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Delivering Low-dose CT Screening for Lung Cancer: A Pragmatic Approach

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Complete List of Authors:	Horst, Carolyn; University College London, Lungs for Living Research Centre, UCL Respiratory Dickson, Jennifer; University College London, Lungs for Living Research Centre, UCL Respiratory Tisi, Sophie; University College London Lungs for Living Research Centre, ; Basildon University Hospital, Ruparel, Mamta; University College London, Lungs for Living Research Centre, UCL Respiratory Nair, Arjun; University College London Hospitals NHS Foundation Trust Devaraj, Anand; Royal Brompton Hospital, Janes, Sam; University College London, Lungs for Living Research Centre, UCL Respiratory
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TITLE PAGE

Delivering Low-dose CT Screening for Lung Cancer: A Pragmatic Approach

Carolyn Horst[1$], Jennifer Dickson[1$], Sophie Tisi[1], Mamta Ruparel[1], Arjun Nair[1*], Anand Devaraj[2*], Sam M Janes[1*]

[1]Lungs for Living Research Centre, UCL Respiratory, University College London, 5 University Street, London, WC1E 6JF, UK.
[2]Royal Brompton and Harefield NHS Foundation Trust, Britten Street, London, SW3 6NJ, UK.

[$] C Horst and J Dickson contributed equally to this work.
* Corresponding Authors:
Arjun Nair, arjun.nair1@nhs.net
Anand Devaraj, a.devaraj@rbht.nhs.uk
Sam M Janes, s.janes@ucl.ac.uk

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ABSTRACT

Low-dose CT screening for lung cancer saves lives by identifying lung cancers at an early stage when the disease can be cured. The challenge that remains for Lung Cancer Screening (LCS) is delivering it in a way that minimises harms and maximises benefits for both patients and health care practitioners. We present here the SUMMIT Study's approach to classification and management of pulmonary nodules and incidental findings identified through LCS, and the way in which this approach to management may enable safe and efficient implementation of LCS in the future.

MAIN TEXT

Lung cancer kills an estimated 35,000 people in the UK every year. Despite the improvements in treating late stage disease, lung cancer outcomes have changed little in the last 40 years. Low-dose CT (LDCT) screening for lung cancer reduces lung cancer mortality by 20-24%, and all-cause mortality by 7%(1,2). Lung cancer screening (LCS) however remains contentious, particularly how to implement it in an efficient and efficacious way. This contention extends to the potential costs of screening—financial to the NHS, and physical and psychological harms to patients. These concerns are particularly relevant to how we manage both the findings we aim to detect through screening (pulmonary nodules) and those we pick up inadvertently (incidental findings). The SUMMIT Study is the largest CT screening study in Europe and a key endpoint is detailing the feasibility of delivering CT screening across a complete population within the NHS. We present here SUMMIT's approach to nodule and incidental findings management; a pragmatic model that is neither overly burdensome, nor unsafe, and provides a practical solution to some of the challenges of LDCT LCS.

The SUMMIT Study

The SUMMIT Study (clinicaltrials.gov NCT03934866) is a lung cancer screening study, recruiting 55-77 year olds at high risk of lung and other smoking-related cancers to LDCT screening. Its twin aims are to examine the performance of delivering an LDCT screening service for lung cancer to a high-risk population, and to validate a cell-free nucleic acid blood test for detection of multiple cancers. The study began enrolment in April 2019 after the development of protocols for the management of pulmonary nodules and incidental findings that enabled a consistent approach to management across the entirety of the study (target recruitment of 25,000). The study aims to deliver a programme of LCS that is pragmatic, evidence-based, and practically deliverable by primary and secondary care, importantly avoiding overzealous investigation of all findings (and therefore potentially increasing harms). Examination of the evidence that medical intervention of incidental findings makes a difference to participants turns out to be sparse, making detailed radiological reporting probably unnecessary. The reader will see here that we provide only limited and highly specific information beyond the presence of lung cancer or pulmonary nodules. It is our hope that this balanced approach will be borne out in the data we collect, bolstering a safe, effective and efficient implementation of LCS. Studies on whether a future health service could manage a more holistic approach, aligning the reporting of incidental findings such as coronary artery calcification, early emphysema and other findings to a more personalised health intervention with intensive smoking advice, cardio-vascular disease prevention and the like, are urgently needed.

Pulmonary Nodules: The Evidence Base

We utilise the existing evidence-based British Thoracic Society (BTS) guidelines on the management of pulmonary nodules, with some specific alterations. The BTS

guidelines use nodule size and type, along with other criteria such as a nodule malignancy risk score (Brock score) and volume doubling time (VDT), to calculate appropriate follow-up management on a per-nodule basis. The SUMMIT algorithm follows this method closely, but was adapted in several key ways, including: accommodation for a three-year annual screening programme rather than a one-off CT chest; changes in the use of the Brock malignancy score; dispensing with VDT calculations in favour of a growth threshold of ≥25% to inform management at three months; a minimum size requirement ($200mm^3$) before referral to MDT; and 12 month (versus three month) follow up of pure ground glass lesions ≥ 5mm. The complete SUMMIT Pulmonary Nodule Protocol is available as supplementary material (Figure S1). Deviations were made from BTS guidelines either to minimise the burden on secondary care colleagues (e.g. where MDT referral is not made until a growing nodule is $\geq 200mm^3$) or where new evidence suggests a safe but more conservative approach (for example, with GGNs, which often resolve or, if persistent, are unlikely to require immediate intervention). The result, we hope, is a blueprint for managing pulmonary nodules in a safe but measured way, minimising unnecessary stress on patients and providers, while intervening appropriately in those nodules most likely to cause harm.

The Challenge of Incidental Findings

There is considerably less evidence for the appropriate management of incidentally detected non-nodule findings at LCS LDCT, and opinion is split about whether or not to follow up all findings, some, or none (see supplementary material for a detailed description of our approach, Table S1). The NELSON trial have publicly stated that following up even potentially clinically relevant radiological incidental findings does not provide any benefit (3). Other LCS professionals advocate that far more findings are reported back and/or investigated further (4). Given the heterogeneity of evidence, and our wish to create a low interventional burden approach to screening, the SUMMIT protocol reports back incidental findings only where there is an evidence-based clinical action that can be taken to mitigate or further investigate and treat that finding, leading to patient benefit.

