Common and Uncommon Manifestations of Wegener Granulomatosis at Chest CT: Radiologic-Pathologic Correlation

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Wegener granulomatosis is an uncommon necrotizing vasculitis that classically manifests as a clinical triad consisting of upper and lower airway involvement and glomerulonephritis. Other less frequently involved organ systems include the central and peripheral nervous system and large joints. The diagnosis is based on a combination of clinical and laboratory findings. Because thoracic involvement often predominates, chest radiographic findings are often the first to suggest the diagnosis. However, chest computed tomography (CT) has superior sensitivity and specificity for evaluation of the airways, lung parenchyma, and mediastinum, particularly with the use of multiplanar reformatted and three-dimensional images. Common pulmonary radiologic findings include waxing and waning nodules, masses, ground-glass opacities, and consolidation. Airway involvement is usually characterized by circumferential tracheobronchial thickening, which can be smooth or nodular. Pleural effusions are the most common manifestation of pleural disease and can result from primary involvement or be secondary to renal failure. Mediastinal lymphadenopathy is a nonspecific finding and is usually reactive. Uncommon thoracic radiologic manifestations include involvement of the heart and great vessels. CT is the imaging modality of choice for diagnosis, surveillance, and follow-up in patients with Wegener granulomatosis.

Abbreviation: ANCA = antineutrophil cytoplasmic antibody

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LEARNING OBJECTIVES

After completing this journal-based CME activity, participants will be able to:

- Discuss the role of chest CT in the diagnosis and follow-up of Wegener granulomatosis with thoracic involvement.
- Describe the chest CT findings of Wegener granulomatosis.
- Differentiate Wegener granulomatosis from other common conditions that may have a similar radiologic appearance.

TEACHING POINTS

See last page

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**Introduction**
Wegener granulomatosis is an uncommon disorder characterized by a chronic granulomatous necrotizing vasculitis that involves mainly small and medium-sized vessels. It is named after Dr Friedrich Wegener, a German pathologist who first described the disease as rhinogenic granulomatosis in 1936 (1). Although the cause of Wegener granulomatosis is unknown, an autoimmune element has been proposed because of the presence of circulating antineutrophil cytoplasmic antibodies (ANCAs) directed against proteinase 3 and, less commonly, myeloperoxidase (2).

Along with Churg-Strauss syndrome and microscopic polyangiitis, Wegener granulomatosis is considered one of the ANCA-associated vasculitides (3).

In this article, we discuss Wegener granulomatosis in terms of epidemiology, clinical features, classification and staging, treatment and prognosis, histologic features, and thoracic radiologic findings. In addition, we describe imaging and clinical manifestations that can aid in distinguishing this pathologic condition from potential mimics.

**Epidemiology**
Wegener granulomatosis affects three out of every 100,000 people in the United States. Reports suggest a rising prevalence of the disease in the United Kingdom and Norway, but this is likely related to improved detection and earlier diagnosis (4,5). Patients with Wegener granulomatosis can be of any age, although the mean age at diagnosis is 50 years. Males and females are affected equally. The majority (90%) of clinically apparent cases are seen in white persons (6).

Environmental agents such as cadmium, silica, mercury, sand dust, and volatile hydrocarbons, among others, have been studied as possible agents that may predispose to development of the disease; however, no single causative agent has been identified (7–12). Wegener granulomatosis may represent a hypersensitivity reaction to an external antigen, possibly of infectious etiology. This theory is supported by the apparent success of the use of trimethoprim-sulfamethoxazole in treating disease relapse (13).

**Clinical Features**
Wegener granulomatosis affects multiple organ systems and may involve any part of the body (14). The upper respiratory tract is involved in nearly all patients; in addition, a vast majority of patients with Wegener granulomatosis will also have pulmonary (90%) and renal (80%) involvement (15).

The classic clinical triad consists of upper airway involvement (characterized by sinusitis, otitis, nasal mucosa ulcers, bone deformities, and subglottic stenosis), lower respiratory tract involvement (cough, chest pain, hemoptysis), and glomerulonephritis (16).

Although only 40% of patients have renal involvement at presentation, 80%–90% ultimately develop renal disease (17). Wegener granulomatosis has a broad clinical spectrum ranging from localized disease (predominantly restricted to the respiratory tract) to a severe life-threatening form with involvement of multiple organs (predominantly the kidneys and lungs) (18). It is believed that the disease begins as a localized respiratory tract granulomatosis, which then generalizes into a vasculitis that affects small and medium-sized vessels (19).

