ACR Lung-RADS v2022: Assessment Categories and Management Recommendations

CME

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Abstract

The ACR created the Lung CT Screening Reporting and Data System (Lung-RADS) in 2014 to standardize the reporting and management of screen-detected pulmonary nodules. Lung-RADS was updated to version 1.1 in 2019 and revised size thresholds for nonsolid nodules, added classification criteria for perifissural nodules, and allowed for short-interval follow-up of rapidly enlarging nodules that may

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be infectious in etiology. Lung-RADS v2022, released in November 2022, provides several updates including guidance on the classification and management of atypical pulmonary cysts, juxtapleural nodules, airway-centered nodules, and potentially infectious findings. This new release also provides clarification for determining nodule growth and introduces stepped management for nodules that are stable or decreasing in size. This article summarizes the current evidence and expert consensus supporting Lung-RADS v2022.

Key Words: CT, cyst, lung cancer, screening, pulmonary nodule

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INTRODUCTION

Lung cancer is the most common cause of cancer-related death in the United States and worldwide. The National Lung Screening Trial (NLST) demonstrated a 20% reduction in lung-cancer-related mortality with the use of low-dose lung cancer screening (LCS) CT in high-risk patients [1,2]. More recent data from the randomized controlled Dutch-Belgian Randomized Lung Cancer Screening Trial (NELSON) and Multicentric Italian Lung Detection trial reaffirm the utility of LCS CT, reporting lung-cancer-specific mortality reductions of up to 26% and 39%, respectively [3,4]. In conjunction with the CMS approval for coverage of LCS CT in eligible patients, the ACR released the Lung CT Screening Reporting and Data System (Lung-RADS) v1.0 in 2014 to standardize LCS CT reporting, provide consistent management guidance, and facilitate outcomes monitoring [5].

Specific aspects of Lung-RADS have been validated in numerous studies with the primary benefits of survival associated with a shift to earlier-stage lung cancer detection (stage shift) and reducing false-positive screens and unnecessary follow-up [6-14]. There has been widespread adoption of Lung-RADS for LCS CT reporting throughout the United States as the only CMS-approved reporting and classification system for LCS. Lung-RADS has also been implemented in other countries or used as a foundation for international reporting systems [15,16].

Lung-RADS was updated to v1.1 in 2019 adding classification criteria for perifissural nodules, new size criteria for nonsolid nodules, and revised measurement criteria, among other updates [17,18]. The newest version, Lung-RADS v2022, was released in November 2022, coinciding with National Lung Cancer Awareness month [19]. This release was prepared by the ACR Lung-RADS Committee, composed of 15 content experts from the fields of diagnostic radiology, thoracic surgery, and pulmonary medicine representing a range of clinical practice settings. The updates were informed by new science, questions raised by practicing radiologists, and insights from committee members. Each topic underwent a systematic review of the literature, resulting in evidence-based updates when supported, including new assessment criteria for atypical pulmonary cysts and juxtapleural nodules, as well as revised assessment criteria for airway nodules and potentially infectious or inflammatory findings at LCS. For topics of clinical importance lacking sufficient data, expert consensus was obtained through nominal group methodology to establish best practice guidance for commonly encountered clinical scenarios in LCS CT practice. This article, authored by the ACR Lung-RADS Committee, details the updates along with the evidence and rationale for changes introduced in Lung-RADS v2022 (Table 1).

NEW CLASSIFICATION CRITERIA

Atypical Pulmonary Cysts

The incidence of lung cancers associated with atypical pulmonary cysts is overall low, with the largest study indicating a rate of 1.1% for new lung cancer diagnoses [20]. However, the incidence of cystic lung cancers in high-risk populations is much higher. In evaluating International Early Lung Cancer Action Program data, Farooqi et al found that of 706 patients with lung cancers, 3.6% were associated with cysts at either baseline or follow-up LCS [21]. A study of 441 patients diagnosed with primary lung cancer found that 9.3% were associated with cystic components at initial CT imaging [22]. Furthermore, cancers associated with cysts are more likely to be missed at initial screening than those presenting as isolated nodules. In a NELSON analysis, 22% of missed cancers at initial screening were associated with cystic spaces [23].

Precursor lesions of cystic lung cancers are often represented by unilocular thick-walled cysts, cysts with associated nodularity, or multilocular cysts [22]. A meta-analysis of eight studies evaluating lung cancers associated with cystic airspaces in 341 patients found that the most common cystic imaging features were nonuniform shape (91.2%), associated nodular component (64.0%), unilocular cyst (63.6%), wall thickening (37.4%), and irregular margins (37.3%) [24]. Over time, imaging demonstrated nodule growth (68.5%), an increase in wall thickening (48.3%), enlargement of the cystic component (40.4%), or transformation to a completely solid nodule (12.4%). When associated with lung cancer, unilocular cysts typically present with additional features, such as wall thickening or nodularity [24-26]. Multilocular cysts have a

Table 1. Summary of updates in Lung-RADS v2022*

Classification criteria	Description
Atypical pulmonary cysts	New classification and management recommendations for thick-walled, multilocular cysts, and cysts with associated nodules
Juxtapleural nodules	Updated classification and management recommendations for juxtapleural nodules (perifissural, costal pleural, perimediastinal, and peridiaphragmatic)
Inflammatory or infectious findings	Updated classification and management recommendations for findings that may represent an infectious or inflammatory process: segmental or lobar consolidation, multiple new nodules (more than six in number), large solid nodules (≥8 mm) appearing in a short interval, or new nodules in certain clinical contexts (eg, immunocompromised patient)
Airway nodules	Updated classification and management recommendations for airway nodules based on location, morphology, number, and persistence
Clarifications	**Description**
Growth	Updated definition: An increase >1.5-mm in mean diameter within a 12-month interval
Slow growing	New definitions for slow-growing solid, part-solid, and ground glass nodules with associated management recommendations
S modifier	New guidance for when to use and discontinue use of the S modifier for potentially significant or significant findings
Management considerations	**Description**
Stepped management	New stepped management approach for Lung-RADS categories 3 and 4A nodules that are stable or decreasing in size at follow-up
Interval diagnostic CTs	New guidance on managing interval diagnostic CTs obtained in LCS patients, including when a diagnostic CT may substitute for a LCS examination and whether the timing of subsequent LCS imaging should be modified based on an interval diagnostic chest CT

LDCT = low-dose CT; Lung-RADS = Lung CT Screening Reporting and Data System.
*Refer to the complete Lung-RADS v2022 Assessment Category table and notes: https://www.acr.org/-/media/ACR/Files/RADS/Lung-RADS/Lung-RADS-2022.pdf.

high probability of malignancy and are reported to account for up to 20% of cystic lung cancers [25]. Given these findings, Lung-RADS v2022 introduces classification and management recommendations for atypical pulmonary cysts detected at LCS (Table 2). Key principles are as follows:

1. Thin-walled cysts, defined as unilocular cysts with wall thickness < 2 mm, are considered benign and are not classified or managed in Lung-RADS [27]. Multiple pulmonary cysts may indicate a diffuse cystic lung disease; however, these conditions are not classified in Lung-RADS unless a cyst with concerning features is identified (Fig. 1).
2. Thick-walled cysts are unilocular with a wall thickness 2 mm or larger, which may be uniform, asymmetric, or manifest as focal wall nodularity (Fig. 2).
3. Multilocular cysts contain internal septations and may have associated ground glass or solid components (Fig. 3).
4. Thick-walled and multilocular cysts are classified as Lung-RADS 4A with recommended management of 3-month low-dose CT (LDCT) or PET/CT if there is a solid component of at least 8 mm.
5. Growing wall thickness or nodularity of a thick-walled cyst, increasing loculation of a multilocular cyst, or new or increasing opacity (nodular, ground glass, or consolidation) within or adjacent to a multilocular cyst merits a 4B classification with a recommendation for appropriate diagnostic evaluation (Fig. 3).
6. Atypical pulmonary cysts with an associated nodule that is within the cyst lumen (endophytic) or adjacent to the wall (exophytic) are classified and managed by the most suspicious finding. It can be difficult to distinguish between a cyst with nodular wall thickening (eg, a thick-walled cyst, Lung-RADS 4A) and a thin-walled cyst with an adjacent nodule (managed by nodule size and composition). When in doubt, choose the higher Lung-RADS classification (Fig. 4).

