

# Current Role of Cardiac and Extra-Cardiac Pathologies in Clinically Indicated Cardiac Computed Tomography with Emphasis on Status Before Pulmonary Vein Isolation

## Kardiale und extra-kardiale pathologische Befunde in klinisch indizierter Computertomografie bei Patienten vor Pulmonalvenen-Isolation

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### Key words

- cardiac
- CT angiography
- angiography
- thorax
- mediastinum
- cost-effectiveness

### Zusammenfassung

**Ziele:** In dieser Studie wurde bei Patienten mit Vorhofflimmern die Inzidenz von kardialen und signifikanten extra-kardialen Befunden im CT vor Pulmonalvenen-Isolation untersucht.

**Material und Methoden:** 224 Patienten (64 ± 10 Jahre; männlich 63%) mit Vorhofflimmern wurden vor PVI mit einer kardialen 64-Zeilen CT untersucht. Extra-kardiale Befunde wurden als „signifikant“ bezeichnet, wenn zusätzliche Untersuchungen oder Therapien empfohlen wurden; andernfalls wurden sie als „nicht signifikant“ bezeichnet. Die kardialen Befunde wurden ebenfalls ausgewertet. Die Befunde waren dem analysierenden Kardiologen und Radiologen vor dem CT unbekannt. Zusätzlich wurden Kosten für anschließende Bildgebungen ausgewertet, die zur Verifikation von möglichen pathologischen Befunden erforderlich waren.

**Ergebnisse:** Insgesamt wurden 724 kardiale Befunde bei 203 Patienten detektiert (91% der Patienten). Zusätzlich wurden 619 extra-kardiale Befunde in 179 Patienten gefunden (80% der Patienten). Bei diesen extra-kardialen Befunden waren 196 (32%) „signifikant“ und 423 (68%) „nicht signifikant“. Bei 2 Patienten (1%) zeigten sich maligne Befunde, die vorher nicht bekannt waren (Ösophaguskarzinom und Bronchialkarzinom). 203 weiterführende bildgebende Untersuchungen folgten den primär detektierten Befunden im ersten CT, um die signifikanten extra-kardialen Befunde zu verifizieren (124 zusätzliche CT, Kosten 38 314,69 US Dollar). Insgesamt kamen auf einen untersuchten Patienten 3,2 kardiale und 2,8 extra-kardiale Befunde. Extra-kardiale Befunde kamen signifikant häufiger vor bei Patienten über 60 Jahren, Rauchern und Patienten mit einem kardialen pathologischen Befund ( $p < 0,05$ ).

**Schlussfolgerungen:** Kardiale CT Untersuchungen vor Pulmonalvenen-Isolation sollten auf extra-kardiale Nebenfunde untersucht werden, da di-

### Abstract

**Purpose:** The aim of this study was to assess the incidence of cardiac and significant extra-cardiac findings in clinical computed tomography of the heart in patients with atrial fibrillation before pulmonary vein isolation (PVI).

**Materials and Methods:** 224 patients (64 ± 10 years; male 63%) with atrial fibrillation were examined by cardiac 64-slice multidetector CT before PVI. Extra-cardiac findings were classified as “significant” if they were recommended to additional diagnostics or therapy, and otherwise as “non-significant”. Additionally, cardiac findings were documented in detail.

**Results:** A total of 724 cardiac findings were identified in 203 patients (91% of patients). Additionally, a total of 619 extra-cardiac findings were identified in 179 patients (80% of patients). Among these extra-cardiac findings 196 (32%) were “significant”, and 423 (68%) were “non-significant”. In 2 patients (1%) a previously unknown malignancy was detected (esophageal cancer and lung cancer, local stage, no metastasis). 203 additional imaging diagnostics followed to clarify the “significant” findings (124 additional CT, costs 38 314.69 US dollars). Overall, there were 3.2 cardiac and 2.8 extra-cardiac findings per patient. Extra-cardiac findings appear significantly more frequently in patients over 60 years old, in smokers and in patients with a history of cardiac findings ( $p < 0.05$ ).

**Conclusion:** Cardiac CT scans before PVI should be screened for extracardiac incidental findings that could have important clinical implications for each patient.