Patient presentation varies and depends on the organ system affected. Some patients present with chronic nasal obstruction, which may be misdiagnosed as chronic sinusitis; others may present with overt acute renal or respiratory failure. Patients with pulmonary involvement often complain of cough with or without hemoptysis, dyspnea, fever, and chest pain (6).

Multiple laboratory values may be abnormal. Anemia may be profound in the setting of diffuse alveolar hemorrhage. Decreased serum iron and ferritin levels indicate blood loss. Leukocytosis may be present. The presence of eosinophilia is somewhat unusual; the diagnosis of Churg-Strauss syndrome should be considered in this setting. Inflammatory markers are often elevated and can be used to assess treatment response. Elevated serum creatinine levels reflect renal...
failure from vasculitic involvement of the kidneys. Elevation of serum cytoplasmic ANCA (c-ANCA) titers, usually directed toward proteinase 3 and myeloperoxidase (found in neutrophils), occurs in up to 90% of patients with active Wegener granulomatosis (20). The correlation between c-ANCA and Wegener granulomatosis has been well established (21). Although c-ANCA testing can aid in the diagnosis, positivity is not conclusive. Negative c-ANCA test results are not enough to exclude the diagnosis, and biopsy remains the standard means of diagnosis (22). Indirect immunofluorescence testing for c-ANCA and enzyme-linked immunosorbent assays for antibodies directed against proteinase 3 are useful for the diagnosis. Positive findings at immunofluorescence testing for c-ANCA should always be confirmed with enzyme-linked immunosorbent assays (3).

Classification and Staging

According to the Chapel Hill Consensus Conference on the nomenclature of systemic vasculitis (1992), establishing the diagnosis of Wegener granulomatosis requires documentation of granulomatous inflammation involving the respiratory tract and vasculitis of small to medium-sized vessels (23).

The disease is classified into various stages on the basis of organ involvement (Table 1). Strict diagnostic criteria have been established by the American College of Rheumatology (Table 2).

### Table 1
**Clinical Classification of Wegener Granulomatosis**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited</td>
<td>Disease localized to the upper airways, no systemic symptoms, no threatened organ function, no renal involvement</td>
</tr>
<tr>
<td>Early generalized</td>
<td>Constitutional symptoms, no threatened organ function</td>
</tr>
<tr>
<td>Active generalized</td>
<td>Constitutional symptoms with threatened organ function</td>
</tr>
<tr>
<td>Severe</td>
<td>Severe renal involvement, life-threatening disease (16,18)*</td>
</tr>
<tr>
<td>Refractory</td>
<td>Progressive disease that is unresponsive to therapy</td>
</tr>
</tbody>
</table>

*Numbers in parentheses indicate references.

### Table 2
**American College of Rheumatology Diagnostic Criteria for Wegener Granulomatosis**

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasal or oral inflammation</td>
<td>Painful or painless oral ulcers, purulent or bloody nasal discharge</td>
</tr>
<tr>
<td>Abnormal chest radiograph</td>
<td>Nodules, fixed infiltrates, cavities</td>
</tr>
<tr>
<td>Urinary sediment</td>
<td>Microhematuria (&gt;5 red blood cells per high-power field), red cell casts</td>
</tr>
<tr>
<td>Granulomatous inflammation at biopsy</td>
<td>Involvement of the wall of an artery/arteriole, involvement of the perivascular/extra-vascular space</td>
</tr>
</tbody>
</table>

Note.—The presence of two or more of the four criteria is associated with a sensitivity of 88.2% and a specificity of 92% for Wegener granulomatosis (14).
Figure 1. Lung with hemorrhage due to Wegener granulomatosis. Photograph obtained at autopsy shows a solid, red lung that is three times its normal weight. The rounded edges along the fissure (arrows) indicate swelling.

