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February 2022 Imaging Case of the Month: Between A Rock in a Hard Place

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Clinical History: A 46-year-old woman presented to her primary care physician with longstanding complaints of difficulty with aerobic exercise, near syncope, headache, poor sleep, and pain in both legs and arms, exacerbated when flying in commercial aircraft. The patient had also complained of several gastrointestinal disturbances recently that prompted evaluation, revealing a normal colonoscopy. The patient was diagnosed with probable food intolerance by breath testing showing fructose intolerance, managed with a low fermentable oligosaccharides, disaccharides, monosaccharides and polyols (FODMAP) diet with positive results.

PMH, SH, FH: The patient's past medical history was remarkable for a history of Raynaud's phenomenon and head trauma at age 16. She noted that her presenting complaints have been present since childhood to some extent. Her poor sleep was characterized as

frequent awakenings, daytime somnolence, mouth dryness, and waking up with severe headaches. The patient had been diagnosed with COVID-19 4 months earlier, with her presenting complaints all exacerbated and accompanied by shortness of breath, but she recovered uneventfully. The patient denied other significant past medical history and had no surgical history. Her family history was remarkable for a sister diagnosed with obstructive sleep apnea, diabetes, and thyroid carcinoma, and hypertension in a number of her 13 siblings. The patient's mother had been diagnosed with colonic malignancy and her father died of melanoma. The patient's social history was remarkable for abuse during childhood by a male sibling. The patient denied tobacco, alcohol, and illicit drug use.

Physical Examination: The patient's physical examination showed her to be slender and in no distress although anxious, afebrile, pulse rate= 73, normal respiratory rate, with a blood pressure of 116/95 mmHg. Her cardiovascular, pulmonary, musculoskeletal, and neurologic examinations were within normal limits.

Results from prior outside examinations, including funduscopic, abdominal MRI, and brain MRI and MRA were within normal limits. An outside audiology consultation when the patient complained of hearing loss several months after her SARS-CoV-2 infection showed normal findings. Her complete blood count, coagulation parameters, electrolytes, and liver panel showed no abnormal values. A frontal chest radiograph from an outside institution (Figure 1) from 4 months prior to her primary care appointment, around the time when the patient was diagnosed with COVID-19.

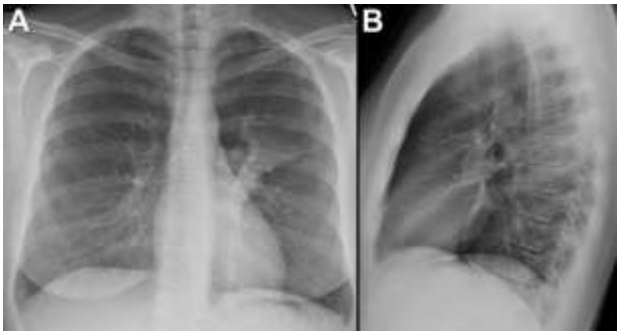

Figure 1. Frontal (A) and lateral (B) chest radiography obtained around the time the patient was diagnosed with COVID-19.

Which of the following represents ***an appropriate interpretation*** of her frontal chest radiograph?

1. Frontal chest radiography shows findings typical for coronavirus (SARS-CoV-2) pulmonary infection
2. Frontal chest radiograph shows bilateral peribronchial lymphadenopathy
3. Frontal chest radiography shows focal consolidation
4. Frontal chest radiography shows multiple lung nodules
5. Frontal chest radiography shows pleural effusion

Correct!
3. Frontal chest radiography shows focal consolidation

The frontal chest radiograph shows a focal poorly defined opacity projected over the left hilum located in the posterior lung, probably in the superior segment of the left lower lobe (Figure 2).