Table 2. Atypical pulmonary cysts in Lung-RADS v2022

Lung-RADS	Description	Management
3	Growing cystic component (mean diameter) of a thick-walled cyst	6-month LDCT
4A	Thick-walled cyst OR Multilocular cyst at baseline OR Thin- or thick-walled cyst that becomes multilocular	3-month LDCT; PET/CT may be considered if there is a ≥8 mm (≥268 mm^3) solid nodule or solid component
4B	Thick-walled cyst with growing wall thickness/nodularity OR Growing multilocular cyst (mean diameter) OR Multilocular cyst with increased loculation or new or increased opacity (nodular, ground glass, or consolidation)	Diagnostic chest CT with or without contrast; PET/CT may be considered if there is a ≥8 mm (≥268 mm^3) solid nodule or solid component; tissue sampling; and/or referral for further clinical evaluation

LDCT = low-dose CT; Lung-RADS = Lung CT Screening Reporting and Data System.

The precise risk of malignancy for atypical pulmonary cysts is not well defined. The ACR Lung-RADS Committee therefore chose to remove the Risk of Malignancy column from the Lung-RADS table. Risk assessment is typically lesion specific and, with the exception of category 4B lesions, is not routinely used in Lung-RADS management recommendations.

Juxtapleural Nodules

Lung-RADS v1.1 introduced new classification and management recommendations for screen-detected perifissural nodules meeting the following size and morphologic criteria: solid; triangular, ovoid, or lentiform in shape; and measuring < 10 mm in maximum diameter. Such nodules are considered benign and likely to represent intrapulmonary lymph nodes with several studies indicating a 0% incidence of malignancy [28,29]. New studies indicate that up to 32% of solid nodules 6 to 10 mm in mean diameter are juxtapleural (perifissural, costal pleural, perimediastinal, or peridiaphragmatic) and that no juxtapleural nodules were malignant when applying similar size and morphologic criteria as those used for perifissural nodules [30-32]. Of note, some of the analyses used a 10-mm mean diameter (average of long- and short-axis diameters) rather than a single maximum diameter threshold; Lung-RADS v2022 criteria have been updated accordingly. Available data indicate that expanding perifissural classification and management recommendations to all juxtapleural nodules, regardless of location, reduces false-positive rates and increases Lung-RADS specificity without a decrease in sensitivity (Fig. 5).

Inflammatory or Infectious Findings

Classification and management of potentially infectious or inflammatory findings were not addressed in Lung-RADS v1.0. Lung-RADS v1.1 introduced a new management recommendation of 1-month LDCT for "new large nodules that develop on an annual repeat screening CT" to address potentially infectious or inflammatory conditions. Precise size and composition guidance were not specified, but the management recommendation was provided under category 4B, suggesting that nodules meeting classification criteria for new 4B nodules may apply. Lung-RADS v2022 provides new guidance on findings that are likely to be inflammatory or infectious, how to classify them, and what constitutes appropriate management (Fig. 6).

The precise incidence of inflammatory or infectious pulmonary pathology at LCS is unknown; however, one series of 3,800 patients found that 8.1% of LCS examinations had findings attributable to inflammatory or infectious etiologies and that most resolved at follow-up imaging with a <1% incidence of malignancy [33]. This same series found that inflammatory or infectious findings were predominantly multifocal (78.5%) and comprised of ground glass (46.8%), clustered opacities (20.2%), tree-in-bud nodules (16.9%), or consolidation (12.4%). In addition, segmental or lobar consolidation, multiple new nodules (more than six), large solid nodules (≥8 mm) appearing in a short interval, and new nodules in certain clinical contexts (eg, immunocompromised patient) are likely to be infectious or inflammatory [34-36]. Because the appearance of potentially infectious or inflammatory pulmonary conditions is heterogeneous, the data do not dictate a single classification and management recommendation. Lung-RADS v2022 provides the following guidance:

1. Findings at LCS suggesting an indeterminate infectious or inflammatory process, as previously noted, or findings that obscure portions of the lungs, such as segmental or lobar consolidation, should be classified as Lung-RADS 0 with a recommendation for 1- to 3-month follow-up LDCT to allow time for resolution and to exclude an underlying suspicious nodule. At follow-up, the study

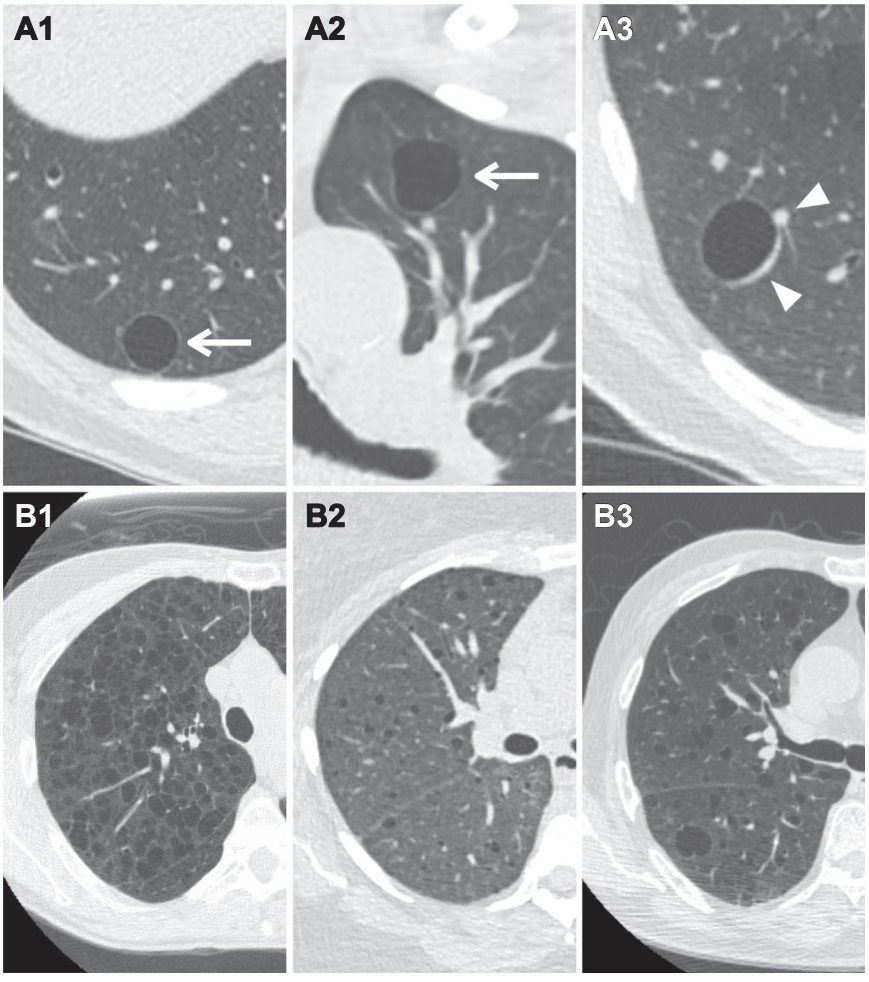

Fig. 1. Thin-walled cysts. (A) Examples of simple thin-walled cysts in three patients (A1, A2, A3). Simple cysts are unilocular with a wall thickness < 2 mm (arrows) and are not classified or managed in Lung CT Screening Reporting and Data System (Lung-RADS). Care should be taken to avoid mistaking vessels (arrowheads) with nodules or wall thickening. (B) Three patients with cystic lung disease: lymphangioleiomyomatosis (B1), Langerhans cell histiocytosis (B2), and lymphocytic interstitial pneumonia (B3). Multicystic lung disease is not classified or managed in Lung-RADS unless a cyst is identified with atypical features (eg, multilocular, thick-wall, associated nodularity).

should be reclassified based on the most concerning finding.

