Benign nodular lesions of the lung: Is it all the same?

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Learning objectives

- To review and illustrate the benign nodular lesions of the lung.
- To present a systematic approach to their differential diagnosis.
Background

The differential diagnosis of solitary or multiple pulmonary nodules is broad, with a significant percentage of cases falling into the group of malignant neoplasms.

The solitary pulmonary nodule is a round or oval opacity smaller than 3cm in diameter. It is a common radiological finding, often detected incidentally. Although most have benign causes such as granulomas or hamartomas, 30-40% of these nodules are malignant \(^{(3)}\).

CT is the gold standard imaging technique for pulmonary nodules characterization. Several morphologic features must be considered, but also is extremely important to integrate the CT findings in the clinical background and sometimes with other imaging modalities.

We must first recognize the clinical factors that make lung cancer a more likely cause of a pulmonary nodule \((\text{risk of malignancy})\): smoking history, history of primary pulmonary or extrapulmonary cancer, pulmonary fibrosis (idiopathic fibrosis or fibrosis due to asbestos exposure, collagen vascular disease, adult respiratory distress syndrome or previous radiation).

**Nodule features** that are important in the benign vs. malignant differentiation, although there is considerable overlap, are the followings:

**Size**

The size of the pulmonary nodule is not a reliable predictor of benignity. However, the larger the nodule \((\text{when approaching 3 cm in diameter})\), the more likely it is to be malignant. Nodules smaller than 1 cm in diameter are more likely to be benign.

**Growth rate assessment**

Prior imaging examinations or periodic follow-up with computed tomography for two years showing no growth of the nodule are indicative of benignancy and no further imaging is required.

The exception is the suspicion of bronchioloalveolar carcinoma or adenocarcinoma in case of nonsolid nodules, in which a longer time of follow-up may be needed because of the slower grow rate \(^{(7)}\).
**Margin**

An irregular margin is indicative of malignancy, but it can occasionally be seen in benign disease such as granulomatous disease, lipoid pneumonia, organizing pneumonia and progressive massive fibrosis. The edge irregularity and spiculation is associated with radial extension of malignant cells along the interlobular septa.

Nodules with a halo margin (peripheral nonsolid component) and lobulated nodules include a significant percentage of malignant lesions.

A smooth margin does not indicate benignity, as up to one third of malignant lesions have smooth margins and many of these are metastatic.

Actually, Kim et al (8) reported in their study that there were no differences between benign and malignant lesions when assessed by shape, marginal characteristics or the presence of pleural tags. Polygonal shape, nodule lobulation or presence of irregular margins or spiculation was found in both malignant and benign lesions.

**Internal characteristics:**

**Calcification**

The most important imaging feature used to confidently diagnose a benign nodule is the presence of calcification involving more than 10% of the cross-sectional area of the nodule and exhibiting one of the following benign patterns:

- Central nidus;
- Laminated;
- Popcorn;
- Solid diffuse.

When the calcification pattern is eccentric, amorphous and diffuse or punctuated, it raises suspicion of malignancy.
Also, some lung cancers may have dense foci of calcification or be entirely calcified, with a pattern resembling that of benign disease, such as carcinoids, metastatic osteosarcomas and chondrosarcomas.

**Presence of fat**

Focal fat attenuation (-40 to -120 UH) is a reliable indicator of a hamartoma or less likely a lipoma. This feature is seen in over 50% of hamartomas.

However, some malignancies such as metastasis from lipossarcoma or renal cells carcinoma may occasionally contain fat.

**Nodule Attenuation**

There are solid, partly solid and nonsolid (ground-glass) nodules.

Nonsolid nodules are often caused by benign conditions such as inflammatory disease, but also may contain premalignant lesions (atypical adenomatous hyperplasia or bronchoalveolar hyperplasia). Malignancies such as bronchioalveolar carcinoma or invasive adenocarcinoma with bronchioalveolar # are more likely to be malignant than nonsolid nodules, particularly if the solid component is in the center of the nodule (often representing invasive adenocarcinoma).

Solid nodules # Although solid nodules are the most common type of nodule and of cancerous nodules, they are less likely to be malignant than partly solid or nonsolid nodules. Inflammatory diseases of the lung usually produce solid nodules (granulomas) that may eventually calcify.

