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## Extra-cardiac findings at cardiac CT: experience with 1,764 patients

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**Abstract** To investigate incidental extra-cardiac findings (ECF) at cardiac CT based on indication and impact on patient management. We retrospectively reviewed the reports of 1,764 patients who underwent a cardiac CT study between January 1, 2004 and December 31, 2006, including 463 calcium scorings (CS), 737 coronary CT angiograms (CTA), 341 pulmonary vein stenoses (PVS), and 223 bypass grafts (CABG). ECFs were categorized by type of examination, anatomical location and clinical significance. Comparisons were made between examination types to determine if incidental findings varied by indication. There were 507 ECFs with at least one ECF in 441 patients (25.0%). By examination, there was at least 1 ECF in 79/463 CS studies (17.1%), 196/737 CTAs (26.6%), 80/341 PVSs (23.4%) and 86/223 CABGs (38.6%). In 325 patients (18.4%), the findings were considered

clinically important and occurred in 60/463 (12.9%) CSs, 149/737 (20.2%) CTAs, 56/341 (16.4%) PVSs and 60/223 (26.9%) CABGs. Differences between CABG and other indications and CTA vs. CS for incidental and clinically important findings were statistically significant ( $p < 0.05$ ). Extra-cardiac findings requiring follow-up occur in 18% of patients and are significantly more frequent in coronary artery CTA and coronary artery bypass studies than in calcium scoring studies.

**Keywords** Cardiac CT · Cardiac CTA · Extra-cardiac findings

**Abbreviations** CABG: Coronary artery bypass graft · CS: Calcium scoring · CTA: Computed tomography angiography · ECF: Extra-cardiac finding · FOV: Field of view · PVS: Pulmonary vein stenosis

### Introduction

Cardiac CT is well established for the evaluation of cardiac anatomy, determining the coronary atherosclerotic plaque burden and excluding significant coronary artery stenosis. These capabilities have heralded many valuable roles for cardiac CT, including, but not limited to, establishing the presence or absence of coronary artery atherosclerosis, evaluating patients with atypical chest pain, assessment of coronary artery bypass graft (CABG) patency and evaluation of pulmonary veins in the context of radiofrequency ablation for cardiac arrhythmia. Owing to its high negative

predictive value, cardiac CT is positioning itself as the primary non-invasive modality for coronary artery imaging in the low- and intermediate-risk patient [1]. Compared to traditional cardiac imaging tests, such as echocardiography, conventional coronary angiography and nuclear stress imaging, cardiac CT is unique because the cross-sectional data obtained during cardiac CT inherently contain information on the surrounding lungs, mediastinum, chest wall and upper abdomen with exquisite anatomical detail.

Owing to its cross-sectional nature, unlike the traditional tests for cardiac evaluation, cardiac CT also provides the opportunity to obtain alternative diagnoses that may

account for the patient's symptoms or detect important but clinically silent lesions, such as early stage lung cancer and aortic aneurysms. Reports suggest that incidental extra-cardiac findings (ECF) can be detected on cardiac CT studies in 15–90% of cases [2–12]. While the vast majority of these will turn out to be benign, pathologically important findings have been reported in 4.2–38% of cases [2–12]. These studies have generally focused on a single examination (calcium scoring, coronary CTA, CABG evaluation, etc.), and therefore comparisons between study indication and frequency of ECFs were not investigated. We therefore report our institutional 3-year experience with 1,764 consecutive patients in the detection of incidental ECFs at cardiac CT, their frequency based on indication for study and potential impact on patient management.

## Materials and methods

This study was approved with a waiver of consent from our local institutional review board (IRB), and the study was performed in compliance with the Health Insurance Portability and Accountability Act (HIPAA) regulations.

We retrospectively reviewed the reports of 1,764 patients who underwent cardiac CT imaging over a 3-year period (January 1, 2004–December 31, 2006), including 463 calcium scorings (CSs), 737 coronary CTAs (CTAs), 341 pulmonary vein stenosis (PVSs) and 223 CABG evaluations.