2. Findings at LCS in which malignancy seems more likely than an infectious or inflammatory process should be classified based on size and composition. Such findings are often new solid or part-solid nodules that meet Lung-RADS 4B size criteria with recommended management of diagnostic or clinical evaluation.
3. Some findings at LCS indicative of an infectious process may not warrant short-term follow-up (eg, tree-in-bud nodules or new <3-cm ground glass nodules). These nodules may be evaluated using existing size and composition criteria with a Lung-RADS classification and management recommendation based on the most suspicious finding, often corresponding to Lung-RADS 2 with a recommendation for 12-month LDCT.

Airway Nodules

Although rare, patients eligible for LCS have risk factors for developing primary airway squamous cell carcinoma. Scrutiny of the airways at LCS is an important component of a comprehensive imaging evaluation. Data characterizing airway findings at LCS are limited. In the largest study to date, Kim et al evaluated 50,036 patients undergoing LCS CT and found that only 0.6% had airway nodules [37]. The majority of endobronchial opacities resolved at repeat imaging (96.2%); of those that did not resolve, bronchoscopic evaluation found that all represented benign pathology with no cases of malignancy identified. A smaller study found airway nodules in 0.5% of LCS examinations, and 97.8% of these were benign [38]. Although the incidence of airway malignancies at screening is very low, an analysis

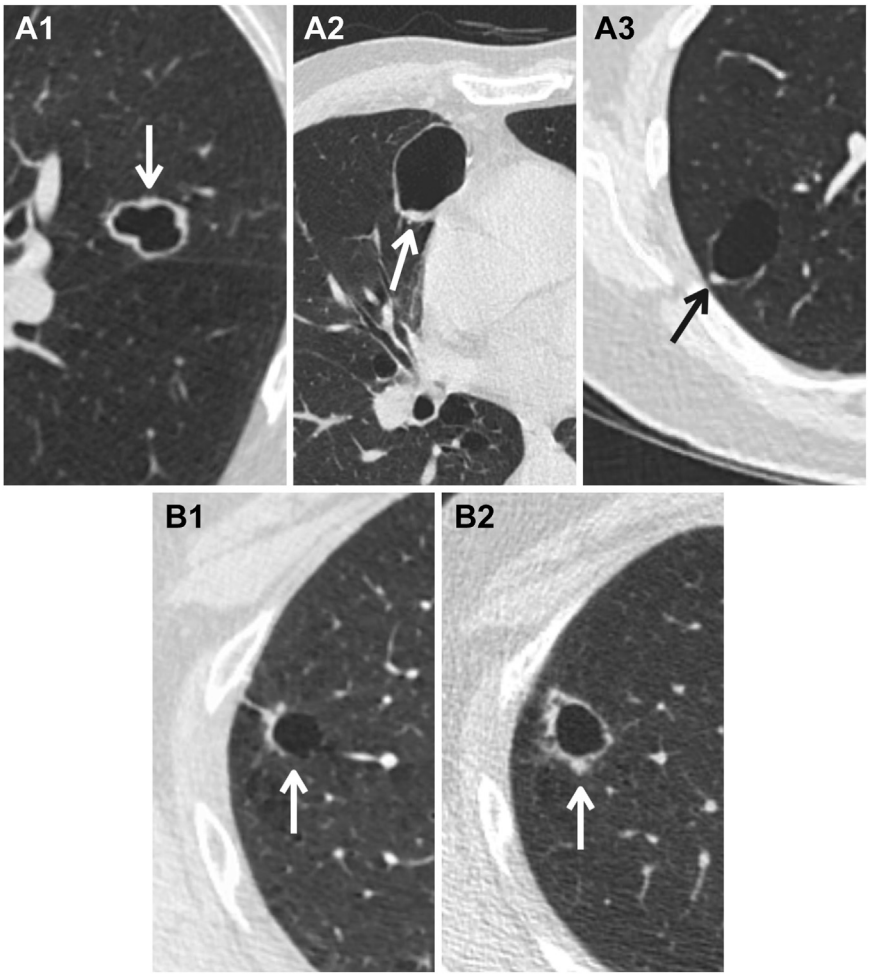

Fig. 2. Atypical pulmonary cysts: thick walled. (A) Pulmonary cysts with wall thickness ≥ 2 mm are "thick-walled" (arrows) and are classified and managed in Lung CT Screening Reporting and Data System (Lung-RADS) v2022. Wall thickness may be circumferential (A1), asymmetric (A2), or focal (A3). Thick-walled cysts are classified as Lung-RADS 4A. (B) A 62-year-old patient at baseline screening CT with a thick-walled cyst (arrow, B1)—Lung-RADS 4A. The nodule was stable at 3-month follow-up and returned to annual screening per Lung-RADS v1.1 management. At annual screening, the atypical pulmonary cyst had increased in size with increased wall thickness and new nodularity (arrow, B2). The patient underwent surgical resection with a confirmed diagnosis of adenocarcinoma. In Lung-RADS v2022, thick-walled cysts with growing wall thickness or nodularity are classified as Lung-RADS category 4B.

of the NELSON data found that 22% of cancers missed at initial screening presented as central endobronchial lesions, indicating that attention to airway findings is clinically important [23].

Lung-RADS v1.0 and v1.1 categorized the presence of an endobronchial nodule as category 4A with a 3-month follow-up LDCT recommended; however, no additional management guidance was provided for persistent nodules at the time of follow-up imaging. In some instances, persistent nodules were being downgraded to Lung-RADS 2 as recommended for "Category 3 or 4 nodules unchanged for ≥ 3 months"—management intended for pulmonary nodules rather than airway nodules. Lung-RADS v2022 provides additional guidance on the classification and management of airway findings at LCS, taking into consideration location, morphology, number, and persistence at follow-up imaging (Table 3).

1. *Location:* Large airways are defined as segmental or more proximal in nature and have diameters > 3 mm [39]. Such airway nodules may be classified as Lung-RADS 4A with a management recommendation of 3-month LDCT follow-up to assess for resolution versus persistence. Evaluation of the small airways (subsegmental and more distal) is limited at LCS but can manifest as post-obstructive atelectasis or other secondary imaging findings not readily assessed on screening CT, such as air

