Original research

Clinical and economic impact of extracardiac lesions on coronary CT angiography

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ABSTRACT

Objective When reporting coronary CT angiography (CCTA), extracardiac structures are routinely assessed, usually on a wide field-of-view (FOV) reconstruction. We performed a retrospective observational cross-sectional study to investigate the impact of incidental extracardiac abnormalities on resource utilisation and treatment, and cost-effectiveness.

Methods All patients undergoing CCTA at a single institution between January 2012 and March 2020 were identified. The indication for CCTA was chest pain or dyspnoea in >90%. Patients with ≥1 significant extracardiac findings were selected. Clinical follow-up, investigations and treatment were documented, and costs were calculated.

Results 4340 patients underwent CCTA; 717 extracardiac abnormalities were identified in 687 individuals (15.8%; age 62±12 years; male 336, 49%). The abnormality was already known in 162 (23.6%). Lung nodules and cysts were the most common abnormalities (296, 43.1%). Clinical and/or imaging follow-up was pursued in 292 patients (42.5%). Treatment was required by 14 patients (0.3% of the entire population), including lung resection for adenocarcinoma in six (0.1%). All but two abnormalities (both adenocarcinomas) were identifiable on the limited cardiac FOV. The cost of reporting (£20) and follow-up (£33) of extracardiac abnormalities was £53 per patient. The cost per discounted quality-adjusted life year was £23 930, increasing to £46 674 for reporting the wide FOV rather than the cardiac FOV alone.

Conclusions Extracardiac abnormalities are common on CCTA, but identification and follow-up are costly. The few requiring treatment are usually identifiable without review of the wide FOV. The way in which CCTAs are scrutinised for extracardiac abnormalities in a resource-limited healthcare system should be questioned.

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INTRODUCTION

Coronary CT angiography (CCTA) is increasingly the first-line investigation for patients presenting with angina.[1] To analyse the coronary arteries, tomograms are reconstructed using a relatively tight field of view (FOV) encompassing the heart. However, because the X-ray beam has traversed the entire width of the chest, it is easy to reconstruct an additional wide FOV dataset. This allows a more extensive assessment of extracardiac structures (especially the lungs) that were not of primary interest to the referrer. Incidental findings are common,[2–12] and review of the available reconstructions for extracardiac abnormalities is routine in radiology departments in many countries, increasing the time required to report CCTA. When cardiac findings have been reported by a cardiologist, this may necessitate a separate read by a radiologist.

Although incidental extracardiac abnormalities—typically lung nodules—are frequently seen on CCTA,[2–12] only a minority will ultimately require specific treatment with the potential for prognostic benefit. To achieve this, a large proportion will be subjected to further imaging—often requiring additional radiation exposure—and clinical follow-up. This generates patient anxiety, risk and healthcare expense. We performed a retrospective observational cross-sectional study of patients undergoing CCTA in our tertiary cardiac centre over a period of >8 years. We quantified the burden of clinical and imaging follow-up triggered by incidental extracardiac abnormalities, in relation to the proportion that subsequently required specific treatment. The cost-effectiveness of scrutinising CCTA studies for extracardiac abnormalities was also considered.

MATERIALS AND METHODS

Patients

We identified all patients undergoing clinically indicated gated cardiovascular CT studies between January 2012 and March 2020 from our Computerised Radiology Information System. Patients in whom craniocaudal coverage was extended above the carina or below the diaphragm were excluded (figure 1). This was a retrospective observational study in patients who had undergone clinical scans, so written informed consent and ethical committee approval were not obtained. Patients and the public were not involved in the design, conduct, reporting or dissemination plans of our research.

CT imaging and reporting

The indication for CCTA was chest pain or dyspnoea in >90% of cases. Scans were performed using several General Electric 64-detector and 256-detector scanners and a Canon Aquilion One 320-detector scanner. Best-phase cardiac reconstructions were reviewed and reported by experienced imaging cardiologists (>90%) or radiologists. A wide FOV dataset was reconstructed for all patients and was reported by a radiologist. Cardiac and extracardiac findings were combined into a single clinical report.

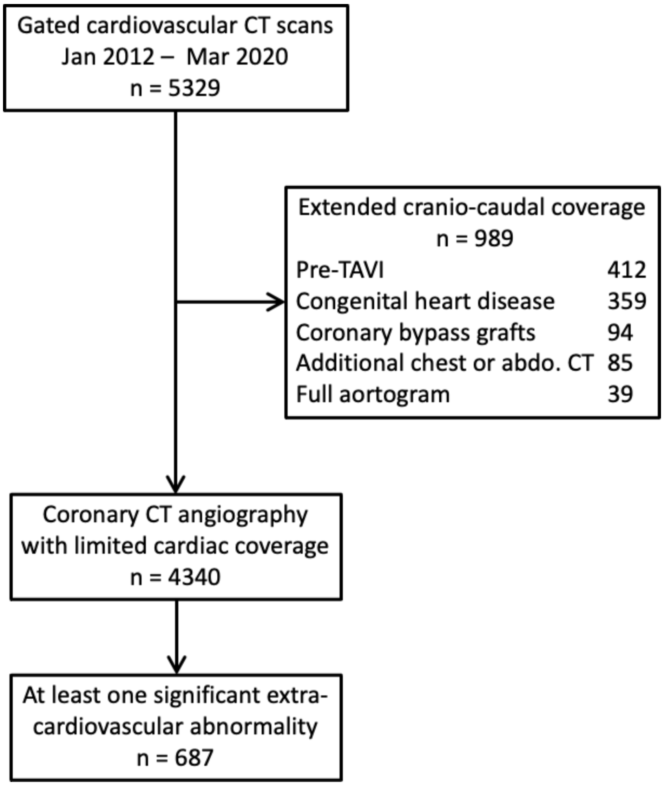

Figure 1 Study flow chart. TAVI, transcatheter aortic valve implantation.

