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The Prevalence of Extracardiac Findings by Multidetector Computed Tomography Prior to Atrial Fibrillation Ablation

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Abstract

BACKGROUND and OBJECTIVES—The study was designed to determine the prevalence of extracardiac findings discovered during multidetector computed tomography (MDCT) examinations prior to atrial fibrillation ablation. MDCT has become a valuable tool in detailing left atrial anatomy prior to catheter ablation. The incidence of extracardiac findings has been reported for electron beam CT calcium scoring (EBCT) and coronary MDCT, but no data exists for the prevalence of extracardiac findings discovered prior to atrial fibrillation ablation with MDCT.

METHODS and RESULTS—Clinical reports from MDCT examinations prior to atrial fibrillation ablation and interpretations by 2 radiologists blinded to the clinical reports were reviewed for significant additional extracardiac findings and recommendations for follow-up. In 149 patients who underwent MDCT, the average age was 55.9±11.0 years, 75% were men, and 47% had a history of smoking. Extracardiac findings were identified in 69% of patients with clinical, 90% of Reader 1, and 97% of Reader 2 interpretations (kappa=0.086). Follow-up was recommended in 30% of clinical, 50% of Reader 1, and 38% of Reader 2 interpretations (kappa=0.408). Pulmonary nodules were the most common additional finding and reason for suggested follow-up for all interpreters.

CONCLUSIONS—The prevalence of extracardiac abnormalities detected by MDCT is considerable. Significant variability in their identification exists between interpreters but there is good agreement about the need for further follow-up. It is important that those who interpret these examinations are adequately trained in the identification and interpretation of both cardiac and extracardiac findings.

Introduction

Computed tomography (CT) has found increasing use in the evaluation of cardiac structure. Advances with the introduction of multidetector computed tomography (MDCT) in the late 1990's allowed for gantry rotation times less than 500 milliseconds (msec), sub millimeter

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Conflicts of Interest: none

(mm) slice collimation thickness, and greater field coverage with multiple detectors. These improvements in temporal and spatial resolution as well as decreased breath hold times have made MDCT a modality with expanding indications and utilization including coronary angiography^{1–3}.

One such application is detailing the left atrium and pulmonary veins prior to atrial fibrillation catheter ablation. Since Haissaguerre et al⁴ first described the elimination of atrial fibrillation by catheter based ablation at the ostia of pulmonary veins, over ten thousand ablation procedures have been performed worldwide⁵. Concurrently, the technology for atrial fibrillation ablation continues to evolve with a major focus being the incorporation of anatomical data into advanced three-dimensional mapping and navigational systems. These systems are pivotal to the procedure as 40% of patients will have an anatomical variant⁶. The utility of MDCT assessment of the pulmonary veins prior to ablation has been described⁷ and has contributed to high procedural success rates⁸. MDCT can provide pivotal information about the size, location, and number of pulmonary vein ostia, but it also contains data from the lungs, abdomen, spine, and chest wall.

The prevalence of extracoronary findings for coronary artery calcium screening by electron beam CT (EBCT) has been previously examined. In four EBCT studies^{9–12}, the reported prevalence of incidental findings varied from 7.8 to 53%, and the need for follow-up was noted in 4.2 to 11% of exams. These studies used different CT technology and definitions of incidental findings, and thus the prevalence rates reported may not be applicable to MDCT. One recent review from Japan reported on extracardiac findings in 503 patients receiving coronary MDCT¹³. The applicability of their experience to a U.S. atrial fibrillation population is unknown. Therefore, the aim of this study was to determine the prevalence and distribution of extracardiac findings noted during cardiac gated MDCT in patients referred prior to an atrial fibrillation ablation.

METHODS

Study Group

The study group consisted of 149 consecutive patients who received MDCT examinations at our institution. All patients were referred from the Atrial Fibrillation Center, and these examinations were performed to identify the size, number, and orientation of the pulmonary veins to assist with atrial fibrillation ablation.