**Air bronchograms**

Air bronchograms and air bronchiolograms (also referred to as bubble-like lucencies or pseudocavitation) are more common in pulmonary carcinomas than in benign nodules, particularly in bronchioalveolar cell carcinomas. This appearance is probably caused by a desmoplastic reaction to the tumor that distorts and remain patent the airways.

**Cavitation**

Benign cavitated lesions usually have thinner smooth walls and irregular-walled cavities thicker than 16mm tend to be malignant, but there is considerable overlap.
Enhancement (if = or > to 1cm of diameter)

Many nodules will remain undetermined after the initial thin-section CT examination. A contrast material-enhanced examination may then be performed. It should not be done in nodules smaller than 1cm, cavitary lesions or lesions with central necrosis.

If the nodular lesion enhances less than15HU it is strongly indicative of benignity. Although enhancement of more than 15HU is more likely to represent malignancy, only 58% of nodules are malignant (2). The remainder represents inflammatory active disease, such as granulomas or organizing pneumonias.

PET / PET-CT

The important role of PET in the diagnosis and management of lung cancer is well established. For lesions as small as 8-10mm in size, fluorine 18 fluorodeoxyglucose (FDG) PET is accurate in differentiating benign from malignant lesions, with an overall sensitivity, specificity and accuracy of 96, 88 e 94%, respectively.

However, FDG-PET has a lower sensitivity for small (<1cm) or slow growing lesions, such as carcinoid and bronchoalveolar cell carcinoma.

False positive PET findings are associated with focal infections (like tuberculosis and fungal diseases) and inflammatory non neoplastic diseases (such as sarcoidosis and rheumatoid disease).

Other diagnostic possibilities

In patients with nonspecific or no conclusive CT and/or PET findings, the definitive diagnosis can be made by transthoracic aspiration or core needle biopsy (TNB - Transthoracic Needle Biopsy) of accessible lung lesions, mainly peripherally located.

The other available diagnostic methods are the bronchoscopic biopsies for endobronchial or more central lesions, by means of bronchial washing, bronchial brushing or transbronchial needle biopsy .

Nowadays, with the arising equipment it is possible to perform endobronchial US evaluation (EBUS) and US-guided endobronchial biopsies of lung lymph nodes or lung nodules.
Imaging findings OR Procedure details

A retrospective search of pathology proven cases of benign nodular lesions of the lung was done, allowing a pictorial review of several diseases that manifest themselves as pulmonary nodules.

The group of the benign entities include infectious, inflammatory, vascular, congenital and benign neoplastic causes.

Fig.: Benign causes of nodular lesions of the lung.

References: Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
**Fig.** Infectious entities that can cause pulmonary nodules.

**References:** Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
**Fig.**: Granulomatous infections that can present with lung nodules.

**References**: Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT

**Mycobacterium tuberculosis**

**Primary Tuberculosis**

- Ghon focus - initial parenchymal focus may enlarge and result in an area of airspace consolidation or more commonly undergo healing with fibrosis and often dystrophic calcification.
- Ranke complex - combination of the parenchymal Ghon focus and nodal involvement.

**Postprimary Tuberculosis**
• In approximately 5% of patients with postprimary tuberculosis (1), the main manifestation is a tuberculoma (central caseous material and peripheral epitheloid histiocytes, multinucleated giant cells and collagen).
• Tuberculoma - sharply marginated round or oval nodule usually measuring 0.5 to 4 cm in diameter; it usually occurs in the upper lobes and is multiple in about 20% of cases.
• Satellite nodules measuring 1 to 5mm are present in most cases.

Histoplasma capsulatum

Acute Histoplasmosis

• CT may reveal unilateral or bilateral nodules or areas of consolidation and lymphadenopathy.
• Satellite nodules and centrilobular nodules (sometimes with a tree-in-bud pattern) also may be seen.
• With resolution, a nodule may persist and develop central, laminated or diffuse calcification (benign patterns) - calcified granuloma (CT without intravenous contrast administration).
• Associated lymph nodes may calcificate, as also granulomas in the liver and spleen that may be present.

Chronic Histoplasmosis

• Occurs almost exclusively in middle-aged men with emphysema - underlying changes of emphysema.
• Unilateral or bilateral upper lobe airspace opacities.
• Bulla with surrounding airspace opacity mimicking a cavitary lesion - can mimic tuberculosis.
• Lymphadenopathy is usually absent.