The technique used depended on the indication for study. All studies were performed on a 64-slice CT (Somatom Sensation Cardiac or Somatom Definition; Siemens, Forchheim, Germany). For calcium scoring, the studies were performed using prospective electrocardiogram (ECG) triggering from the carina of the trachea through the base of the heart with a 1.2-mm detector collimation, 120 kV, 150 effective mAs and 0.33-s gantry rotation time. Studies were reconstructed from the same raw data at 3-mm intervals for calcium scoring with a limited field of view (FOV) and a soft tissue reconstruction algorithm and 5-mm intervals for full FOV interpretation of the thorax using a lung reconstruction algorithm. The CTA and PVS studies were performed with retrospective ECG gating usually from below the level of the carina through the base of the heart with 0.6-mm collimation, 120 kV, 900 effective mAs (Sensation) or 360 effective mAs (Definition) and 0.33-s gantry rotation time. Because indications occasionally varied for CTA examinations, in 89 cases (12.1% of CTA studies) the z-axis was extended to the thoracic inlet. Studies were reconstructed at 0.75 mm for the cardiac data set and at 5-mm intervals for full FOV interpretation of the thorax, again using soft tissue and lung reconstruction algorithms, respectively. For CABG evaluation, the study protocol was similar to CTA except the z-axis was extended cephalad to include the subclavian arteries. For CTA, PVS and CABG, the pre-imaging delay was determined using a 20-ml test bolus injection. Intravenous contrast medium

(Iopamidol, Isovue 370; Bracco, Princeton, NJ) was injected at a rate of 5–6 ml/s with a total volume adjusted to imaging time followed by a 30–50 ml saline flush.

We always complete a qualitative assessment of the overall image quality then review the full available field of view, extending from outer rib to outer rib, encompassing the entire z-axis of the lung parenchyma within the imaged portion of the thorax, using lung, soft tissue, mediastinal and bone windows. Cardiac CT studies were clinically evaluated by the attending cardiothoracic radiologist of the day and one or two radiology residents. Based on the retrospective review of the radiology reports, only findings that were deemed to be significant enough to be included in the original final dictated impression were included in the study.

ECFs were classified in three separate ways: (1) by examination indication (CS, CTA, PVS and CABG), (2) by anatomical location of the abnormality (vascular, mediastinal, lung parenchyma, chest wall/pleura and abdominal) and (3) by clinical significance and the timing of diagnostic action/follow-up. Categories were emergent, i.e., needing immediate action or treatment (e.g., acute dissection, pulmonary embolus, pneumonia); urgent, i.e., needing workup within 30 days (e.g., pulmonary nodules  $\geq 10$  mm, findings suspicious for malignancy in the mediastinum, breast or abdomen, and aortic aneurysm); important, i.e., needing follow-up in 1–12 months (e.g., pulmonary nodules  $> 4$  mm and  $< 10$  mm, interstitial lung disease, pleural effusion and indeterminate liver/adrenal lesions); and minor, i.e., needing no specific imaging follow-up (e.g., atelectasis, emphysema, benign adrenal/liver lesions). As such, the classification of need for follow-up was based on the time course for clinical follow-up rather than the true severity of disease. For the purpose of our study, pneumonia was defined as any focal air-space opacity. These classifications were used because of their simplicity, self-explanatory nature and easy reproducibility. Finally, we determined the amount of findings that were considered clinically relevant enough to warrant short-term follow-up/further workup (groups 1–3) and compared them across the imaging indication.

## Statistical analysis

All statistical analyses and graphs were performed with Sigma Stat 3.5 and Sample Power 2.0 (SPSS, Chicago, IL).

**Table 1** Demographics by indication

Examination	Male	Female	Mean age (years)	Range
Calcium score	272 (58.7%)	191 (41.3%)	56.2	33–88
Coronary CTA	381 (51.7%)	356 (48.3%)	57.2	17–91
PVS	254 (74.5%)	87 (25.5%)	59.7	20–82
CABG	164 (73.5%)	59 (26.5%)	67.1	38–89