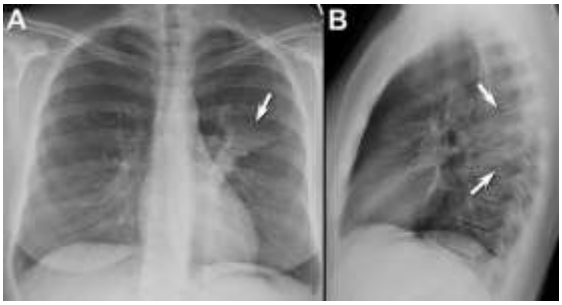

Figure 2. Frontal (A) and lateral (B) chest radiography obtained around the time the patient was diagnosed with COVID-19 shows focal poorly defined opacity projected over the left hilum (A, arrow) located in the posterior lung (B, arrows). No pleural abnormality, pulmonary nodules, or evidence of mediastinal or peribronchial lymph node enlargement is present.

These findings are not typical of coronavirus infection; the typical manifestations of COVID-19 at chest radiography include multifocal, bilateral peripheral poorly defined pulmonary opacities without pleural effusion or visible lymph node enlargement.

Which of the following represents ***the least likely consideration*** for the patient's imaging findings?

1. Bronchogenic malignancy
2. Bacterial pneumonia
3. Neuroendocrine neoplasm
4. Coccidioidomycosis
5. All are equally likely

Correct!
2. Bacterial pneumonia

While the chest radiographic opacity is ultimately very non-specific, the fact that a focal pulmonary opacity is present in the absence of significant clinical symptoms, particularly fever, and no abnormal laboratory values are present in particular the white blood cell count is normal, makes bacterial pneumonia less likely than the other considerations.

Which of the following represents ***an appropriate next step*** for the patient's management?

1. Follow up / repeat chest radiography
2. Comparison to prior chest radiographs
3. Lateral decubitus chest radiography
4. ^{18}FDG-PET scan
5. More than one of the above

Correct!
5. More than one of the above

Whenever an abnormality is discovered at chest radiography, determining the chronicity of the finding through comparison to prior chest examinations is of paramount importance, particularly in the case of pulmonary nodules, focal pulmonary opacities, and diffuse lung disorders. Lateral decubitus chest radiography is most commonly employed to evaluate for pneumothorax, by examining the non-dependent lung for the characteristic visceral pleural line, or freely mobile pleural effusion through examination of the dependent hemithorax. However, lateral decubitus chest radiography would be of little benefit for the focal lung opacity on this patient's chest radiograph. ^{18}FDG-PET scan is useful for the assessment of focal pulmonary abnormalities, particularly nodules, but neither positive nor negative results for the opacity detected at chest radiography in this patient would be management-altering because the opacity is relatively non-specific and could be the result of neoplasm, infection, or numerous other possibilities. Whenever focal lung opacities are detected at chest radiography in adult patients, follow up imaging to demonstrate interval resolution is wise, as pulmonary neoplasm may present as nonspecific focal opacities, but will be detected by persistence at follow up. Therefore, both comparison to prior chest radiographs and follow up chest radiography are correct answers.

Testing for coccidioidomycosis was indeterminate for IgM and negative for IgG. The patient underwent nerve blocks for her headaches over the next few months. She was treated as an outpatient for presumed bronchitis with azithromycin after she had presented to an outside emergency room with complaints of cough. Repeat chest radiography (Figure 3) performed 6 weeks after the initial chest radiograph (Figure 1) was performed.

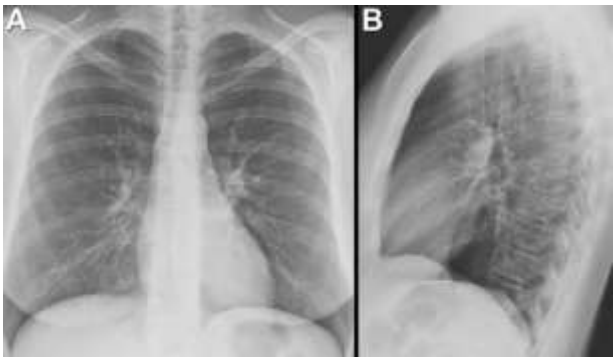

Figure 3. Frontal (A) and lateral (B) chest radiography performed 3 months following the patient's diagnosis of COVID-19 (Figure 1).

Which of the following represents ***the most appropriate interpretation*** for the patient's imaging findings?

