org/0000-0002-8636-925X
Bradley Spieler http://orcid.org/0000-0002-7346-2885

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