**Table 2** Total number of extra-cardiac findings by indication

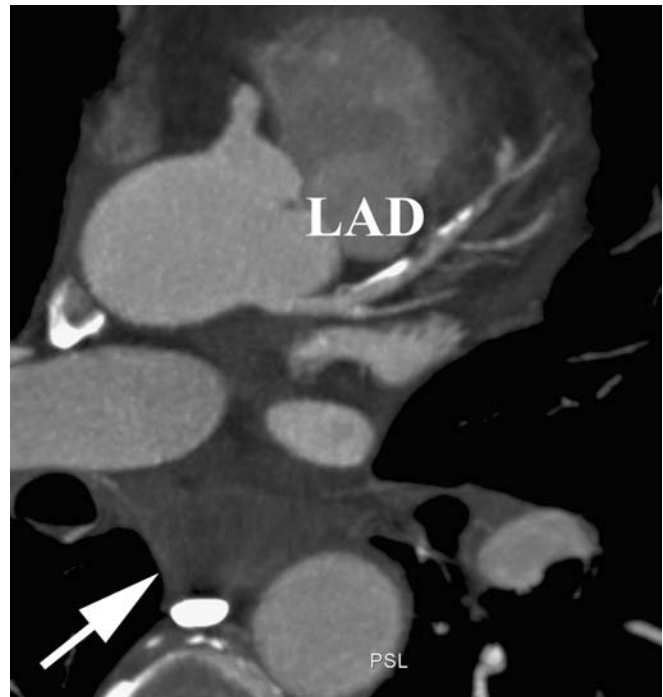
Examination	% With at least one ECF	% With at least one class I-III ECF
Calcium score	17.1% (79/463)	12.9% (60/463)
Coronary CTA	26.6% (196/737)	20.2% (149/737)
Pulmonary vein stenosis	23.4% (80/341)	16.4% (56/341)
Follow-up CABG	38.6% (86/223)	26.9% (60/223)

Differences statistically significant for CABG vs. CS, CTA and PVS, and CTA vs. CS for both categories ( $p < 0.05$ )

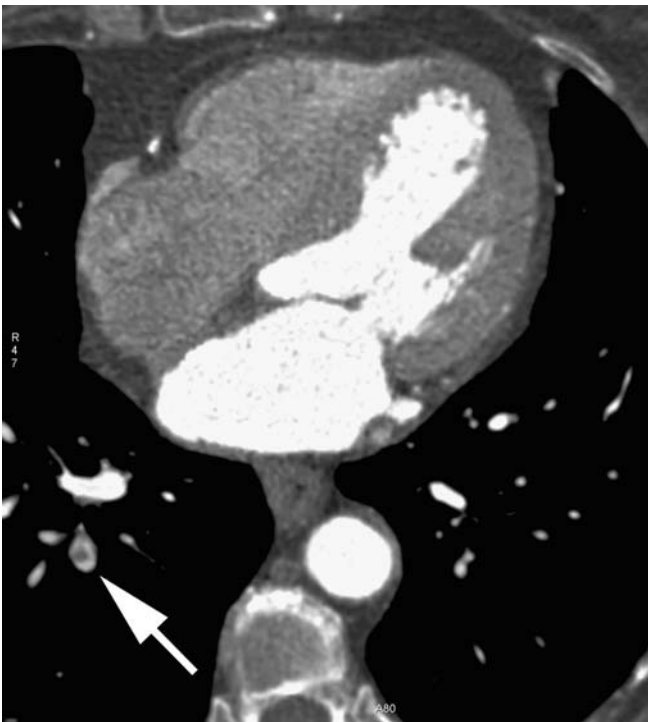
For both text and tables, categorical variables are presented as percentage (%), and continuous variables are presented as mean and range. A chi-square ( $X^2$ ) test was used to compare all findings and clinically important findings between indications. A  $P$  value of 0.05 or less was considered to indicate a statistically significant difference.

## Results

Overall, 1,764 examination reports were reviewed from 1,071 men and 693 women. The average age was 58.4 years (range 18–91). The patient demographics by indication are shown in Table 1. There was at least one ECF in 441 patients (25.0%) and 507 total findings. By



**Fig. 2** A 68-year-old man incidentally found to have esophageal cancer at cardiac CTA. Five-millimeter-thick maximum intensity projection transverse image reveals thickening of the esophageal wall and obstruction of lumen (arrow). Note also atherosclerotic disease with calcified and non-calcified plaque in left anterior descending artery (LAD)



**Fig. 1** A 78-year-old woman with incidental pulmonary embolus at cardiac CTA. ECG-gated contrast-enhanced transverse image reveals filling defect (arrow) in right lower lobe subsegmental artery



**Fig. 3** A 77-year-old man with incidentally detected lung cancer at CABG follow-up. ECG-gated contrast-enhanced transverse image reveals 1-cm mixed density nodule (arrow) in superior segment of left lower lobe



**Fig. 4** A 70-year-old woman with sternal metastasis from breast cancer at cardiac CTA. Sagittal reformatted image from ECG-gated contrast-enhanced study reveals soft tissue mass (arrow) eroding the posterior wall of the sternum

examination indication, there was at least 1 ECF in 79/463 CSs (17.1%), 196/737 CTAs (26.6%), 80/341 PVSs (23.4%) and 86/223 CABGs (38.6%). ECFs were significantly more frequent in CABG examinations compared with CS ( $p < 0.0001$ ), CTA ( $p < 0.05$ ) and PVS ( $p < 0.001$ ) and CTA studies compared to CS ( $p < 0.002$ ). In the CTA group, 30/89 (33.7%) of studies with an extended FOV had at least one ECF, compared to 166/648 (25.6%) in the standard FOV ( $p = 0.1357$ ) (Table 2).