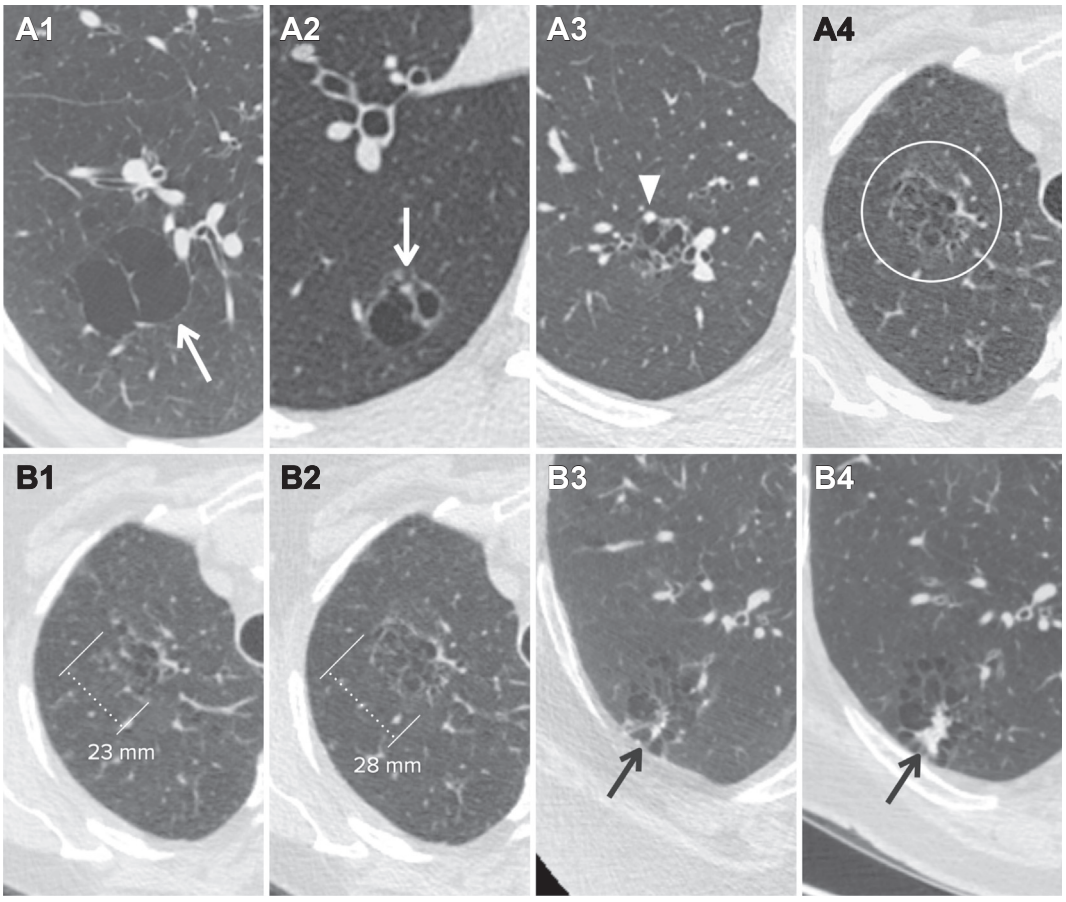

Fig. 3. Atypical pulmonary cysts: multilocular. (A) Multilocular cysts are heterogeneous in appearance, contain internal septations (A1, A2, A3, A4), and may have solid or ground glass components such as thick walls (A2, arrow), nodules (A3, arrowhead), or internal opacities (circle). Multilocular cysts are classified as Lung CT Screening Reporting and Data System (Lung-RADS) category 4A at baseline. (B) A 68-year-old patient with a 23-mm mean diameter multilocular cyst at baseline (B1), which grew to 28 mm at 12-month CT screening (B2). A 56-year-old patient with a multilocular cyst containing a solid component at baseline (B3, arrow) that grew on follow-up screening (B4, arrow). Multilocular cysts that grow (>1.5-mm increase in mean diameter), have increased loculation, or have new or increased opacities are very suspicious for malignancy and are classified as Lung-RADS 4B.

trapping. Subsegmental airway nodules often represent mucous plugging or are associated with infectious or inflammatory conditions and can be classified as Lung-RADS 2 with a management recommendation of 12-month screening LDCT (Fig. 7).

2. *Morphology:* Although differentiating between airway neoplasms and secretions at initial imaging can be challenging, shape and density are important morphologic features that can be considered before assigning a Lung-RADS category. CT findings that favor secretions include complex or tubular shape, the absence of soft tissue, the presence of air, or Hounsfield unit < 21.7 and may be classified as Lung-RADS 2 with a recommendation for 12-month screening LDCT [40]. Other CT features are indeterminate and may be classified as Lung-RADS 4A with a recommendation for 3-month LDCT follow-up to ensure resolution (Fig. 7).
3. *Number:* Most malignant airway nodules are solitary [41]. Multiple airway opacities, such as new tree-in-bud nodules or multifocal mucoid impaction, favor a non-neoplastic process, may not necessarily warrant a Lung-RADS 4A classification, and could be managed as a potentially infectious or inflammatory process as previously outlined (Fig. 7).
4. *Persistence:* Most benign central airway findings resolve at short-term follow-up; therefore, segmental or more proximal airway nodules that persist at 3-month LDCT follow-up are potentially concerning and should not be downgraded to a lower Lung-RADS category as is recommended for other stable 4A findings. Persistent segmental or more proximal airway nodules require

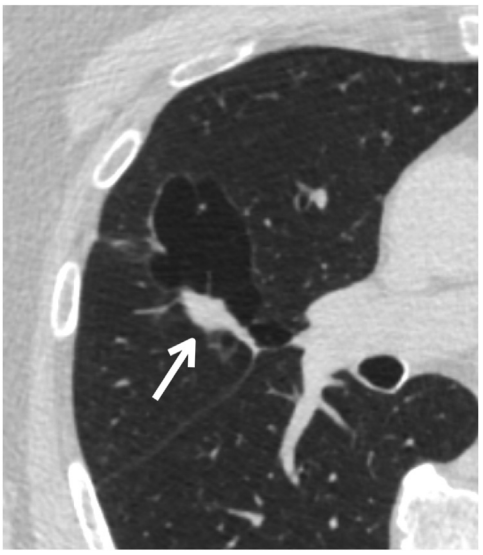

Fig. 4. Cysts with associated nodules. A 71-year-old with an atypical pulmonary cyst multilocular containing a 17-mm mean diameter solid component (arrow). Nodules can arise within the wall (thick walled), lumen (endophytic), or external (exophytic) to pulmonary cysts. Classification and management are determined by the most concerning feature. In this example, multilocular cysts are classified as Lung CT Screening Reporting and Data System 4A; however, the presence of a solid nodule ≥ 15 mm in mean diameter warrants a 4B classification.

additional evaluation and are upgraded to category 4B for diagnostic assessment by PET/CT (if a solid component ≥ 8 mm) or referral for clinical evaluation and bronchoscopy (Fig. 7).

Of note, the National Comprehensive Cancer Network management guidelines for airway nodules found at LCS recommend a 1-month follow-up CT instead of a 3-month follow-up CT as recommended by Lung-RADS v2022 [42]. Both recommend subsequent bronchoscopy for persistent nodules. Given the low incidence of malignancy in airway lesions found at LCS and the relative minimal difference in timing, there is currently insufficient data to indicate which management recommendation may be preferable.

CLARIFICATIONS

Volumetrics

The efficacy of volumetric analysis of pulmonary nodules in LCS was validated by the NELSON trial, which used volumes to quantify size and growth for risk stratification and management [4,43]. However, the NELSON study was highly controlled, with all examinations performed on the same scanner make and model and centralized volumetric analysis performed with the same software—all factors that do not accurately reflect clinical practice. Additional studies have identified the potential benefits of nodule volumetrics in LCS, including automation, reproducibility, and increased sensitivity [30,44,45]. Lung-RADS v1.1 introduced nodule volume measurements corresponding to mean diameters for each category but did not include a volume threshold defining growth. Despite the potential benefits, there are currently no data to suggest that the use of volumetrics leads to improved patient outcomes over mean diameter measurement methodologies. In fact, in the only study to date comparing the performance of Lung-RADS versus the NELSON classification and management criteria, Lung-RADS mean diameter assessment outperformed volumetrics at lung cancer detection [46]. Lung-RADS will appropriately evolve as new data regarding the utility and impact of volumetrics become available.

Growth

Nodule growth in both Lung-RADS v1.0 and 1.1 was defined as an increase in size > 1.5 mm but did not specify whether this was in any dimension, total diameter, or mean diameter, and Lung-RADS v1.0 and 1.1 did not specify a time interval (eg, growth rate) [17]. In practice, growth rate is an important consideration; for example, an increase in size of 2.0 mm over 6 months is potentially more concerning than over 2 years. Likewise, slow-growing nodules that increase in size < 1.5 mm each year may be missed by prior Lung-RADS criteria. However, using a fixed dimension and time interval for assessing growth is not without limitations. For example, an increase of >1.5 mm can represent a more significant increase in size and volume in a small nodule than for similar growth in a large nodule; notwithstanding, growing small nodules are often still typically below the size threshold for biopsy or PET/CT characterization and may be safely managed by current Lung-RADS criteria. For larger nodules, the updated growth definition captures nodules that fall within concerning volume doubling times with 3- and 6-month follow-up intervals. Volumetric analysis may more accurately detect subtle changes in nodule size than mean diameter measurements, leading to earlier intervention or diagnosis, but whether such findings lead to improved patient outcomes remain in question.