MDCT Scans

All MDCT exams were performed at one site. Intravenous metoprolol was administered in 5 milligram doses every 5 minutes for up to four total doses to achieve heart rates less than 65 beats per minute. The 16 slice multidetector CT data was acquired on one of two CT scanners (GE Lightspeed 16 and GE Lightspeed 16 Pro, General Electric Medical Systems, GEMS, Milwaukee, WI). Both scanners have a 16×0.625 mm detector collimation, tube current of 440 – 800 mAs, gantry rotation time of 400 – 500 msec, helical pitch of 0.25– 0.3 sec per 1 mm depending on the gated heart rate, and tube voltage of 120 kVp. Axial slices were reconstructed using electrocardiographic- gated half scan reconstruction algorithm (temporal resolution of 200 – 250 msec) with slice thickness of 0.625 – 1.25 mm. Numerous phases were reconstructed within the cardiac cycle to optimize structure visualization without motion artifacts.

An initial non-contrast, non-gated localizer was performed from the aortic arch to diaphragm with a 2.5 mm slice thickness and field of view 25 cm to identify the pulmonary veins and establish the contrast imaging boundaries. The position and field coverage could be modified

at the technologist's discretion. The contrasted enhanced portion was set to span from a cranial border 2 cm above the left pulmonary vein and a caudal border 2 cm below the posterior descending coronary artery. Omnipaque 350 iodinated contrast medium (GE Healthcare) was administered via the antecubital vein to opacify the left atrium and pulmonary veins. A contrast medium transit time was used to establish optimal opacification of the left atrium and pulmonary veins. Initially, full concentration contrast was injected at 6 cc/sec followed by 60% contrast to 40% normal saline solution at 5 cc/sec. The contrast injections were followed with a 20 cc normal saline flush at 4 cc/sec. All post processing and analysis of the pulmonary veins was performed on a GE Advantage Windows Workstation.

Image and Statistical Analysis

Per standard practice at our institution, an attending cardiologist evaluated the intracardiac structures including all pulmonary veins, and an attending radiologist provided additional scan interpretation using bone, lung, and soft tissue window settings.

All data was acquired from the subjects' medical records and MDCT examinations as approved by the University of Virginia Institutional Review Board. The official clinical MDCT report was reviewed for any described abnormal extracardiac structures with the exception of vascular findings, degenerative spine disease, or atelectasis. Any other structures noted in the report were defined as additional findings and their anatomical distribution, and follow-up recommendations were collected and categorized into one of four anatomical systems: lung, lymph node, organ, or bone. Each of the four anatomical systems was then subcategorized and multiple findings accounted for. For example, if a patient had a liver and adrenal lesion, it was counted as a single scan with an organ system additional finding, but within that system category both the liver lesion and adrenal lesion were identified. A benign pulmonary nodule was considered any pulmonary nodule with benign calcification. Follow-up was defined by any recommendation within the clinical report for additional imaging or clinical correlation or history. Many of the MDCT examinations were performed prior to the Fleischner Society guidelines for small pulmonary nodules¹⁴ and recommendations for follow-up reflect the interpreter's judgment.

Additionally, an independent blinded interpretation was performed by 2 diagnostic radiologists (with 6 and 12 years post-residency experience, respectively). They identified additional findings and recommend appropriate follow-up. Pulmonary nodules recommendations were based on the Fleischner Society guidelines; nodules less than or equal to 4 mm require clinical history, such as smoking history, to proceed to imaging and nodules greater than 4 mm require imaging.

Comparison of readings was performed by a statistician (HW) with kappa values as a measure of agreement. Kappa values are presented as mean and 95% confidence limits.

RESULTS

The average age of 149 patients was 55.9 ± 11.0 years old, 75% were men, and 47% had a history of tobacco smoking. Hypertension was the most prevalent co morbid condition (Table 1).

The prevalence of additional findings was 69% of patients with clinical, 90% of Reader 1, and 97% of Reader 2 interpretations (Table 2). There was poor overall agreement between the 3 types of interpretations (kappa=0.086, 95% CI -0.006, 0.178). The predominant findings were in the lung in 47% of clinical, 73% of Reader 1, and 83% of Reader 2 interpretations. Of the additional lung findings, pulmonary nodules were the most common in 26%, 44%, and 46% of patients, respectively, and there was fair agreement between readings (kappa=0.472, 95%

CI 0.38, 0.56). Organ system additional findings were present in 22%, 38%, and 42%, respectively

