

Pictorial Essay

Ground-Glass Opacity of the Lung Parenchyma: A Guide to Analysis with High-Resolution CT

Christopher E. Engeler,¹ Joseph H. Tashjian, Stephen W. Trenkner, and James W. Walsh

Ground-glass opacity is a frequent but nonspecific finding on high-resolution CT scans of the lung parenchyma. The underlying abnormality is diverse; any condition that decreases the air content of the lung parenchyma without totally obliterating the alveoli can produce ground-glass opacity. These processes are not visible on high-resolution CT scans. However, in specific clinical settings, the information provided by high-resolution CT is considerable when the anatomic distribution and associated structural changes to the lung parenchyma are analyzed. This pictorial essay illustrates the pathologic basis of ground-glass opacity and provides a guide to the differential diagnosis of the disorders that can produce this appearance.

Radiologic Criteria and Pathologic Correlation

Ground-glass opacity is defined as nonspecific increased opacity of the lung parenchyma caused by a change in the relative proportions of air and alveolar walls that is not visible on high-resolution CT scans [1, 2]. This appearance is observed when, histologically, thickening of the alveolar walls and septal interstitium is minimal or the alveolar lumen is partially filled with fluid, macrophages, neutrophils, or amorphous material (Fig. 1). The degree of increased lung opacity is not sufficient to obscure pulmonary vessels, as would be the case in true consolidation. Ground-glass opacity is potentially reversible with appropriate therapy, if the underlying disorder is treated early, because none of the changes in lung structure are permanent. Some active but potentially reversible processes that produce ground-glass opacity include pulmonary edema; alveolar proteinosis; and many causes of alveolitis or interstitial pneumonitis, including idiopathic pulmonary fibrosis, sarcoidosis, hypersensitiv-

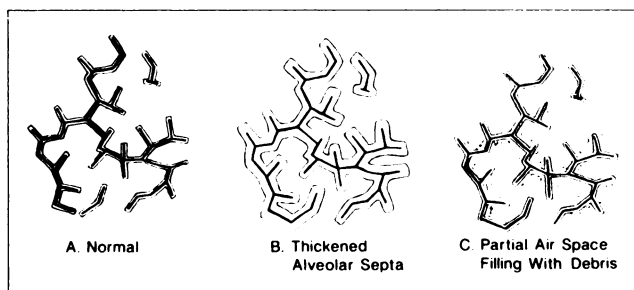


Fig. 1.—Anatomic basis of ground-glass opacity. Hazy increase in lung opacity reflects morphologic changes at alveolar level that cannot be resolved with high-resolution CT. Alveolar septa can be thickened or air space can be partially filled with fluid, cells, or debris.

ity pneumonitis, and early radiation pneumonitis [2–4]. In idiopathic pulmonary fibrosis (fibrosing alveolitis), early alveolitis is represented histologically by increased cellularity of the alveolar walls [3].

Significance of Ground-Glass Opacity

In some diseases, such as idiopathic pulmonary fibrosis (fibrosing alveolitis) and sarcoidosis, the appearance of ground-glass opacity correlates with disease activity, as indicated by biopsy, bronchoalveolar lavage, or gallium lung scans [3, 4]. These areas of ground-glass opacity have been shown to correspond to regions of active alveolitis and precede irreversible changes such as fibrosis and honeycombing. It has been reported that ground-glass opacity can be reversible in patients receiving steroids [3]. Some authors

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¹All authors: Department of Radiology, University of Minnesota Hospital, Box 292 UMHC, 420 Delaware St. S.E., Minneapolis, MN 55455. Address reprint requests to C. E. Engeler.

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believe that the presence of ground-glass opacities correlates with disease activity and thus indicates which patients should receive steroids [4]. High-resolution CT, therefore, should also be used to guide biopsies to areas of ground-glass opacity rather than to fibrotic areas of inactive disease.

Diagnostic Pitfalls

Ground-glass opacity normally can be seen in the dependent lung cortex and is reversible with deeper inspiration or prone positioning of the patient. With standard 8- to 10-mm-thick sections, partial-volume effects in true consolidations may appear as ground-glass opacities that do not obscure vessels (Fig. 2). Sometimes it is difficult to decide which lung's density is abnormal, that is, whether lung opacity has increased or decreased. Normal lung tissue may have a ground-glass appearance relative to hypoventilated and hypoperfused emphysematous lung (Fig. 3). In emphysema, the peripheral pulmonary vasculature is abnormally attenuated. This feature is helpful for distinguishing between normally perfused lung, emphysema, and true ground-glass opacity [1].

Analysis and Differential Diagnosis

The differential diagnosis of ground-glass opacity is based on analysis of both the anatomic distribution of the abnormality and the alterations in the structure of the lung parenchyma. An effective approach requires a deeper understanding of the pathophysiology and anatomy of the lung, which is beyond the scope of this essay. Nevertheless,

knowledge of the distribution of the abnormality and the structural alterations is instrumental in the interpretation of high-resolution CT scans.