The ACR Lung-RADS Committee reviewed several methods and thresholds for assessing nodule growth but ultimately decided to maintain the >1.5-mm marker while specifying a growth interval within 12 months. When modeled for nodules of varying size, this definition approximates other methodologies for quantifying

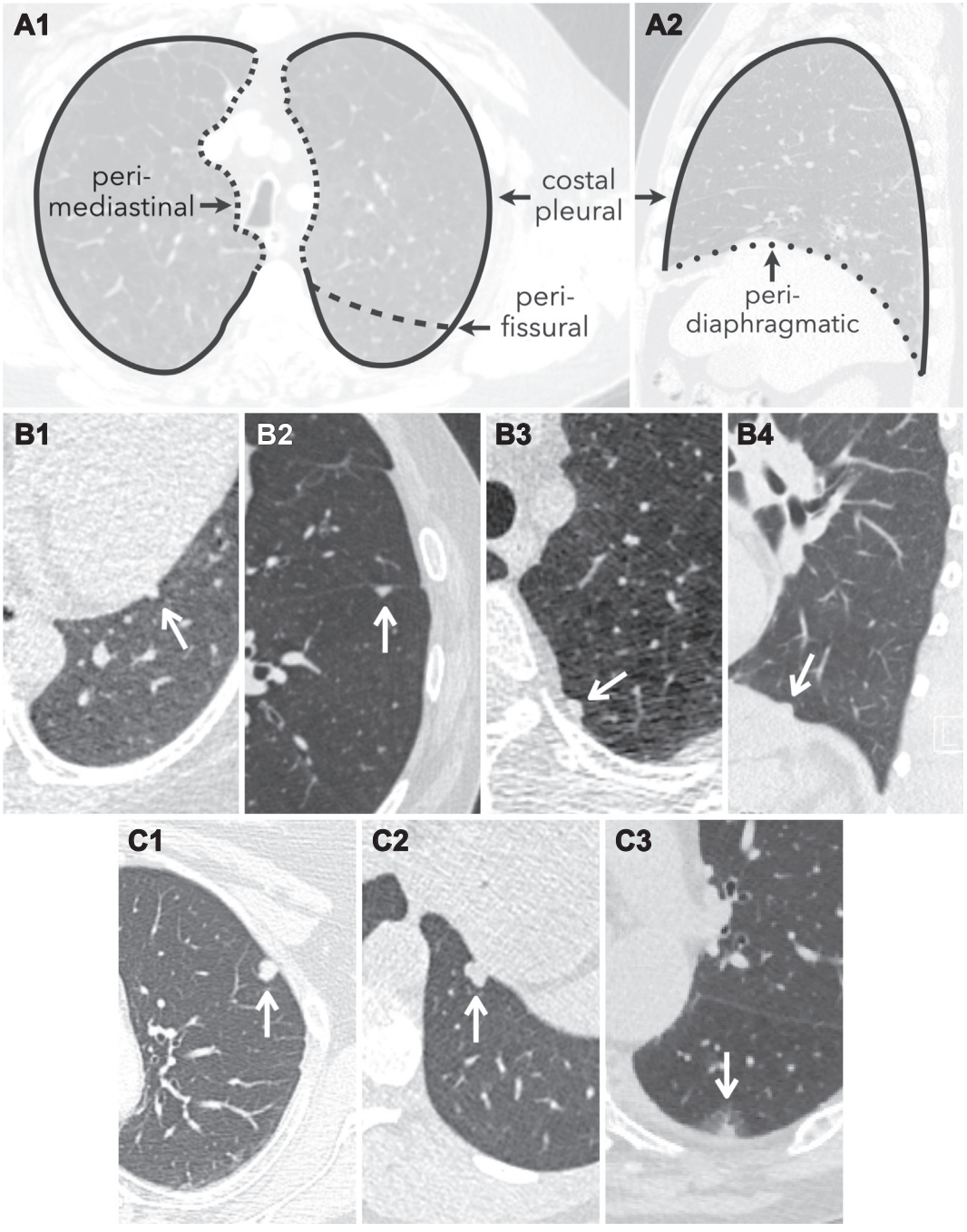

Fig. 5. Juxtapleural nodules. (A) Illustration of juxtapleural nodule distribution (perimediastinal, perifissural, costal pleural, and peridiaphragmatic) in axial (A1) and sagittal (A2) planes. (B) Juxtapleural nodules < 10 mm in mean diameter that are solid with smooth margins and oval, lentiform, or triangular shape (arrows) are considered benign and can be classified as Lung CT Screening Reporting and Data System (Lung-RADS) 2. Examples of benign juxtapleural nodules: perimediastinal (B1), perifissural (B2), costal pleural (B3), and peridiaphragmatic (B4). (C) Juxtapleural nodules that do not meet Lung-RADS 2 criteria (arrows) are classified based on size and composition: 9-mm solid round costal pleural nodule, Lung-RADS 4A (C1); 11-mm solid lobular peridiaphragmatic nodule, Lung-RADS 4A (C2); 15-mm part-solid costal pleural nodule with 6 mm solid component, Lung-RADS 4A (C3).

growth, including those from the International Early Lung Cancer Action Program and the NELSON trial [47-49]. In addition, Lung-RADS v2022 provides additional clarity for clinical application, particularly for slow-growing nodules. The following guidance is provided:

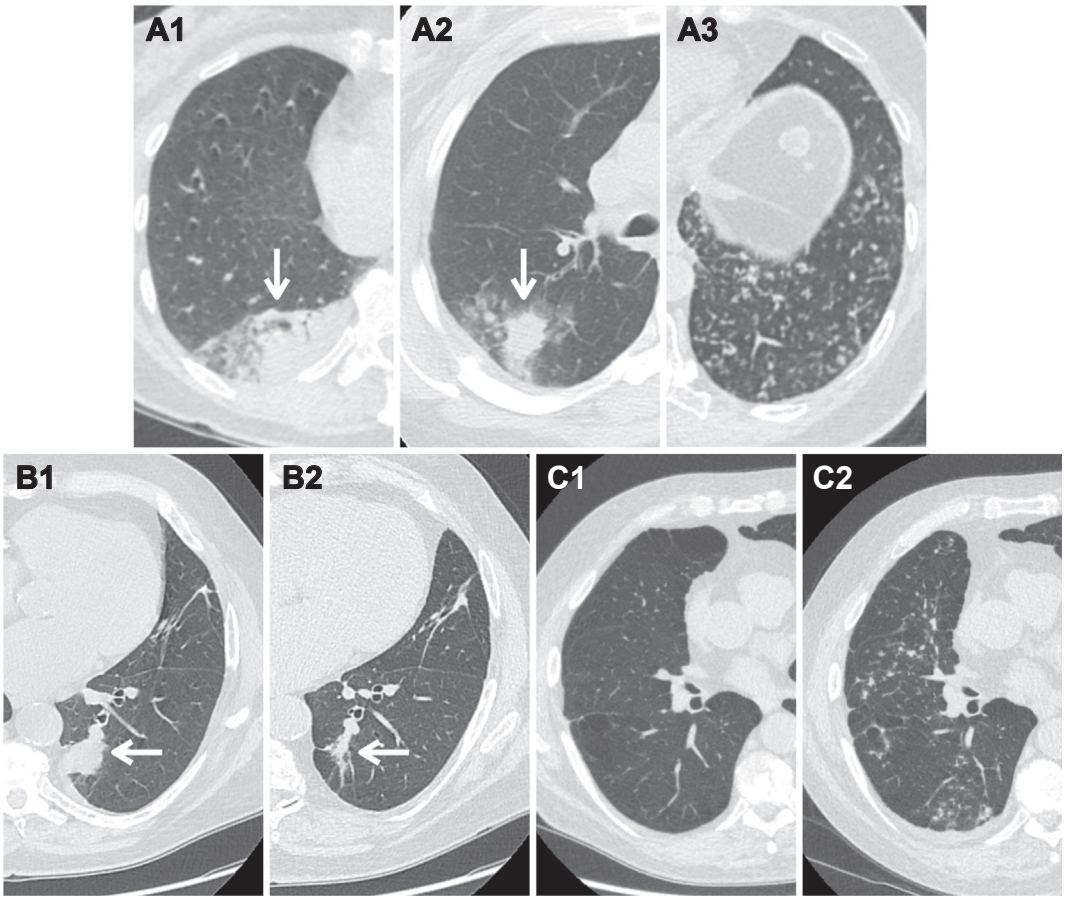

Fig. 6. Infectious or inflammatory findings. (A) Findings at lung cancer screening (LCS) that suggest an infectious or inflammatory process include new segmental or lobar consolidation (A1, arrow), large new nodules (≥8 mm) appearing within a short interval (A2, arrow), or multiple new nodules (A3). Such findings may be classified as Lung CT Screening Reporting and Data System (Lung-RADS) 0 based on clinical suspicion of an infectious or inflammatory process with a recommendation for follow-up low-dose CT (LDCT) in 1 to 3 months to ensure resolution. The study is then reclassified at follow-up according to the most concerning finding. (B) A 55-year-old patient had a baseline LCS CT classified as Lung-RADS 3 (not shown) and presents for 6-month follow-up LDCT. There is a new lobular 28-mm mean diameter soft tissue nodule in the left lower lobe (B1, arrow). Given the size and lack of an abnormality in this area on the prior examination, the study was classified as Lung-RADS 0 for a likely infectious process. The patient returned for follow-up LDCT at 3 months, which showed a marked decrease in size but not complete resolution (B2, arrow). No new findings were identified, and other nodules were stable. The examination was reclassified as Lung-RADS 2 with a management recommendation of a 12-month LCS CT from the date of the current study. Had the nodule remained stable, increased, or only slightly decreased in size, an infectious or inflammatory process would be less likely; the examination would be reclassified as Lung-RADS 4B based on size and composition with a recommendation for diagnostic evaluation. (C) A 61-year-old patient presenting for annual LCS CT is found to have multiple new tree-in-bud nodules bilaterally with a basilar predominance (C2) relative to the prior annual LCS examination (C1). Although an infectious process is most likely, a Lung-RADS 0 classification with 1- to 3-month follow-up LDCT is unnecessary. In this case, the examination may be classified based on the size and composition of the new nodules (solid, < 4 mm), corresponding to Lung-RADS 2.

1. Growth is defined as >1.5-mm mean diameter increase within a ≤12-month interval.
2. Nodules with a ≤1.5-mm increase in size in a >12-month interval are defined as slow-growing, meaning they do not meet growth criteria from one annual screen to the next.
3. Slow-growing nodules may be appropriately classified as stable until reaching a new size threshold when they should be reclassified and managed accordingly.
4. Radiologists are advised to always compare the current examination with the oldest available chest CT (diagnostic or screening) to determine a nodule's characteristics over time.
5. Slow-growing nonsolid (ground glass) nodules: A slow-growing nonsolid nodule may be classified as Lung-RADS 2 until the nodule meets criteria of another category, such as developing a solid component (then manage per part-solid nodule criteria).

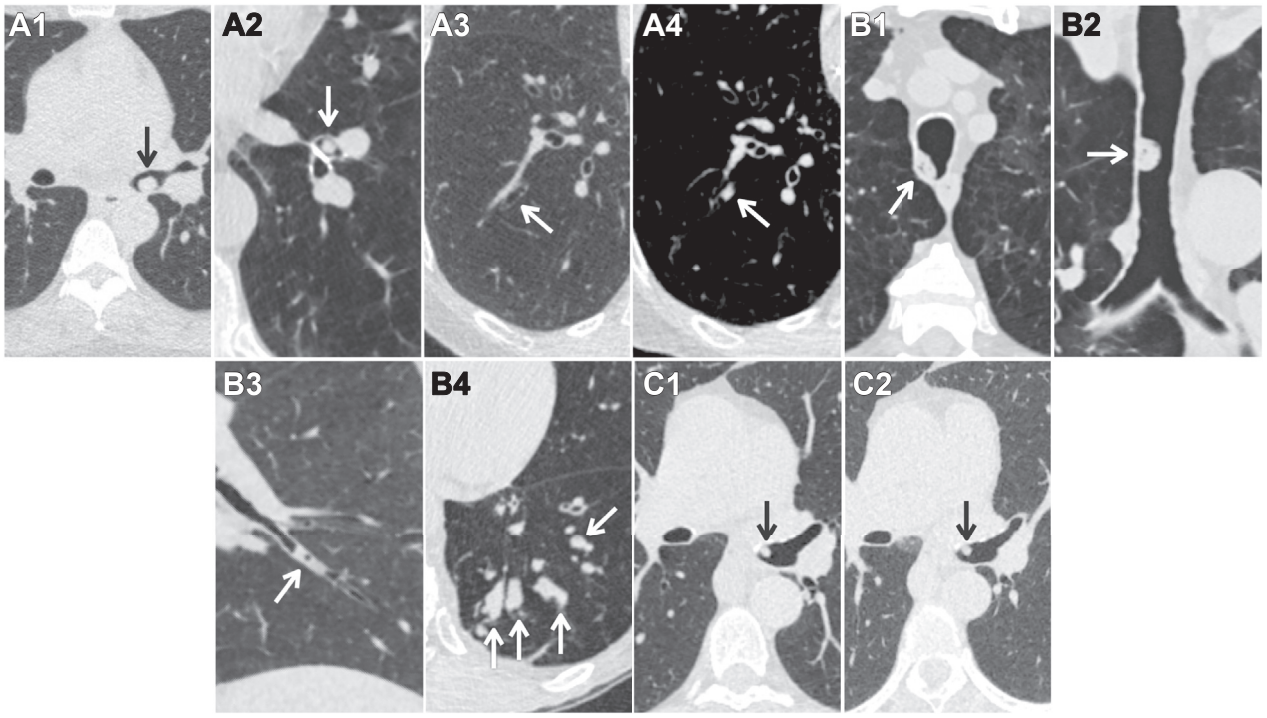

Fig. 7. Airway nodules. (A) Airway nodules in Lung CT Screening Reporting and Data System (Lung-RADS) v2022 are characterized by location, morphology, number, and persistence. New segmental or more proximal airway nodules with a lack of benign features are classified as Lung-RADS 4A with a recommendation of 3-month low-dose CT (LDCT) to assess for resolution (A1: left main stem nodule [arrow], A2: left lower lobe segmental bronchus nodule [arrow]). Subsegmental airway nodules are classified as Lung-RADS 2 (A3: baseline lung cancer screening [LCS] with patent subsegmental airway [arrow], A4: annual LCS CT with new subsegmental airway nodule [arrow]). (B) The presence of air within an airway nodule, specifically in the absence of a soft tissue component, with mean attenuation < 21 Hounsfield units favors secretions (B1, B2, B3 [arrows]). Multiple tubular airway opacities favor mucous plugging (B4, arrows). These findings may be classified as Lung-RADS 2. (C) A 70-year-old patient with a left main stem bronchus soft tissue nodule at annual LCS (C1, arrow) is classified as Lung-RADS 4A and is stable at 3-month LDCT (C2, arrow). Airway nodules that persist at follow-up remain suspicious and are upgraded to Lung-RADS 4B with a recommendation for diagnostic evaluation, typically referral for clinical evaluation and bronchoscopy.