Table 1 Findings in 687 patients with ≥1 extracardiac abnormality

Lesion	Total (%)	As sole finding	With other finding(s)
Lung nodule or cyst	296 (41.3)	279 (42.3)	17 (29.3)
Lung infection	134 (18.7)	126 (19.1)	8 (13.8)
Interstitial lung disease	78 (10.9)	65 (9.9)	13 (22.4)
Oesophagus/stomach	62 (8.6)	52 (7.9)	10 (17.2)
Upper abdominal organ	44 (6.1)	42 (6.4)	2 (3.4)
Chronic airways disease	30 (4.2)	29 (4.4)	1 (1.7)
Mediastinal lymphadenopathy	20 (2.8)	16 (2.4)	4 (6.9)
Breast	16 (2.2)	14 (2.1)	2 (3.4)
Pleura	13 (1.8)	13 (2.0)	0 (0)
Mediastinal mass	8 (1.1)	8 (1.2)	0 (0)
Metastatic cancer	5 (0.7)	5 (0.8)	0 (0)
Lung collapse	4 (0.6)	3 (0.5)	1 (1.7)
Spine	3 (0.4)	3 (0.5)	0 (0)
Pulmonary vascular	2 (0.3)	2 (0.3)	0 (0)
Diaphragm	1 (0.1)	1 (0.2)	0 (0)
Thyroid	1 (0.1)	1 (0.2)	0 (0)
Total	717 (100)	659 (100)	58 (100)

Follow-up

Reports were scrutinised to identify patients with ≥1 potentially significant non-cardiovascular findings. Patients with abnormalities that were stated to be of no clinical importance by the reporting radiologist were not included. The Computerised Radiology Information System and Electronic Patient Record were interrogated for each patient to establish what additional investigations, clinical follow-up and treatment resulted directly from the identification of each extracardiac abnormality. For patients undergoing follow-up, both the cardiac FOV and wide FOV were reviewed (by author AK) to see if the extracardiac abnormality was clearly identifiable on the former.

Follow-up of each abnormality was at the discretion of the referring clinician, informed by the advice of the reporting radiologist. During the 8-year period covered by the study, both the British Thoracic Society (2015) and the Fleischner Society (2017) published updated guidelines for the follow-up of lung nodules.[13 14] We compared the prevalence and rate of follow-up of lung nodules during periods before, between and after publication of the two documents.

Costs

Costs for investigations and outpatient clinics were the NHS tariffs for the year 2019–2020 (online supplemental table 1).[15] The reporting tariff for a CT scan of one area (£20) was used to reflect our usual practice of extracardiac reporting by a radiologist following cardiac reporting by a cardiologist. A cost of £20 was allocated for any discussion at a multidisciplinary meeting. We included only costs accruing up to the point of discharge from follow-up or initiation of treatment. The cost of treatment itself, whether surgical or medical, was not included: had patients not had their extracardiac lesion detected on CCTA, we assumed that they would have required similar treatment at a later (symptomatic) stage.

Clinical benefit of early detection of lung cancer

We anticipated that the main health gain of extracardiac reporting would arise from identification of lung cancer at an early stage. In the context of CT screening programmes, Whynes[16] has described a method for estimating this benefit (online supplemental methods). The UK's National Institute for Health and Care Excellence (NICE) requires that health gains be expressed as quality-adjusted life years (QALYs), discounted at the same interest rate as that used for discounting costs (3.5% per annum).[17] Applying this to real-life data from the UK Lung Cancer Screening pilot trial yields an average gain per cancer identified of 1.6 QALYs discounted.[18]

Statistical analysis

Continuous variables are expressed as mean±SD if normally distributed, or median (25th–75th centile) otherwise. A χ^2 test was used to compare the prevalence and rate of follow-up of lung nodules during the three consecutive time periods.

RESULTS

Range of extracardiac abnormalities

Between January 2012 and March 2020, 5329 gated cardiovascular CT studies were performed (figure 1). Nine hundred and eighty-nine involved extended craniocaudal coverage and were excluded. Among the remaining 4340, 717 significant extracardiac abnormalities were identified in 687 patients (15.8%; mean age 62±12 years; male 336, 49%) (table 1). Lung nodules and cysts constituted the largest category and were found in 296 patients (43.1%; 41.3% of total lesions). Appearances suggestive of subclinical lung infection and interstitial lung disease were also frequent.

