Imaging of Pulmonary Nodules

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Imaging of Pulmonary Nodules: Objectives

• Review imaging modalities and their use
• Describe imaging features that either decrease or increase the likelihood of malignancy
• Present a framework for integration of imaging and clinical information to assist in the management of pulmonary nodules on an individual patient basis
Imaging of Pulmonary Nodules: Overview

• Background: From Nodules to Lung Cancer
• Review of Imaging Modalities: Tools of the Trade
• Review of Imaging Features: “To benign or not to benign, that is the question.”
• Likelihood of Malignancy: “... damned lies, and statistics”
• Recommendations: Putting it together
Background: From Nodules to Lung Cancer
Background: Pulmonary Nodules

• “A round opacity, at least moderately well marginated, and no greater than 3 cm in maximum diameter”

• “Round” meaning roughly circular or oval shaped but also “spherical” in its 3-dimensional nature (not flat or plaque-like)

• Completely surrounded by lung parenchyma and not associated with adenopathy, atelectasis, or pneumonia
Background: Pulmonary Nodules

• May be solitary (SPN) or multiple, which affects likelihood of various differential diagnostic considerations
• When multiple, imaging features of each nodule identified must be considered, in addition to consideration as a whole
• Our discussion primarily relates to solitary (or clearly dominant) pulmonary nodules, but is also useful in the setting of multiple nodules
Background: Pulmonary Nodules

- Very common imaging finding, particularly since advent of helical and multidetector CT
- Studies report prevalence of one or more nodules from 8% to 69% on CT
- Vast majority (95%-98% in most studies) are benign
Background: Lung Cancer

• Our discussion of pulmonary nodules ultimately falls within the context of lung cancer, which directly influences our management decisions regarding nodules

• A few points are worth noting for our discussion ...
Background: Lung Cancer

• It is, overall, an aggressive disease:
  – “More people in the United States die from lung cancer than from any other type of cancer. This is true for both men and women.”
Background: Lung Cancer

• It is a heterogeneous disease:
  – Non-small cell lung cancer (NSCLC)
    • 80%-85% of lung cancer
    • Can be detected at earlier stages with CT—possible role for screening with CT
    • NSCLC is our primary focus when discussing imaging of pulmonary nodules
  – SCLC
    • Detection of limited-stage disease unlikely due to its aggressive nature
    • Not the focus of our discussion of nodules
Background: Lung Cancer

• There are known risk factors:
  – Smoking:
    • Accounts for 90% of lung cancers in the U. S.
    • 15x to 30x more likely to develop or die from lung cancer than nonsmokers
    • Risk increases with degree and duration (pack years)
    • Currently estimated 94 million current or former smokers in the U. S. at increased risk
Background: Lung Cancer

• Other known risk factors include:
  – Second hand smoke
  – Asbestos, radon, or uranium exposure
  – Radiation therapy to the thorax, such as with lymphoma or breast cancer
  – Family history of lung cancer in 1st degree relative
  – Age: risk increases with age; rare under age 35
  – Chronic lung diseases
  – Personal history of prior lung cancer
Background: Lung Cancer

• It is a costly disease:
  – Estimated impact on U. S. economy is over $300 billion annually
  – As much as possible, management decisions should include consideration of cost effectiveness that is based on proven clinical outcomes research
Review of Imaging Modalities: Tools of the Trade
Review of Imaging Modalities:

- Chest radiograph (CXR)
-Computed Tomography (CT)
-Positron Emission Tomography (PET)
-PET-CT (no, it’s not the same thing)
-(Flouroscopy, MRI, US)
Review of Imaging Modalities: Chest Radiograph

- Low cost
- Low radiation exposure
- Low utility as primary imaging modality of pulmonary nodules
- No utility for lung cancer screening
Review of Imaging Modalities: Chest Radiograph