Histoplasmoma

• Slow growing nodule resulting from histoplasmosis.
• It's a small necrotic nodule surrounded by a massive fibrous capsule.
• Typically asymptomatic.
• Most often located peripherally and in a lower lobe.
• May have central, laminated or diffuse calcification.
• Associated satellite nodules and calcified hilar lymph nodes are common.
Saprophytic Aspergillosis (Aspergilloma)

- It's the most common form of *Aspergillus* infection - fungus ball or mycetoma. Clinically asymptomatic or mild/severe hemoptysis.
- Usually develops in a preexisting lung cavity.
- Round or oval solid mass within a cavity, usually at the upper lobe. Fronds or sponge-like appearance and areas of calcification may be seen.
- "Air crescent" sign - crescent of air around the mass.
- The mass may be mobile - move with varying patient positions.
- The wall of the cavity and adjacent pleura may show thickening.
Fig.: Aspergilloma - A solid mass within a cavity and the "air crescent" sign can be shown in this CT image.

References: Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
Fig.: Aspergilloma - Scans were made both in supine (previous image) and prone position (as shown in this image) and mass mobility within the cavity could be confirmed

**References:** Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT

**Angioinvasive Aspergillosis**

- Primarily affects severely immunocompromised patients.
- Hyphal invasion of blood vessels results in infarction and necrosis.
- CT halo sign - ground-glass halo because of surrounding hemorrhage (hemorrhagic infarcts), with a central nodule or mass of necrotic fungal infected lung tissue.
- Nonspecific patchy or lobar consolidation or multiple, ill-defined nodular opacities.
- The nodules or masses subsequently may develop cavitation or an air crescent sign.
**Echinococcus granulosus**

**Echinococcosis (Hydatid disease)**

- Hydatid cyst - well circumscribed, spherical or oval cyst (water attenuation, near 0HU) surrounded by normal lung.
- Most commonly single, but may be multiple in about 30% of patients.
- Most are located in the lower lobes.
- Smooth, thin wall that enhance after contrast material injection.
- If communication with the airways develops - meniscus or crescent sign.
- When rupture occurs, the endocysts membranes may float on residual fluid - air and water/mass level in the interior with the classic "water lily" sign.
- Most patients are asymptomatic.

**Fig.**: Bacterial and viral infections that can present with lung nodules.

**References**: Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
Nocardia

- Aerobic gram-positive bacilli. *N. asteroides* is the most common pathogen.
- In risk - immunocompromised patients.
- Homogeneous peripheral multilobar nonsegmental airspace consolidation.
- Multifocal peripheral nodules or masses with irregular margins also may be seen.
- Cavitation is common and occurs within areas of consolidation, nodules or masses.
- Localized areas of low attenuation with rim enhancement are suggestive of abscess formation.

Round Pneumonia

- Round focal infectious consolidation that simulates a mass.
- Occurs more frequently in children.
- Most commonly no organism is identified, although in adults may result from *Streptococcus pneumoniae* and *Haemophilus influenzae* infection.
- Patients usually have acute to subacute symptoms of community-acquired pneumonia and some may be asymptomatic.

Abscess

- Inflammatory mass within the lung parenchyma.
- Central region of lower attenuation - purulent liquefaction necrosis.
- Smooth or irregular thick wall (<15mm). Peripheral (rim) contrast enhancement.
- Causes: aspiration (more common) - anaerobic bacteria; complication of bacterial pneumonia - *Staphylococcus aureus*, *Pseudomonas aeruginosa*; septic embolism.
- Occurs more commonly in the posterior segment of an upper lobe or in the superior segment of a lower lobe.
- Often erode into an airway, resulting in drainage of necrotic material and formation of a cavity.
Fig.: Lung abscess - This CT image shows a smooth thick wall nodule with central cavitation eroding into a distal airway.

References: Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT

Septic embolism

- Occurs more often in immunocompromised patients with central venous lines and in intravenous drug users.
- Multiple nodules and wedge-shaped peripheral opacities, usually measuring 1 to 3 cm in diameter. They are frequently cavitated.
• The nodules tend to be most numerous in the periphery of the lung and lower lobes.
• Multiplanar and MIP reformatted images show the so called "feeding vessel" (vessel appearing to enter the nodule), usually representing the veins that drain the nodule. Arteries course around the nodule.
• Arterial occlusion may result in hemorrhage, infarction or both and wedge-shaped or less well-defined foci of disease.
• CT "halo" sign may be present - rim of ground-glass attenuation.

