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Review

Pulmonary Nodule Management: A Narrative Review of Clinical Decision-Making and Continuity of Care

Yueming Peng, Lei Xue, Qiang Yang, Degang Liu, Jun Li and Jiangzhou Peng*

Department of Thoracic Surgery, The Third Affiliated Hospital of Southern Medical University, Guangzhou, China

* Correspondence: jiangzhou83@163.com; Tel.: +86-02062784490

Abstract

Management of pulmonary nodules detected on computed tomography requires assessment of malignancy risk, treatment suitability and the benefits and harms of available options. This narrative review examines clinical decision-making and continuity of care for screening-detected and incidental nodules. Core searches of PubMed/MEDLINE, Embase, Web of Science and the Cochrane Library covered English-language literature from 2010 through August 2026, supplemented by targeted searches and citation tracing. Evidence was selectively synthesized around management decisions. Nodule type, prior imaging and consistent measurement methods guide risk assessment and surveillance. Surveillance intervals and intervention criteria remain specific to the detection setting, the nodule type and the applicable management framework. Further testing is appropriate when its results could change a feasible management plan; negative or nondiagnostic results require interpretation in light of residual malignancy risk. Treatment selection should balance expected benefit against procedural harm and overtreatment, considering cardiopulmonary reserve, frailty, comorbidity, competing mortality risks and patient preferences. Within the reviewed literature, patient-outcome benefit from artificial intelligence has not been established. Continuity of care requires completion of planned actions, review and communication of results, and clear responsibility for subsequent follow-up. Risk-informed decisions should be linked to reliable follow-up, with reassessment as imaging findings or patient circumstances change.

Keywords: pulmonary nodules; risk assessment; surveillance; shared decision-making; continuity of care

1. Introduction

After a pulmonary nodule is detected on chest computed tomography (CT), clinicians must decide whether surveillance, further diagnostic evaluation or intervention is appropriate. Malignancy probability, the potential benefits and harms of each option, and patient preferences all influence this decision [1,2]. Imaging establishes nodule type and a baseline for comparison, while multidisciplinary assessment considers the feasibility of tissue sampling and treatment. Similar imaging findings can lead to different decisions because patients differ in cardiopulmonary reserve, comorbidity and priorities. Management may need to change as new findings emerge or the patient's circumstances change [1].

Follow-up coordination is important when putting decisions into practice. A multidisciplinary nodule-clinic report described how a nurse navigator gathered records, explained plans and arranged follow-up, although its observational design could not isolate the effect of navigation on patient outcomes [3]. Established frameworks also require clinical interpretation. In a category-enriched screening sample, differences in nodule selection, classification and measurement produced discordant Lung CT Screening Reporting and Data System (Lung-RADS) categories and recommendations [4]. Screening guidance assumes organised programmes with defined recall arrangements [5].

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Previous reviews have addressed decision analysis and diagnostic testing [1], subsolid nodules [6], and the assessment and management of pulmonary nodules, including communication with patients [7]. We focus on the connections between these decisions: how imaging findings become a management plan, when additional information can alter that plan, and how the agreed action is completed and reviewed. Screening-detected and incidental nodules are considered where management questions are comparable. Artificial intelligence (AI) support is evaluated in relation to these clinical tasks, alongside responsibility for subsequent care and return to routine screening for eligible patients.

2. Methods

2.1. Review Design and Literature Searches

This narrative review examined pulmonary nodule management after detection. Core searches of PubMed/MEDLINE, Embase, Web of Science Core Collection and the Cochrane Library were conducted on 26–27 August 2026 and covered publications from 2010 onwards. Only English-language publications were eligible for inclusion. Searches combined screening or low-dose CT (LDCT) terms with pulmonary-nodule terms, using database-specific syntax and controlled vocabulary where available. A targeted PubMed search on 29 August 2026 addressed frailty, comorbidity and other patient factors relevant to nodule management. Database searches were supplemented by backward citation searching and consultation of original management guidance. Publications before 2010 were considered selectively for historical attribution or original model derivation. Detailed search and selection methods, including database-specific search dates, language filters and deduplication procedures, are provided in the Supplementary Methods.

2.2. Study Selection and Evidence Appraisal

Eligible publications included original studies, reviews, guidelines and consensus statements relevant to management decisions or clinically actionable assessment of pulmonary nodules. After database-level exclusion of MEDLINE overlap in Embase, 4,691 records were identified; identifier-based and bibliographic deduplication yielded 3,025 unique records. Two authors reviewed screening and full-text inclusion decisions and key supporting evidence. Full-text assessment was selective, guided by clinical relevance, availability and evidence gaps. Of 323 reports assessed, 272 were included. Six reports from the targeted search and one reconsidered core record increased the evidence base to 279 records. Historical sources and original framework documents were considered separately and excluded from this total. Included reports were appraised qualitatively for study design, directness, clinical applicability and relevance to management; no numerical quality score was assigned.