- However, CXR is a common entry point into the evaluation of pulmonary nodules when detected incidentally.
- Prevalence of nodules on CXR is about 0.2% to 9% depending on population.
Review of Imaging Modalities: Computed Tomography

- Tomographs (slices) eliminate the problem of superimposed structures on radiographs
- Volumetric data acquisition on modern scanners allows slice reconstruction in any plane
- Highly sensitive for detection of pulmonary nodules as small as 1-2 mm
- Unfortunately limited specificity
- Can be performed with or without IV contrast enhancement
Review of Imaging Modalities: Computed Tomography

• High spatial and contrast resolution allow determination of important morphologic features of nodules

• Thin-sections (1-3 mm slice thickness) should be utilized for evaluation of nodule morphology (IV contrast unnecessary)
Review of Imaging Modalities: Computed Tomography

- IV contrast-enhanced densitometry can be performed to assess nodule enhancement characteristics
- More accurate determination of important ancillary findings: adenopathy, bronchial involvement, pleural involvement, etc.
- Low-dose (radiation) imaging may be used for any needed follow-up exams (or screening)
Review of Imaging Modalities: Positron Emission Tomography

- IV administration of 18F-fluorodeoxyglucose (FDG)
- Degree of tissue uptake reflects its relative metabolic activity (glucose)
- Many malignancies demonstrate significantly greater uptake of FDG compared with normal tissues and appear “hot” on PET images
- >90% sensitivity for nodules 1-3 cm; lower specificity of about 80%
Review of Imaging Modalities: PET-CT

• It’s like Reese’s Peanut Butter Cups
• It’s a PET scan with an anatomic contrast agent
• It’s a CT scan with a metabolic contrast agent
• Either way, combines benefits of both modalities with higher sensitivity and specificity than for either PET or CT alone
Review of Imaging Modalities: Other

- Fluoroscopy:
  - Biopsy guidance
  - Can be used as an inexpensive problem solving tool

- MRI has little role in imaging of pulmonary nodules but has utility in the evaluation of thoracic malignancies

- Ultrasound has little role in imaging of pulmonary nodules although may occasionally be used for biopsy localization
Review of Imaging Features:
“To benign or not to benign, that is the question.”
Review of Imaging Features:
“To benign or not to benign ...”

• There are a few imaging features that allow for a confidant benign diagnosis
• None are reliably diagnostic of malignancy
Review of Imaging Features: Goals of Imaging

• Idealistic:
  – Early and definitive identification of all malignant nodules, and thereby improve patient outcomes
  – Definitively identify all benign nodules, and thereby avoid the morbidity and cost of invasive procedures or further imaging that provide no true benefit

• Disappointingly, this remains elusive despite extensive experience and research
Review of Imaging Features: Goals of Imaging

- Realistic:
  - Determine which nodules are benign and need no further evaluation
  - Determine which are suspicious for malignancy and refer for definitive resolution
  - For nodules that remain indeterminate:
    - Determine which require biopsy
    - Determine which require follow-up
Review of Imaging Features: Benign

- Benign pattern of calcification
- Stability of size
- Presence of fat
- (Need to keep in mind the definition of a pulmonary nodule)
Review of Imaging Features: Benign

- Benign patterns of calcification in a smoothly marginated nodule (or smoothly lobulated if hamartoma):
  - Diffuse (granuloma)
  - Central (granuloma)
  - Laminated or concentric (granuloma)
  - Popcorn (hamartoma)
Review of Imaging Features: Benign

- **Any** other pattern of calcification is indeterminate
- “Caveat”: patients with history of bone malignancy may have calcified nodules that resemble benign granulomas
Review of Imaging Features: Benign

• Stability of size:
  – Comparison with older exams is essential in evaluation of pulmonary nodules (retrospect?)
  – Measurement accuracy is critical: For “spherical” structures, a diameter increase of only 26% is a doubling of volume: Equates to a mere 1 mm diameter increase for a 4mm nodule!
Review of Imaging Features: Benign