1. The chest radiographic opacity has resolved
2. The chest radiographic opacity has regressed but not completely resolved
3. The chest radiograph shows new small pulmonary nodules
4. The chest radiograph shows new pleural effusions
5. The chest radiographic opacity has worsened since prior

Correct!

1. The chest radiographic opacity has resolved

The left perihilar opacity seen at the initial chest radiograph (Figure 1) has resolved. No nodules, new opacities, or pleural abnormalities are apparent. The follow up chest radiograph is largely unremarkable. There is subtle relative lucency involving the left hilum compared to the right, possibly reflecting oligemia. The finding is subtle, perhaps better seen on a magnified, detail image (Figure 4), but is questionable both in terms of presence and significance.

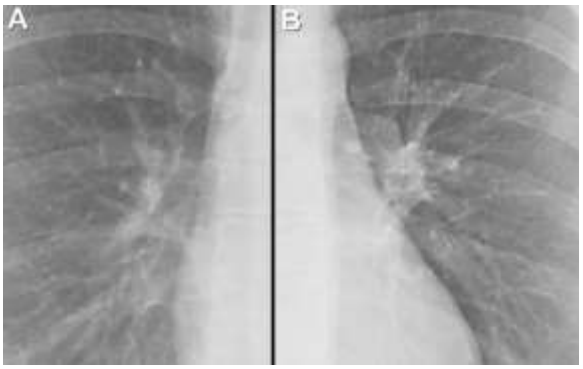

Figure 4. Magnified, detail views of the medial lungs (A= right, B= left) from the chest radiograph performed 3 months following the diagnosis of COVID-19 (Figure 2) shows subtle oligemia in the medial left lung compared with the medial right lung. Note how the vessels radiating from the left hilum appear similar in size to their right-sided counterparts, but that the pulmonary parenchyma in the background appears somewhat "sparse" and mildly lucent compared to the medial right lung.

Placement of region of interest measurements lateral to the interlobar arteries showed approximately 100 HU lower values on the left side compared to the right side. The finding is quite subtle and usually the presence of oligemia at chest radiography is the result of artifact, particularly patient rotation.

While oligemia on a chest radiograph can be a result of emphysema, airway obstruction, volume loss with overexpansion of remaining aerated lung, and decreased vascularity, most commonly the appearance of oligemia is the result of patient rotation and technical factors affecting the image acquisition.

The patient developed chest pain, worsened headache, facial pain, post-nasal drip, and subjective fever to 101.8°F), and presented to the emergency room. In the emergency room, her physical examination showed a respiratory rate of 81, pulse= 71, blood pressure= 132/85 mmHg, room air oxygenation= 98%, and temperature= 98°F. Physical examination was normal. Serum chemistries, a complete blood count, a liver panel, and troponins were all within normal limits. Influenza testing was negative as was testing for SARS-CoV-2. An ECG showed sinus rhythm with mild ST segment depression of unknown chronicity.

Which of the following represents ***an appropriate next step*** for the patient's management?

1. Perform unenhanced chest CT
2. Perform CT pulmonary angiography
3. Repeat chest radiography
4. Perform ^{18}FDG-PET scan
5. Perform contrast-enhanced thoracic MR

Correct!

3. Repeat chest radiography

While unenhanced chest CT is not an incorrect answer, there is relatively little in the patient's clinical history that suggests the need for cross sectional imaging, given that her most recent chest radiograph appeared relatively normal. No objective evidence of active intrathoracic infection is present. The indeterminate results for coccidioidomycosis could represent an indication to proceed with chest CT rather than repeat chest radiography, although follow up for the indeterminate serologies will be required regardless of the chest CT findings. There are no identified risk factors for pulmonary embolism nor is the patient's presentation overtly suggestive of such. It would be appropriate to consider d-dimer testing, given her non-high risk for acute pulmonary embolism; negative results would allow any consideration for CT pulmonary angiography to be deferred. Neither ^{18}FDG-PET scan nor contrast-enhanced MR have a role for the evaluation of this patient's complaints, particularly form the emergency room.

The patient underwent CT pulmonary angiography (Figure 5).