Of the 507 total ECFs, in anatomical group 1 (vascular - aorta and pulmonary arteries) there were 24 (4.7%) findings (Fig. 1), in group 2 (mediastinal) 18 (3.6%) findings (Fig. 2), in group 3 (lung parenchyma) 337 (66.5%) findings (Fig. 3), in group 4 (chest wall/pleura) 69 (13.6%) findings (Fig. 4) and in group 5 (abdominal) 59 (11.6%) findings. The types of findings are summarized in Tables 3, 4, 5, 6, 7. On a percentage basis, the lung was the most frequently involved anatomical compartment. Notably, 200 (11.3%) of the patients had at least one pulmonary nodule and/or mass  $> 4$  mm.

Overall, 25 (4.9%) of the findings were considered emergent, 56 (11.1%) urgent, 280 (55.3%) important and 145 (28.7%) incidental. Classes 1–3 were considered clinically relevant for patient management, and combining these classes, there were 362 clinically relevant findings in 325 (18.4%) patients in our study. Comparing by indication, findings clinically relevant for patient management occurred in 60/463 (12.9%) CSs, 149/737 (20.2%) CTAs, 56/341 (16.4%) PVSs and 60/223 (26.9%) CABG studies on a per-patient basis. Clinically relevant ECFs were significantly more common in CABG examinations compared with CS ( $p < 0.0001$ ), CTA ( $p < 0.05$ ) and PVS ( $p < 0.004$ ) and CTA studies compared to CS ( $p < 0.002$ ).

## Discussion

During the acquisition of cardiac CT, images of the entire x-y dimensions of the thorax are available for interpretation following a simple wider FOV reconstruction of the same raw data. These reconstructions do not require extra radiation or degrade the quality of the cardiac examination. Using these reconstructions, the full FOV covers approximately twice the exposed chest volume that would be included by the limited FOV [4], which is typically used for cardiac interpretation. Prior reports suggest that ECFs can be detected on coronary CTA in 15–90% of cases depending on the patient population studied and definition of reportable ECF [2–12]. Some of these findings, such as small pleural effusion, subsegmental atelectasis and previously known diseases, may be of little consequence in altering the patient's clinical course. However, depending on the definition, 4.2–38% of findings in previous studies were considered clinically important, including findings such as lung neoplasms, pneumonia, aortic aneurysms and pulmonary embolism [2–12]. The somewhat large percent range of patients with "important" ECF is likely influenced by the variable definition of what constitutes a clinically significant finding and the patient population being studied. We have found in a large cohort of patients undergoing cardiac CT examinations that clinically relevant ECFs with impact on patient management occur in 18.4% of all patients and in 12.9% of CSs, 20.2% of CTAs, 16.4% of PVSs and 26.9% of CABG examinations.

Three studies of ECF in CS studies have been performed encompassing almost 4,000 subjects [5, 6, 12]. Although

**Table 3** Incidental findings related to aorta and pulmonary arteries (N=24)

Finding	Total	CS	CTA	CABG	PVS
Aneurysm	18 (1.0%)	3 (0.6%)	10 (1.4%)	3 (1.3%)	2 (0.6%)
PE	6 (0.4%*)	N/A	5 (0.7%)	1 (0.4%)	0

\*Calcium scoring examinations omitted from percentage calculation (6/1,301)



**Table 4** Incidental findings relating to mediastinum (N=18)

Finding	Total	CS	CTA	CABG	PVS
Adenopathy	13 (0.7%)	0	9 (1.2%)	3 (1.3%)	1 (0.3%)
Cyst	2 (0.1%)	0	0	0	2 (0.6%)
Mass	2 (0.1%)	0	2 (0.3%)	0	0
Other	1 (0.1%)	0	1 (0.1%)	0	0

the definition varied, the rate of “important” findings ranged from 4.2%–7.8%, and the rate of “incidental” findings ranged from 16.2%–31.0%. Only one of these studies reported on the detection of pulmonary nodules. In Horton’s study there were 12 (0.9%) nodules >1 cm and 53 (4.0%) nodules <1 cm [5]. Our data for CS studies are similar in the rate of incidental findings (17.1%), but pulmonary nodules were more frequently detected in our study (49/463, 10.6%) compared to Horton’s study.