- Stability of size:
  - Especially for smaller nodules, visual comparison has been shown inaccurate, and physical measurement should be performed
  - Measurement is most accurate on soft-copy images with electronic calipers
  - Automated volumetric analysis software has promise to allow for more precise determination of nodule growth
Review of Imaging Features:
Benign

• Stability of size:
  – Any enlargement compared with baseline measurement considered suspicious and should prompt further evaluation
  – Caution: cancers may occasionally demonstrate temporary decrease of overall size—a single follow-up study demonstrating decrease of size may not be adequate to confirm a benign etiology
Review of Imaging Features:

Benign

• Stability of size:
  – 2 years of stability widely accepted as consistent with benign etiology based on studies of volume doubling-time of benign versus malignant lesions:
    • 30-480 days typical of malignant nodules with median about 160-180 days
    • However, reported range is actually quite broad
  – Caveat: subsolid (ground-glass opacity) nodules that are malignant are more likely to have significantly longer doubling time and should undergo longer surveillance (3+ years)
Review of Imaging Features: Benign

- CT 2004
- CT 2012
Review of Imaging Features: Benign

• Presence of fat:
  – Within a smooth or smoothly lobulated SPN essentially diagnostic of hamartoma
  – Present in approximately 60%

• Caution: be certain the lesion contains fat as artifact from volume averaging may mimic

• “Caveat”: metastases from liposarcoma and renal cell carcinoma may occasionally contain fat
Review of Imaging Features: Benign
Review of Imaging Features: Probably Benign

- Other probably benign imaging findings:
  - FDG PET standardized uptake value (SUV) <2.5
  - Clustered nodules
  - Very small size (<4 mm <<1%)
  - Concave margins

- Follow-up CT imaging
Review of Imaging Features: Mimics

- Some benign pulmonary imaging findings may mimic a nodule (experience...or cojones):
  - Arteriovenous malformation—feeding and draining vessels
  - Mucocele—tubular branching mucus filled dilated bronchi
  - Rounded atelectasis—comet tail appearance and associated with pleural thickening
  - Flat lesions—scarring that may be appreciated with multiplanar imaging
Review of Imaging Features: Mimics

- Rounded atelectasis
- Flat lesion/scar
Review of Imaging Features: Mimics

- Mucocele
- Mucocele
Review of Imaging Features: Suspicious for Malignancy

• Larger size: as size approaches 3 cm, likelihood of malignancy approaches 90%
• Spiculated margin: approximately 90% predictive value for cancer
• Lobulated margin more suspicious than smooth
Review of Imaging Features: Suspicious for Malignancy

- Subsolid attenuation with ground-glass opacity (GGO) in part or entirety:
  - 34%-43% of GGO nodules malignant
  - 40%-50% of mixed GGO/solid nodules <1.5 cm cancer and likelihood increases with size

- Cavitation with thick walls:
  - 84%-95% cancer if wall thickness >16 mm
  - 95% benign when wall thickness <4 mm
Review of Imaging Features: Suspicious for Malignancy

- Air containing: air bronchograms, air bronchiolograms, and air filled cystic spaces occur more commonly in malignant than benign nodules

- Upper lobe location: 70% of cancers in upper lobes; also 1.5x more likely in right lung
Review of Imaging Features: Suspicious for Malignancy

• These findings prompt further evaluation...
Review of Imaging Features: Further Imaging Evaluation

• FDG PET-CT
  – Usable for nodules >8-10 mm diameter
  – Caveat: Because volume averaging from motion can artificially decrease apparent FDG activity, PET may be less useful for nodules located near diaphragm or heart, especially if small
Review of Imaging Features: Further Imaging Evaluation