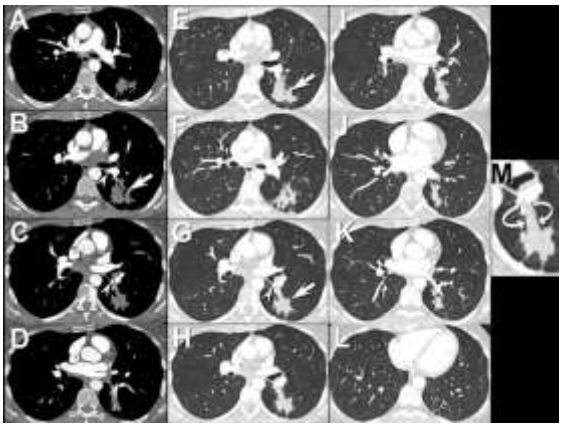

Figure 5. Axial enhanced chest CT performed according to a pulmonary embolism protocol shows superior segment left lower lobe consolidation (arrows) and mild left peribronchial lymph node enlargement. Calcified left peribronchial lymph nodes are present (arrowheads). A patent superior segmental left lower lobe bronchus is not seen; rather a tubular-shaped opacity is present in this location (curved arrows, inset image M) with a focus of calcification at the orifice of the bronchus.

Which of the following represents ***an appropriate interpretation*** for this examination?

1. Chest CT shows findings suspicious for primary pulmonary neoplasia
2. Chest CT shows findings suggestive of fungal pneumonia
3. Chest CT shows suggestive of bacterial pneumonia
4. Chest CT radiography suggestive of post-obstructive pneumonia
5. Chest CT shows findings suggestive of lipoid pneumonia

Correct!
4. Chest CT radiography suggestive of post-obstructive pneumonia

The CT pulmonary angiography examination shows focal, somewhat mass-like, consolidation restricted to the superior segment of the left lower lobe. Mild presumably reactive left peribronchial lymph node enlargement is also present. Calcified left peribronchial lymph nodes are also seen. An aerated left lower lobe superior segmental bronchus is not visible; rather, a tubular-shaped opacity is present in the location of the superior segmental bronchus, with a small focus of calcification at the orifice of the bronchus. These findings are seen to advantage using multiplanar reconstructions (Figure 6).

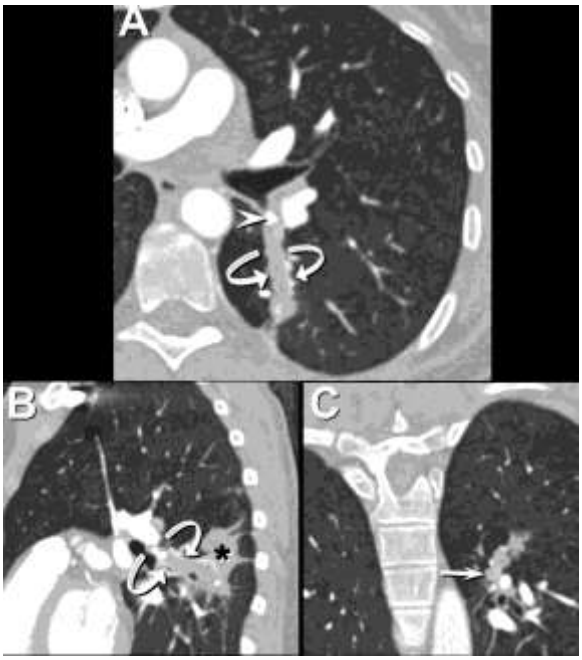

Figure 6. Oblique axial (A), sagittal (B) and coronal (C) CT multiplanar reconstructions show the tubular-shaped, impacted superior segmental left lower lobe bronchus (curved arrows) extending into consolidation (*) to advantage. A focus of calcification (A, arrowhead) is present at the origin of the superior segmental left lower lobe bronchus. The impacted left lower lobe superior segmental bronchus is seen en face in the coronal projection (arrow, C).

While the focal lung opacity is non-specific and could technically represent bacterial pneumonia, fungal pneumonia, or neoplasm, the impacted bronchus leading to the

consolidation suggests an obstructive etiology. There is no visible fat within the focal lung opacity to suggest exogenous lipoid pneumonia.