2.3. Evidence Synthesis and Limitations

Evidence was synthesized qualitatively around clinical management questions. Numerical estimates and thresholds were included only when verified in full text and interpreted within their original populations and management frameworks. For AI, technical performance was distinguished from effects on workflow, management decisions and patient outcomes. No meta-analysis or formal assessment of evidence certainty was undertaken. The English-language restriction, screening-centred searches and selective full-text assessment may have limited coverage and influenced the synthesis. Evidence was applied to incidental nodules only where management questions were comparable.

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3. Nodule Characterisation and Malignancy Risk Assessment

3.1. Detection Setting and Nodule Type

Initial assessment should establish whether a nodule was detected through lung cancer screening or incidentally, so that the appropriate management recommendations can be applied [5,8]. Prior CT examinations should be reviewed to determine whether the nodule was present previously and whether its size or morphology has changed. A nodule first identified on a baseline examination may have been present for an unknown period, whereas a newly appearing nodule was absent on a comparable earlier CT. Without prior imaging, the timing of appearance and interval growth cannot be established [5,9].

Nodules should be classified on CT as solid, pure ground-glass or part-solid. For pure ground-glass nodules, assessment should consider persistence, size, changes in attenuation and the development of a solid component. For part-solid nodules, both total nodule size and the size and interval change of the solid component should be assessed [10,11]. In patients with multiple nodules, assessment should identify the most suspicious lesion or lesions while considering the distribution and characteristics of the remaining nodules [11]. These findings inform malignancy risk assessment and subsequent management (Figure 1).

3.2. Measurement and Risk Prediction

Nodule size should be assessed using the diameter or volume definitions specified by the applicable management guideline. Serial comparisons require consistent acquisition and measurement methods, with allowance for measurement variability. Volumetric estimates depend on CT technique, segmentation and software; different algorithms within the same software package can produce different results [12,13]. Differences between readers in nodule selection, classification or measurement can also alter the assigned management category [4]. Reports should identify the nodule guiding management, the measurement method and any uncertainty in classification.

The PanCan (Brock) model estimates malignancy probability from patient and nodule characteristics [14]. Its applicability in other populations should be assessed through external validation, considering both discrimination and calibration [14,15]. Risk estimates should inform decisions about surveillance or further diagnostic evaluation, alongside the detection setting, nodule type and the patient's suitability for treatment [1,8] (Table 1).

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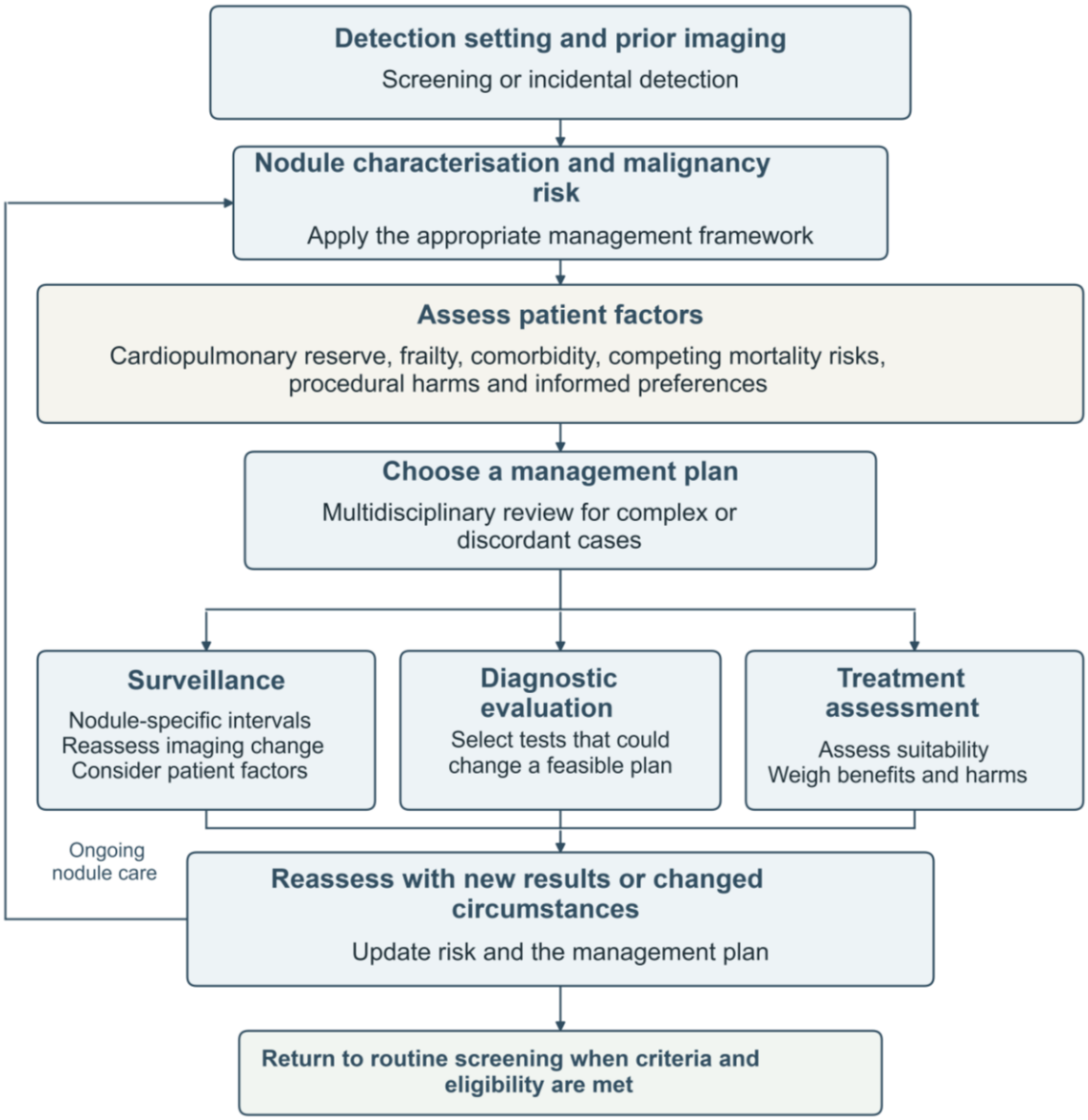