![Diagram of Inflammatory causes of lung nodules]

**Fig.**: Inflammatory causes of lung nodules.

**References:** Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT

**Wegener's granulomatosis**

- Necrotizing granulomatous inflammation of the upper and lower respiratory tracts, glomerulonephritis and necrotizing vasculitis of the lung - c-ANCA present.
• Multiple bilateral nodules or masses (from few millimeters to 10 cm) without preferential distribution that can increase in size and number.
• May occasionally present as a solitary nodule.
• In about 50% of cases, the radiographic manifestations consist of areas of airspace consolidation or ground-glass opacities, wedge-shaped and pleura based, with peribronchial or diffuse patchy distribution \(^{(1)}\).
• Cavitation occurs in approximately 50% of cases \(^{(1)}\) - irregular thick wall.

Fig.: Wegener's granulomatosis - Multiple bilateral areas of consolidation, some with a wedge-shaped pleura based morphology. In this figure, a mild cavitation in a small nodule can be seen.

References: Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
Fig.: Wegener's granulomatosis - Multiple bilateral areas of consolidation, some with a wedge-shaped pleura based morphology.

References: Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
**Fig.**: Wegener's granulomatosis - Multiple bilateral areas of consolidation, some with a wedge-shaped pleura based morphology.

**References**: Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT

**Organizing pneumonia**

- Intraluminal granulation tissue polyps within alveolar ducts, surrounding alveoli and respiratory bronchioles.
- Bilateral symmetric or asymmetric areas of consolidation with a patchy distribution, mainly at the middle and lower lung zones.
- A predominantly subpleural or peribronchial distribution is commonly present.
- The areas of consolidation may be migratory.
- Nodular opacities or ground-glass opacities associated with areas of consolidation are also seen.
• A perilobular pattern is also a characteristic feature - polygonal linear opacities marginating the secondary lobules (consolidation in the alveoli adjacent to the interlobular septa).
• Reversed halo sign may appear - crescentic, ring-shaped or polyhedral opacity surrounding an area of ground-glass opacification.

**Fig.**: Organizing pneumonia - CT images showing bilateral areas of consolidation with a patchy distribution, predominantly subpleural and mainly at the lower lung zones.  
**References:** Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
Fig.: Organizing pneumonia - Ground-glass and nodular opacities are also present.

References: Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
Fig.: Organizing pneumonia - CT images showing bilateral areas of consolidation with a patchy distribution, predominantly subpleural and mainly at the lower lung zones.

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**Churg-Strauss syndrome**

- Necrotizing vasculitis and extravascular granulomatous inflammation with parenchymal eosinophilic infiltration. ANCA-associated small vessel vasculitis (p-ANCA).
- Transient, bilateral, patchy ground-glass opacities or consolidation.
- Symmetric distribution with peripheral predominance (similar to chronic eosinophilic pneumonia) or less commonly a random distribution.
- Interlobular septal thickening - edema due to cardiac involvement or eosinophilic infiltration.
• Less common finding: small centrilobular nodules and multiple nodules or masses, with or without a halo of ground-glass attenuation.

Lipoid pneumonia

• **Chronic exogenous lipoid pneumonia** - uncommon disorder resulting from repetitive aspiration or inhalation of oil substances (present in food, medication or radiographic oral contrast) into the distal lung.
• Once in the alveolar spaces, the aspirated oil material elicits a foreign body reaction.
• Focal areas of fat density (negative values of -30 to -120 HU)\(^{(1)}\).
• Single or multiple bilateral nodules or masses can appear at the lower lobes, with irregular and poorly defined margins.
• May result in a crazy-paving pattern.
• In most cases, the patient remains asymptomatic.

Nodular parenchymal amyloidosis

• Abnormal protein (amyloid) deposition in the extracellular space may involve the trachea, the bronchi or more commonly the lung parenchyma.
• Solitary or less commonly multiple nodules or masses.
• Usually with a regular or lobulated margin.
• More frequently at the lower lobes with peripheral localization.
• Foci of calcification occur in up to 50% of cases\(^{(1)}\).
• Can also present cavitation, necrosis or hemorrhage.
• Usually asymptomatic and in the majority of cases without evidence of extrathoracic disease.
**Fig.**: Nodular parenchymal amyloidosis - Axial CT image revealing a nodule with regular margins, located near the hilum.