With regard to coronary CTA, there are more prior published investigations compared with CS, but overall fewer subjects with study sizes ranging from 100–625 subjects [2–4, 7, 8, 10]. As such, our cohort of 737 subjects is the largest compilation of extra-cardiac findings in the coronary CTA population. Because of differences in reporting, it is difficult to match categories of results; however, in these studies the rate of “important” findings ranged from 4.2–34.5% and rate of “incidental” findings ranged from 10–67% [2–4, 7, 8, 10]. The most detailed report, by Onuma et al., revealed 319/552 (58%) of patients with at least one ECF of which 22.7% were considered to be “important,” including 1 aortic dissection, 3 breast tumors, 1 extra pleural mass, 7 thoracic aortic aneurysms and 2 patients (0.4%) with adenocarcinoma of the lung [10]. The rate of pulmonary nodules reported in CTA studies ranges from 9.3–19.0% for nodules <1 cm and 0.6–2.4% for nodules >1 cm [3, 7, 10]. The results of our study fall within the range of prior studies for “important” findings (20.2%), pulmonary nodules >4 mm and <10 mm (80/737, 10.9%) and pulmonary nodules ≥1 cm (7/737, 0.9%).

To our knowledge, only one study has evaluated extra-cardiac findings in post-CABG patients. Mueller et al.

found that 13.1% of patients in the immediate postoperative period have significant ECF, and an additional 9.3% had a significant cardiac finding [9]. In a subset analysis of 40 subjects imaged approximately 1 year after surgery, 4 (10%) were found to have new unsuspected findings. The authors did not report on the number that initially had an ECF and did not include previously documented ECF. In comparison, we found important findings in 26.9% of patients; however, our database includes only patients outside the immediate postoperative period, whereas their study predominately involved subjects who had had their surgery recently. Thus, this study is also the first to extensively document the types of findings that might be encountered during follow-up for bypass graft location and patency. The increased rate of detection in CABG patients compared to other groups presumably reflects differences in age, health status and co-morbidities.

There is only one other study reviewing the frequency of ECF in the PVS population. Schietinger et al. reviewed their experience with ECF on imaging prior to atrial fibrillation ablation utilizing the clinical interpretation and two blinded readers and found that additional clinical or imaging follow-up was needed for ECFs in 30–50% of patients depending on the reader [11]. Pulmonary nodules made up the large majority of ECF requiring follow-up occurring in up to 19% of patients on the primary clinical interpretation [11]. In our PVS population, the rate of clinically important findings was 16.4%, and pulmonary nodules were detected in 12.3% of patients. The reason for the discrepancy is not clear, but presumably reflects the variability in what constitutes an ECF, the impression of which nodules require follow-up and environmental factors, such as prevalence of granulomatous disease. The fact that our post-ablation patients did not have a

**Table 5** Incidental findings related to the lungs (N=337)

Finding	Total no.	CS	CTA	CABG	PVS
Nodules <1 cm	187 (10.6%)	49 (10.6%)	80 (10.9%)	20 (9.0%)	38 (11.1%)
Nodules ≥1 cm	15 (0.9%)	0	7 (0.9%)	4 (1.8%)	4 (1.2%)
Pneumonia	19 (1.1%)	4 (0.9%)	8 (1.1%)	4 (1.8%)	3 (0.9%)
Interstitial disease	16 (0.9%)	2 (0.4%)	7 (0.9%)	4 (1.8%)	3 (0.9%)
Airways disease	12 (0.7%)	2 (0.4%)	8 (1.1%)	1 (0.4%)	1 (0.3%)
Atelectasis	51 (2.9%)	4 (0.9%)	20 (2.7%)	18 (8.1%)	9 (2.6%)
Emphysema	37 (2.1%)	1 (0.2%)	20 (2.7%)	11 (4.9%)	5 (1.4%)

**Table 6** Incidental finding related to chest wall and pleura (N=69)

Finding	Total	CS	CTA	CABG	PVS
Effusion	50 (2.8%)	2 (0.4%)	17 (2.3%)	27 (12.1%)	4 (1.1%)
Pleural plaque	10 (0.6%)	1 (0.2%)	4 (0.5%)	5 (2.2%)	0
Breast	5 (0.3%)	0	5 (0.7%)	0	0
Thyroid	2 (0.1%)	0	1 (0.1%)	1 (0.4%)	0
Bone met	2 (0.1%)	0	2 (0.3%)	0	0

higher incidence of ECF suggests that the ablation procedure itself may not lead to a greater number of ECF findings on follow-up.