Follow-up

The clinical courses of the 687 patients are shown in table 2. Information was unavailable for 16 patients who were out of area. In 162 patients (23.6%), the extracardiac abnormality was known from previous imaging. Further follow-up was

Table 2 Clinical outcome in 687 patients with ≥1 extracardiac abnormality

Outcome	All (%)	Nodules (%)	ILD (%)	Other (%)
Out of area	16 (2.3)	12 (4.1)	1 (1.3)	3 (0.9)
Unknown finding				
No follow-up	226 (32.9)	42 (14.2)	19 (24.4)	166 (49.6)
No action after follow-up	236 (34.4)	175 (59.1)	18 (23.1)	56 (16.7)
Ongoing follow-up	30 (4.4)	25 (8.4)	4 (5.1)	4 (1.2)
Surgical or medical treatment	14 (2.0)	9 (3.0)	4 (5.1)	1 (0.3)
Treatment of unexpected pathology	3 (0.4)	1 (0.3)	2 (2.6)	0 (0.0)
Known finding				
No new follow-up	153 (22.3)	29 (9.8)	29 (37.2)	100 (29.9)
No action after follow-up	9 (1.3)	3 (1.0)	1 (1.3)	5 (1.5)
Total	687 (100)	296 (100)	78 (100)	335 (100)

Numbers in rows do not sum to the total because of patients with multiple abnormalities.
ILD, interstitial lung disease

triggered in nine of these, but none of them subsequently required any alteration in treatment. Of 509 patients with previously unknown findings, clinical and/or imaging follow-up was pursued in 283 (55.6%). Follow-up remains ongoing in 30 patients (25 with lung nodules), with a median duration to November 2021 of 27 (23-36) months. Patients with lung nodules (210/252, 83.3%) or findings suggestive of interstitial lung disease (28/47, 59.6%) were more likely to undergo follow-up and/or treatment than those with other findings (61/227, 26.9%).

In 231 of the 292 patients who underwent follow-up, both the cardiac FOV and wide FOV reconstructions were accessible for review from the radiology Picture Archiving and Communication System. The extracardiac abnormality was clearly visible on the cardiac FOV in 130 (56.3%). One hundred and seventy of the patients were followed for lung nodules or cysts, and the lesion was clearly visible on the cardiac FOV in 82 (48.2%).

The prevalence of reported lung nodules was similar during the time periods 2012–2015, 2016–2017 and 2018–2020 (table 3). There was no significant difference in the proportions of nodules undergoing follow-up or leading to resection for lung cancer.

Table 3 Temporal trends in reported prevalence and rate of follow-up of previously unknown lung nodules

	Total	2012–2015	2016–2017	2018–2020	p value
Total CCTAs	4308	1050	1024	2234	
Lung nodules (% CCTAs)	264 (6.1)	65 (6.2)	49 (4.8)	150 (6.7)	NS
Follow-up (% nodules)*	210/252 (83.3)	49/59 (83.1)	40/49 (81.6)	121/144 (84.0)	NS
Lung cancer (% nodules)	6 (2.3)	2 (3.1)	1 (2.0)	3 (2.0)	NS

*Excludes patients out of area.
CCTA, coronary CT angiography; NS, not statistically significant (p value >0.05).

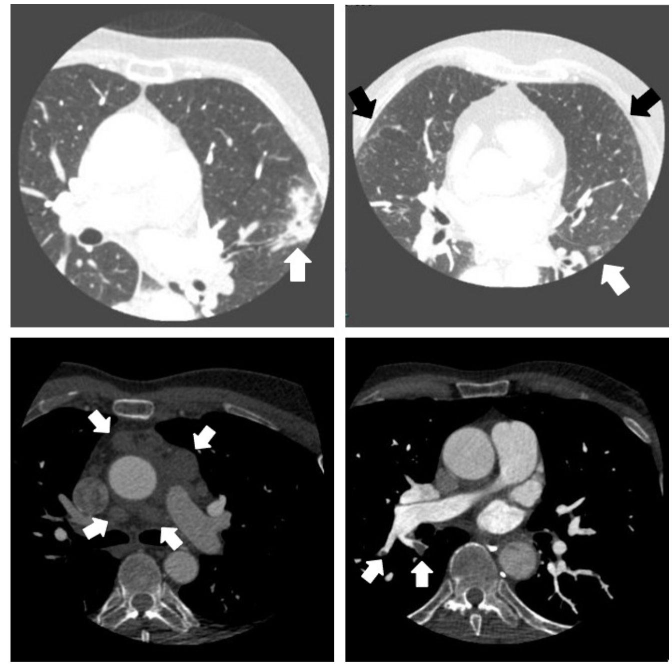

Figure 2 Four example cases where an extracardiac abnormality seen on CCTA led to a change in treatment. All images are transaxial tomograms from the cardiac (limited FOV) reconstruction. Top left: adeno-squamous carcinoma; a 30 mm spiculated cavitating mass is seen in the left upper lobe (white arrow). Top right: idiopathic pulmonary fibrosis; reticulation is seen peripherally (black arrows) and more densely in the anterior left lower lobe along the oblique fissure, with a small focal area of opacification (white arrow). Bottom left: Hodgkin's disease; enlarged mediastinal and subcarinal lymph nodes are seen (white arrows). Bottom right: emboli in right lower lobe segmental pulmonary arteries (white arrows).