6. Slow-growing solid or part-solid nodules: A solid or part-solid nodule demonstrating slow growth over multiple screening examinations is suspicious and may be classified as Lung-RADS 4B. Slow-growing nodules may not have increased metabolic activity on PET/CT; therefore, biopsy, if feasible, or surgical evaluation may be the most appropriate management recommendation.

S Modifier

Significant or potentially significant findings unrelated to lung cancer at LCS may be indicated by the addition of an S modifier to Lung-RADS categories 0 to 4. Such findings are common with 19.6% of NLST study participants having potentially significant pathology, although other studies have reported an incidence of 10% to 45% [33,50-52]. Unlike the highly structured classification for lung nodules at LCS, findings that warrant an S modifier and associated management are not prescribed by Lung-RADS and are left to the discretion of the interpreting radiologist. Although some authors have proposed more defined criteria, the classification and management of incidental findings unrelated to lung cancer are beyond the purview of Lung-RADS [53]. Notwithstanding, Lung-RADS v2022 provides additional guidance and clarification for reporting significant or potentially significant findings.

1. The interpreting radiologist determines which findings constitute a significant or potentially significant finding (S modifier). The reporting and communication of such findings should adhere to ACR practice standards.
2. Management recommendations for the S modifier should be included in the report impression and conform to established ACR Incidental Findings recommendations, when available. A reference guide summarizing ACR management recommendations for commonly encountered incidental findings at LCS is available [54,55].

Table 3. Airway nodules in Lung-RADS v2022

Lung-RADS	Description	Management
2	Subsegmental—at baseline, new, or stable	12-month screening LDCT
4A	Segmental or more proximal—at baseline	3-month LDCT; PET/CT may be considered if there is a ≥8 mm (≥268 mm^3) solid nodule or solid component
4B	Segmental or more proximal—stable or growing	Referral for further clinical evaluation*

LDCT = low-dose CT; Lung-RADS = Lung CT Screening Reporting and Data System.
*A segmental or more proximal airway nodule at baseline (Lung-RADS 4A) that persists at 3-month follow-up LDCT is not downgraded (stepped management) and should undergo appropriate clinical and diagnostic evaluation (typically bronchoscopy).

3. Significant or potentially significant findings that are already known, treated, or in the process of clinical evaluation do not require an S modifier (for example, a patient with severe coronary artery disease who has already undergone percutaneous coronary intervention). However, any evidence of change in a known finding that is unexpected warrants an S modifier, such as interval enlargement of a known ascending aortic aneurysm. It is not always evident whether a significant or potentially significant finding is already known; therefore, radiologists should exercise judgment in reporting and communicating such findings and associated management recommendations.

MANAGEMENT CONSIDERATIONS

Stepped Management

The concept of stepped management was first introduced in Lung-RADS v1.0 as category 3 or 4A nodules "unchanged for ≥3 months" were downgraded to Lung-RADS category 2 with a management recommendation to "continue annual screening with LDCT in 12 months" [18]. Some radiologists interpreted this recommendation as 12 months from the current examination, but others adhered to 12 months from the baseline or annual LCS study. The original intent was for annual LCS to be performed 12 months from the date of the baseline examination, as the NLST validated this protocol in reducing lung cancer mortality with LCS CT [1]. With this approach, a baseline Lung-RADS 3 nodule stable at 6-month follow-up is reclassified to category 2 with a return to annual screening in 6 months from the current examination (12 months from the baseline study). In practice, targeting follow-up recommendations from the baseline or annual screening examination can be problematic. Patients may not always comply with follow-up recommendations, and some were being imaged at later time points, such as 9 months from baseline. In such a case, a patient reclassified as Lung-RADS 2 would be expected to return in 3 months for annual LCS. Similar difficulties were encountered in managing category 4A (suspicious) nodules stable at 3-month follow-up CT. Such nodules were reclassified as category 2, and patients would not return to imaging for 9 months—a longer follow-up interval than that recommended for stable probably benign category 3 nodules (return to imaging at 6 months), which was paradoxical.

There are limited data on the impact of screening intervals. As previously noted, the reduction in lung cancer mortality in the NLST was predicated on annual CT screening. The NELSON study examined staggered

Table 4. Stepped management criteria in Lung-RADS v2022

Lung-RADS*	Description	Management
3	Category 4A lesions stable or decreased on 3-month follow-up CT	6-month LDCT (from the date of the current examination)
2	Category 3 lesions stable or decreased on 6-month follow-up CT Category 3 or 4A lesions that resolve on follow-up CT Category 4B lesions proven benign after workup or that resolve on follow-up CT	12-month screening LDCT (from the date of the current examination)

LDCT = low-dose CT; Lung-RADS = Lung CT Screening Reporting and Data System.
*Classification and management are based on the most concerning nodule at follow-up. The classification and management recommendations above assume no new or growing nodules are identified.

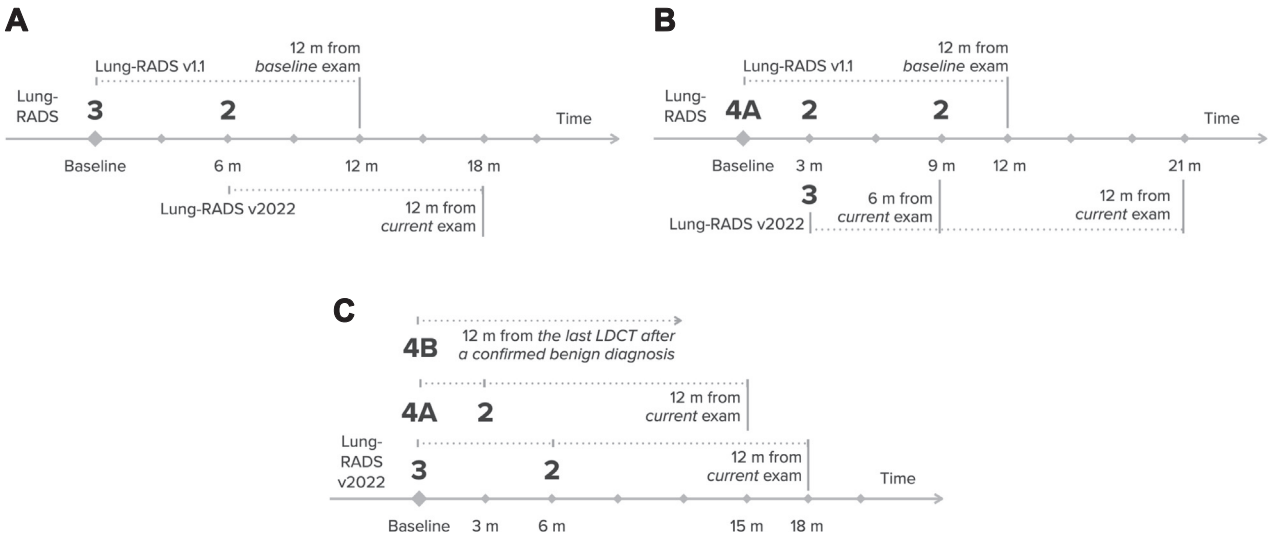

Fig. 8. Stepped management: comparison of Lung CT Screening Reporting and Data System (Lung-RADS) v1.1 and v2022. (A) Lung-RADS Category 3 management—stable or decreased. In Lung-RADS v1.1, category 3 nodules stable or decreased at 6-month LDCT follow-up were downgraded to Lung-RADS 2 with subsequent LCS performed 12 months from the baseline or annual LCS CT (6 months from the current exam). In Lung-RADS v2022, subsequent LCS is performed 12 months from the date of the current exam. (B) Lung-RADS Category 4A management—stable or decreased. In Lung-RADS v1.1, category 4A nodules stable or decreased at 6-month LDCT follow-up were downgraded to Lung-RADS 2 with subsequent LCS performed 12 months from the baseline or annual LCS CT (9 months from the current exam). In Lung-RADS v2022, subsequent LCS is performed 12 months from the date of the current exam. (C) Lung-RADS Category 3, 4A, and 4B Management—resolved or benign. In Lung-RADS v2022, category 3 or 4A findings that resolve on follow-up and category 4B findings that are proven benign after diagnostic evaluation can be reclassified based on the most concerning nodule. In this figure, we assume that there are other stable nodules, resulting in a Lung-RADS 2 classification. The timing of subsequent follow-up is from the date of the current examination. If the current exam is a PET-CT, which may not meet screening technical requirements for inspiration and thin-cut collimation, then the timing of subsequent follow-up is from the date of the most recent LDCT exam–typically the study that prompted the PET-CT.