It is not necessarily surprising to find a discrepancy in the rates of ECF on the basis of examination indication. Patients presenting to our institution for calcium scoring usually do so electively and thus tend to be younger, more health conscious and we presume less likely to use tobacco products, although we were unable to confirm this impression systematically. Furthermore, calcium scoring is performed in asymptomatic subjects, while the patients in the remaining categories either had signs and symptoms of or known cardiac disease. Extending the FOV through the lung apices might also result in a greater frequency of ECF, and although there was a trend toward more ECF in the extended FOV CTA, the results were not statistically significant compared to a standard CTA. Results were statistically significant comparing CABG to CTA, but this may be a function more of health status than extending the FOV. Although the minority of findings depend on the use of intravenous contrast for detection, it is reasonable to think that the number of ECF will be increased slightly on contrast-enhanced examination, including the detection of pulmonary embolus and liver lesions. The net clinical effect, however, may be minimal, given that PE and dissection (6/1,301 (0.4%) in patients undergoing contrast-enhanced cardiac examinations) are the only urgent/emergent lesions that would be missed.

This ability to detect lesions throughout the entire thorax can be a mixed blessing. On the one hand, in some cases cardiac CT will provide a definitive diagnosis either cardiac or non-cardiac cases and therefore facilitate the workup and expedite treatment. In other cases, it will yield indeterminate findings that may not be clinically important, but

require additional workup to exclude significant disease, which some may argue has the potential of increasing patient anxiety, incurring complications during invasive workup (e.g., biopsy of lung nodules) and increasing overall health-care cost. In fact, some even argue that more harm than good may come from the detection and reporting of ECFs [13]. As one can see from some of the types of clinically relevant diagnoses that were established in our population, we believe that this is a fallacious argument and in the vast majority of cases ECFs can be handled with minimal stress to the patient and cost to the health-care system. Also, considering some of the more life-threatening conditions that were incidentally detected and the radiation exposure that patients receive during cardiac CT, we feel that there is an ethical obligation to obtain as much information from cardiac CT as possible and analyze the full patient anatomy that is being irradiated. Nonetheless, there clearly is the need for a practical, rational approach for detecting, evaluating and following ECFs using appropriate imaging algorithms, such as the Fleischner criteria for small pulmonary nodules [14], which we use in our practice.

Our study does have several important limitations. The standard bias introduced by a retrospective design must be considered. We attempt to mitigate this by including all consecutive subjects during the entire study period. Only findings mentioned in the final impression on our medical record system were abstracted, so that a number of ECFs that were not considered of sufficient relevance for inclusion in the impression section may have been omitted. For example, findings such as hiatal hernias or emphysema may not be reported in the final impression, but are present and potentially important findings for the respective individual. Thus, our rate of ECF probably represents the minimum percentage that can be detected, but presumably

**Table 7** Incidental findings in upper abdomen (N=59)

Finding	Total no.	CS	CTA	CABG	PVS
Hepatic cyst	32 (1.8%)	12 (2.6%)	10 (1.4%)	2 (0.9%)	8 (2.3%)
Indeterminate liver	20 (1.1%)	5 (1.1%)	9 (1.2%)	1 (0.4%)	5 (1.5%)
Liver mass	1 (0.1%)	0	1 (0.1%)	0	0
Adrenal	3 (0.2%)	0	2 (0.3%)	0	1 (0.3%)
Miscellaneous	3 (0.2%)	1 (0.2%)	2 (0.3%)	0	0

reflects what can be expected in clinical practice. Since we did not re-analyze the actual imaging studies, some ECFs may have been missed entirely. Finally, some findings may have been previously documented, and therefore the clinical significance assigned may not always reflect the clinical significance at the time of study.

In conclusion, ECFs occurred in over 25% of cardiac CT studies, and 18.4% of patients undergoing cardiac studies required further follow-up for ECFs. ECFs are more common in CABG studies than any other category and in CTA examinations compared to screening for coronary artery calcium.

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