Changes in treatment

Treatment was changed in 14 patients (0.3% of the entire population) after identification of an extracardiac finding and its subsequent follow-up (examples in figure 2). Eight patients with lung nodules underwent video-assisted thoracoscopic surgical (VATS) lung resection, all within 9 months of CCTA: six for carcinoma, one for a typical carcinoid and one for an inflammatory myofibroblastic tumour. All of the carcinomas were adenocarcinomas, only one of whom (16.7%) was known to have smoked. The smallest was 13 mm on the index CCTA. One patient with lung nodules was diagnosed with classic Hodgkin's disease and received chemotherapy. Four patients with newly diagnosed interstitial lung disease received medical therapy: all of these were dyspnoeic at the time and had deteriorating pulmonary function tests. One patient with dyspnoea had segmental pulmonary emboli and was anticoagulated. All but two of the treated lesions (both adenocarcinomas) were clearly visible on the cardiac FOV as well as on the wide FOV images.

In three other patients, follow-up imaging for an extracardiac abnormality seen on CCTA identified a previously occult and unrelated lesion requiring treatment. (1) CT follow-up for atelectasis revealed new and progressive multifocal ground glass opacification, which resolved on stopping amiodarone. (2) CT follow-up for possible interstitial lung disease identified a large left renal cell carcinoma, which was resected. (3) CT follow-up for a lung nodule demonstrated multiple lytic bone lesions due to multiple myeloma, which was treated with chemotherapy.

Table 4 Additional appointments and diagnostic procedures attended by patients followed as a result of one or more extracardiac finding on CCTA

Imaging procedure or appointment	All patients (n=292)	Lung nodules (n=213)
Clinical		
Outpatient clinic	149	92
Virtual (mainly lung nodule) clinic	328	316
Multidisciplinary meeting	52	44
Cost	*£47 553*	*£37 260*
Imaging		
CT	490	414
PET-CT	28	28
Mammography with breast ultrasound scan	9	4
Ultrasound scan	11	4
MRI	17	5
CT-guided lung biopsy	8	8
Ultrasound-guided breast biopsy	5	2
Other tests		
Pulmonary function tests	64	37
Bronchoscopic procedures	14	9
Cost	*£95 375*	*£76 483*
Total cost	***£142 928***	***£113 743***

Total numbers of appointments/procedures are shown, with the total cost in each section.
PET-CT, positron emission tomography with CT.

Costs and cost-effectiveness of follow-up

Table 4 shows the total numbers and costs of additional appointments and diagnostic procedures attended by the 292 patients following extracardiac findings. Further CT scans, chiefly non-contrast scans of the chest, were the most common downstream investigation (490), and the majority were performed in patients with lung nodules (414, 84.5%). The majority of patients completing follow-up for previously unknown lung nodules required only one subsequent chest CT (104/183, 56.8%).

The cost of reporting the wide FOV in all 4340 patients (£20 per patient) was £86 800. The cost of consequent clinical and imaging follow-up was £142 928 (£33 per patient), making a total of £229 728 (£53 per patient). For those with lung nodules, the cost of follow-up was £113 743: £537 per patient followed. The total health gain from identification of the six carcinomas was 9.6 discounted QALYs, implying a cost per discounted QALY of £23 930.

Compared with inspection of the cardiac FOV alone, separate examination of the wide FOV in all patients cost £86 800 for initial reporting plus an estimated £62 558 for follow-up of additional abnormalities, making a total of £149 358 (£34 per patient). Given that only two of the resected lung carcinomas were identifiable on the wide FOV alone, the cost per discounted QALY was £46 674.

DISCUSSION

This is one of the largest studies to have investigated the prevalence of extracardiac abnormalities on CCTA (online supplemental table 2).[2–12] We have focused on the need for a change in treatment as the most meaningful indication of a clinically 'significant' lesion. Importantly, we have considered the downstream costs and cost-effectiveness associated with detection of extracardiac abnormalities.

In 2016, NICE recommended CCTA as the first-line investigation for patients with angina of recent onset.[1] In response, the British Society of Cardiovascular Imaging/CT estimated that full implementation would require a sevenfold increase in CCTA activity.[19] The Royal College of Radiologists has calculated 'a current estimated shortage of 1939 consultant radiologists, equivalent to a third (33%) of the workforce' in the UK.[20] The shortfall is likely to be amplified in the aftermath of the COVID-19 pandemic. Detailed reporting of extracardiac findings in every patient undergoing CCTA is time consuming and generates downstream testing and follow-up. This expenditure of limited resources can only be justified if it leads to cost-effective benefits for patients.

Burden of extracardiac findings

In our large series, 16% of patients had ≥1 significant extracardiac abnormality on CCTA, of which 43% (7% of the overall population) were lung nodules or cysts with the potential to represent cancer. While this burden of extracardiac findings is significant, it is lower than that found in most previous studies where values up to 70% have been quoted (online supplemental table 2).[2–12] The discrepancy may be due to the varying threshold of radiologists for reporting borderline abnormalities. Moreover, in some previous studies extracardiac vascular findings (eg, aortic abnormalities) were included among the noncardiac abnormalities.

Lung cancers undergoing resection

In our study, treatment was ultimately changed in 14 patients (0.3%), of whom six patients (0.1%) underwent VATS lung resection of an adenocarcinoma: this is typical of the prevalence of lung cancer reported in previous studies (online supplemental table 2).[2–12] All six patients had a large nodule on the index CCTA (≥13 mm), and all underwent lung resection within 9 months of initial detection, rather than after prolonged CT follow-up. It should be noted that 25 patients with lung nodules remain under follow-up, and it is possible that one or more of these will ultimately require cancer surgery.