Treatment and Prognosis

Wegener granulomatosis is associated with considerable morbidity and mortality from irreversible organ damage caused by inflammatory injury or chronic or overzealous immunosuppressive therapy. Without treatment, approximately 90% of patients with Wegener granulomatosis die within 2 years of diagnosis (24). Therapy involves aggressive immunosuppression; therefore, complications are common and can be severe. To minimize adverse effects, the degree of immunosuppression is based on severity of disease and c-ANCA titers. For limited disease localized to the upper airways, the administration of corticosteroids, methotrexate, or azathioprine may suffice. For more advanced disease, cyclophosphamide administration is the first-line therapy for inducing remission. Maintenance therapy is usually based on the administration of azathioprine or methotrexate (16). Pharmacologic treatment is associated with an increased risk of cancer (5.6% increased risk of bladder cancer after cyclophosphamide treatment), infection, and reduced fertility. End-stage renal failure eventually occurs in up to 26% of patients with Wegener granulomatosis; however, remission can still be achieved in these patients (24). Disease recurrence may have different radiologic appearances and can manifest as cavitary nodules, consolidations, airspace opacities, and airway stenosis (25).

Histologic Features

Although Wegener granulomatosis is widely recognized among pathologists as a necrotizing vasculitis involving vessels of all sizes (26), some authors consider it to be the result of an intrin-
Granulomatous collagen lesion, including collagen found in vascular walls (27,28). Granulomatous vasculitis is characteristic but not always present. Wegener granulomatosis has many histopathologic features. In the lung, it may involve arteries, veins, capillaries, airways, interstitium, and pleura (Fig 1) (28). The affected vessels show transmural infiltration of the wall by inflammatory cells (Fig 2) with microabscess formation, resulting in thrombotic occlusion, rupture (Fig 3), and hemorrhage (29). Distinctive microabscesses and palisading granulomas (Fig 4), which are the result of primary collagen necrosis, occur in up to 75% of patients with active Wegener granulomatosis (27,30). Necrotic granulomatous lesions are characteristic (Fig 5). Several other histologic variants (eg, bronchocentric, eosinophilic, cryptogenic organizing pneumonia–like, and capillaritis variants) are less common (31). Compact sarcoïd or tuberculoid type granulomas are very rare (28,31).

**Common Thoracic Radiologic Manifestations**

**Pulmonary Nodules and Masses**

Pulmonary nodules and masses are the most common radiologic findings of Wegener granulomatosis and are seen in up to 70% of patients either at presentation or during the course of the disease. Waxing and waning of the pulmonary nodules and masses are features of the disease. Lesions can be single or multiple (usually <10 lesions) (Fig 6) and range in size from a few millimeters to over 10 cm (Fig 7). When multiple, nodules usually have a random distribution.
Figure 7. CT scan at the level of the aortic arch obtained in a 45-year-old patient with known Wegener granulomatosis who presented with worsening shortness of breath shows a high-attenuation mass in the right upper lobe with a surrounding ground-glass halo and internal air bronchograms.

Figure 8. CT scan through the lower lobes obtained in a 40-year-old patient who presented with shortness of breath and mild hemoptysis demonstrates multiple cavitary (arrows) and noncavitary (arrowheads) pulmonary nodules, findings that proved to be Wegener granulomatosis at biopsy.

Figure 9. CT scan of a patient with known Wegener granulomatosis demonstrates a pulmonary nodule in the periphery of the right lower lobe with a faint surrounding ground-glass halo (arrow) that is consistent with adjacent parenchymal hemorrhage.

However, peribronchovascular, subpleural, angiocentric, and (rarely) centrilobular distributions have been described (32). A centrilobular distribution may mimic tuberculosis, hypersensitivity pneumonitis, or acute bronchiolitis (15).

Central cavitation occurs in up to 50% of cases and is more common in nodules larger than 2 cm (33). Cavity walls may be smooth and thin or irregular and thick (Fig 8) (32).

A surrounding ground-glass halo (“CT halo” sign) or reverse halo (“atoll” sign), radiating linear scarring, and pleural tags are ancillary findings that, if present, may help distinguish Wegener granulomatosis from other pathologic conditions. The CT halo sign (Fig 9) is the result of adjacent parenchymal hemorrhage and can be seen in up to 15% of patients (34). The atoll sign, previously thought to specifically indicate organizing pneumonia, can also be seen in Wegener granulomatosis (35) and presumably reflects an organizing pneumonia reaction in the periphery of focal hemorrhage (15). Radiating linear scarring, spiculation, and tags to the adjacent pleural surfaces are prominent features of nodules and masses secondary to Wegener granulomatosis. These features are not usually seen in other causes of peripheral masses such as acute pulmonary infarcts, septic emboli, or hematogenous metastases (36). Several discriminators may help differentiate Wegener granulomatosis from other entities that may also manifest as nodules or masses (Fig 10, Table 3).
Figure 10. CT scans demonstrate pathologic conditions that may manifest with pulmonary nodules or masses, thereby mimicking Wegener granulomatosis: metastatic disease (a), miliary tuberculosis (b), sarcoidosis (c), and rheumatoid arthritis (d).