Figure 1. Management options for pulmonary nodules detected on computed tomography. Management decisions integrate nodule findings, treatment suitability, procedural harms and patient preferences [1,2,16]. Follow-up and diagnostic results guide reassessment [1,12,17]. Return to routine screening requires the applicable criteria and continued eligibility [5,8].

Table 1. Selected guidance and risk models for pulmonary nodule management.

Source	Intended setting	Role and key considerations
Lung-RADS v2022	Screening CT	Assigns an examination category based on the most suspicious nodule to guide follow-up or diagnostic evaluation. Management of highly suspicious findings requires individual assessment [18].
Fleischner Society 2017	Incidental nodules in adults ≥35 years	Provides follow-up recommendations; selected subsolid pathways are summarised in Table S1. Excludes screening, immunocompromised patients and known primary cancer [11,19].
JSCTS 6th edition	Screening referral and specialist assessment	Defines phenotype-specific assessment and follow-up. Screening and specialist pathways use different diameter definitions [8].

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ESTI	Baseline, previously detected and new screening nodules	Combines volume, morphology and interval-specific growth. Morphology can alter categories; slow growth does not automatically justify annual screening [5].
PanCan/Brock	Baseline screening-derived risk prediction	Estimates per-nodule malignancy probability. Applicability depends on external validation and adequate calibration in the target population; predicted risk alone does not determine treatment [14,15].
STS	Selected screen-detected, generally peripheral clinical stage I lesions	For high-probability lesions in patients fit for curative resection, consider surgery after staging, with planned intraoperative diagnosis before anatomical resection. Central lesions requiring lobectomy for diagnosis favour preoperative biopsy and multidisciplinary review [2].

Selected thresholds and measurement definitions are provided in Table S1. These sources have different purposes and should be applied within their intended settings. CT, computed tomography; Lung-RADS, Lung CT Screening Reporting and Data System; JSCTS, Japanese Society of CT Screening; ESTI, European Society of Thoracic Imaging; PanCan, Pan-Canadian Early Detection of Lung Cancer Study; STS, Society of Thoracic Surgeons.

4. Risk-Stratified Surveillance and Reassessment

4.1. Growth Assessment and Volume Doubling Time

Growth should be assessed using the diameter- or volume-based criteria of the applicable management guideline, with allowance for measurement variability [12,13]. These definitions may classify the same nodule differently [12]. Volume doubling time (VDT) estimates the time required for a nodule to double in volume, based on serial volumetric measurements. NELSON incorporated VDT into follow-up and referral decisions [20]. In a retrospective analysis of fast-growing solid nodules, lowering the VDT referral cutoff reduced false-positive referrals after 3-month follow-up without reducing sensitivity in the analysed subgroup. At the second screening round, the cutoff could not be lowered while preserving sensitivity [21]. VDT thresholds should therefore be interpreted in relation to the interval between scans. Further management should integrate confirmed growth with nodule size, morphology and patient factors. In a lung cancer screening cohort, 53 growing solid nodules measuring ≤200 mm^3 at the 3-month scan underwent further CT surveillance. Eight were diagnosed as lung cancer within 2 years: seven were stage I and one was stage III [17]. Continued surveillance of growing nodules requires scheduled reassessment and predefined criteria for multidisciplinary referral.