The importance of taking a pragmatic approach is highlighted by the fact that incidental findings may be seen in nearly 100% of participants undergoing lung screening, according to some reports. Identifying and potentially investigating such a high frequency of incidental findings clearly has the potential to constrain lung screening implementation.

Based on the study team's experience delivering the Lung Screen Uptake Trial (LSUT), we had a good understanding of the impact on primary and secondary care primary care colleagues and participants alike when all radiological findings are reported back. The most common incidental findings at LCS are coronary artery calcification (CAC) and emphysema, whose detection and management in the LCS population have been widely discussed but variably applied. CAC is often detected at LDCT and the screening target demographic is at increased risk of cardiovascular disease (CVD) due to their smoking histories and ages; because of

this, American LCS screening programmes are encouraged to report back CAC to screenees in order to instigate primary prevention, where appropriate (4). In the UK, however, instigation of appropriate management of CVD is based on the calculation of a QRISK2 score. From LSUT data, the vast majority (projected figure >90%) of the SUMMIT population are expected to have a QRISK2 score greater than 10%, the threshold for instigation of primary prevention (5). After consultation with cardiology and general practice colleagues, the study team elected to include a prompt in all letters to participants' GPs recommending assessment via QRISK2 score, an approach which avoids communicating a CAC score, which provides no additional prognostic information nor evidence base for intervention.

Emphysema on CT is another area of contention within the screening and wider lung cancer community. The appearance of emphysema is not currently a criterion for the diagnosis of COPD in the GOLD guidelines, unlike spirometric demonstration of airflow limitation and symptomatology. Reporting back the presence and/or severity of emphysema on LDCT will not lead to a diagnosis of COPD; however, the study does report back to GPs pre-bronchodilator spirometry values and, if the participant does not report a pre-existing diagnosis of COPD but has symptoms and airflow limitation on spirometry (FEV1:FVC<0.7), a recommendation is provided to the GP to investigate the person formally for COPD. There may be good reasons to report back emphysema, or indeed CAC, to participants as a 'teachable moment' to aid smoking cessation, but evidence is still being gathered to support this assertion. Labelling a participant as having emphysema or CAC may also have psychological downsides as well as adverse consequences for health insurance.

The SUMMIT clinical team is cognizant that undiagnosed non-lung cancers may present on an LDCT performed as part of LCS. Again, the appearances that are sometimes consistent with cancer may also represent benign pathology. Currently there is no evidence that screening for thoracic or upper abdominal cancer (other than lung cancer) with CT is beneficial to screenees. But instead of deciding that there is 'neglectable benefit' (3) in investigating appearances potentially consistent with non-lung cancers, we have implemented what we think is a sensible, often stepped, approach to further investigation and management. For example, adrenal nodules identified at LDCT are assessed for size and density, with those of smaller diameter (1-4cm) or Houndsfield Units (HU)>10 being re-scanned within the study in a year's time to look for stability, and those of larger size instigating immediate referral. This approach is consistent with the American College of Radiology's (ACR) white paper on abdominal incidental findings and, we believe, strikes a balance between intervening in potentially longstanding and stable appearances, and aiding the diagnosis of otherwise unknown cancers. A similarly pragmatic approach was taken to thyroid nodules and other non-malignant findings (see supplementary material in table S1for more information).

While these protocols may appear complicated, because bespoke reporting proformas and software have been developed for use in SUMMIT, and findings indicated therein are ingested into the software directly, users are automatically presented with the 'correct' management for each scan, and are not required to

reference these protocols directly themselves. Radiologists may override the management suggested by the software if they feel another management approach is indicated. This means that while the protocols may be detailed, their implementation is user-friendly but flexible where appropriate. Ultimately, the utility of identifying and investigating non-lung-cancer findings in LCS is yet to be determined, and outcome data from SUMMIT may help the wider LCS community understand which findings should be investigated, and those that should be ignored.

SUMMIT has utilised the evidence available in order to develop and implement a consistent approach to findings at LDCT. Compared to breast and cervical cancer screening programmes, LCS is in its relative infancy. We cannot yet be expected to have all the answers on how to deliver it. A pragmatic approach to pulmonary nodules and incidental findings management at LDCT screening will enable us to build a screening programme without causing the collapse of supporting primary and secondary care services, and can be refined in the future, allowing a fledgling service to begin to change lung cancer outcomes now.

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CONTRIBUTORSHIP

Dr C Horst and Dr J Dickson contributed equally to the writing of this article, and to the development of the guidelines and protocols discussed. All other authors contributed to the development of the materials discussed in the article and to refining the finished manuscript.

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COMPETING INTERESTS

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Supplementary Material

Delivering Low-dose CT Screening for Lung Cancer: A Pragmatic Approach

C Horst[1], J Dickson[1], S Tisi[1], M Ruparel[1], A Nair[1]*, A Devaraj[2]*, SM Janes[1]*

[1]Lungs for Living Research Centre, UCL Respiratory, University College London, London, UK.
[2]Royal Brompton and Harefield NHS Foundation Trust, London, UK.

*Corresponding authors

The SUMMIT Study Pulmonary Nodule and Incidental Finding Management Protocol

The SUMMIT Pulmonary Nodule Protocol

This protocol is based largely on the British Thoracic Society Guideline for the Investigation and Management of Pulmonary Nodules(1). The SUMMIT guidelines have been adapted to a three-year screening programme [baseline (Y0), year 1 (Y1), and year 2 (Y2)] with a randomisation element at the second visit (Y1). Deviations or additions to the BTS guidelines are denoted in **bold** boxes. Evidence for these changes are cited in call-outs at the bottom of each protocol (*, § etc) and incorporate best practice recommendations from the Fleischner Society (2,3).