Fair agreement ($\kappa=0.408$, 95% CI 0.316, 0.50) was present in recommended follow-up in 30%, 50% and 38%, respectively (Table 3). For the clinical readings, 24% of patients had suggested imaging follow-up and 6% clinical follow-up. Reader 1 and 2 recommended imaging follow-up in 26% and 28% and clinical follow-up in 28% and 10%, respectively. The lungs were the anatomical site which generated the most recommendations for follow-up. For all interpretations, pulmonary nodules were the most frequent reason for follow-up. Reader 1 and 2 advised that 20% and 24% receive additional imaging and 22% and 6% clinical correlation, respectively. For all interpretations there was good agreement in the need for imaging follow-up per patient ($\kappa=0.511$, 95% CI 0.42, 0.60), per pulmonary findings ($\kappa=0.583$, 95% CI 0.49, 0.68), and per pulmonary nodules ($\kappa=0.575$, 95% CI 0.48, 0.67).

DISCUSSION

MDCT has become a valuable tool in detailing left atrial anatomy prior to catheter ablation ^{7,8}. The detection of extracardiac findings by MDCT in patients with atrial fibrillation is considerable. In four large EBCT studies, the reported prevalence of incidental findings were 7.8% ¹⁰, 8% ⁹, 20.5% ¹², and 53% ¹¹ with the higher prevalence in the latter due to the inclusion of “other cardiovascular findings” which accounted for 61% of all incidental findings. Thus, the prevalence rates of extracardiac findings in these studies are comparatively less than found in our patients, as are the follow-up rates. Hunold et al ¹¹ performed contrast-enhanced noninvasive coronary angiography in addition to coronary calcium EBCT in 32% of their studies. The additional findings discovered accounted for 33% of all pulmonary findings and 45% of all pulmonary tumors. This suggests that the addition of a contrast examination contributes to the identification of extracardiac findings.

The current investigation differs from these earlier EBCT studies in patient population, study methodology, and imaging techniques. Elgin et al ⁹ studied a cohort of active military personnel who volunteered for coronary calcium screening. This population was younger than our atrial fibrillation population (42 ± 2 vs. 55.9 ± 11.0 years old) and may explain their lower prevalence of incidental findings. Our patients had a higher smoking prevalence than any other reported series (47% vs. 13–41%) and previous studies have shown that approximately one half of all smokers over age 50 will have at least one pulmonary nodule ¹⁴. The high incidence of lung nodules and granulomas in our study, may also be attributed to the fact that our institution draws referrals from much of the southeastern United States. In this region, the soil based fungus, *Histoplasma capsulatum*, is endemic. Early chest radiography studies showed that half of all pulmonary nodules are granulomas, the majority being histoplasmosis ¹⁵. Identification of these benign lesions can be confirmed by the presence of calcium via Hounsfield Unit density measurements. Like Horton et al ¹⁰, we examined all studies by computer workstation in mediastinal, lung, and bone window settings. Schragin et al ¹² only used mediastinal and lung windows printed onto film, and Hundold et al ¹¹ did not utilize any lung window settings.

In addition to these study design distinctions, EBCT and MDCT are fundamentally different. EBCT does not use a rotating gantry around the patient and therefore achieves high temporal resolution (acquisition time of 50 – 100 msec per image). EBCT coronary calcium scoring also does not require a contrast injection. During MDCT, both a non-contrast enhanced localizer image set as well as a contrast-enhanced image set can be obtained, increasing the sensitivity to extracardiac findings. Although MDCT with its gantry rotation of 330 – 420 msec cannot achieve the temporal resolution of EBCT, its multiple detectors allow for thinner slice thickness and therefore improved spatial resolution. MDCT also employs higher tube current (440 – 800 mA) allowing for improved tissue penetration. It is reasonable to conclude that differences in

the patient populations studied, image acquisition techniques, and image evaluation account for our higher prevalence of additional findings discerned by MDCT.

The incidence of extracardiac findings in coronary studies with MDCT was demonstrated by Onuma et al.¹³. They performed cardiac gated MDCT for the evaluation of coronary artery disease and non-blinded interpretation of additional findings. Their rates of extra cardiac findings and need for additional work-up were analogous to our experience, (58% vs. 69%) and (23 vs. 24%) respectively. Similarly, the majority of their extracardiac findings were pulmonary (72%) and almost a quarter were pulmonary nodules. This is not surprising given the majority of their patients had angina, and were an older cohort (66 ± 10 years) with high rates of smoking (52%). Cardiac analysis was performed using a FOV defined by the same anatomical landmarks utilized in the present study, but they reconstructed an additional image set with a large FOV to include the entire chest. The percentage of findings that came from this additional, larger image set was not delineated. Despite differences in methodology and geography in the two studies, similar clinical results were found.