### Key points:

- ▶ Cardiac and extra-cardiac findings are common in patients with an indication for pulmonary vein isolation on previous CT scans.
- ▶ Malignancies can be detected in 1% of all patients.

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### Bibliography

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ese für die Patienten relevant sein können, wie beispielsweise die Detektion von Malignomen.

#### Kernaussagen:

- ▶ Kardiale und extra-kardiale Befunde treten bei Patienten mit der Indikation zur Pulmonalvenen-Isolation relativ häufig auf.
- ▶ Bei 2 Patienten (1 %) zeigten sich maligne Befunde, die vorher nicht bekannt waren (Ösophaguskarzinom und Bronchialkarzinom ohne Metastasierung).
- ▶ Unter den extra-kardialen Befunden fanden sich 196 (32 %) die als „signifikant“ bezeichnet wurden und die teils für die Patienten klinisch relevant waren.

- ▶ 32 % of all extra-cardiac findings can be of significant relevance with consequences for patients.
- ▶ Altogether, there are 3.2 cardiac and 2.8 extra-cardiac findings in patients with indication for pulmonary vein isolation and CT.
- ▶ Extra-cardiac findings appear significantly more frequently in patients over 60 years old, in smokers and in patients with a history of cardiac findings ( $p < 0.05$ ).

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## Introduction

Cardiac computed tomography (CT) including coronary CT angiography is applied for several clinical indications. Specifically the exclusion of significant coronary artery stenosis ( $\geq 50\%$  luminal reduction) is becoming a major indication in patients with a low to intermediate risk of coronary artery disease [1, 2]. Atrial and ventricular anatomy can be evaluated comprehensively [3, 4]. Cardiac CT before pulmonary vein isolation (PVI) in patients with atrial fibrillation is useful and is regularly performed for evaluating the anatomy of pulmonary veins and left atrium for optimized procedure planning or three-dimensional mapping [5, 6]. When clinically indicated, CT may be used in a triple-rule-out strategy to exclude aortic dissection and pulmonary embolism in addition to cardiac pathology [7–9].

In the patient's interest all relevant information from cardiac CT imaging should be utilized. This requires assessing not only the heart, but also all surrounding structures that were imaged during the CT scan. According to other authors, the incidence of extra-cardiac findings at cardiac CT ranged from 8 % in asymptomatic patients [10] to 58 % in symptomatic patients with known or suspected coronary artery disease (CAD), and up to 22 % if the patients had clinically significant findings that required at least a follow-up [11]. Schietinger et al. reported extra-cardiac incidental findings even in 69 % of patients who were scanned prior to pulmonary vein isolation [12]. Most previous studies about cardiac CT concentrated on either cardiac findings or incidental extra-cardiac findings and did not evaluate the cost of subsequent diagnostics [10, 11, 13, 14].

The purpose of this retrospective study was to jointly assess cardiac and extra-cardiac findings in patients undergoing clinically indicated cardiac CT due to atrial fibrillation and pulmonary vein isolation, and to determine the implications of the extra-cardiac findings for patient management.

## Materials and Methods

### Study population

Between February 2009 and September 2011, cardiac CT was performed in 224 consecutive patients for pulmonary vein isolation with atrial fibrillation ( $n = 220$  cases 1–2 days before intervention,  $n = 4$  cases 1 day after). All cardiac CT scans had diagnostic image quality. For this retrospective study the patients were identified using the local digital patient database and radiological information system (RIS) during the study period. The follow-up period ranged from about 1 year for the latest CT scan to about

3 years for the first CT scan and included searching for additional imaging, continuing the patient history, and collecting existing histopathological reports. Informed consent had been obtained from each patient for the CT scan and for study evaluations. This study was in consensus with the Declaration of Helsinki and was approved by the local Ethics Committee.