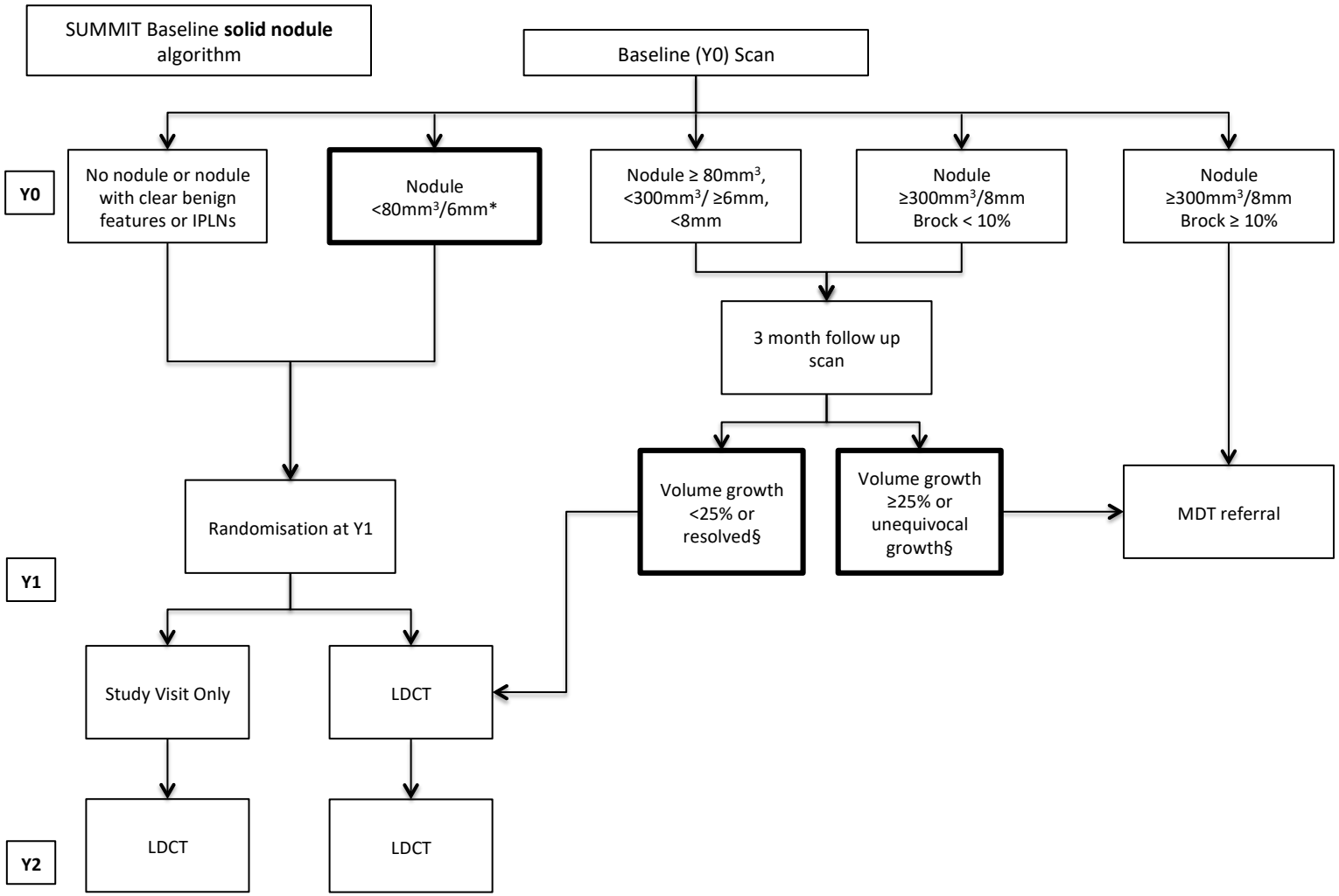
Some general principles when using this protocol:

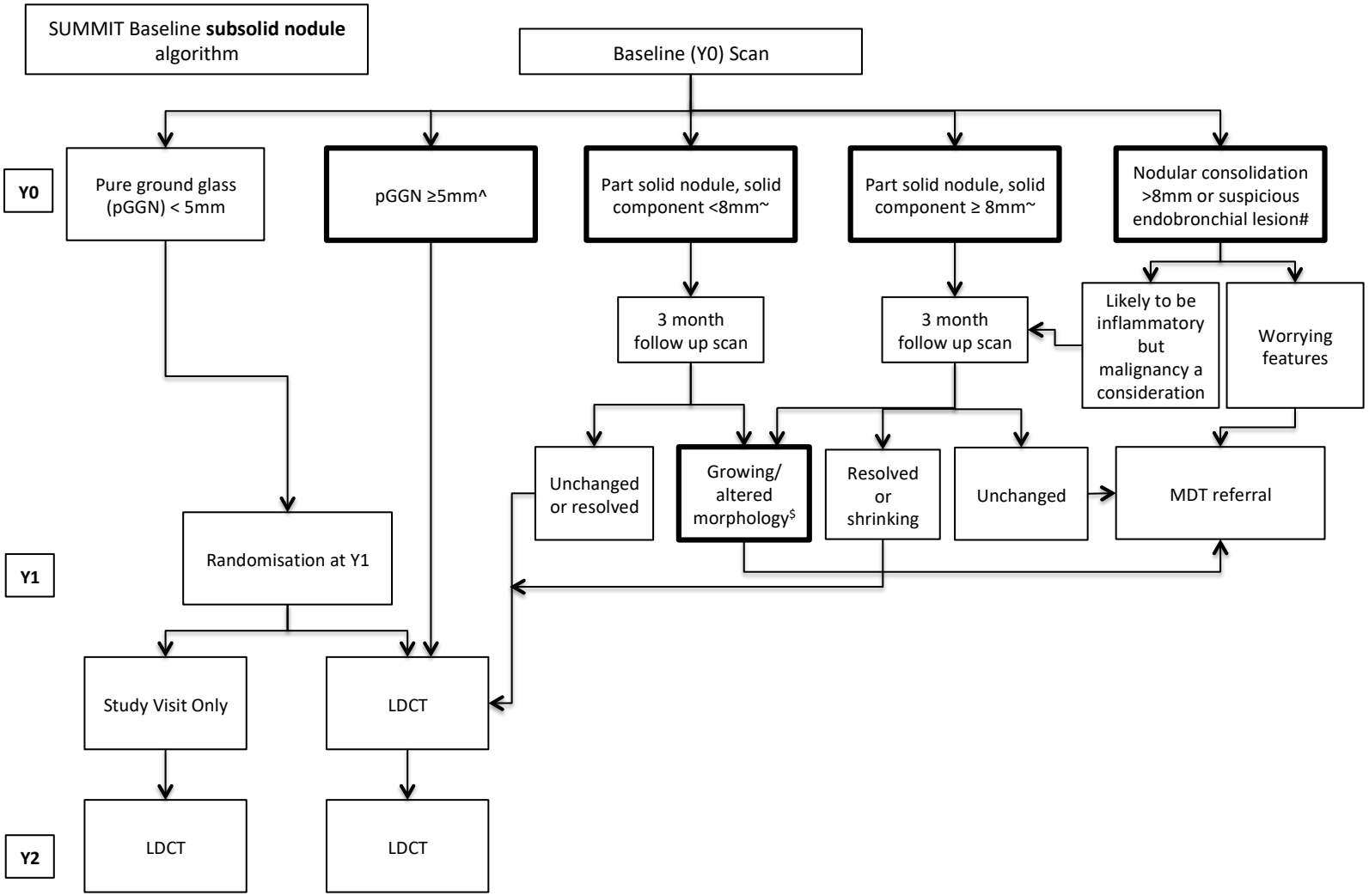
- Overall management is based on the largest nodule, or the nodule requiring most immediate follow-up.
- At any time point, radiologists can upgrade to next level of management if nodules are felt to have suspicious features and recommended management is felt not to be sufficient.
- Growing solid nodules should be >200mm^3 (or 8mm in diameter if unreliably segmented) before referral to multidisciplinary teams (MDTs) in order to prevent unnecessary referrals to secondary care sites. This is because for smaller nodules, MDTs are likely to recommend surveillance CT anyway, in which case this is best delivered within the screening programme. For nodules that have volumetrically grown ≥25% at 3 months but are ≤200mm^3, and nodules with unreliable volumetry that appear to have equivocally grown on visual inspection, a repeat CT in 3 months is performed within the study.
- In cases where volumetry is not possible for a solid nodule and diameter measurements are made, assessment should be based on unequivocal growth (as per BTS Guidelines).
- For sub-solid nodules (SSNs), 'growing morphology' refers to a new or increasing solid component. SSNs with 'altered morphology' refers to bubble-like lucencies or pleural retraction. If the solid component grows but is still <8mm, then the increase should be at least 2mm since the previous LDCT or observed on two CTs before MDT referral.
- Nodular consolidation >8mm or endobronchial lesions or other nodules >8mm that appear more likely to be inflammatory, but where malignancy is a consideration, may be scanned again at three months. If unchanged or growing at the follow-up scan, these should be referred to MDT. Opacities that are clearly

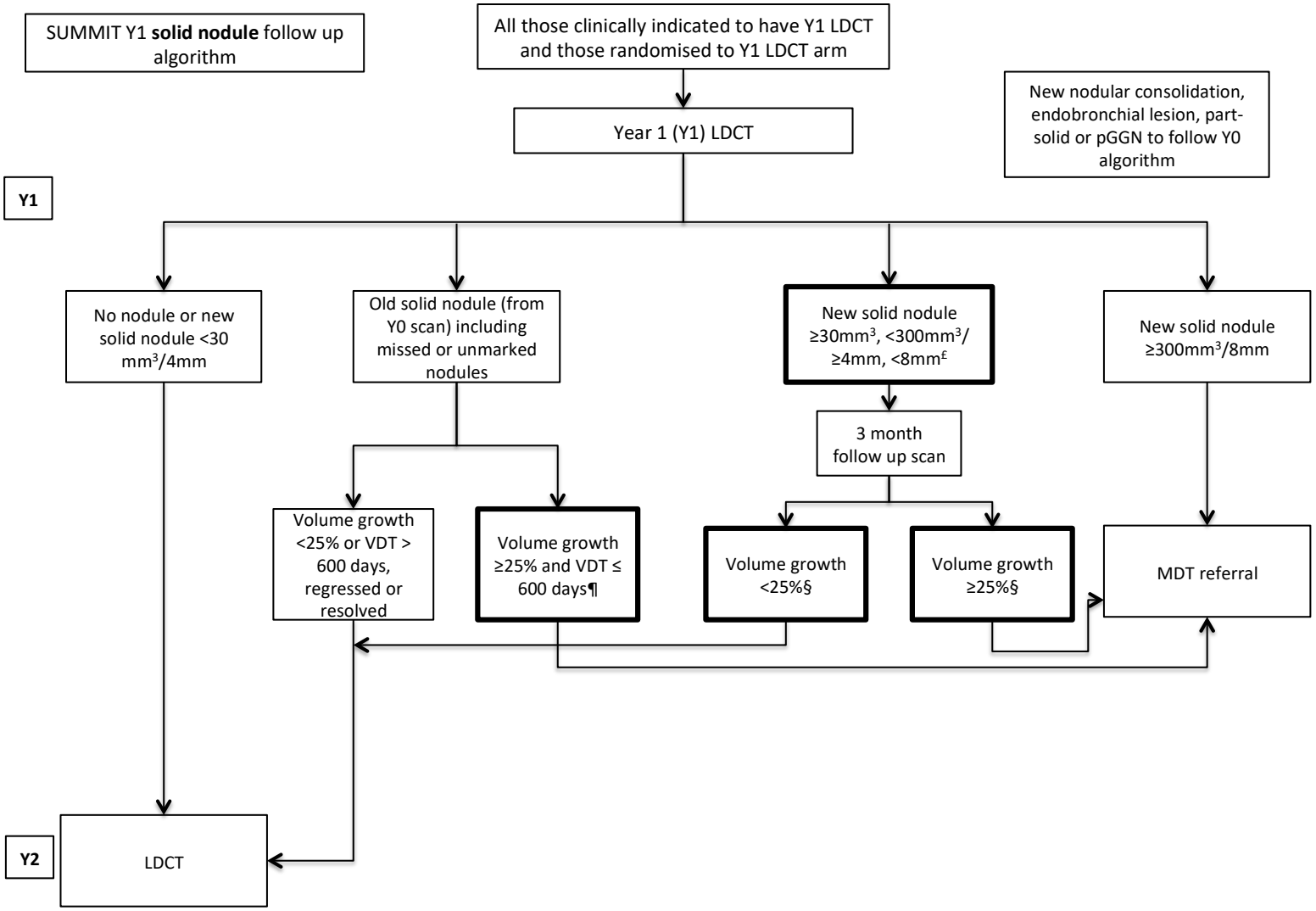
inflammatory (eg tree-in-bud or endobronchial mucous) and where malignancy is not a consideration do not require follow up.