screening follow-up at 1, 3, and 5.5 years from baseline (1-, 2-, and 2.5-year intervals) and found an increase in cancers at longer screening intervals, with a statistically significant reduction in LCS efficacy at the 2.5-year interval [56]. At least two studies have been performed evaluating the Lung-RADS management follow-up intervals for 4A nodules finding the initial 3-month recommendation is optimal, but downgrading stable 4A nodules to Lung-RADS 2 is potentially problematic, as previously discussed [14,57]. To address these concerns, Lung-RADS v2022 modifies stepped management using the following guidelines:

1. Nodules that are stable or decreased at follow-up are downgraded to the next lower Lung-RADS category.
2. Nodules that completely resolve or are proven benign after an appropriate diagnostic evaluation are reclassified based on the most concerning finding.
3. Follow-up recommendations are timed from the current examination.

Stepped management recommendations are listed in Table 4 with comparative management between Lung-RADS v1.1 and Lung-RADS v2022 outlined in Fig. 8. In application, a category 3 nodule that is stable or smaller at 6-month follow-up CT will be reclassified as category 2, with a 12-month screening CT from the date of the current examination. Therefore, in Lung-RADS v2022, the patient is imaged 6 months later than in Lung-RADS v1.1 (Fig. 8A). In the small percentage of these nodules representing lung cancer, stepped management still allows for early detection and is unlikely to affect patient outcomes.

Stepped management for a category 4A nodule that is stable or smaller at 3-month follow-up CT results in reclassification to category 3, with a 6-month LDCT from the date of the current study. If the nodule is stable or smaller at the 6-month examination, it is reclassified as category 2 with a recommendation for 12-month screening LDCT from the date of the current examination (Fig. 8B). If the nodule resolves at the initial 3-month follow-up CT, and no new or growing nodules are identified, then the

study is reclassified as category 1 or 2, without an intervening stepped management to category 3. Likewise, category 4B lesions that are proven benign after diagnostic evaluation can be reclassified as category 1 or 2 depending on the presence of other stable nodules. As LCS and follow-up examinations are classified in Lung-RADS according to the most concerning finding, new or growing nodules supersede this approach. Stepped management in Lung-RADS v2022 provides consistent recommendations for the follow-up of category 3 and 4A nodules and addresses the 4A timing paradox of more concerning nodules.

Interval Diagnostic CTs

Patients participating in annual LCS may receive diagnostic chest CT (DCT) imaging evaluation outside of recommended LCS management. Although follow-up LDCT examinations obtained from Lung-RADS category 0 (1-3 month), 3 (6-month), and 4A (3-month) findings are considered DCTs based on current procedural terminology billing codes, for the purposes of this discussion, interval DCT refers to chest CT imaging performed outside LCS follow-up recommendations. To date, there has been no formal guidance on how to account for interval DCTs obtained in screening patients. Given that the findings on DCT are potentially relevant and may impact the timing of annual LCS, we offer the following guidance:

1. *Use of prior diagnostic CTs when evaluating a baseline LCS CT:* Information from prior DCTs should be evaluated when interpreting baseline LCS and determining classification and management recommendations. For example, an 8-mm solid nodule on baseline screening CT would typically be classified as Lung-RADS 4A; however, if a prior diagnostic CT is available from 1 year ago documenting stability, then the baseline LCS examination can appropriately be classified as Lung-RADS 2. Likewise, if the 8-mm nodule is new from 1 year ago, then the appropriate classification would be Lung-RADS 4B (new $\geq$8-mm solid nodule).
2. *Use of prior (interval) diagnostic CTs when evaluating an annual LCS or follow-up LDCT:* Information from interval DCTs should be evaluated in conjunction with prior LCS and follow-up LDCT examinations for interpretation and determining classification and management recommendations.
3. *Use of interval diagnostic CT as a substitute for annual LCS CT:* A DCT may be used as a substitute for annual (not baseline) LCS if the examination is of sufficient diagnostic quality and meets technical parameters of LCS CT with the exception of dose. If known prospectively, the DCT report should indicate that the study is also being performed as an annual LCS assessment and include a Lung-RADS classification and management recommendation. Alternatively, a DCT can include a Lung-RADS classification and management recommendation as an addendum, with follow-up imaging timed from the date of the study. The diagnostic study can also be recorded in the ACR National Lung Cancer Screening Registry for quality measures and program review.

Patients No Longer Eligible for LCS

Current US Preventative Services Task Force guidelines recommend LCS CT in high-risk patients until the age of 80 or until they are otherwise no longer eligible for LCS [58,59]. CMS eligibility criteria exclude patients beyond the age of 77 [60]. Patients who initially qualified for annual LCS may eventually be ineligible as a result of age or smoking quit time longer than 15 years [60]. Patients who are no longer able or willing to receive treatment if a cancer is diagnosed, or whose life expectancy is limited, are also no longer eligible for LCS CT. Continued eligibility is best determined by the ordering provider. For patients who are no longer eligible for continued LCS, expert consensus among the ACR Lung-RADS Committee recommends the following:

1. The interpreting radiologist should assign an appropriate Lung-RADS classification and corresponding management recommendation based on the current examination, even if the patient may not be eligible for continued screening (eg, aging out, quit smoking $>$ 15 years).
2. We recommend adding a statement to LCS reporting templates indicating that the management recommendation is based on continued patient eligibility for annual LCS. This approach should avoid the need for addended reports and, more importantly, facilitate shared decision-making discussions between patients and providers in situations in which a recommendation for continued screening is made in the report, yet the patient no longer meets eligibility criteria or no longer qualifies for other reasons.

There are currently no consensus guidelines on subsequent management for patients who no longer qualify for annual LCS but have known lung nodules; however, many practices apply Fleischner Society nodule management recommendations for high-risk patients. For example, solid nodules stable for $\geq$2 years may no longer require follow-up, whereas a nodule that is new on the last screening CT may warrant continued diagnostic CT evaluation [61].

TAKE-HOME POINTS

- ACR Lung-RADS v2022 introduces important evidence-based updates to the classification and

management of findings at LCS CT including criteria for atypical pulmonary cysts, juxtapleural nodules, infectious or inflammatory findings, and airway nodules.

- Lung-RADS v2022 provides additional clarity through data and expert consensus on the role of volumetrics, the definition of nodule growth, the classification and management of slow-growing nodules, and use of the S modifier.
- Lung-RADS v2022 introduces the concept of stepped management for Lung-RADS category 3 and 4A nodules while clarifying that follow-up LDCT management recommendations are from the date of the current examination.
- Additional guidance is provided for addressing the role of interval diagnostic CTs in LCS patients and the management of nodules in patients no longer eligible for LCS.

ACKNOWLEDGMENTS

With the release of Lung-RADS v2022, the ACR Lung-RADS Committee recognizes in memoriam the significant contributions to medicine and lung cancer screening by our friend and colleague, Brady McKee, M.D. His pioneering work on the development and validation of Lung-RADS will be an enduring legacy.

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