The higher prevalence of additional findings and follow-up recommendation in the blinded readings is not unexpected given the difference between these and standard clinical reads. The disparity in additional lung findings has been previously described by Leader et al.¹⁶. In 293 low-dose CT examinations they found a total of 470, 729, and 876 pulmonary nodules with 3 independent readers. For non-calcified pulmonary nodules the interobserver agreement was only 18.9%, but on a per examination basis, there was modest agreement, similar to the current study ($\kappa=0.343$ vs. 0.472). Of interest, they noted “inconsistent measurements of nodule size” which directly impacted the method of follow-up advised when utilizing Fleischner Society guidelines.

Although all examinations in the current study identified many incidental findings, there was poor agreement between them ($\kappa=0.086$). However, there was good agreement for those findings warranting follow-up. For lung findings, for example, the agreement on their identification was poor whereas there was good agreement as to which should receive imaging follow-up. Since lung findings accounted for the majority of follow-up recommendations this agreement between interpretations is encouraging.

One important question is whether the recognized additional findings signify clinically significant pathology. Hunold et al.¹¹ found that in 1812 EBCT examinations, 3 cases of malignant disease were found, and Onuma et al.¹³ detected 4 malignancies with MDCT in 503 patients with just 6 months of follow-up. The Early Lung Cancer Action Project (ELCAP) evaluated 1000 asymptomatic smokers who were at least 60 years old with low dose CT (140 kV and 40 mA) and a 10 mm slice thickness¹⁷. They discovered noncalcified pulmonary nodules in 23% of all scans. Of these 233 scans, 12% were associated with a malignancy. Importantly, 74% of these malignancies were not evident on chest radiography. Larger nodules were more likely malignant than smaller lesions.

It is unclear, in patients receiving an asymptomatic, procedural staging examination, if the potential additional cost, radiation, and invasive procedures to follow-up these findings will provide patients with a mortality benefit or improved quality of life¹⁸. Although less than 1% of sub 5 mm nodules are malignant^{17,18}, the fear of missing a potential early stage cancer has caused wide variation in follow-up recommendations.

Limitations

One strategy to address extracardiac incidental findings could be the development of imaging protocols that minimize imaging of extracardiac structures. For example, the field of view could be decreased from 250mm as used in the present protocol, which would tend to reduce

these findings. However, in the previously discussed EBCT^{10,11} and MDCT¹³ studies, the field of view used was larger than that of ours but did not result in a marked increase in additional findings.

This study was performed in an academic institution and its applicability to the practice environment is uncertain. Another limitation is that follow-up of these findings is not yet complete. Therefore, their ultimate clinical impact is unknown.

Conclusion

Due to the complexity of these examinations, a strategy in which a team of cardiologists and radiologists reviews these studies in concert is optimal. In the absence of such a strategy it is reasonable to conclude, as did the recent American College of Cardiology Training in Advanced Cardiovascular Imaging Task Force¹⁹, that further training is necessary to enable the recognition of extracardiac findings. Those who perform MDCT examinations must recognize these potentially significant extracardiac findings and be able to establish a diagnosis and/or the need for further evaluation.

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Figure 1. Collection of representational additional findings (white arrows) during 149 MDCT examinations. (a) Pathologically enlarged mediastinal lymphadenopathy. (b) Left breast lesion. (c) Right upper lobe 14 × 10 mm pulmonary nodule. (d) Peri-pancreatic mass.

Table 1

Patient characteristics.

	Patients
	n = 149
Male Gender, n (%)	112 (75)
Age, years	55.9 ± 11.0
Type of Atrial Fibrillation, n (%)	
Paroxysmal	106 (71)
Persistent	43 (29)
Atrial Fibrillation Duration, years	5.9 ± 5.9
Smoking history, n (%)	70 (47)
Co-Morbid Conditions, n (%)	
Hypertension	70 (47)
Hypercholesterolemia	64 (43)
Thyroid disorders	17 (11)
Diabetes mellitus	12 (8)
Chronic lung disease	12 (8)
Coronary artery disease	11 (7)
Congestive heart failure	10 (7)
Valvular heart disease	8 (5)
Congenital heart disease	3 (2)

Table 2

The prevalence and distribution of additional findings discovered in 149 patients during MDCT prior to atrial fibrillation ablation.