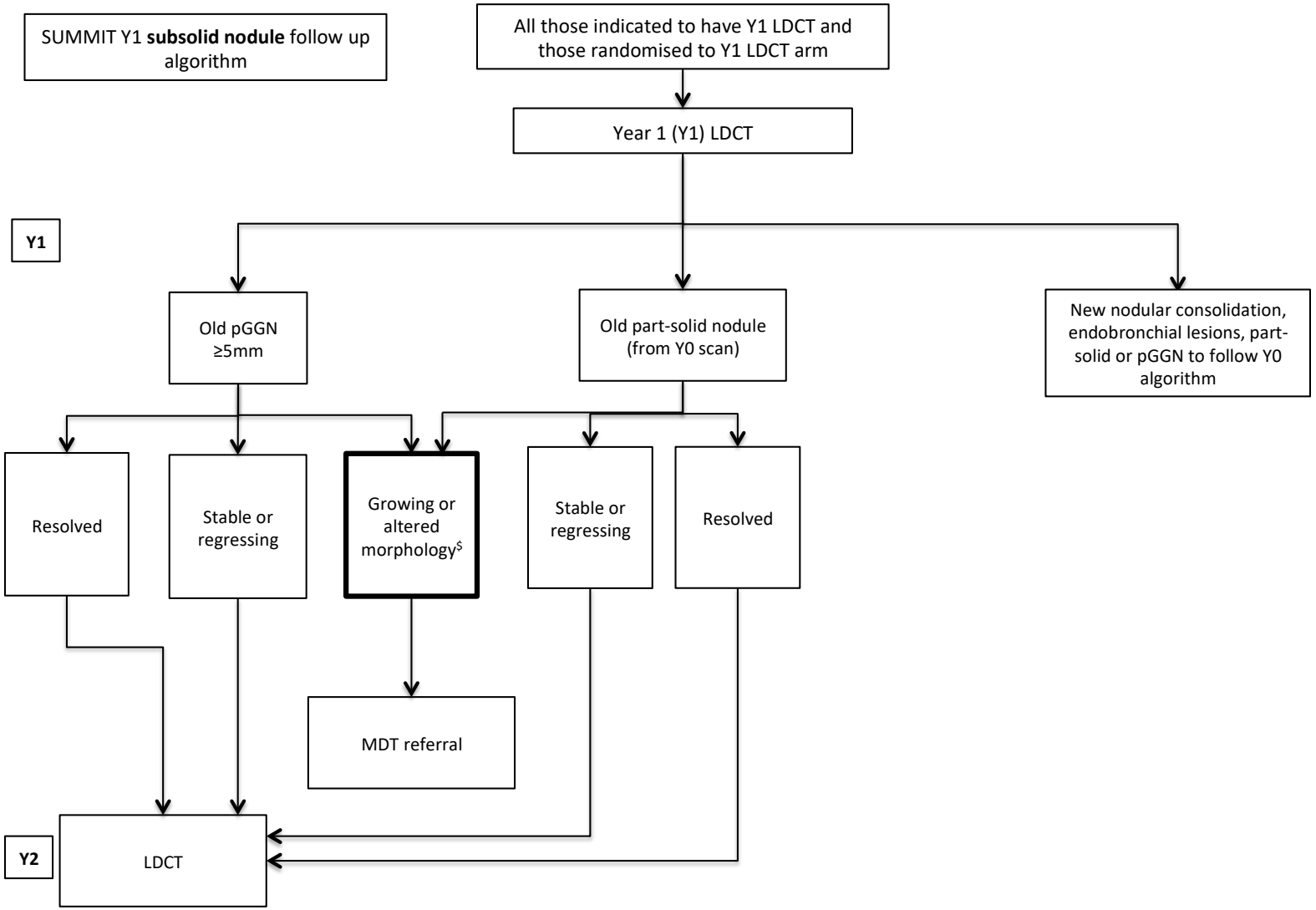
- If a part solid nodule has a solid component that is >90% of the total nodule size, then this nodule is considered solid and is assessed as such(4).
- Intrapulmonary lymph nodes (IPLNs), also known as perifissural nodules, are nodules with specific benign characteristics, including triangular or lentiform shape, often attached to a fissure. Nodules with these characteristics are highly unlikely to be malignant, and therefore can be marked and tagged with the appropriate classifier, but do not affect management and do not confer any follow-up requirement(5). This approach is consistent with BTS guidelines.