• FDG PET-CT
  – Test result determined by degree of activity in nodule relative to other body structures:
    • Subjective visual evaluation
    • Quantitative evaluation (SUV 2.5)
  – Much more reliable for solid than GGO nodules:
    • >90% sensitivity for cancer in solid nodules (with exception of carcinoid tumor—probably 50%)
    • Probably <50% sensitive for purely GGO cancers such as adenocarcinoma in situ (formerly BAC)
Review of Imaging Features: Further Imaging Evaluation

- Solid nodule
- GGO nodule
Review of Imaging Features: Further Imaging Evaluation

• FDG PET-CT
  – Excellent test when used appropriately but probably a tendency for overutilization
  – Questions to consider:
    • Is it uncertain whether to simply watch and wait or to proceed with biopsy/resection? If yes then...
    • Will the PET result determine whether or not to proceed with biopsy/resection? If yes then...
    • Proceed with PET imaging
Review of Imaging Features: Further Imaging Evaluation

- FDG PET-CT
  - Most useful and cost effective when:
    - Low to moderate (5%-60%) pre-test probability of malignancy
    - Clinical risk assessment and nodule morphologic characteristics are discordant
    - Indeterminate nodule in a high risk patient
Review of Imaging Features: Further Imaging Evaluation

• FDG PET-CT
  – May be useful in other situations but can be an unnecessary and added expense—be judicious:
    • If very low likelihood of malignancy (<5%), PET is not needed to justify observation (watch and wait) with follow-up CTs
    • If high likelihood of malignancy (>60%), PET is not needed to justify biopsy/resection
Review of Imaging Features: Further Imaging Evaluation

• FDG PET-CT
  – All PET negative nodules should be observed with follow-up CTs to confirm stability for at least 2 years: If grow then biopsy
Review of Imaging Features: Further Imaging Evaluation

• Contrast Enhanced CT Densitometry:
  – Usable for nodules at least 10 mm diameter without cavitation or central necrosis
  – Compare baseline unenhanced attenuation with peak contrast-enhanced attenuation
  – <15 Hounsfield units (HU) enhancement is essentially diagnostic of benign etiology (99%)
  – >15 HU is nonspecific
  – “Ask your doctor if this test is right for you...”
Likelihood of Malignancy:
“...damned lies, and statistics”
Likelihood of Malignancy

• Determining the statistical probability of malignancy for a given nodule is essential to proper management, including decisions regarding use of imaging studies:
  – Qualitatively by an experienced clinician—there is probably a tendency to overestimate the probability of malignancy in low risk patients
  – Quantitatively using mathematical model
Likelihood of Malignancy: Logistic Regression Model

- Mayo clinic study using multiple logistic regression analysis identified 6 independent predictors:
  - 3 clinical: Age, smoking, and history of prior extrathoracic cancer more than 5 years earlier
  - 3 Imaging related: Nodule diameter, spiculated margin, and upper lobe location
Likelihood of Malignancy: Logistic Regression Model

- Probability of Malignancy = $\frac{e^x}{1+e^x}$
  - Where $x = -6.872 + (0.0391 \times \text{Years of age})$
    + $(0.1274 \times \text{Diameter in mm})$
    + 0.7917 if smoker
    + 1.3388 if prior extra-thoracic cancer $>5$ yrs ago
    + 1.0407 if spiculated margin
    + 0.7838 if upper lobe
Likelihood of Malignancy: Logistic Regression Model

• 40 year old, nonsmoker, no prior malignancy, with a 5 mm smoothly marginated nodule in a lower lobe: Probability of malignancy = 0.9%
• 65 year old, smoker, no prior malignancy, with a 15 mm spiculated nodule in an upper lobe: Probability of malignancy = 55%
• 70 year old, smoker, no prior malignancy, with a 25 mm spiculated nodule in an upper lobe: Probability of malignancy = 87%
Likelihood of Malignancy: Bayesian Analysis