	Clinical	Reader 1	Reader 2	kappa (95% CI)
Patients with Additional Findings, n(%)	102 (69)	134 (90)	144 (97)	0.086 (−0.006, 0.178)
Lung Finding, n(%)	70 (47)	109 (73)	124 (83)	0.252 (0.16, 0.344)
Pulmonary Nodule, n(%)	39 (26)	65 (44)	68 (46)	0.472 (0.38, 0.56)
Parenchymal Disease, n(%)	26 (18)	49 (33)	75 (50)	0.177 (0.08, 0.27)
Granulomatous Disease, n(%)	18 (12)	34 (23)	41 (28)	0.525 (0.43, 0.62)
Pleural Disease, n(%)	12 (8)	16 (11)	18 (12)	0.394 (0.30, 0.49)
Organ, n(%)	32 (22)	57 (38)	62 (42)	0.43 (0.34, 0.52)
Liver, n(%)	16 (11)	32 (22)	24 (16)	0.552 (0.46, 0.64)
Breast, n(%)	2 (1)	10 (7)	11 (7)	0.446 (0.35, 0.54)
Hiatal Hernia, n(%)	6 (4)	8 (5)	13 (9)	0.612 (0.52, 0.70)
Vascular, n(%)	1 (1)	1 (1)	0	−0.0007 (−0.09, 0.09)
Other, n(%)	8 (5)	11 (7)	21 (14)	0.285 (0.19, 0.38)
Lymph Node, n(%)	39 (26)	42 (28)	43 (29)	0.174 (0.08, 0.27)
Bone, n(%)	3 (2)	6 (4)	7 (5)	0.288 (0.196, 0.38)

CI = confidence interval.

Table 3
The prevalence and distribution of recommended follow-up in 149 patients during MDCT prior to atrial fibrillation ablation.

	Reader 1				Reader 2				kappa (95% CI)
	Imaging FU	Clinical FU	Imaging FU	Clinical FU	Imaging FU	Clinical FU	Imaging FU	Clinical FU	
Patients Needing FU, n(%)	44 (30)				56 (38)				0.408 (0.316, 0.5)
Patients Needing FU, n(%)	36 (24)	9 (6)	39 (26)	42 (28)	41 (28)	15 (10)	0.511 (0.42, 0.60)	0.057 (-0.04, 0.15)	
Lung Finding, n(%)	28 (19)	3 (2)	30 (20)	36 (24)	36 (24)	14 (10)	0.583 (0.49, 0.68)	0.038 (-0.05, 0.13)	
Pulmonary Nodule, n(%)	26 (18)	2 (1)	30 (20)	33 (22)	36 (24)	9 (6)	0.575 (0.48, 0.67)	0.019 (-0.07, 0.11)	
Parenchymal Disease, n(%)	1 (1)	2 (1)	0	2 (1)	0	4 (3)			
Granulomatous Disease, n(%)	0	0	0	0	0	0			
Pleural Disease, n(%)	2 (1)	0	1 (1)	1 (1)	0	1 (1)			
Organ, n(%)	8 (5)	2 (1)	12 (8)	6 (4)	4 (3)	1 (1)	0.252 (0.20, 0.34)	-0.02 (-0.11, 0.07)	
Liver, n(%)	3 (2)	1 (1)	6 (4)	2 (1)	1 (1)	1 (1)			
Breast, n(%)	1 (1)	1 (1)	3 (2)	2 (1)	3 (2)	0			
Hiatal Hernia, n(%)	0	0	0	0	0	0			
Vascular, n(%)	1 (1)	0	0	1 (1)	0	0			
Other, n(%)	3 (2)	0	3 (2)	1 (1)	0	0			
Lymph Node, n(%)	1 (1)	3 (2)	0	1 (1)	2 (1)	2 (1)	0.02 (-0.07, 0.11)	-0.026 (-0.12, 0.07)	
Bone, n(%)	0	1 (1)	0	0	0	0			

FU = follow-up, CI = confidence interval.