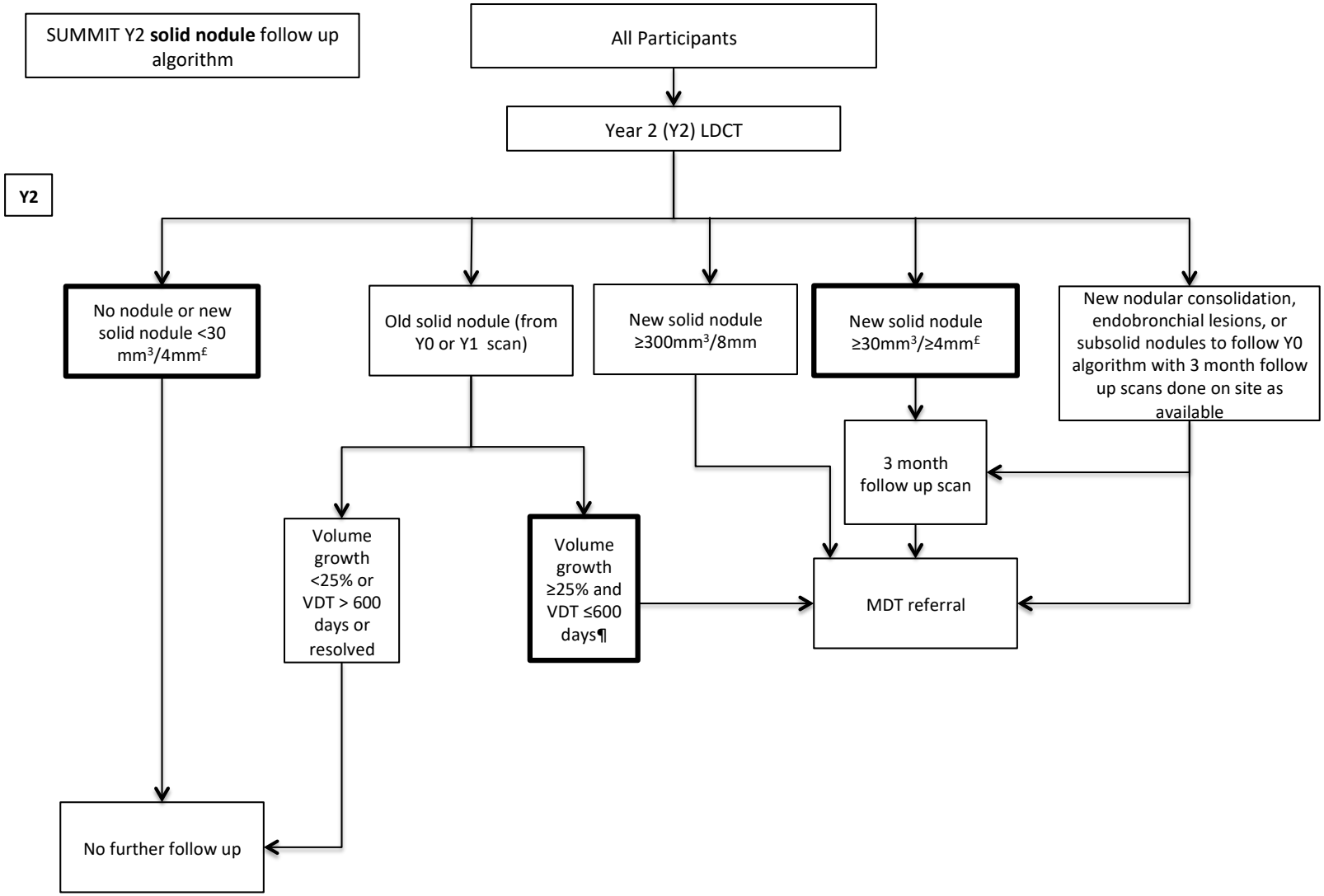
Figure S1—SUMMIT Pulmonary Nodule Protocol Flow Diagrams