Table 3
Differential Diagnosis for Nodules and Masses

<table>
<thead>
<tr>
<th>Pathologic Condition</th>
<th>Number</th>
<th>Size</th>
<th>Distribution</th>
<th>Cavitation</th>
<th>Ancillary Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wegener granulomatosis</td>
<td>Multiple</td>
<td>Few millimeters up to 10 cm</td>
<td>Usually bilateral and random, but may be peribronchovascular, subpleural, and angiocentric</td>
<td>Seen in up to 50% of lesions &gt;2 cm</td>
<td>CT halo and atoll signs, radiating linear scarring, pleural tags</td>
</tr>
<tr>
<td>Metastasis</td>
<td>Multiple</td>
<td>Variable</td>
<td>Bilateral and random</td>
<td>Not common but, if present, suggests squamous, sarcomatous, or transitional cell primary</td>
<td>Lymphadenopathy</td>
</tr>
<tr>
<td>Infection</td>
<td>Variable</td>
<td>Usually &lt;10 mm</td>
<td>Peripheral (eg, septic emboli) or miliary (eg, tuberculosis and fungal infection)</td>
<td>Rare</td>
<td>Tree-in-bud opacities, consolidation, reactive lymphadenopathy</td>
</tr>
<tr>
<td>Sarcoïdosis</td>
<td>Multiple</td>
<td>2–10 mm</td>
<td>Perilymphatic</td>
<td>Rare</td>
<td>Architectural distortion, symmetric adenopathy</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>Solitary or multiple</td>
<td>5–7 mm</td>
<td>Usually peripheral</td>
<td>Rare</td>
<td>Waxing and waning, subcutaneous nodules</td>
</tr>
</tbody>
</table>
If left untreated, nodules can enlarge or cavi- tate; with treatment, they often resolve or evolve into discoid scars (Figs 11, 12) (32). Suspicious- looking nodules that do not correlate with clinical or immunologic activity should be biopsied because of the twofold increased risk of malignancy in patients with Wegener granulomatosis (Fig 13) (37).
Figure 13. CT scan of a 55-year-old patient with known Wegener granulomatosis shows a large pulmonary nodule that did not correlate with the clinical activity of the disease. CT-guided lung biopsy was performed, and pathologic analysis demonstrated lung adenocarcinoma.

Figure 14. Coronal reformatted chest CT image of a patient with known Wegener granulomatosis who presented with hemoptysis shows perihilar ground-glass opacities consistent with pulmonary hemorrhage.

Figure 15. CT scan through the carina obtained in a patient with a recent diagnosis of Wegener granulomatosis (confirmed at renal biopsy) who presented with hemoptysis and marked shortness of breath shows bilateral perihilar ground-glass opacities consistent with pulmonary hemorrhage.

Ground-Glass Opacity and Consolidation

Diffuse ground-glass opacity and consolidation occur in up to 50% of patients with Wegener granulomatosis (38) and may result from pulmonary hemorrhage or infection. When ground-glass opacity and consolidation occur in isolation, infection is the most common initial diagnosis, and Wegener granulomatosis is considered only after failure of adequate antibiotic therapy (15,39).

Although ground-glass opacity and consolidation in Wegener granulomatosis may be quite variable, bilateral perihilar (Figs 14, 15) and peribronchovascular (Fig 16) distributions are the most common. As with pulmonary nodules and masses, ground-glass opacities and consolidations may also wax and wane regardless of therapy. Consolidations are usually dense and may contain air bronchograms (Fig 17) (33,40,41).
Ground-glass opacity results from either alveolar hemorrhage or intraalveolar cellular debris (39). Ground-glass opacity in association with a mosaic pattern of lung attenuation may result from arteriolar involvement (42). Fewer than 10% of patients have extensive ground-glass opacity with subpleural sparing, findings that are usually suggestive of diffuse alveolar hemorrhage (33,43). Areas of diffuse hemorrhage may coalesce into denser areas of hemorrhagic consolidation (15). Alveolar hemorrhage is generally acute and may be fatal if left untreated. However, treatment usually leads to complete resolution, and in some cases resolution may occur spontaneously (33).