- Uses validated likelihood ratios for various independent clinical and imaging variables to estimate the probability of malignancy
- Based on Bayes Theorem:
  \[ \text{New odds} = \text{Prior odds} \times \text{Likelihood Ratio} \]
- Likelihood ratios >1 increase the probability of malignancy while ratios <1 lower it
Likelihood of Malignancy: Bayesian Analysis

- Clinical variables increasing probability:
  - Age >50 years
  - Smoking history ≥30 pack years
  - Hemoptysis
  - History of prior malignancy
Likelihood of Malignancy: Bayesian Analysis

• Imaging variables increasing probability:
  – Diameter >2.0 cm
  – Upper or middle lobe location
  – Spiculated margin
  – Thick walled cavitation
  – Absence of calcification
  – FDG PET SUV >2.5
  – CT densitometry enhancement >15 HU
Likelihood of Malignancy: “SPN Calculator”

• An easily accessible and useable “SPN Calculator” with both the Bayesian analysis and logistic regression models can be found on the web at: www.chestx-ray.com

• Extremely cool so check it out
Probability of Malignancy in SPN: Bayesian Analysis

Calculate Doubling Time: Have two films with a growing nodule? This is the place to calculate the rate of exponential growth.

A common radiographic problem is the evaluation of the patient with a solitary pulmonary nodule (SPN). Ninety percent of SPNs are due to 6 causes: lung cancer, granuloma, solitary metastases, hamartoma, and chronic tumors. Because the frequency of malignancy is high, accurate evaluation is important. Both clinical and radiographic factors are important in this determination. It can be difficult to subjectively combine all of the radiographic and clinical findings in a given patient and arrive at a diagnosis. Often, important factors such as smoking history, are either ignored or overemphasized. The main objective of Bayesian analysis is to use all of the clinical and radiographic characteristics to derive a quantitative estimate of the probability that a SPN is malignant.

The following form can be used to derive the probability of malignancy and is based on data provided in the first reference.

The prior odds of malignancy can be subjectively estimated or based on the prevalence of malignancy in your patient population with solitary pulmonary nodules. The latter will vary by geographic location (due to histoplasmosis) or vary by referral pattern (tertiary care hospitals vs. clinics).

<table>
<thead>
<tr>
<th>Clinical Characteristics</th>
<th>Prior Probability of Malignancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>50-59</td>
</tr>
<tr>
<td>Smoking (PKyrs)</td>
<td>Not Known</td>
</tr>
<tr>
<td>Hemoptysis</td>
<td>Absent</td>
</tr>
<tr>
<td>Hi Prev Malign</td>
<td>Absent</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Radiographic Characteristics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (cm)</td>
<td>2.1-3.0</td>
</tr>
<tr>
<td>Location</td>
<td>Upper/Middle</td>
</tr>
<tr>
<td>Edge</td>
<td>Smooth</td>
</tr>
<tr>
<td>Growth Rate</td>
<td>Not Known</td>
</tr>
<tr>
<td>Cavity/ Wall Thickness</td>
<td>Not cavitiated</td>
</tr>
<tr>
<td>Calcification</td>
<td>None</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Additional Characteristics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Contrast Enhancement</td>
<td>Not Performed</td>
</tr>
<tr>
<td>PET</td>
<td>Not Performed</td>
</tr>
</tbody>
</table>

Calculate Probability of Malignancy

The Probability of malignancy is: [probability value]
Recommendations: Putting It Together
Recommendations:

• Clinical management of an imaging finding
• Distill the clinical and imaging variables and formulate a plan of action that is broadly applicable and adheres to the standard of care
Recommendations:

• First things first:
  – Comparison with old imaging studies cannot be overemphasized! (Turn on the retrospectoscope)
    • May obviate need for any further expensive and potentially harmful evaluation. Team effort of clinician, radiologist, and patient.
    • In general, clearly growing nodules should move to tissue diagnosis if not contraindicated
  – If suspected infectious etiology, further diagnostic intervention, therapy, and short-term follow-up imaging may be best initial management
Recommendations:

• Three management categories:
  – Management of small solid nodules ≤8-10 mm
  – Management of subsolid nodules
  – Management of larger solid nodules >8-10 mm
Small Solid Nodules ≤8-10 mm
Recommendations: Small Solid Nodules ≤8-10 mm

• 2005 Fleischner Society guidelines for management of small nodules have been widely adopted

• Apply to:
  – Incidentally detected solid nodules on CT
  – Patients 35 years of age and older

• Do not apply to:
  – Patient with known or suspected malignancy
  – Patient with unexplained fever
Recommendations:
Small Solid Nodules ≤8-10 mm

Recommendations for Follow-up and Management of Nodules Smaller than 8 mm Detected Incidentally at Nonscreening CT

<table>
<thead>
<tr>
<th>Nodule Size (mm)*</th>
<th>Low-Risk Patient†</th>
<th>High-Risk Patient‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤4</td>
<td>No follow-up needed§</td>
<td>Follow-up CT at 12 mo; if unchanged, no further follow-up‖</td>
</tr>
<tr>
<td>&gt;4–6</td>
<td>Follow-up CT at 12 mo; if unchanged, no further follow-up‖</td>
<td>Initial follow-up CT at 6–12 mo then at 18–24 mo if no change‖</td>
</tr>
<tr>
<td>&gt;6–8</td>
<td>Initial follow-up CT at 6–12 mo then at 18–24 mo if no change</td>
<td>Initial follow-up CT at 3–6 mo then at 9–12 and 24 mo if no change</td>
</tr>
<tr>
<td>&gt;8</td>
<td>Follow-up CT at around 3, 9, and 24 mo, dynamic contrast-enhanced CT, PET, and/or biopsy</td>
<td>Same as for low-risk patient</td>
</tr>
</tbody>
</table>

Note.—Newly detected indeterminate nodule in persons 55 years of age or older.

* Average of length and width.
† Minimal or absent history of smoking and of other known risk factors.
‡ History of smoking or of other known risk factors.
§ The risk of malignancy in this category (<1%) is substantially less than that in a baseline CT scan of an asymptomatic smoker.
‖ Nonsolid (ground-glass) or partly solid nodules may require longer follow-up to exclude indolent adenocarcinoma.

Recommendations: Small Solid Nodules ≤8-10 mm

• A few key rationales for Fleischner Society Guidelines (FSG):
  – Follow-up intervals for low and high risk categories differ because malignant nodules generally grow faster in smokers
  – Even in smokers, <1% of nodules <4 mm will become lethal cancers, but this increases to 10-20% for nodules about 8 mm
Recommendations:
Small Solid Nodules ≤8-10 mm

• A few points regarding FSG:
  – Are for managing nodules ≤8 mm and not meant to define management of larger nodules—FSG clearly indicate flexibility in this category
  – 2005 FSG do not distinguish between single and multiple nodules although “primarily focused on solitary solid nodules”
  – Size is average of length and width
  – Different management of subsolid nodules
Recommendations:
Small Solid Nodules ≤8-10 mm

• Other patient groups:
  – Patients <35 years old:
    • In general, follow-up CT imaging should be avoided
    • Consider a 6-12 month follow-up CT if have known malignancy
  – Patients with known or suspected malignancy fall outside of the 2005 FSG (not part of the “high risk” group) and should be managed according to the specific clinical situation or protocol
Recommendations:
Small Solid Nodules ≤8-10 mm

• Additional considerations:
  – For nodules detected incidentally on a CT exam that did not include the entire thorax and future imaging follow-up is planned, consider first obtaining a dedicated CT thorax to assess for other nodules (no consensus)
  – Consider limited coverage on follow-up CTs to reduce radiation exposure
Subsolid Nodules
Recommendations: Subsolid Nodules