4.2. Persistent Subsolid Nodules

Selected persistent subsolid nodules can undergo surveillance when follow-up is reliable and criteria for further evaluation are defined. BioMILD incorporated assessment of the solid component when managing screening-detected subsolid nodules conservatively [22]. For part-solid nodules, assessment should consider changes in the solid component even when total nodule size remains stable. A new or enlarging solid component warrants reassessment; persistence alone does not mandate resection [11]. Some ground-glass nodules (GGNs) grew after 5 years of stability in a health-check cohort [23], and some screening-detected pure GGNs grew after 10 years of stability [24]. The optimal surveillance duration remains uncertain because late growth events were few, long-term follow-up was selective and pathological confirmation was limited. These observations do not establish that every stable nodule requires indefinite intensive CT surveillance or that late growth necessarily represents clinically important progression.

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4.3. Surveillance Intervals and Return to Screening

Surveillance intervals and duration should reflect nodule type, size, serial findings, patient condition, competing risks and the feasibility of follow-up [8,22] (Table 2). New solid nodules may require shorter follow-up intervals or further diagnostic evaluation than baseline nodules of the same size [5]. New subsolid nodules frequently resolved in NELSON, suggesting that they may not require the more intensive follow-up used for new solid nodules [9].

Patients who meet the applicable management criteria and remain eligible for screening may return from nodule-specific surveillance to routine screening [5]. The next screening date and the clinician or service responsible for follow-up should be documented [25]. Longer screening intervals have been proposed for selected lower-risk participants [26]. In NELSON, the 2.5-year interval was associated with more interval cancers than the 1- and 2-year intervals. At the subsequent screening round, the proportion of stage IIIB/IV cancers was higher than after the 1-year interval; the difference from the 2-year interval was not statistically significant [27].

Table 2. Clinical decisions in pulmonary nodule management.

Clinical situation	Management options	Key considerations
Suitable for CT surveillance	Continue CT surveillance according to nodule type and the applicable guideline; reassess after imaging or clinical changes.	Interpret stability according to nodule type and follow-up duration [1,8].
Growth, change in nodule type or discordant risk estimates	Check measurement comparability and reassess malignancy risk; consider surveillance, diagnostic evaluation or multidisciplinary review.	Interpret growth alongside nodule size, morphology and patient factors [1,12,17].
PET/CT could change management	Consider PET/CT to update malignancy probability, assess disease extent or select a biopsy target.	Negative findings do not exclude malignancy; increased uptake does not provide histological confirmation [1,28].
Tissue diagnosis could change management	Select bronchoscopic or CT-guided transthoracic biopsy according to nodule accessibility and local expertise.	Balance expected diagnostic accuracy against procedural risk [1,29].
Negative, nonspecific or nondiagnostic biopsy	Assess concordance with clinical and imaging findings; consider surveillance, repeat or alternative biopsy, or surgical assessment.	Base further management on residual malignancy risk; nondiagnostic results do not establish benignity [1,29].
Surgery without preoperative tissue confirmation	For selected high-probability, screen-detected clinical stage I lesions, assess staging and operative fitness; plan intraoperative diagnosis before anatomical resection.	Central lesions requiring lobectomy for diagnosis favour preoperative biopsy and multidisciplinary review [2].
Empiric SBRT without tissue confirmation	Seek tissue confirmation whenever feasible. Consider empiric SBRT only for selected suspected peripheral clinical stage I NSCLC with high malignancy probability, appropriate staging and multidisciplinary consensus.	Review imaging evolution, benign alternatives, surgical candidacy, reasons for nonsurgical care and barriers to biopsy [30].
Further testing is unlikely to change management	Discuss omitting the test and agree on an alternative management plan.	Explain diagnostic uncertainty and agree when to reassess [1].

Management should account for treatment suitability, procedural harms and informed patient preferences [1,2,16]. Selected numerical criteria are provided in Table S1. CT, computed tomography; PET/CT, positron-emission tomography/computed tomography; NSCLC, non-small-cell lung cancer; SBRT, stereotactic body radiation therapy.