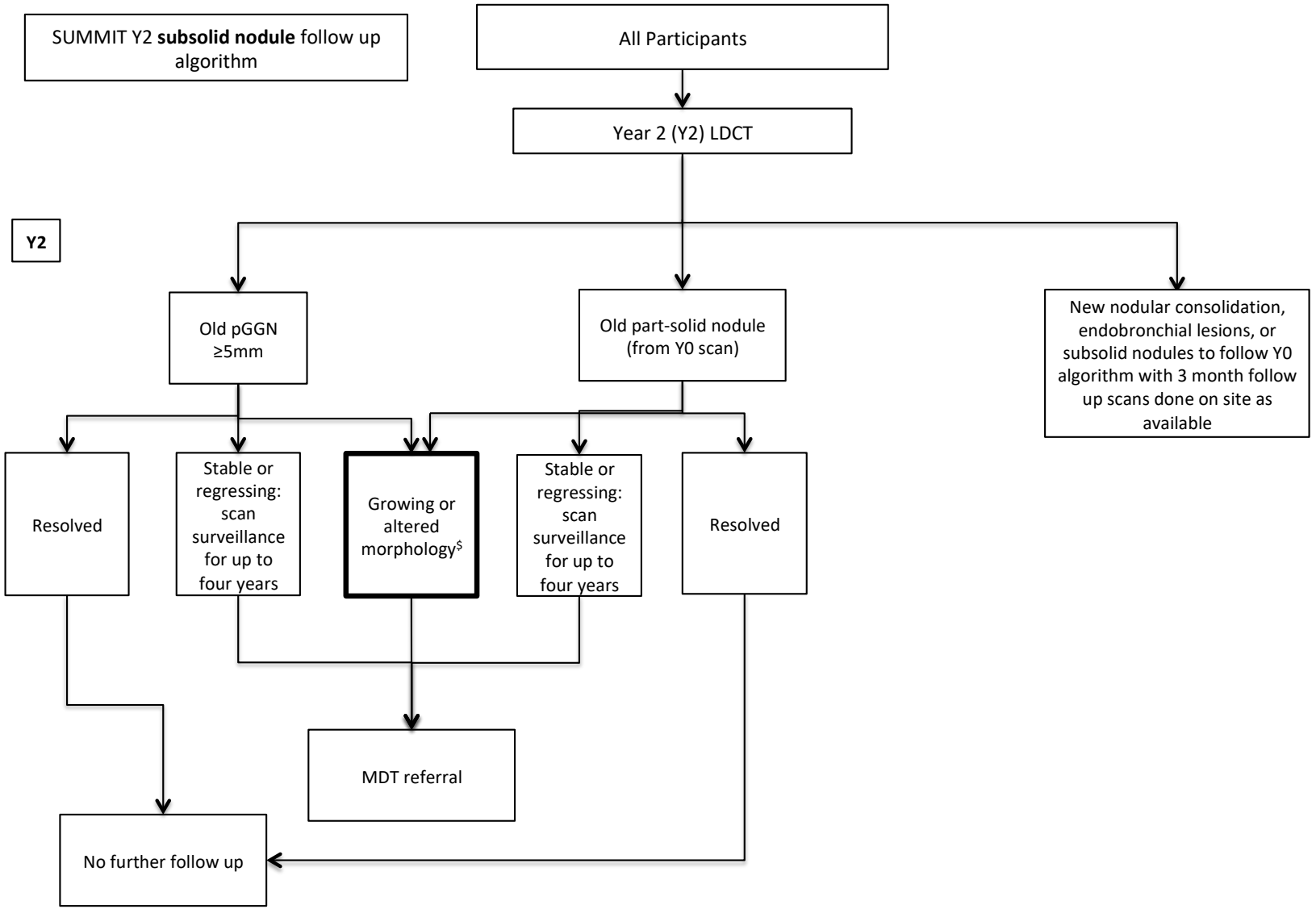

SUMMIT Baseline **solid nodule** algorithm
Baseline (Y0) Scan
Y0
No nodule or nodule with clear benign features or IPLNs
Nodule <80mm³/6mm*
Nodule ≥ 80mm³, <300mm³/ ≥6mm, <8mm
Nodule ≥300mm³/8mm Brock < 10%
Nodule ≥300mm³/8mm Brock ≥ 10%
3 month follow up scan
Volume growth <25% or resolved§
Volume growth ≥25% or unequivocal growth§
MDT referral
Randomisation at Y1
Y1
Study Visit Only
LDCT
Y2
LDCT
LDCT


SUMMIT Baseline **subsolid nodule** algorithm
Baseline (Y0) Scan
Y0
Pure ground glass (pGGN) < 5mm
pGGN ≥5mm^
Part solid nodule, solid component <8mm~
Part solid nodule, solid component ≥ 8mm~
Nodular consolidation >8mm or suspicious endobronchial lesion#
3 month follow up scan
3 month follow up scan
Likely to be inflammatory but malignancy a consideration
Worrying features
Unchanged or resolved
Growing/ altered morphology$
Resolved or shrinking
Unchanged
MDT referral
Y1
Randomisation at Y1
Study Visit Only
LDCT
Y2
LDCT
LDCT


SUMMIT Y1 **solid nodule** follow up algorithm
All those clinically indicated to have Y1 LDCT and those randomised to Y1 LDCT arm
Year 1 (Y1) LDCT
New nodular consolidation, endobronchial lesion, part-solid or pGGN to follow Y0 algorithm
Y1
No nodule or new solid nodule <30 mm³/4mm
Old solid nodule (from Y0 scan) including missed or unmarked nodules
New solid nodule ≥30mm³, <300mm³/ ≥4mm, <8mm£
New solid nodule ≥300mm³/8mm
3 month follow up scan
Volume growth <25% or VDT > 600 days, regressed or resolved
Volume growth ≥25% and VDT ≤ 600 days¶
Volume growth <25%§
Volume growth ≥25%§
MDT referral
Y2
LDCT


SUMMIT Y1 **subsolid nodule** follow up algorithm
All those indicated to have Y1 LDCT and those randomised to Y1 LDCT arm
Year 1 (Y1) LDCT
Y1
Old pGGN ≥5mm
Old part-solid nodule (from Y0 scan)
New nodular consolidation, endobronchial lesions, part-solid or pGGN to follow Y0 algorithm
Resolved
Stable or regressing
Growing or altered morphology$
Stable or regressing
Resolved
MDT referral
Y2
LDCT


SUMMIT Y2 **solid nodule** follow up algorithm
All Participants
Year 2 (Y2) LDCT
Y2
No nodule or new solid nodule <30 mm³/4mm£
Old solid nodule (from Y0 or Y1 scan)
New solid nodule ≥300mm³/8mm
New solid nodule ≥30mm³/≥4mm£
New nodular consolidation, endobronchial lesions, or subsolid nodules to follow Y0 algorithm with 3 month follow up scans done on site as available
3 month follow up scan
Volume growth <25% or VDT > 600 days or resolved
Volume growth ≥25% and VDT ≤600 days¶
MDT referral
No further follow up


SUMMIT Y2 **subsolid nodule** follow up algorithm
All Participants
Year 2 (Y2) LDCT
Y2
Old pGGN ≥5mm
Old part-solid nodule (from Y0 scan)
New nodular consolidation, endobronchial lesions, or subsolid nodules to follow Y0 algorithm with 3 month follow up scans done on site as available
Resolved
Stable or regressing: scan surveillance for up to four years
Growing or altered morphology$
Stable or regressing: scan surveillance for up to four years
Resolved
MDT referral
No further follow up

KEY

* Deviation from BTS: no provision for nodules 5-6mm in diameter (where volume not measured) to have 12 month follow up. These will be randomised at Y1 to annual or biennial scans.

§ Simplification of BTS: Volume doubling time (VDT) is not used for growth assessments at 3 month follow up for new or baseline nodules, as ≥25% growth at 3 months implies a VDT of less than 400 days. If volume growth is ≥25% but the nodule still has a volume ≤200mm^3, a repeat scan within the study is indicated, as an MDT referral for a nodule of that size is likely only to instigate further surveillance, which can take place within the study.

^Deviation from BTS: GGNs ≥5mm in diameter will be scanned at Y1 and Y2 for monitoring, but not before. Data has shown that GGNs, if persistent, are likely to represent adenocarcinoma in situ (AIS) are are therefore unlikely to require immediate intervention (4,6).

~Deviation from BTS: The Brock Score is not used for assessing PSNs, due to its likelihood of underestimating malignancy in this nodule type. Instead, a distinction has been made regarding the solid component diameter (<8mm≥) to try to minimise unnecessary referrals to MDTs, for nodules with small solid components that are stable, and may represent indolent or overdiagnosed cancers. For PSNs with larger solid components that persist, referral to MDT is indicated.

Addition to BTS: Opacities that are clearly inflammatory (eg tree-in-bud or endobronchial mucous) and where malignancy is not a consideration do not require follow up. Nodular consolidation >8mm or endobronchial lesions or other nodules >8mm that appear more likely to be inflammatory, but where malignancy is a consideration, may be scanned again at three months. If these nodules remain unchanged or are growing at the follow-up scan, they should be referred to MDT. Such opacities if <8mm should follow the normal nodule algorithm.