**References**: Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
Fig.: Nodular parenchymal amyloidosis - The soft-tissue window shows a small focus of calcification within the nodule.

References: Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT

Talcosis

• Talc exposure includes the inhalatory and intravenous routes.
**Intravenous talcosis** is seen almost exclusively in chronic intravenous drug users. Most patients are asymptomatic.

- In the early stages of disease, "pinpoint" nodules are usually distributed diffusely and uniformly throughout the lungs. Diffuse ground-glass opacities can appear.
- In more advanced disease, the upper lobe nodules may coalesce to form an opacity that frequently shows air bronchogram and is located close to the hilum. Associated volume loss occurs due to fibrosis.
- Demonstration of focal areas of high attenuation within the conglomerate mass is consistent with talc deposition, a feature highly suggestive of the diagnosis.

**Inhalatory talcosis** - the various types of talc can produce several distinctive radiographic appearances: nodular, linear and conglomerate fibrosis.

- Small centrilobular and subpleural nodules and conglomerated masses containing focal areas of high attenuation.
- Lymph node enlargement containing focal areas of high attenuation consistent with talc deposition is also seen.
- The nodular pattern resembles silicosis and the conglomeration of nodules may result in large opacities similar to silicotic conglomerations or coal progressive massive fibrosis.
- A diffuse linear interstitial pattern also may occur, resembling the findings in asbestosis.

**Progressive massive fibrosis**

- In long-term exposure to low concentrations of silica or coal dust, the lung changes often can progress and may result in PMF.
- Nodules conglomeration frequently occurs to form larger masses of PMF, usually at the upper lobes where nodular profusion is greatest.
- Lesions may cross the interlobar fissure.
- Associated adjacent emphysema is common.
- Cavitation can occur because of infection or ischemia, with extensive destruction of lung parenchyma.

**Rheumatoid Arthritis**
• Pulmonary rheumatoid nodules (necrobiotic nodules) can vary in size from 0.5 to 7 cm of diameter and are pathologically identical to subcutaneous rheumatoid nodules. This form of lung involvement is rare.
• Rheumatoid nodules contain a necrotic center.
• Although generally asymptomatic, they can cavitate and result in hemoptysis or pneumothorax.
• Organizing Pneumonia (BOOP) can coexist.
• Caplan’s syndrome - association of pulmonary nodules and pneumoconiosis in patients with RA, initially described in coal miners.

Sarcoidosis

• Interstitial non-caseous granulomas with a characteristic perilymphatic distribution, most prominent in the peribronchovascular, interlobular septal and pleural interstitial tissue.
• A nodular pattern is common, with small nodules presenting smooth or irregular margins and resulting from confluence of microscopic granulomas.
• Involves mainly the middle and upper lung zones.
• Confluence of granulomas may also result in large nodules or masses (15-25% of patients)\(^1\), which can cavitate and predominate in the upper lobes and peribronchovascular regions.

Inflammatory Pseudotumor

• Rare fibroinflammatory lesion. May affect individuals of any age, but have a predilection for children and young adults.
• Also known as plasma cell granuloma, inflammatory myofibroblastic tumor or fibrous histiocytoma. Consists of variable proportions of inflammatory cells, myofibroblastic spindle cells and plasma cells.
• Usually benign, but occasionally may be invasive and recur after surgical resection.
• The etiology is unknown, possibly a hypersensitivity reaction. Some seem to be secondary to infection (various bacteria and \textit{Mycoplasma}).
• Solitary, peripheral, sharply circumscribed, lobulated mass with smooth or spiculated margins and 1 to 6 cm in diameter. Usually closely associated with a bronchus. It's more common at the lower lobe and is a slow growing lesion.
• Show homogeneous or heterogeneous enhancement with intravenous contrast material and high uptake on PET.
Fig.: Vascular entities that can present with lung nodules.