Clinical presentation, distribution, and ancillary findings may help differentiate Wegener granulomatosis from other pathologic conditions manifesting as airspace and ground-glass opacities (Fig 18, Table 4).

**Airway Involvement**

The tracheobronchial tree is the second most commonly affected area in the thorax in Wegener granulomatosis (44). Tracheal involvement typically occurs in the setting of multisystem disease, although cases of isolated involvement of large airways have been described (45). Patients present with nonspecific symptoms including dyspnea, hoarseness, and stridor, and an incorrect diagnosis of asthma may be made initially. Tracheal involvement (present in 16%–23% of cases) can be segmental, unifocal, or multifocal but is usually focal, involving a 2–4-cm span of
Table 4  
Differential Diagnosis for Airspace Opacities

<table>
<thead>
<tr>
<th>Disease</th>
<th>Presentation</th>
<th>Distribution</th>
<th>Adenopathy</th>
<th>Tree-in-Bud Opacities</th>
<th>Cavitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wegener granulomatosis</td>
<td>Most often acute</td>
<td>Multifocal, bilateral perihilar and peribronchovascular</td>
<td>Rare</td>
<td>Rare</td>
<td>Rare</td>
</tr>
<tr>
<td>Bacterial pneumonia</td>
<td>Acute</td>
<td>Lobar and patchy</td>
<td>Reactive</td>
<td>Yes</td>
<td>Rare</td>
</tr>
<tr>
<td>Aspiration</td>
<td>Most often acute</td>
<td>Dependent, associated with bronchiectasis in lower lobes</td>
<td>Reactive</td>
<td>Yes</td>
<td>Sometimes</td>
</tr>
<tr>
<td>Organizing pneumonia</td>
<td>Chronic</td>
<td>Multifocal, peripheral, migratory; atoll sign</td>
<td>Rare</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Neoplasm (adenocarcinoma versus adenocarcinoma in situ)</td>
<td>Chronic</td>
<td>Uni- or multifocal, ranging from ground-glass opacity to consolidation</td>
<td>Yes</td>
<td>No</td>
<td>Pseudocavitation</td>
</tr>
</tbody>
</table>

Figure 18. CT scans demonstrate pathologic conditions that may manifest as airspace opacities and thereby mimic Wegener granulomatosis: bacterial pneumonia (a), aspiration pneumonia (b), organizing pneumonia (c), and primary lung adenocarcinoma (d).
the trachea. The subglottic portion of the trachea is most often affected (Figs 19–21). Wall thickening is usually circumferential and can be smooth or nodular. Involvement of the posterior membrane of the trachea is the rule (Fig 22), thereby helping distinguish Wegener granulomatosis from other entities such as relapsing polychondritis and tracheobronchopathia osteochondroplastica, both of which characteristically spare this area (Fig 23, Table 5) (46–48). Wall thickening and bronchiectasis are present in distal airway involvement and may result in obstructive atelectasis or pneumonia. Stenosis may be seen in up to 18% of patients with airway involvement (33). Airway thickening often decreases with adequate treatment, but persistent stenosis may require stent placement or surgery (34).

**Teaching Point**

19. Figures 19, 20. (19) Coronal reformatted chest CT image of a patient with tracheal and pulmonary involvement by known Wegener granulomatosis demonstrates subglottic tracheal narrowing (arrow). (20) Photograph of the gross pathologic specimen obtained in a patient with known Wegener granulomatosis shows involvement of the proximal trachea (T) and subglottic larynx (SL) with necrosis and deformation (arrows).

20. Figure 21. Photomicrograph (original magnification, ×63; hematoxylin-eosin stain) of the trachea obtained in a patient with Wegener granulomatosis shows respiratory epithelium (RE) with neutrophils (arrows) beneath intact surface epithelium.
Figure 22. (a) Wegener granulomatosis. Chest CT scan at the level of the aortic arch shows circumferential tracheal thickening (arrow). There is involvement of the posterior membranous trachea, which helps differentiate Wegener granulomatosis from relapsing polychondritis or tracheobronchopathia osteochondroplastica. A small amount of oral contrast material (arrowhead) is seen in the esophagus. (b) Wegener granulomatosis with tracheobronchial involvement in a different patient. Three-dimensional reformatted image from virtual bronchoscopy shows significant narrowing of the distal trachea, carina, and bronchi (arrows).