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5. Further Diagnostic Evaluation

5.1. Malignancy Risk and Test Selection

Before further diagnostic testing, clinicians should consider how positive, negative or inconclusive results would influence the choice between surveillance, biopsy and surgical evaluation. Test selection should account for malignancy probability, procedural risks, treatment suitability and patient preferences [1]. If testing is deferred, an alternative management plan and indications for reassessment should be agreed with the patient [1]. Disagreement between model-based risk estimates and guideline classifications should prompt review of the detection setting, nodule type, measurements and applicability of each approach [5,31]. In a retrospective Danish screening study, PanCan showed better discrimination than Lung-RADS v1.0 and the National Comprehensive Cancer Network (NCCN) v1.2016 classification. NCCN performance also varied with the diameter definition used. The analysis excluded nodule growth and did not evaluate complete clinical management pathways [31] (Figure 2).

5.2. PET/CT

Positron-emission tomography/computed tomography (PET/CT) can assist malignancy risk assessment, staging and biopsy-site selection [1]. The Herder model incorporates visually assessed fluorodeoxyglucose uptake into the Mayo/Swensen malignancy estimate and was developed in a retrospective cohort referred for PET assessment of indeterminate solitary pulmonary nodules [32]. A negative PET/CT result does not exclude malignancy, and increased uptake is not specific for cancer [1,28]. In a single-centre retrospective cohort of 75 patients with LDCT-detected nodules, radiological follow-up was chosen for 33 of 38 patients whose PET/CT reports suggested benignity. Two patients with reports suggesting benignity were subsequently diagnosed with carcinoid tumours. False-positive findings included granulomatous disease. Most nodules were solid, and most measured at least 10 mm, limiting applicability to small or subsolid nodules [28].

5.3. Tissue Sampling and Interpretation

Biopsy route selection should account for lesion accessibility, expected diagnostic performance, procedural risk and local expertise [1]. In a retrospective cohort, smaller lesions, greater lesion-to-pleura distance, emphysema and impaired pulmonary function were associated with complications of CT-guided transthoracic biopsy [33]. VERITAS randomised patients with intermediate- or high-risk peripheral nodules measuring 10–30 mm and accessible by both routes to navigational bronchoscopy or CT-guided transthoracic biopsy. Most nodules were solid. Diagnostic accuracy, based on specific diagnoses confirmed through 12 months of follow-up, was 79.0% versus 73.6%, meeting the noninferiority criterion without demonstrating superiority. Pneumothorax occurred in 3.3% versus 28.3% in the primary-analysis groups. The bronchoscopy arm used electromagnetic navigation with integrated digital tomosynthesis [29].

A specific benign biopsy diagnosis should be concordant with clinical and imaging findings. Nonspecific inflammation, normal lung tissue or a nondiagnostic sample does not reliably exclude malignancy. Subsequent management should be guided by residual malignancy risk and patient suitability, with options including CT surveillance, repeat or alternative biopsy, and surgical evaluation [1,29].