Anatomic Distribution of Ground-Glass Opacity

A centrilobular distribution indicates early air-space consolidation, which may be due to bronchial dissemination of either infection (Fig. 4) or blood [1, 5]. Hypersensitivity pneumonitis and desquamative interstitial pneumonitis also can manifest as centrilobular ground-glass opacity. The term *air-space nodule* is used in conventional radiography and high-resolution CT to describe poorly defined nodular opacities ranging in diameter from a few millimeters to 1 cm. Air-space nodules represent peribronchiolar areas of air-space consolidation.

A panlobular distribution of ground-glass opacity can sharply demarcate a diseased secondary pulmonary lobule from unaffected, normally aerated neighboring parenchyma. The boundaries between normal and abnormal areas will be indistinct if only portions of a secondary pulmonary lobule are diseased. When ground-glass opacity is found to involve a large area, either in a patchy or homogeneous, lobar pattern, many diagnoses can be excluded, because those diseases usually progress to complete consolidation. Possible diagnoses include alveolar proteinosis (Fig. 5), drug toxicity (e.g., from bleomycin), lipid pneumonia, sarcoidosis, and *Pneumocystis carinii* pneumonia. Resolving pneumonia or hemorrhage also may manifest as ground-glass opacity (Fig. 6).

A peripheral distribution of ground-glass opacity is typical of early idiopathic pulmonary fibrosis (fibrosing alveolitis) [3].

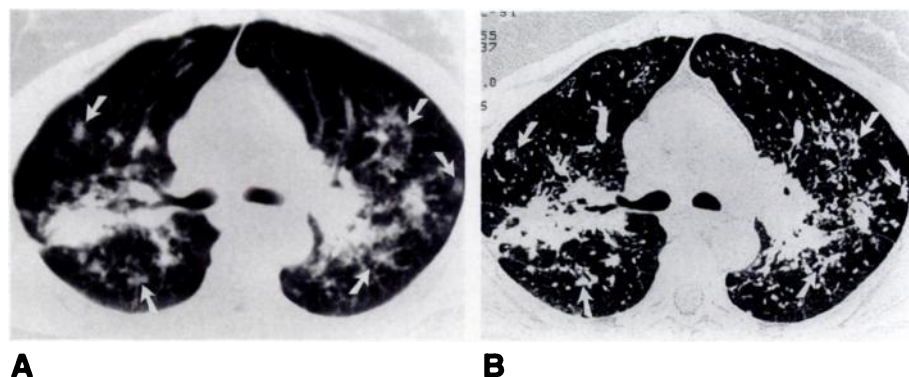


Fig. 2.—Stage III sarcoidosis.

A, CT scan of 10-mm-thick section with low-spatial-frequency algorithm shows fibrotic changes and apparent ground-glass opacities (arrows).

B, High-resolution CT scan of 1-mm-thick section at same level as A shows centripetal fibrosis and small peripheral parenchymal nodules (arrows) without ground-glass opacity. Disease was clinically inactive.

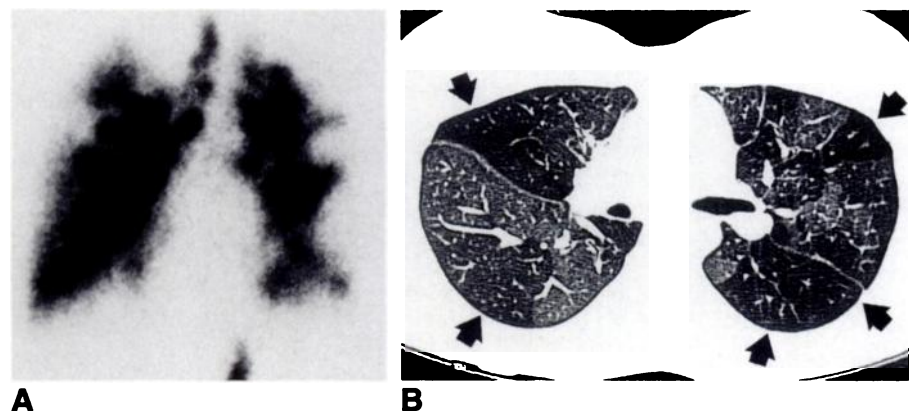


Fig. 3.—Bronchiolitis obliterans.

A, Aerosol ventilation scan shows moderate to large ventilatory defects on both sides.

B, High-resolution CT scan shows extensive peripheral low-attenuation changes corresponding to areas of ventilatory abnormalities (arrows). Relative ground-glass opacity actually represents normally ventilated and perfused lung, not alveolitis, and CT attenuation values in that area were not increased.



Fig. 4.—*Aspergillus* infection in an immuno-compromised patient. High-resolution CT scan shows multiple air-space nodules characterized by centrilobular/peribronchiolar ground-glass opacities (arrows). Central black dots represent lobular bronchioles. Endobronchial spread to right lung originated in masslike consolidations containing air bronchograms (sputum culture positive for *Aspergillus*).