Figure 23. CT scans demonstrate pathologic conditions that may manifest with airway thickening: relapsing polychondritis (a), tracheobronchopathia osteochondroplastica (b), and amyloidosis (c).
Pleural Involvement

Pleural effusions are the most common pleural abnormality in Wegener granulomatosis and are present in 12%–20% of patients (33,49). Effusions may be unilateral or bilateral and vary in size (Fig 24). They may reflect primary pleural involvement by Wegener granulomatosis or result from renal failure. Pleural granulomatous inflammation and vasculitis have been described in up to 6% of patients. Nonspecific acute or chronic fibrinous pleuritis may be seen adjacent to nodular inflammatory lesions (49). Other pleural manifestations such as pleural thickening, nodularity, and pneumothorax are rare; when present, however, they should raise suspicion for superimposed infection or malignancy (38).

Table 5
Differential Diagnosis for Airway Thickening

<table>
<thead>
<tr>
<th>Tracheal Disease</th>
<th>CT Appearance</th>
<th>Differentiating Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wegener granulomatosis</td>
<td>Circumferential tracheal wall thickening, most often involving the subglottic region</td>
<td>Subglottic tracheal narrowing; history of sinus or renal disease, pulmonary cavity nodules, or pulmonary hemorrhage; posterior wall involvement; no wall calcification</td>
</tr>
<tr>
<td>Relapsing polychondritis</td>
<td>Thickening of the cartilaginous trachea and tracheal wall</td>
<td>Sparing of the posterior tracheal wall, cartilaginous abnormalities of the ears or nose, tracheal narrowing, wall calcification (occasionally)</td>
</tr>
<tr>
<td>Tracheobronchopathia</td>
<td>Calcified/ossified nodules in the cartilaginous trachea</td>
<td>Nodular calcified/ossified tracheal wall (almost always) with wall thickening and sparing of the posterior tracheal membrane and superior trachea</td>
</tr>
<tr>
<td>osteochondroplastica</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amyloidosis</td>
<td>Calcified/ossified, nodular concentric tracheal wall thickening</td>
<td>Nodular concentric calcified/ossified wall (often present) with wall thickening and without posterior sparing, possibly involving the larynx and upper trachea</td>
</tr>
</tbody>
</table>

Figure 24. Chest CT scan of a patient with known Wegener granulomatosis shows a nonspecific small left pleural effusion and a pulmonary nodule in the left lower lobe.

Mediastinal Involvement

Although lymphadenopathy is relatively uncommon, it most frequently involves the paratracheal and hilar nodes and is thought to be reactive.
Figure 25. Chest CT scan of a patient with involvement of the paranasal sinuses and kidneys by Wegener granulomatosis who presented with worsening renal function shows extensive mediastinal adenopathy. Results of biopsy performed to exclude malignancy proved that the adenopathy was secondary to Wegener granulomatosis.

Uncommon Thoracic Radiologic Manifestations

Cardiac Involvement
Cardiac involvement is relatively rare in Wegener granulomatosis, even though autopsy results show that Wegener granulomatosis–related cardiac abnormalities are present in one-third of patients (53). Cardiac manifestations can be seen at imaging in patients with no clinical signs or symptoms of cardiac disease (54). In a study by Hoffman et al (17), cardiac involvement—predominantly pericarditis—was seen in 10 (6%) of 158 patients with Wegener granulomatosis. Coronary involvement is rare and is characterized by coronary arteritis and subsequent coronary artery thromboembolism (17,55–57). Myocardial ischemia can result from vasculitic occlusion of small and medium-sized coronary arteries (58).

Table 6
Differential Diagnosis for Lymphadenopathy

<table>
<thead>
<tr>
<th>Pathologic Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sarcoidosis or other granulomatous disease</td>
<td>Symmetric hilar and mediastinal involvement</td>
</tr>
<tr>
<td>Primary lung cancer</td>
<td>Usually asymmetric involvement, follows course of lymphatic drainage</td>
</tr>
<tr>
<td>Lymphoma</td>
<td>Bulky anterior and middle mediastinal masses</td>
</tr>
<tr>
<td>Infection</td>
<td>May be hypoattenuating (as in tuberculosis and MAC infection) or calcific (as in tuberculosis and fungal infection)</td>
</tr>
</tbody>
</table>

Note.—MAC = Mycobacterium avium complex.