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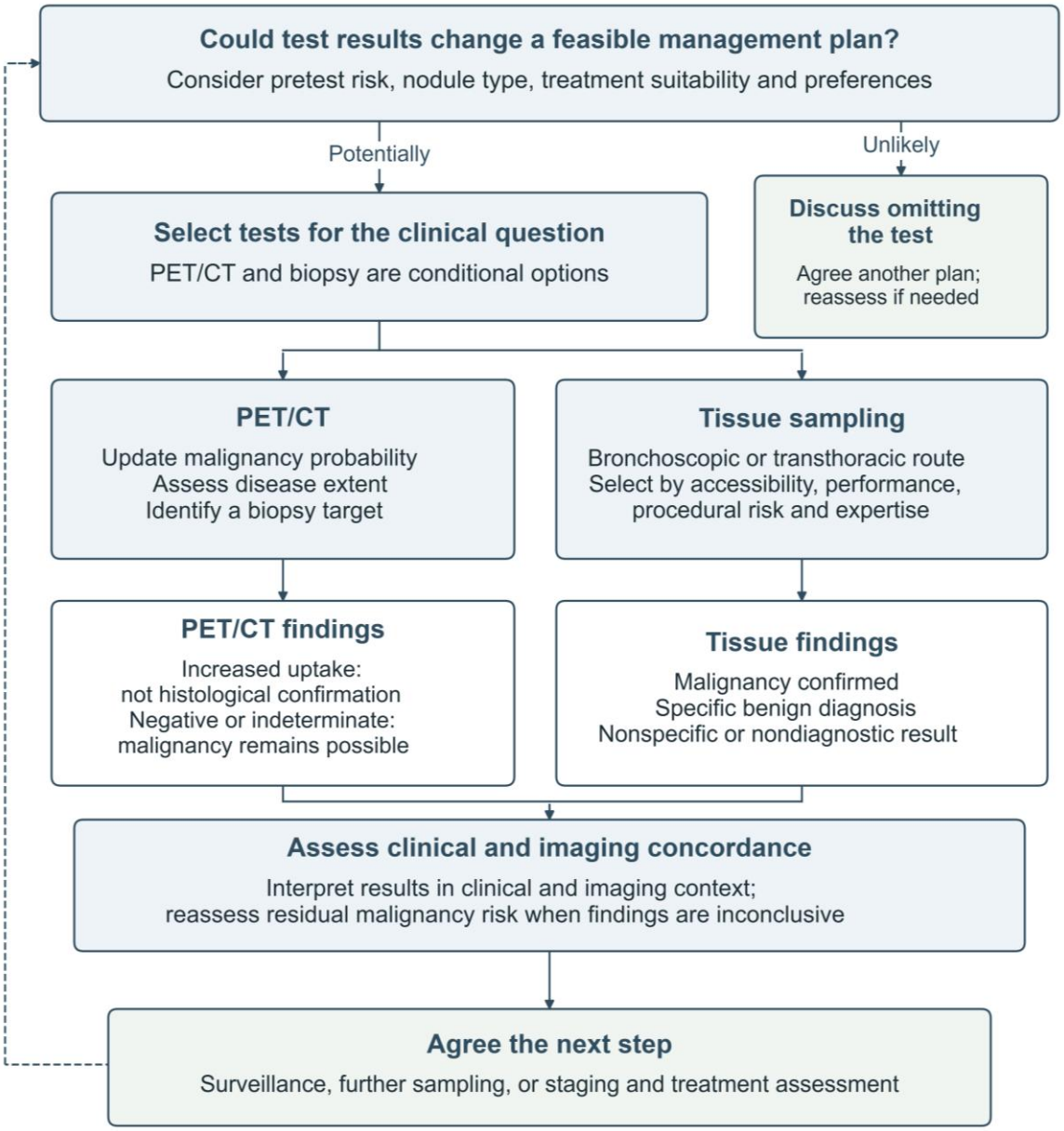

Figure 2. Diagnostic testing to inform pulmonary nodule management. Test results are interpreted alongside clinical and imaging findings to guide subsequent management [1,28,29]. The dashed arrow indicates reassessment of whether further testing could change management. PET/CT, positron-emission tomography/computed tomography.

6. Treatment Selection

Treatment selection should consider cardiopulmonary reserve, functional status, frailty, comorbidity and life expectancy [2,34–36]. Operative fitness should be assessed in relation to the planned extent of resection [2,34,36]. The European Respiratory Society and European Society of Thoracic Surgeons guideline supports frailty assessment before lung cancer treatment [36]. Age alone should not determine treatment; expected benefit should be weighed against procedural harm and competing mortality, taking patient preferences into account [1,35]. Patients unable to tolerate major resection may remain eligible for other local treatments, and inability to undergo biopsy safely does not itself establish surgical inoperability [2,30].

When resection is indicated, European guidance favours wedge resection for peripheral pure ground-glass nodules and segmentectomy for centrally located lesions of this type. Segmentectomy should be considered over lobectomy for peripheral part-solid nodules ≤2 cm. Systematic lymph node

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dissection is recommended for part-solid nodules. For sublobar resection of pure ground-glass or part-solid nodules, a margin ≥1 cm or a margin-to-tumour ratio ≥1 should be considered. Preoperative or intraoperative localisation may assist resection of small, deep or nonpalpable nodules [11].

Stereotactic body radiation therapy (SBRT) is an option for selected medically inoperable patients with early-stage non-small-cell lung cancer (NSCLC); conditions for treatment without tissue confirmation are summarised in Table 2 [30]. Percutaneous ablation may be considered for selected patients unsuitable for surgery [37]. Retrospective studies of ablation and SBRT have included selected patients, some without pathological confirmation, and do not establish equivalence to surgery or the relative effectiveness of ablation and SBRT [37,38].

Continued surveillance may be appropriate when the expected benefit of immediate treatment is limited or selected subsolid nodules can be monitored reliably [1,35,39]. The surveillance plan should specify when to reassess, including changes in the solid component, patient fitness or preferences. Observational evidence supports surveillance in selected patients but does not establish equivalence to immediate resection [39].

7. Harms and Shared Decision-Making

False-positive screening findings can lead to additional imaging, invasive procedures and complications [40,41]. In a single-centre retrospective screening cohort, benign pathology was found in 19 of 148 patients undergoing nodule resection (12.8%) [42]. Whether resection of a benign nodule was avoidable depends on preoperative malignancy risk and the available alternatives [16]. Overdiagnosis refers to the detection of a cancer that would not cause symptoms or death during the patient's remaining lifetime. It is distinct from a false-positive finding or resection of a benign lesion and may lead to treatment without clinical benefit [35].