Previous studies have suggested that only a minority of lung nodules visible on the wide FOV reconstruction can be identified on the cardiac reconstruction.[2 6] Kim *et al*[7] used an imaging protocol that included a full chest CT following CCTA in a group of 11 654 patients. Of 36 lesions seen on the full chest CT that turned out to be lung cancer, 19 (53%) were visible on the wide cardiac FOV. Of these only four (21%) were detectable on the limited cardiac FOV. In contrast, we found that four of the six (66.7%) resected lung cancers were clearly visible on the limited cardiac reconstruction. The discrepancy may reflect interdepartmental differences in the rigour with which the lungs are excluded from the limited 'cardiac' reconstruction. It could also reflect differences in patient population or the play of chance, given the relatively small numbers of cancers.

Reporting lung nodules as a screening exercise

Asymptomatic lung nodules identified on a wide FOV reconstruction are equivalent to those discovered by deliberate screening. In response to the positive results of the National Lung Screening Trial (NLST) in the USA,[21] the Society of Cardiovascular CT (SCCT) has suggested that the wide FOV dataset should be routinely reconstructed and reported following CCTA in patients meeting the inclusion criteria for that study: age 55–74 years, ≥30 pack years of smoking.[22] An Australian prospective survey of 229 CCTA patients calculated that only 6% would fall into that category.[23] In NLST, only 36% of lung cancers were adenocarcinomas,[21] whereas in our cohort they all were. This predominance of adenocarcinomas is consistent with previous studies in CCTA patients.[7] Of the various types of lung cancer, adenocarcinomas show the weakest association with smoking,[24] and indeed only one of our six cancer patients is known to have smoked and might have been included in NLST. Therefore, the data provide little support for the SCCT's approach to selective lung cancer screening in CCTA patients.

Other pathologies receiving treatment

Eight patients with non-carcinomatous abnormalities received treatment, and all were clearly identifiable on the cardiac FOV. The prognostic value of presymptomatic detection is questionable in this group. Typical low-grade bronchial carcinoids and inflammatory myofibroblastic tumours are slow growing with little or no tendency to metastasise.[25 26] For Hodgkin's disease, cure rates remain high even at an advanced stage, with little difference between stages III and IV.[27] In the four patients with interstitial lung disease, treatment was initiated for progressive dyspnoea with deteriorating pulmonary function tests. There is no evidence that early detection would have improved prognosis.[28] The patient with segmental pulmonary emboli was being investigated as an outpatient for stable rather than acute dyspnoea, and any prognostic benefit of earlier anticoagulation in this setting is hard to quantify. Important non-cardiac diagnoses requiring treatment were made in a further three patients during imaging follow-up for an unrelated finding. Such indirectly identified lesions cannot reasonably be used as an argument for reporting extracardiac findings in CCTA.

Direct and downstream costs of reporting extracardiac findings and cost-effectiveness

Few previous studies have quantified the downstream costs of noncardiac findings on CCTA (online supplemental table 2). Machaalany *et al*[3] estimated a cost of Canadian $60 per patient (£36 at current exchange rates), Bendix *et al*[8] 58 euro per patient (£50) and Williams *et al*[10] £10 per patient. In our larger study, the cost of clinical and imaging follow-up was £33 per patient. None of the previous studies considered the resource implications of the initial extracardiac reporting, which we estimate adds a further £20 to the cost of each study in our practice. We recognise that this is controversial: a radiologist reporting extracardiac alongside cardiac findings does so seamlessly, and the additional time required may be modest (although not negligible). However, given the national shortage of radiologists in the UK, we would argue that future growth of CCTA will depend on cardiologists. Assigning a reasonable cost for separate radiological review of the wide FOV reflects this reality.

Neither Machaalany nor Williams considered the impact of extracardiac diagnoses on treatment or its likely benefit,[3 10] and hence they calculated costs but not cost-effectiveness. Bendix calculated a cost 'per life saved' of 40 190 euro (£34 307)[8] but used the questionable assumption that surgery for lung cancer was straightforwardly curative. Goehler *et al*[29] calculated a much larger cost per QALY of $154 700 (£115 319). Using lower UK costs and a higher estimate of prognostic benefit per cancer, we calculated a cost per discounted QALY of £23 930. This lies above the £20 000 threshold below which NICE would routinely consider an intervention to be cost-effective for the NHS.[17] However, if reporting the wide FOV reconstruction is analysed as a stand-alone procedure, the cost per discounted QALY is even higher at £46 674. Our findings and conclusions may not be straightforwardly applicable to other healthcare systems. Setting aside the variable costs of clinical and imaging follow-up, in more litigious countries a missed lung cancer could result in a costly lawsuit, which we have not considered in our calculations.

During the 8-year period covered by this study, guidelines were published that might have reduced the proportion of lung nodules undergoing follow-up.[13 14] However, we found no evidence of a change in the prevalence of 'significant' lung nodules being reported or the proportion undergoing follow-up. It is therefore unlikely that the cost-effectiveness of extracardiac reporting has improved with time in our population.