(Fig 25) (34,50). Lymphadenopathy improves as the disease remits. When lymphadenopathy is the predominant finding, other causes such as sarcoidosis, infection, or lymphoma must be excluded (Table 6) (51,52).
Valvular dysfunction is the result of inflammation and thickening of the valvular apparatus and may manifest as either stenosis or regurgitation (Fig 26). Other reported cardiac manifestations of Wegener granulomatosis include conduction abnormalities from inflammation of the atrioventricular conduction system, pericarditis, pancarditis, focal myocarditis, cardiomyopathy, noninfectious endocarditis, and heart failure (59–67).

Figure 26. Coronal reformatted chest CT image of a 39-year-old patient with Wegener granulomatosis and symptomatic aortic stenosis shows extensive calcification of the aortic valve (arrow). The patient underwent aortic valve replacement. Pathologic analysis demonstrated postinflammatory aortic valvulopathy secondary to Wegener granulomatosis. The leads of a pacemaker that was placed for an associated Wegener granulomatosis–induced conduction abnormality are partially visualized in the superior vena cava and right heart.

Figure 27. Axial CT scans at the level of the aortic arch (a) and right pulmonary artery (b) and sagittal reformatted CT image (c) obtained in a 45-year-old patient with known Wegener granulomatosis show extensive peri-aortitis (arrows).
Figure 28. (a) Parasagittal reformatted chest CT image obtained in a 56-year-old patient with known Wegener granulomatosis shows inflammatory changes surrounding the main pulmonary artery (arrow) with involvement of the artery due to direct extension. (b) Photomicrograph (original magnification, ×63; hematoxylin-eosin stain) shows granulomatous inflammation in the main pulmonary artery, with lymphocytes, histiocytes, and multinucleated histiocytes (circled) separating broad fibers of elastic (arrows).

Involvement of the Great Arteries
Although Wegener granulomatosis is a vasculitis that primarily affects small and medium-sized vessels, aortitis and periaortitis have also been described (Fig 27) (68). Periaortic inflammation is believed to result from the extension of granulomatous tissue through the vessel wall, in contrast to (a) granulomatous inflammation that is limited to the layers of the wall (as in Takayasu arteritis) or (b) vasa vasorum vasculitis (as in polyarteritis nodosa). Direct extension of granulomatous tissue into the pulmonary artery can also occur (Fig 28).

Conclusions
Wegener granulomatosis is an uncommon necrotizing vasculitis that classically manifests as a clinical triad of upper and lower respiratory tract and renal disease. Diagnosis is based on a combination of clinical and laboratory findings. Although any organ system can be affected, thoracic involvement often predominates. Manifestations of Wegener granulomatosis are often identified at chest CT, and the radiologist may be the first physician to suggest the diagnosis. Common thoracic radiologic findings include pulmonary nodules, masses, ground-glass opacity, and consolidation. Airway, mediastinal, cardiac, and pleural involvement are less common. CT is the imaging modality of choice for diagnosis, surveillance, and follow-up in patients with Wegener granulomatosis.


References


Although the cause of Wegener granulomatosis is unknown, an autoimmune element has been proposed because of the presence of circulating antineutrophil cytoplasmic antibodies (ANCAs) directed against proteinase 3 and, less commonly, myeloperoxidase (2).

Wegener granulomatosis affects multiple organ systems and may involve any part of the body (14). The upper respiratory tract is involved in nearly all patients; in addition, a vast majority of patients with Wegener granulomatosis will also have pulmonary (90%) and renal (80%) involvement (15).

Pulmonary nodules and masses are the most common radiologic findings of Wegener granulomatosis.

Diffuse ground-glass opacity and consolidation occur in up to 50% of patients with Wegener granulomatosis (38) and may result from pulmonary hemorrhage or infection. When ground-glass opacity and consolidation occur in isolation, infection is the most common initial diagnosis, and Wegener granulomatosis is considered only after failure of adequate antibiotic therapy (15,39).

Wall thickening is usually circumferential and can be smooth or nodular.