Patients may have limited understanding of their nodules and experience distress that increases around follow-up imaging [43,44]. Discussions should explain malignancy risk, diagnostic uncertainty and the benefits and harms of clinically appropriate management options. Some patients prioritise avoiding invasive procedures, whereas others place greater value on resolving diagnostic uncertainty. Clinicians should explore these priorities and check understanding before agreeing on a management plan [1,2,43]. In a quality-improvement initiative involving patients with small solid nodules, patients reported better understanding and less anxiety immediately after reading a factsheet; however, the measures were not validated and sustained benefit was not assessed [45]. Written information should complement individual discussion. Preferences and concerns should be revisited during surveillance and when findings or the management plan change [44].

8. AI and Follow-Up Coordination

8.1. AI Validation and Clinical Evaluation

AI systems should be evaluated for their intended detection, measurement or malignancy-prediction task and target population. Models evaluated only in their development population require external validation [46]. For malignancy risk prediction, both discrimination and calibration should be assessed; performance in cancer-enriched samples may not establish reliable absolute risk estimates in routine screening [47].

Clinical evaluation should assess effects on management, patient outcomes and cost-effectiveness [48] (Table 3; Table S2). In a single-centre randomised trial involving asymptomatic health-check participants, AI assistance increased nodule reporting and follow-up recommendations without significantly reducing interpretation time per examination. These findings do not establish improved patient outcomes [49]. Radiologists should review AI outputs for detection, segmentation and classification errors that could alter management [50].

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Table 3. Selected evidence on artificial intelligence in pulmonary nodule assessment and management.

Domain	Evidence	Findings and limitations
Model validation	Risk prediction studies [46,47,51,52]	Discrimination varied across models and validation cohorts. Calibration and applicability to routine screening require further assessment.
AI-assisted interpretation	Software comparison and saliency-map study [50,53]	Measurement and classification errors can alter management categories. Radiologists' interpretations of saliency maps varied in a small study of selected CT slices.
Workflow and management	Feasibility, implementation and randomised studies [49,54,55]	Studies evaluated potential workload reduction and reporting changes. A health-check trial increased nodule reporting and follow-up recommendations without significantly reducing interpretation time.
Patient outcomes and cost-effectiveness	Technology assessment and randomised trial [48,49]	Improved patient outcomes were not established in these sources. Modelled cost-effectiveness estimates remained uncertain.

Study characteristics and detailed results are provided in Table S2. AI, artificial intelligence; CT, computed tomography.

8.2. Follow-Up Coordination and Transfer of Care

Follow-up plans should specify the next action, its timing and the responsible clinician or team [56]. In a before-and-after study of community-based lung cancer screening for veterans, centralised support was associated with better completion of recommended imaging or pulmonary consultation for Lung-RADS 3–4 findings. The programme combined referral review, result tracking and follow-up coordination [57]. Follow-up records should document scheduling, examination completion, result review and subsequent action [58,59] (Figure 3).

Missed follow-up should prompt checks for imaging performed elsewhere and patient contact to identify access barriers or changes in preferences, with clinical review when the plan needs revision [57,58]. Noncompletion alone should not be recorded as patient refusal. For return to routine screening, we propose documenting current management status and the next screening date, and confirming that the receiving service accepts responsibility for recall and abnormal results.