Identification of unexpected noncardiac findings on CCTA has additional non-financial costs that are harder to quantify. Radiation exposure from downstream imaging has carcinogenic potential that cannot be ignored given the low prevalence of cancers being sought. Moreover, significant psychological distress may be caused to patients by unexpected extracardiac findings—which might represent cancer—and the need for ongoing follow-up.[30]

CONCLUSIONS

Extracardiac findings are common on CCTA and generate a substantial burden of expensive clinical and imaging follow-up. However, subsequent changes in treatment are uncommon and, in our series, usually occurred in patients with lesions that were clearly visible on the cardiac reconstruction without recourse to the wide FOV. We conclude that formal review of the wide FOV dataset may represent a poor use of a radiologist's time, and an argument can be made that its reconstruction should be avoided unless clinically indicated. A quick examination of the cardiac

Key messages

What is already known on this subject?

⇒ Incidental extracardiac abnormalities are commonly identified on coronary CT angiography (CCTA). Some of these lesions, for example, potentially malignant lung nodules, may have prognostic implications. Their identification often triggers clinical and imaging follow-up, but few studies have attempted to quantify this relative to the proportion that subsequently require specific treatment. The overall cost-effectiveness of scrutinising CCTA studies for extracardiac abnormalities is poorly defined.

What might this study add?

⇒ Significant extracardiac abnormalities are identified on 16% of CCTA studies, and clinical and imaging follow-up is pursued in 43% of these. Specific changes in treatment are uncommon (0.3% of all scans), and 86% of these patients have obvious lesions on the limited field-of-view (FOV) cardiac reconstruction, with no need for a wide FOV reconstruction (that maximises lung coverage). The overall cost-effectiveness of detailed scrutiny of CCTA studies for extracardiac abnormalities is questionable: £23 930 per discounted quality-adjusted life year, increasing to £46 674 for reporting the wide FOV in addition to the cardiac FOV.

How might this impact on clinical practice?

⇒ Routine reconstruction and careful examination of the wide FOV dataset could be discontinued. A quick check of extracardiac structures visible on the cardiac reconstruction would suffice to identify the most clinically relevant lesions.

reconstruction for extracardiac lesions by the cardiac reporter might suffice to identify the most clinically relevant lesions.

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REFERENCES

1 NICE. Available: https://www.nice.org.uk/guidance/cg95 [Accessed 6 Jan 2022].
2 Northam M, Koonce J, Ravenel JG. Pulmonary nodules detected at cardiac CT: comparison of images in limited and full fields of view. *AJR Am J Roentgenol* 2008;191:878–81.
3 Machaalany J, Yam Y, Ruddy TD, *et al*. Potential clinical and economic consequences of noncardiac incidental findings on cardiac computed tomography. *J Am Coll Cardiol* 2009;54:1533–41.
4 Yorgun H, Kaya EB, Hazirolan T, *et al*. Prevalence of incidental pulmonary findings and early follow-up results in patients undergoing dual-source 64-slice computed tomography coronary angiography. *J Comput Assist Tomogr* 2010;34:296–301.
5 Lazoura O, Vassiou K, Kanavou T, *et al*. Incidental non-cardiac findings of a coronary angiography with a 128-slice multi-detector CT scanner: should we only concentrate on the heart? *Korean J Radiol* 2010;11:60–8.
6 Johnson KM, Dennis JM, Dowe DA. Extracardiac findings on coronary CT angiograms: limited versus complete image review. *AJR Am J Roentgenol* 2010;195:143–8.
7 Kim TJ, Han DH, Jin KN, *et al*. Lung cancer detected at cardiac CT: prevalence, clinicoradiologic features, and importance of full-field-of-view images. *Radiology* 2010;255:369–76.
8 Bendix K, Jensen JM, Poulsen S, *et al*. Coronary dual source multi detector computed tomography in patients suspected of coronary artery disease: prevalence of incidental extra-cardiac findings. *Eur J Radiol* 2011;80:109–14.
9 La Grutta L, Malagò R, Maffei E, *et al*. Collateral non cardiac findings in clinical routine CT coronary angiography: results from a multi-center registry. *Radiol Med* 2015;120:1122–9.
10 Williams MC, Hunter A, Shah ASV, *et al*. Impact of noncardiac findings in patients undergoing CT coronary angiography: a substudy of the Scottish computed tomography of the heart (SCOT-HEART) trial. *Eur Radiol* 2018;28:2639–46.
11 Karius P, Lembcke A, Sokolowski FC, *et al*. Extracardiac findings on coronary computed tomography angiography in patients without significant coronary artery disease. *Eur Radiol* 2019;29:1714–23.
12 Ramanathan S, Ladumor SB, Francis W, *et al*. Incidental non-cardiac findings in coronary computed tomography angiography: is it worth reporting? *J Clin Imaging Sci* 2019;9:40.
13 Callister MEJ, Baldwin DR, Akram AR, *et al*. British thoracic Society guidelines for the investigation and management of pulmonary nodules. *Thorax* 2015;70 Suppl 2:ii1–54.
14 MacMahon H, Naidich DP, Goo JM, *et al*. Guidelines for management of incidental pulmonary nodules detected on CT images: from the Fleischner Society 2017. *Radiology* 2017;284:228–43.
15 NHS. Available: https://www.england.nhs.uk/publication/past-national-tariffs-documents-and-policies/ [Accessed 6 Jan 2022].
16 Whynes DK. Could CT screening for lung cancer ever be cost effective in the United Kingdom? *Cost Eff Resour Alloc* 2008;6:5–16.
17 NICE. Available: https://www.nice.org.uk/process/pmg9 [Accessed 6 Jan 2022].
18 Field JK, Duffy SW, Baldwin DR, *et al*. Uk lung cancer RCT pilot screening trial: baseline findings from the screening arm provide evidence for the potential implementation of lung cancer screening. *Thorax* 2016;71:161–70.
19 BSCI. Available: https://bsci.org.uk/standards-and-guidelines/nice-cg95-update-2016/ [Accessed 6 Jan 2022].
20 RCR. Available: https://www.rcr.ac.uk/system/files/publication/field_publication_files/clinical-radiology-uk-workforce-census-2020-report.pdf [Accessed 6 Jan 2022].
21 National Lung Screening Trial Research Team, Aberle DR, Adams AM, *et al*. Reduced lung-cancer mortality with low-dose computed tomographic screening. *N Engl J Med* 2011;365:395–409.
22 Leipsic J, Abbara S, Achenbach S, *et al*. SCCT guidelines for the interpretation and reporting of coronary CT angiography: a report of the Society of cardiovascular computed tomography guidelines Committee. *J Cardiovasc Comput Tomogr* 2014;8:342–58.
23 Lyne C, Zaw S, King B, *et al*. Low rates of eligibility for lung cancer screening in patients undergoing computed tomography coronary angiography. *Intern Med J* 2018;48:1265–8.
24 Lee PN, Forey BA, Coombs KJ. Systematic review with meta-analysis of the epidemiological evidence in the 1900s relating smoking to lung cancer. *BMC Cancer* 2012;12:385.
25 Yoon JY, Sigel K, Martin J, *et al*. Evaluation of the prognostic significance of TNM staging guidelines in lung carcinoid tumors. *J Thorac Oncol* 2019;14:184–92.
26 Panagiotopoulos N, Patrini D, Gvinianidze L, *et al*. Inflammatory myofibroblastic tumour of the lung: a reactive lesion or a true neoplasm? *J Thorac Dis* 2015;7:908–11.
27 ONS. Available: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/datasets/cancersurvivalratescancersurvivalinenglandadultsdiagnosed [Accessed 6 Jan 2022].
28 NICE. Available: https://www.nice.org.uk/guidance/cg163 [Accessed 6 Jan 2022].
29 Goehler A, McMahon PM, Lumish HS, *et al*. Cost-effectiveness of follow-up of pulmonary nodules incidentally detected on cardiac computed tomographic angiography in patients with suspected coronary artery disease. *Circulation* 2014;130:668–75.
30 Slatore CG, Wiener RS, Golden SE, *et al*. Longitudinal assessment of distress among veterans with incidental pulmonary nodules. *Ann Am Thorac Soc* 2016;13:1983–91.