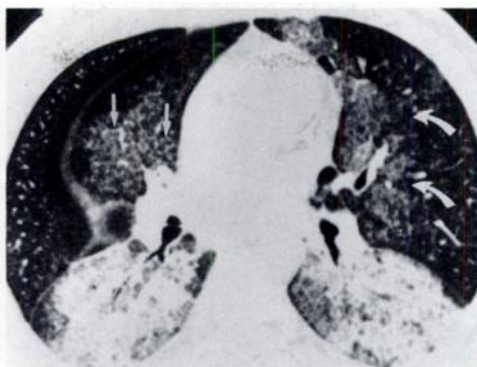


Fig. 5.—Alveolar proteinosis. High-resolution CT scan shows dense consolidation of both lower lobes with patchy and confluent areas of ground-glass opacity best seen in lingula (curved arrows). Ground-glass opacity is due to alveolar filling with proteinaceous material rich in lipid. Interstitial thickening due to edema (after recent lavage) or fibrosis is evident in right middle lobe (straight arrows).

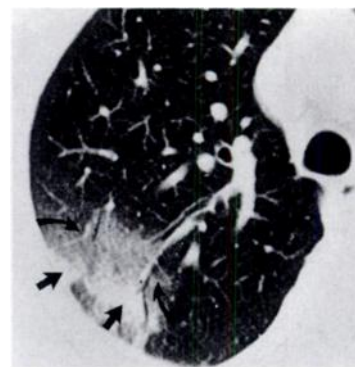
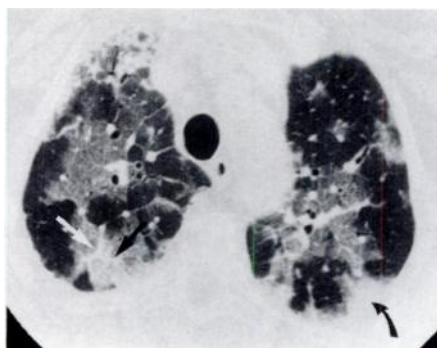


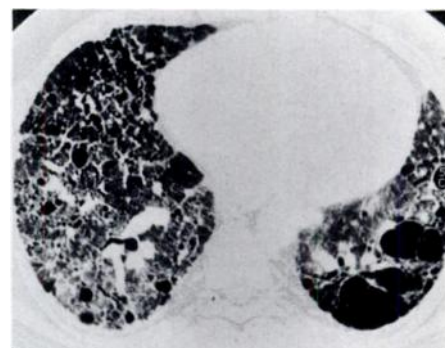
Fig. 6.—Resolving subsegmental pneumonia. High-resolution CT scan shows that areas of complete air-space consolidation (straight arrows) remain and are surrounded by ground-glass opacity. Vessels, bronchi, and pulmonary interstitium are no longer obscured as pneumonia clears from periphery (curved arrows).

Fig. 7.—Bronchiolitis obliterans with organizing pneumonia. High-resolution CT scan shows large areas of ground-glass opacity. Obscured peripheral vessels (straight arrows) and nodular parenchymal changes (curved arrow) reflect typical tendency toward subpleural consolidation. Septal thickening is seen in right upper lobe.

Fig. 8.—Pigeon-breeder's lung in a 44-year-old patient. High-resolution CT scan shows irregular interstitial thickening and destruction with multiple cystic spaces on a background of increased lung opacity. These are nonspecific findings of end-stage lung disease.



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Bronchiolitis obliterans with organizing pneumonia is characterized by patchy areas of consolidation and ground-glass opacities side by side. These consolidations are often found in a peripheral, subpleural location (Fig. 7).

Ground-Glass Opacity with Structural Alterations of the Lung Parenchyma

Ground-glass opacity of the lung parenchyma can be associated with bronchiectasis [6]. In this case, possible diagnoses include "traction" bronchiectasis due to advanced idiopathic pulmonary fibrosis or bronchiectasis associated with bronchiolitis obliterans, Swyer-James syndrome, and graft-vs-host disease. Cystic, destructive parenchymal changes associated with ground-glass opacity are seen in *Pneumocystis carinii* pneumonia and with honeycombing in end-stage lung disease, including idiopathic pulmonary fibrosis, scleroderma, sarcoidosis, and many other diseases [6] (Fig. 8). Subpleural linear opacities are encountered in asbestosis and idiopathic pulmonary fibrosis, and they can be reversible.

Interstitial thickening can be identified as thickened interlobular septa, which are best seen in the cortical portions of the lungs, or the thickening may be evident along central

axial structures such as airways and pulmonary arteries. Centrally, peribronchovascular interstitial thickening or nodularity is characteristic of sarcoidosis (see Fig. 2), whereas peripheral septal thickening can indicate edema or pulmonary fibrosis. Lymphangitic tumor spread, which is characterized by nodular interlobular septal thickening, rarely is associated with ground-glass opacities.

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