References: Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT

Arteriovenous malformations

- The majority of pulmonary AVMs are associated to Rendu-Osler-Weber syndrome, where they are often multiple.
- In chest radiograph, an AVM presents as a nodular lesion. In some cases, a "comet-tail" appearance results from the presence of the feeding and draining vessels.
- More frequently found at the lower lobes due to the higher blood flow.
- CT allows identification of the malformation and its feeding and draining vessels. CT is even more sensitive than conventional angiography.
- Treatment is indicated in symptomatic patients and also in asymptomatic patients who have an AVM supplied by an afferent artery with a diameter greater than 3mm in order to prevent potential paradoxical embolism.
Pulmonary Sequestration

- Malformation in which a portion of the lung is detached from the remaining normal lung and receives its blood from a systemic artery (anomalous vessel).
- May be **intralobar** (mostly acquired secondary to chronic bronchial obstruction and chronic infection) or **extralobar** (always congenital):

**Intralobar** (80%) - Contiguous with normal parenchyma (should be suspected in young adults with nonresolving or recurrent lower lobe pneumonia).

**Extralobar** - Enclosed within its own pleural membrane (usually asymptomatic).

- Mostly at the basal posterior segment of the lower lobe (left > right).
- **Intralobar** - can present as a homogeneous opacity or a cystic mass.
- **Extralobar** - can present as a homogeneous opacity or well-circumscribed mass.
- The adjacent lung frequently has focal areas of emphysema and air trapping.
- In **extralobar** sequestration: systemic venous drainage.
- In **intralobar** sequestration: normal pulmonary venous drainage.

Pulmonary artery aneurysms

- Pulmonary artery aneurysms and pseudoaneurysms are uncommon.
- The differential diagnosis includes Behçet's disease (vasculitis), infection (mycotic pseudoaneurysm) and previous trauma (often iatrogenic).
- In Behçet's disease, complication of vasculitis and transmural necrosis results in aneurysm formation, which are in fact pseudoaneurysm.
- Aneurysms present as round perihilar opacities or as a rapidly developing unilateral hilar enlargement.
- Can be single or more commonly multiple and unilateral or bilateral.
- Aneurysms are seen as saccular or fusiform dilatations that show homogeneous filling by contrast material simultaneously with the pulmonary artery.
- Partial or total occlusive thrombosis can occur and infarction may result in localized areas of consolidation, oligemia or atelectasis.

Hematoma
• It results from a previous trauma.
• Pulmonary hematoma manifests as a soft tissue mass.
• Can be associated with areas of consolidation (pulmonary contusion) or traumatic pneumatoceles (laceracion).
• Pulmonary laceration resulting from trauma results in a traumatic lung cyst, which may be filled with air (pneumatocele), blood (hematoma) or both. If clot remains in the cavity, these cysts can be mistaken for pulmonary nodules.

Pulmonary Infarction

• Pulmonary consolidation in case of infarction is usually due to parenchymal hemorrhage and edema.
• Homogeneous wedge-shaped consolidation in the periphery of the lung.
• The consolidation presents a rounded, convex apex toward the hilum - Hampton's hump.
• Cavitation can occur, but is rare.
• Associated primary (endovascular) features of acute pulmonary embolism can be present.
Bronchial atresia with mucoid impactation

- Rare congenital anomaly characterized by short-segment obliteration of a lobar, segmental or subsegmental bronchus at or near its origin. The pathogenesis is unknown.
- Most commonly affects the apicoposterior segmental bronchus of the left upper lobe.
- The airways and airspaces distal to the obstruction develop normally, what results in:
  - Hyperinsuflation and "air trapping" of the involved segments (because of air entrance via collateral channels).
  - Muci accumulation immediately distal to the atresia: mucocele/bronchocele - pseudonodule (ovoid, round or branching).
• The radiographic findings are usually characteristic:
  • Area of pulmonary hyperlucency (combination of oligemia and increased volume). Expiratory examination shows air trapping.
  • Hilar nodule or mass (mucoid impaction).
  • Patients may be asymptomatic or have recurrent pneumonia.

Cystic adenomatoid malformation

• It's a congenital pulmonary airway malformation of unknown pathogenesis, characterized by a multicystic mass of lung tissue with an abnormal proliferation of bronchial structures. The vast majority of cases are diagnosed in the first 5 years of life.

• Type I - Contain large cysts (>2cm), usually multiloculated.
• Type II - Contain small cysts (<2cm), more uniform.
• Type III - Solid appearing lesions (with microscopic small cysts).