- Complementary report to Fleischner Society Guidelines regarding management of subsolid nodules published January 2013
- Apply to purely GG nodules and part-solid GG nodules and management differs for each
- Necessarily more varied due to the greater complexity of these lesions
Recommendations: Subsolid Nodules

• Unlike 2005 FSG for small solid nodules:
  – Management **does not** differentiate smokers and non-smokers
  – Management differs for solitary versus multiple nodules
  – Known or suspected extra-thoracic malignancy does not preclude application
  – No age distinction
Recommendations: Subsolid Nodules

Recommendations for the Management of Subsolid Pulmonary Nodules Detected at CT: A Statement from the Fleischner Society

<table>
<thead>
<tr>
<th>Nodule Type</th>
<th>Management Recommendations</th>
<th>Additional Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solitary pure GGNs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤5 mm</td>
<td>No CT follow-up required</td>
<td>Obtain contiguous 1-mm-thick sections to confirm that nodule is truly a pure GGN</td>
</tr>
<tr>
<td>&gt;5 mm</td>
<td>Initial follow-up CT at 3 months to confirm persistence then annual surveillance CT for a minimum of 3 years</td>
<td>FDG PET is of limited value, potentially misleading, and therefore not recommended</td>
</tr>
<tr>
<td>Solitary part-solid nodules</td>
<td>Initial follow-up CT at 3 months to confirm persistence. If persistent and solid component ≤5 mm, then yearly surveillance CT for a minimum of 3 years. If persistent and solid component &gt;5 mm, then biopsy or surgical resection</td>
<td>Consider PET/CT for part-solid nodules &gt;10 mm</td>
</tr>
<tr>
<td>Multiple subsolid nodules</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pure GGNs ≤5 mm</td>
<td>Obtain follow-up CT at 2 and 4 years</td>
<td>Consider alternate causes for multiple GGNs ≤5 mm</td>
</tr>
<tr>
<td>Pure GGNs &gt;5 mm without a dominant lesion(s)</td>
<td>Initial follow-up CT at 3 months to confirm persistence and then annual surveillance CT for a minimum of 3 years</td>
<td>FDG PET is of limited value, potentially misleading, and therefore not recommended</td>
</tr>
<tr>
<td>Dominant nodule(s) with part-solid or solid component</td>
<td>Initial follow-up CT at 3 months to confirm persistence. If persistent, biopsy or surgical resection is recommended, especially for lesions with &gt;5 mm solid component</td>
<td>Consider lung-sparing surgery for patients with dominant lesion(s) suspicious for lung cancer</td>
</tr>
</tbody>
</table>

Note.—These guidelines assume meticulous evaluation, optimally with contiguous thin sections (1 mm) reconstructed with narrow and/or mediastinal windows to evaluate the solid component and wide and/or lung windows to evaluate the nonsolid component of nodules, if indicated. When electronic calipers are used, bidimensional measurements of both the solid and ground-glass components of lesions should be obtained as necessary. The use of a consistent low-dose technique is recommended, especially in cases for which prolonged follow-up is recommended, particularly in younger patients. With serial scans, always compare with the original baseline study to detect subtle indolent growth.
Recommendations: Subsolid Nodules

• A few key rationales for 2013 FSG:
  – Adenocarcinomas (often subsolid) occur more frequently in younger and nonsmoking individuals
  – Presence of multiple subsolid nodules is frequently encountered
  – Purely GGO nodules are rarely metastatic cancer
  – Subsolid nodules may resolve at short term follow-up
  – Accurate nonsurgical diagnosis is problematic
Recommendations: Subsolid Nodules

- A few key rationales for 2013 FSG:
  - Evidence that delay in surgical resection of slow-growing pure GGNs does not alter outcome
  - Part-solid nodules that persist are considered malignant until proved otherwise
  - Larger solid components increase likelihood of malignancy and invasive disease (5 mm “threshold”)
  - Multiple subsolid nodules that are neoplastic are more likely synchronous primary lesions
Recommendations: Subsolid Nodules