Based on the findings at CT pulmonary angiography, which of the following represents ***an appropriate next step*** for the evaluation of this patient?

1. Short-term follow up CT
2. ^{18}FDG-PET scan
3. Pulmonary medicine consultation for bronchoscopy
4. Chest MRI
5. CT-guided percutaneous lung biopsy

Correct!

3. Pulmonary medicine consultation for bronchoscopy

The consolidation is likely due to obstruction of the superior segmental left lower lobe bronchus and bronchoscopic examination, possibly tissue sampling if feasible and required, is the optimal approach to management. CT-guided percutaneous transthoracic needle biopsy could easily sample the left lower lobe superior segmental consolidation, but it is likely this opacity merely contains inflammatory material and mucous, given that the lung parenchymal findings appear post-obstructive in nature. Follow up CT is commonly used when relatively small, indeterminate and non-specific opacities, commonly lung nodules, are present, to assess treatment efficacy or if growth occurs in such opacities; the latter often prompts more definitive management. Follow up CT would not play an immediate role for the management of this patient because the bronchial obstruction merits directed evaluation directly and is unlikely to spontaneously improve or resolve if untreated. Neither ^{18}FDG-PET scan nor contrast-enhanced MR have a role for the evaluation of this patient's chest CT findings. ^{18}FDG-PET scan would likely show increased tracer utilization but this result would be expected given the presumed post-obstructive consolidation; in contrast lack of tracer utilization would not preclude definitive assessment with bronchoscopy.

The patient underwent bronchoscopy (Figure 7), which showed occlusion of the orifice of the superior segmental left lower lobe bronchus.

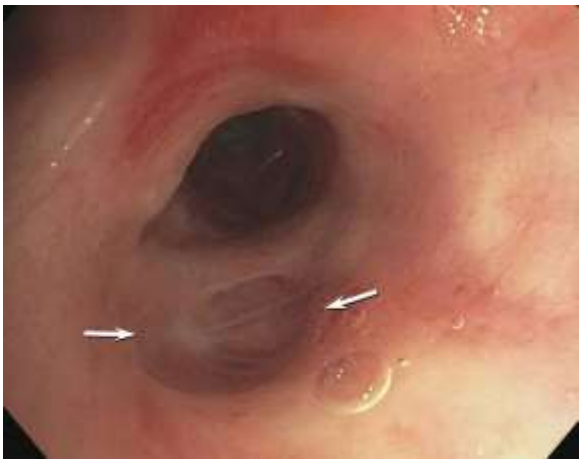

Figure 7. Bronchoscopy shows occlusion of the superior segmental left lower lobe bronchus (arrows). Forceps could not be passed through this occlusion.

A lucent structure could be faintly visualized beyond the point of obstruction, but forceps could not be passed into the bronchus itself. A needle was passed through the area of obstruction, but bleeding occurred and the procedure was terminated once the bleeding was controlled.

Which of the following represents ***an appropriate next step*** for the patient's management?

1. Perform rigid bronchoscopy
2. Perform repeat bronchoscopy using a laser
3. Perform cryobiopsy
4. Consult thoracic surgery for potential resection
5. Conservative management

Correct!

4. Consult thoracic surgery for potential resection

Rigid bronchoscopy is a consideration but the lesion, and potential complications, would be better controlled with a surgical approach. Cryobiopsy would not be useful for this patient's lesion, and is typically reserved for sampling of diffuse interstitial lung diseases. Bronchoscopy with lasers may be useful for fibrous bronchial stenoses or treatment of neoplasms, but the nature of the obstruction in this patient would not necessarily be conducive to laser therapy. Furthermore, the bronchoscopic procedure already resulted in hemorrhage, and therefore an approach using direct control of the area is warranted.).

Thoracic surgery was consulted. The surgeon considered a minimally invasive approach, a robotic approach, and the possibility of superior segmentectomy, but the proximal nature of the obstruction precluded placing a stapler across the left lower lobe superior segmental bronchus and therefore excluded the possibility of segmentectomy. Furthermore, owing to the normally close apposition of the segmental artery and bronchi, and that in this patient this close relationship would be obliterated by inflammation, a minimally invasive approach was considered to likely be unsuccessful. Therefore, the decision was made to plan for an open surgical procedure.