Supplementary Methods

Clinical benefit of early detection of lung cancer

We anticipated that the main health gain of extracardiac reporting would arise from identification of lung cancer at an early stage. In the context of CT screening programmes, Whynes has described a method for estimating this benefit.[16] Survival data for screened and unscreened cohorts is combined with data from actuarial life tables to estimate the increase in life expectancy of each patient with lung cancer identified with screening as opposed to a later presentation with symptoms. An estimate of the stage-specific time between identification with screening and symptomatic presentation is incorporated to account for lead-time bias.

The United Kingdom's (UK's) National Institute for Health and Care Excellence (NICE) requires that health gains be expressed as quality-adjusted life years (QALYs), to facilitate comparisons between health care interventions.[17] These are expected to be discounted at the same interest rate as that used for discounting costs (3.5% per annum). There are only limited longitudinal data on quality of life following treatment for lung cancer, particularly for those detected by screening. Based on evidence from patients presenting symptomatically, Whynes used a rounded value for the quality adjustment coefficient of 0.6 (ie a gain of 1 life year equates to 0.6 QALYs). These approaches were applied to real-life data from the UK Lung Cancer Screening pilot trial, and yielded an average gain per cancer identified by screening of 3.3 life years undiscounted, 2.1 life years discounted, 2.5 QALYs undiscounted, and 1.6 QALYs discounted.[18]

Supplementary Table 1: National Health Service tariffs for outpatient appointments and diagnostic tests (2019-2020)

HRG = Healthcare Resource Group; PET-CT = positron emission tomography with computed tomography

** Tariff for PET-CT, which is negotiated locally, was the median value calculated from the "Submitted local prices, 2015/16 to 2017/19" workbook*

HRG code	Procedure	Visit	Tariff (£)
	Clinical events		
103	Breast surgery outpatient appointment	First	179
		Follow-up	76
173	Thoracic surgery outpatient appointment	First	290
		Follow-up	114
302	Endocrinology outpatient appointment	First	235
		Virtual	64
303	Clinical haematology outpatient appointment	First	275
306	Hepatology outpatient appointment	First	279
		Follow-up	146
340	Respiratory medicine outpatient appointment	First	215
		Follow-up	96
		Virtual	65
341	Respiratory physiology	First	155
		Follow-up	77
370	Medical oncology outpatient appointment	First	272
	Multidisciplinary meeting		20