• CT findings in the adult typically consist of a large cyst, often multiloculated (type I), ranging from 4 to 12 cm. May contain fluid, air or both.
• More common at the lower lobes.
• Associated with recurrent infection and risk for the development of carcinoma. Surgery is generally indicated.

Bronchogenic cyst

• Result from abnormal separation of localized portions of the tracheobronchial tree between the 3rd and 24th weeks of gestation.
• Approximately 75% are located at the mediastinum and 25% in the lung more commonly at a lower lobe.
• Bronchogenic cysts are sharply circumscribed, thin walled, uniloculated and round or oval solitary lesions filled with mucoid or serous fluid (-10 to +10HU).
• They do not communicate with the tracheobronchial tree until secondarily to infection or instrumentation (then contain air, with or without fluid).
• May simulate a solid nodule (in about 50% of cases) - attenuation superior to fluid due to the presence of dense proteinaceous, hemorrhagic or calcium material.
• Do not show contrast enhancement unless if complicated of infection.
- The majority is asymptomatic, but in some cases there is compression of the trachea and bronchi, esophagus or a pulmonary vein.

**Hamtoma**

- It's the most common benign neoplasm, accounting for approximately 8% of primary lung tumors\(^{(1)}\). Probably derives from bronchial wall mesenchymal cells.
- Most hamartomas are solitary, well-circumscribed, smoothly marginated and slightly lobulated nodules located within the parenchyma, usually in a peripheral location. Endobronchial hamartomas are much less common.
- Approximately 60% of cases have focal areas of fat attenuation (-40 to -120 HU) - this is a diagnostic feature\(^{(1)}\).

**References:** Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT

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**Fig.:** Benign lung neoplasms presenting as a nodule or mass.

**Hamartoma**

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- Most hamartomas are solitary, well-circumscribed, smoothly marginated and slightly lobulated nodules located within the parenchyma, usually in a peripheral location. Endobronchial hamartomas are much less common.
- Approximately 60% of cases have focal areas of fat attenuation (-40 to -120 HU) - this is a diagnostic feature\(^{(1)}\).
• Calcifications may be present (approximately in 15% of tumors) with a "pop-corn" pattern - although very suggestive, this appearance is uncommon (1).
• Hamartomas are slow growing lesions.

**Fig.**: Hamartoma - CT scan showing a solitary peripheral nodule, well-circumscribed and slightly lobulated.

**References:** Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
Fig.: Hamartoma - In a soft-tissue window a partially calcified nodule can be seen.

References: Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
**Fig.**: Hamartoma - This CT image demonstrates an oval well-circumscribed lung mass, slightly lobulated.

**References:** Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT

**Sclerosing hemangioma**

- Rare benign primary lung tumor of epithelial origin, with sclerosis and vascular proliferation.
- Oval or spherical well-circumscribed nodule.
- More frequently at the lower lobes.
- Occasionally with calcifications.
- Rare cases with metastatic potential.
**Fig.**: Sclerosing hemangioma - Round shape well-circumscribed nodule at the lower right lobe.

**References:** Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
Fig.: Sclerosing hemangioma - The soft-tissue window allows depiction of a small calcification within the lesion.

References: Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT

Benign metastasizing leiomyoma

- Very rare entity.
- Occurs in female patients with a previous history of resected uterine leiomyomas that ranges from several years up to 20 years.
- Controversial - some pathologists argue that these lesions are actually metastatic low grade leiomyosarcoma.
- Radiographic features are nonspecific, with single or multiple well-circumscribed nodules throughout the lungs.
- Do not enhance after contrast material administration.
• A slow grow rate is characteristic.

Fig.: Other causes of lung nodules.

References: Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT

Rounded atelectasis

• Round or oval opacity that is peripheral and abuts an area of pleural thickening or effusion.
• Associated crowding and curving of pulmonary vessels and bronchi into the edge of the lesion:
  • "Comet tail" sign - bronchi and vessels with a curvilinear trail.

• More common in the lower lobes, associated with volume loss.
• Can show marked enhancement after contrast administration, because represents collapsed lung parenchyma.
In cases of irregular shape or area of opacity dimensionally out of proportion for the volume loss, suspicion should be raised.

**Fig.**: Round shaped consolidation with pleural contact revealing a rounded atelectasis.  
**References**: Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
**Fig.**: Round shaped consolidation with pleural contact revealing a rounded atelectasis - soft tissue window.