$ Addition to BTS: 'Growing morphology' refers to a new or increasing solid component. SSNs with 'altered morphology' refers to bubble-like lucencies or pleural retraction. If the solid component grows but is still <8mm, then the increase should be at least 2mm since the previous LDCT or observed on two CTs before MDT referral, as a repeat surveillance scan is the most likely outcome from from MDT for a nodule of this size, and this can be performed within the study.

£ Addition to BTS for a screening programme: new nodules which have developed since the previous annual scan should have a lower threshold (≥30mm^3 or 4mm diameter) for follow up, due to increased likelihood of malignancy (7).

¶ Deviation from BTS: VDT is applied at annual follow up scans and compared to baseline (or Y1) scans, as per BTS. VDT ≤ 600 days and volume growth of ≥25% is required for MDT referral to be made.; BTS has two VDT cut-offs (400 days and 600 days), which we have amalgamated into one cutoff for simplicity.

The SUMMIT Study Incidental Findings Management Protocol

The SUMMIT Study Incidental Findings Management Protocol was developed using guidelines and evidence available at the time of protocol development (2018). Where evidence or guidelines were not available, expert opinion was sought. The table below captures the clinically actionable findings that we are either following up within the study, or are asking that primary or secondary care colleagues follow up, where appropriate. Other data points, not listed here, are being collected for research purposes only, for example coronary artery calcification (CAC) and emphysema, as described in the main article text.

Table S1—SUMMIT Actionable Incidental Findings Protocol

Condition/finding	Description	Action by	Recommended action	Rationale
Lung cancer	Abnormality suggestive of lung cancer including consolidation and pleural thickening with worrying features, or unilateral pleural effusion.	Study team	Urgent referral to local lung cancer MDT.	Routine standard of care
Other cancer (non-lung)	Abnormality suggestive of cancer (non-lung) including breast lesions requiring triple assessment	Study team	Urgent referral to local site-specific cancer MDT.	Routine standard of care
Emphysema and COPD	Evidence of airflow limitation on pre-bronchodilator spirometry ($FEV_1/FVC<70\%$) who are not known to have COPD and report persistent chronic cough (duration > 6 weeks) and/or breathlessness (MRC score >1)	GP	Clinical review and consider post bronchodilator spirometry assessment for COPD.	NICE guidelines (8)
Bronchiectasis	Severe = luminal diameter relative to the accompanying artery diameter is greater than three times the size.	GP	Clinical review and if symptomatic a non-urgent referral to the local respiratory team.	Relationship between bronchiectasis imaging and disease severity(9)
Interstitial lung	>10% reticulation with fibrotic features i.e. traction	GP	Clinical review and non-urgent referral to local	ILD studies

disease	bronchiectasis, as this denotes significant degree of ILD that may be clinically significant.(10,11)		respiratory team.	(10,11) Specialist opinion
Diffuse Pleural Thickening	Diffuse pleural thickening without overtly worrying features.	Study team	Annual scan within the study.	Specialist opinion
Bilateral pleural effusions	Bilateral pleural effusions.	GP	Participant and GP informed of finding and a recommendation made to investigate further for transudative causes, as per British Medical Journal (BMJ) article.	BMJ(12)
Lower respiratory tract infection (LRTI)	Self-reported acute (or deterioration in chronic) cough <3 weeks duration plus one or more of; fever, pleuritic pain, increased sputum production, shortness of breath or wheeze OR currently taking antibiotics prescribed for LRTI.	Study team	Delay study enrolment and LDCT by 6 weeks on one occasion only. Advise individual to seek review by usual pathway e.g. GP where required for antibiotic treatment if concerned.	SIGN guidelines (13)
Anterior mediastinal mass (suspected thymoma)	<3cm maximum diameter	Study team	Annual scan within study. Inform participant and GP. If stable on successive scans no further action.	ACR White Paper(14)
	≥3cm maximum diameter at baseline, OR <3cm but growing on successive scans OR with suspicious features (invasion, irregularity) OR changing morphology.	Study team	Urgent referral to local lung cancer MDT.	
Ascending thoracic aortic dilatation	<4cm	N/A	No further action required.	ACR Paper(15)
	≥4cm <5.5cm	GP	Non-urgent referral to cardiology team.	
	≥5.5cm	Study team	Urgent referral to local cardiothoracic team.	
Thyroid nodules	Punctate calcification or associated with local lymphadenopathy.	GP	Request outpatient ultrasound scan of neck.	ACR White Paper(16), specialist opinion
Adrenal opacities	<1cm	N/A	No action required.	NLST (17), ACR White Paper (18)
	1-4cm or Houndsfield Units (HU)>10	Study team	Annual scan within study. Inform participant and GP. If stable on successive scans no further action.	

	>4cm	Study team	Refer to local endocrine team.	
Abdominal aortic dilatation	<3cm	N/A	No action required.	NICE guideline(19)
	≥3cm <5cm	GP	Refer to local vascular team for surveillance.	
	≥5cm	Study team	Urgent referral to local vascular team for assessment.	
Abdominal solid organ abnormalities (kidney, liver, spleen)	Case by case basis. Radiologists are encouraged only to refer renal lesions if HU>10 (20) or if very likely to be abnormal (21).	Study team	Any abnormalities will be managed on a case by case basis.	NELSON (21), ACR White Paper (20)
Osteoporotic (wedge) vertebral fracture(s)	If reduction in height is >50% normal	GP	Refer for bone density assessment.	Specialist opinion

Additional notes

- Where the reporting radiologist has a high index of suspicion for cancer, but the study management protocol does not lead to an automatic urgent referral, they have the ability to override the protocolised management plan and the study team will arrange the relevant urgent referral.
- As this is a lung cancer screening programme, every attempt is made to limit the images to the thoracic cavity in order to decrease detection of clinically uncertain incidental findings, and to decrease radiation exposure to non-relevant areas
- Any emergency or very urgent findings will be managed by the study team on a case by case basis according to local services

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