	Imaging investigations	
RD01A	Magnetic resonance imaging, 1 area, no contrast, >19y	108
RD03Z	Magnetic resonance imaging, 1 area, pre- and post-contrast	157
RD04Z	Magnetic resonance imaging, 2-3 areas, no contrast	135
RD20A	Computed tomography, 1 area, no contrast, >19y report only	20
RD20A	Computed tomography, 1 area, no contrast, >19y	69
RD21A	Computed tomography, 1 area, post contrast, >19y	83
RD26Z	Computed tomography, 3 areas, post contrast	97
RD40Z	Ultrasound scan, <20min, no contrast	39
RD42Z	Ultrasound scan, >20min, no contrast	49
RN03B	PET-CT, >3 areas, >19yo (median of local prices) *	837.25
	Invasive investigations	
DZ69A	Diagnostic bronchoscopy, >19y	569
DZ70Z	Endobronchial ultrasound examination mediastinum	1412
YD03Z	Percutaneous biopsy lesion of lung or mediastinum	864
YD05Z	Percutaneous aspiration of pleural cavity	552
YJ02Z	Unilateral core needle biopsy of lesion of breast	275
YJ09Z	Vacuum-assisted biopsy of lesion of breast	445

Supplementary Table 2: Comparison of published studies of >250 patients which quoted prevalences of extracardiac abnormalities, lung nodules and/or lung cancer on cardiac computed tomography

Study	**Patients**	**Extracardiac findings**	**"Suspicious" lung nodules**	**Lung cancer**	**Downstream costs**
		Electron-beam computed tomography			
Horton 2001 [S1]	1326	7.8%	4.9%	<0.1%	No
Hunold 2002 [S2]	1812	52.6%	1.1%	0.1%	No
Elgin 2002 [S3]	1000	7.9%	-	-	No
Schragin 2004 [S4]	1366	20.5%	3.4%	0	No
		Multi-detector computed tomography			
Onuma 2006 [S5]	503	58.1%	12.1%	0.4%	No
Gil 2007 [S6]	258	56.2%	20.2%	-	No
Kawano 2007 [S7]	617	24.1%	10.0%	0.6%	No
Burt 2008 [S8,9]	459	41.4%	17.6%	0	No
Northam	1764	-	11.5%	0.3%	No

2008 [2]					
MacHaalany 2009 [3]	966	41.5%	4.9%	0.3%	Yes
Chia 2009 [S10]	1061	8.0%	0.8%	-	No
Yorgun 2010 [4]	1206	-	7.5%	0.2%	No
Lazoura 2010 [5]	1044	56.3%	6.3%	0.2%	No
Johnson 2010 [6]	6920	23.7%	4.5%	<0.1%	No
Kim 2010 [7]	11,654	-	-	0.3%	No
Bendix 2011 [8]	1383	34.8%	0.7%	0.2%	Yes
La Grutta 2015 [9]	4303	69.6%	-	0.5%	No
Williams 2018 [10]	1778	38.0%	7.1%	0.2%	Yes
Karius 2019 [11]	3898	30.2%	4.3%	0.1%	No
Ramanathan 2019 [12]	1713	35.0%	-	0.1%	No
Our Study	**4340**	**15.8%**	**6.8%**	**0.1%**	**Yes**

Supplementary References

[S1] Horton KM, Post WS, Blumenthal RS, Fishman EK. Prevalence of significant noncardiac findings on electron-beam computed tomography coronary artery calcium screening examinations. *Circulation* 2002;106:532-4.

[S2] Hunold P, Schmermund A, Seibel RM, et al. Prevalence and clinical significance of accidental findings in electronbeam tomographic scans for coronary artery calcification. *Eur Heart J* 2001;22:1748-58.

[S3] Elgin EE, O'Malley PG, Feuerstein I, Taylor AJ. Frequency and severity of "incidentalomas" encountered during electron beam computed tomography for coronary calcium in middle-aged army personnel. *Am J Cardiol* 2002;90:543-5.

[S4] Schragin JG, Weissfeld JL, Edmundowicz D, et al. Non cardiac findings on coronary electron beam computed tomography scanning. *J Thorac Imag* 2004;19:82-6.

[S5] Onuma Y, Tanabe K, Nakazawa G, et al. Noncardiac findings in cardiac imaging with multidetector computed tomography. *J Am Coll Cardiol* 2006;48:402-6.

[S6] Gil BN, Ran K, Tamar G, Shmuell F, Eli A. Prevalence of significant noncardiac findings on coronary multidetector computed tomography angiography in asymptomatic patients. *J Comput Assist Tomogr* 2007;31:1-4.

[S7] Kawano Y, Tamura A, Goto Y, et al. Incidental detection of cancers and other non-cardiac abnormalities on coronary multislice computed tomography. *Am J Cardiol* 2007;99:1608-9.

[S8] Burt JR, Iribarren C, Fair JM, et al. Incidental findings on cardiac multidetector row computed tomography among healthy older adults: prevalence and clinical correlates. *Arch Intern Med* 2008;168:756-61.

[S9] Iribarren C, Hlatky MA, Chandra M, et al. Incidental pulmonary nodules on cardiac computed tomography: prognosis and use. *Am J Med* 2008;121:989-96.

[S10] Chia P-L, Kaw G, Wansaicheong G, Ho K-T. Prevalence of non-cardiac findings in a large series of patients undergoing cardiac multi-detector computed tomography scans. *Int J Cardiovasc Imaging* 2009;25:537-43.