**References:** Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
Fig.: Rounded atelectasis - Delineation of bronchi and vessels with a curvilinear trail ("comet tail" sign)

References: Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT

Pleural

- Pleural thickening
- Pleural plaque
- Fluid in fissure (pseudotumor)
- Pleural tumor (eg, lipoma)

**Fig.**: Well-circumscribed nodule apparently located in the right lower lobe.

**References:** Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
**Fig.:** The soft-tissue window revealed a fat attenuation nodule.

**References:** Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
**Fig.**: The sagittal and coronal reconstructions allowed to accurately determine its location - pleural lipoma.

**References:** Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT

**Pseudotumor**

- Rib fracture

- Extra-thoracic (as a mimicking finding at chest radiography):
  - Nipple
  - Cutaneous lesion
Fig. 0: Benign causes of nodular lesions of the lung.

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Fig. 0: Infectious entities that can cause pulmonary nodules.

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Fig. 0: Granulomatous infections that can present with lung nodules.

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Fig. 0: Bacterial and viral infections that can present with lung nodules.

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Fig. 0: Aspergilloma - A solid mass within a cavity and the "air crescent" sign can be shown in this CT image.

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Fig. 0: Aspergilloma - Scans were made both in supine (previous image) and prone position (as shown in this image) and mass mobility within the cavity could be confirmed

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Fig. 0: Lung abscess - This CT image shows a smooth thick wall nodule with central cavitation eroding into a distal airway.

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Fig. 0: Inflammatory causes of lung nodules.

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**Fig. 0:** Wegener's granulomatosis - Multiple bilateral areas of consolidation, some with a wedge-shaped pleura based morphology. In this figure, a mild cavitation in a small nodule can be seen.

© Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
Fig. 0: Wegener's granulomatosis - Multiple bilateral areas of consolidation, some with a wedge-shaped pleura based morphology.

© Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
Fig. 0: Wegener's granulomatosis - Multiple bilateral areas of consolidation, some with a wedge-shaped pleura based morphology.

© Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
Fig. 0: Organizing pneumonia - CT images showing bilateral areas of consolidation with a patchy distribution, predominantly subpleural and mainly at the lower lung zones.

© Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
**Fig. 0:** Organizing pneumonia - Ground-glass and nodular opacities are also present.

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**Fig. 0:** Organizing pneumonia - CT images showing bilateral areas of consolidation with a patchy distribution, predominantly subpleural and mainly at the lower lung zones.

© Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
**Fig. 0: Nodular parenchymal amyloidosis -** Axial CT image revealing a nodule with regular margins, located near the hilum.

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Fig. 0: Nodular parenchymal amyloidosis - The soft-tissue window shows a small focus of calcification within the nodule.

© Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
Fig. 0: Vascular entities that can present with lung nodules.
Fig. 0: Congenital anomalies that can present with lung nodules.

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Fig. 0: Benign lung neoplasms presenting as a nodule or mass.

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Fig. 0: Hamartoma - CT scan showing a solitary peripheral nodule, well-circumscribed and slightly lobulated.

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Fig. 0: Hamartoma - In a soft-tissue window a partially calcified nodule can be seen.
Fig. 0: Hamartoma - This CT image demonstrates an oval well-circumscribed lung mass, slightly lobulated.

© Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
**Fig. 0:** Sclerosing hemangioma - Round shape well-circumscribed nodule at the lower right lobe.

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Fig. 0: Sclerosing hemangioma - The soft-tissue window allows depiction of a small calcification within the lesion.

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Fig. 0: Other causes of lung nodules.

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Fig. 0: Round shaped consolidation with pleural contact revealing a rounded atelectasis.

© Radiology, Hospital de São José, Centro Hospitalar de Lisboa central, Hospital de São José, Centro Hospitalar de Lisboa Central - Lisbon/PT
Fig. 0: Round shaped consolidation with pleural contact revealing a rounded atelectasis - soft tissue window.

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**Fig. 0:** The soft-tissue window revealed a fat attenuation nodule.

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Fig. 0: The sagittal and coronal reconstructions allowed to accurately determine it location - pleural lipoma.

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Conclusion

Within the appropriate clinical setting, imaging characterization of nodular lung lesions may be an important tool in the diagnosis of some diseases and may have significant implications in the management of these patients.
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