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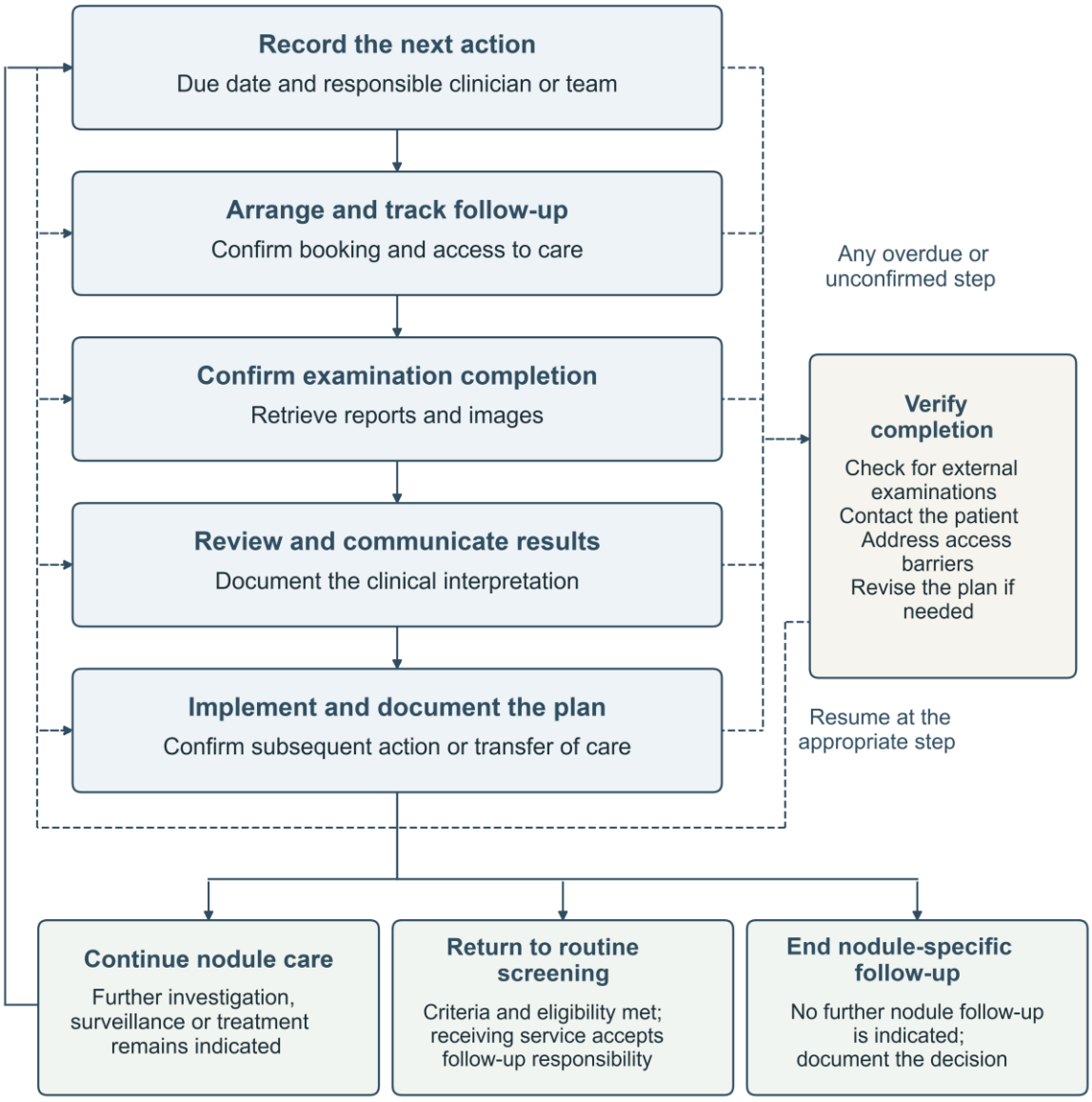

Figure 3. Completion and review of pulmonary nodule follow-up. Solid arrows show planned care; dashed arrows indicate verification of overdue or unconfirmed steps and resumption at the appropriate stage [56–59]. Confirmation that the receiving service accepts responsibility for recall and management of abnormal results is an author-proposed safeguard.

9. Conclusions

Pulmonary nodule management should integrate malignancy risk, treatment suitability and patient preferences within the framework appropriate to the detection setting. The choice between surveillance, diagnostic evaluation and treatment should be reassessed as imaging findings or patient circumstances change. Additional testing should be considered when its results could change a feasible management plan. Follow-up plans should specify the next action, its timing and the responsible clinician or team, with confirmation that results are reviewed, communicated and acted on. The English-language restriction, screening-centred searches and selective full-text assessment may have limited coverage and introduced selection bias. Further research should evaluate the effects of AI support and frailty assessment on management decisions and patient outcomes.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org, Table S1, selected framework-specific numerical branches and measurement

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definitions; Table S2, study-specific evidence on pulmonary-nodule AI validation and clinical use. Supplementary Methods, search strategies and evidence selection.

Data Availability Statement: This narrative review uses published literature. Search strategies, record counts at each selection stage, selected framework details and study summaries are provided in the Supplementary Materials.

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Conflicts of Interest: The authors declare no conflict of interest.

Informed Consent Statement: Written informed consent was not required because this article is a narrative review of published literature and includes no individual patient data.

Institutional Review Board Statement: Institutional review board approval was not required because no human participants, animal subjects, or identifiable patient data were included.

Author Contributions: Jiangzhou Peng and Yueming Peng conceived the review. Yueming Peng and Lei Xue drafted the initial manuscript. Qiang Yang, Degang Liu, and Jun Li contributed to literature interpretation and critical revision. Jiangzhou Peng supervised the work and revised the manuscript for important intellectual content. All authors agree to be accountable for the work.

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Use of Artificial Intelligence: ChatGPT and Codex are utilized to assist with language revision and the development of Python-related scripts. All content was reviewed and approved by the authors, who take full responsibility for the final manuscript.

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