• A few points regarding 2013 FSG:
  – Work in progress, many controversial variables
  – Meticulous evaluation, best with 1 mm slices
  – Consistent CT and measurement technique between studies
  – Size is average of long and short axis dimensions
    • GGO measured on lung window
    • Solid parts measured on mediastinal window
  – Throughout follow-up, sizes should always be compared with the baseline CT
Larger Solid Nodules >8-10 mm
Recommendations:
Larger Solid Nodules >8-10 mm

• Key **imaging** step is morphologic characterization with thin-section (≤3 mm) CT:
  – Clearly benign features?
  – If not, detailed accounting of morphology

• Key **clinical** step is determining probability of malignancy:
  – Accounting of relevant clinical history
  – Estimate or calculate the probability
Recommendations: Larger Solid Nodules >8-10 mm

- More diagnostic options become feasible with larger nodules:
  - Advanced imaging with FDG PET or contrast enhanced CT densitometry
  - Percutaneous needle biopsy or bronchoscopy
- Many management algorithms in the literature—most are very similar
- Best integrate clinical and imaging variables
A management algorithm for patients with SPNs >8 mm and <30 mm in diameter.

Recommendations:
Larger Solid Nodules >8-10 mm

• “Ask your doctor if this test is right for you…”
• Details of application depend on available local resources, expertise, and the wishes of the fully informed patient
Thank you for your attention

brtrotter@sw.org
Resources

- cdc.gov
- Chestx-ray.com
- Winer-Muram HT. The solitary pulmonary nodule. Radiology 2006; 239: 34-49
Once upon a time...

An example of the intersection of imaging and clinical management
Once upon a time...

- 67 year old former smoker who reports a past history of pneumonia and secondary basilar scarring
- CXR 11/2005
Once upon a time...

- CT 11/2005: LLL 2.4 x 1.4 cm irregular nodule “worrisome for neoplasm”
- Moderate to high risk of malignancy
- Bronchoscopy done: no malignant cells
Once upon a time...

• PET 12/2005: No hypermetabolic activity—decreases likelihood of malignancy but not excluded, and short term follow-up CT imaging recommended

• CT bx planned but cancelled after noting possible decreased size
Once upon a time...

- Follow-up CT 2/2006: 2.1 x 1.6 cm “stable to slightly decreased size”
- Life goes on...
Once upon a time...

- Nodule is intermittently seen on abdominal CTs 2007-2008 obtained for other reasons, with fluctuating size measurements:
  - 1.8 cm (follow-up recommended)
  - 1.3 x 2.2 cm ("smaller from 2005")
  - 1.9 x 2.4 cm (fluctuating size, ? atelectasis, chronic infection, or malignancy)
Once upon a time...

- CT 2005
- CT 2008
Once upon a time...

- CT 1/2011: 2.7 x 2.9 cm “malignancy diagnosis of exclusion”
- CT bx 2/2011: path not definitive but “papillary architecture suggests neoplasm and low-grade adenocarcinoma not excluded; surgical excision may be needed for definitive dx
Once upon a time...

- 3/2011 Whole Body PET-CT:
  “hypermetabolic and highly suspicious of malignancy”
- No PET evidence of local or distant metastatic disease
Once upon a time...

- Mediastinoscopy and VATS 4/2011
- Partial lobectomy path: 5.0 x 2.5 x 2.5 cm “adenocarcinoma mucinous, partially papillary”
- Mediastinal lymph nodes path: Negative
- T2 N0 M0, Stage IB NSCLC
Once upon a time...

- Surveillance CT 4/2012: 1.0 cm nodule at postoperative site
- PET-CT 4/2012: No hypermetabolism, but small size and basilar location with respiratory motion may reduce reliability of PET evaluation for the nodule
- CT bx 5/2012: Negative
- Follow-up CT 8/2012: Stable postoperative changes without evidence of recurrence