Which of the following represents ***the most likely diagnosis*** for the patient's condition?

1. Bronchogenic malignancy
2. Broncholithiasis
3. Inflammatory myofibroblastic tumor
4. Neuroendocrine neoplasm
5. Aspirated foreign body

Correct!

2. Broncholithiasis

While bronchogenic malignancies can uncommonly calcify, the calcification is often stippled or eccentric in morphology and invariably a significant component of non-calcified tissue is present. In this patient, the focus of calcification at the orifice of the superior segmental left lower lobe bronchus has no associated soft tissue component. Similarly, neuroendocrine tumors, particularly typical carcinoid tumors, may calcify, but the pattern of calcification may be more chondroid in morphology and substantial non-calcified soft tissue components are also typically present. Inflammatory myofibroblastic tumors are rare proliferative lesions, now considered clonal neoplasms, that present in a number of different ways, including calcified pulmonary opacities and endobronchial lesions. Nevertheless, as with bronchogenic malignancies and neuroendocrine neoplasms showing calcification, significant non-calcified soft tissue components are usually present. Finally, a hyperattenuating aspirated endobronchial foreign body is a definite possibility and would be very difficult to differentiate from a broncholith. However, in this patient, the presence of adjacent peribronchial lymph node calcifications favors broncholithiasis.

The patient underwent left thoracotomy and, as the surgeon suspected, significant inflammation was encountered in the superior segment of the left lower lobe. Significant difficulty identifying and isolating the superior segmental artery and bronchus was encountered, but the broncholith was identified and the left lower lobe successfully resected (Figure 8).

Figure 8. Left lower lobe resection specimen shows a broncholith (arrows) at the origin of

the superior segmental left lower lobe bronchus.

The patient tolerated the procedure well, but a persistent air leak was encountered in the first post-operative week, as the surgeon suspected may happen.

Which of the following represents ***an appropriate next step*** for the patient's management?

1. Re-exploration of the left lower lobe bronchial stump
2. Placement of additional chest tubes
3. Video-assisted thoracoscopic pleural space debridement
4. Endobronchial valve placement
5. Continue conservative management

Correct!

4. Endobronchial valve placement

Re-exploration of the bronchial stump is not necessary as the cause of the prolonged air leak is not the result of dehiscence of the bronchus but the extensive inflammation and adhesions noted at surgery. One approach to a prolonged air leak following surgery is placement of additional thoracostomy tubes to "get ahead" of the air leak, but, more recently, placement of endobronchial valves in the airway subtending the site of bronchopleural fistula may offer a more elegant solution. Pleural space debridement would not address the issue of a prolonged post-surgical air leak and is unnecessary as enlarging pleural collections were not reported on post-operative imaging and no clinical features of pleural space infection were noted.

The patient underwent bronchoscopy. No endobronchial lesions we identified. Air leaks were noted emanating from both left upper lobe segments, so one endobronchial valve was placed within the left upper lobe (Figure 9).

Figure 9. Bronchoscopy shows placement of an endobronchial valve into the left upper lobe bronchus.

Over the ensuing weeks, the post-operative air leak slowed, although a persistent pneumothorax (Figure 10) required percutaneous thoracostomy tube drainage.

Figure 10. Frontal chest radiograph (A) and axial (B) and sagittal (C) chest CT 2 weeks following thoracotomy and 6 days following left upper lobe endobronchial valve placement show the presence of the left upper lobe valve (arrow, only faintly visible in A with a metallic focus external to the patient projected over the same area) as well as the pneumothorax (arrowheads), the latter with a loculated component posteriorly (*, C) that required additional thoracostomy tube drainage.

The endobronchial valve was removed (Figure 11) after cessation of the air leak, approximately 7 weeks following the surgery.

Figure 11. Bronchoscopic removal of the endobronchial valve following cessation of the persistent postoperative air leak.

Diagnosis: Broncholithiasis presenting as post-obstructive pneumonia treated with left lower lobe resection complicated by a prolonged air leak managed with endobronchial valve placement.

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