### Cardiac CT scan protocol and image reconstruction

All cardiac CTs were performed with a 64-row multi-detector CT (VCT Light Speed, GE Healthcare, Milwaukee, USA) and retrospective electrocardiographic (ECG) gating. The CT scan protocol depended on the clinical indications. Usually, scans were performed before pulmonary vein isolation. A typical protocol is described in the following. All patients hyperventilated before scanning. Then the scan was performed in inspiration during a single breath-hold. The scan extended from the supra-aortic region to the heart base, thus including parts of the thorax and upper abdomen into the field-of-view. The scan length ranged from 8 to 15 cm, depending on the patient's stature. For CT, 80–100 mL iodinated contrast agent (Imeron 350 or 400, Bracco Imaging, Konstanz, Germany) was injected into an antecubital vein followed by a 40 ml saline flush, both at a flow rate of 4 ml/s. The scan was triggered by automated bolus tracking with the region-of-interest placed in the ascending aorta. The scan parameters were: Spiral scan, cranio-caudal direction, pitch 0.18–0.22, detector collimation  $64 \times 0.625$  mm, gantry rotation time 350 ms, tube voltage 120 kV, maximum tube current 500 mA, and using tube current modulation. Using retrospective ECG gating, CT slices with a thickness of 0.625 mm were reconstructed at 65–85 % of the RR interval at increments of 5 %. In individual cases further cardiac phases were reconstructed for optimizing the image quality. Typical radiation dose parameters were a volume CT dose index ( $\text{CTDI}_{\text{vol}}$ ) of 50 mGy and dose length product (DLP) of 400–750 mGy $\times$ cm. With a conversion factor of 0.017 for the chest, the effective dose was about 6.8–12.8 mSv.

### Assessment of cardiac and extra-cardiac findings

The cardiac CTs were independently reviewed by two radiologists and one cardiologist who were blinded to the clinical data, with disagreement solved in consensus. Axial and multiplanar CT images were viewed at standard window settings (lung, soft tissue, and bone windows) using a PACS system (Centricity Radiology RA 1000, GE Healthcare, Milwaukee, USA). First, all cardiac CT findings were analyzed and recorded, e.g. coronary artery stenoses or pulmonary vein variations. Then extra-cardiac CT findings were searched, including pulmonary, osseous, abdominal and soft tissue abnormalities. These extra-cardiac findings were clas-

sified into “significant” and “non-significant”, similar to previous studies [10, 11, 13–15]. An extra-cardiac finding was classified as “significant”, if it could change patient management due to subsequent diagnostics and/or therapy. Otherwise, an extra-cardiac finding was classified as “non-significant”. The “significant” findings included newly detected cancer, enlarged lymph nodes sizing > 10 mm, severe lung emphysema, and others. The “non-significant” findings included mild degenerative spine disease, small lymph nodes < 10 mm, unspecific pulmonary scars, and others. There was no comparison with prior imaging findings for both, cardiac and extra-cardiac findings.

### Pulmonary vein isolation

The subsequent pulmonary vein isolation was performed using the high-resolution CT images and electroanatomical mapping with CARTO® for three-dimensional mapping (CartoMerge XP, Biosense Webster, Diamond Bar, CA, USA), and circumferential ablation was performed for each vein ostium using an open-irrigated 3.5 mm ablation catheter (Navistar Thermocool, Biosense Webster, Diamond Bar, CA, USA).

### Additional diagnostics and costs

The following diagnostics (CT, X-ray, ultrasound or MRI) to clarify “significant findings” were analyzed, and costs were calculated in detail using the basic single rates for one patient of the medical fee schedule in Germany 2012 [16].

## Results

### Patients and CT indications

Among the included 224 patients, 63 % were male and 37 % were female. The age of the patients was  $64 \pm 10$  years (mean  $\pm$  SD; range 10 to 84 years). All patients had atrial fibrillation, and their cardiac CT was clinically indicated for the planning of pulmonary vein isolation (PVI). In 220 (98 %) patients this was the first ablation, and in 4 patients (2 %) this was a re-ablation after previous PVI (Table 1).

### Cardiac findings

In 91 % of patients (203 of 224), a total of 724 cardiac findings were identified (Table 2). Most common was coronary artery

**Table 1** Patients and CT indications.

**Tab. 1** Patienten, Risikofaktoren und CT-Indikationen.

descriptive statistics	
patients, total	224
age (mean $\pm$ SD)	$64 \pm 10$ years
male	142 (63 %)
female	82 (37 %)
cardiovascular risk factors	
atrial fibrillation	224 (100 %)
hypertension	125 (56 %)
dyslipidemia	112 (50 %)
smoking	85 (38 %)
diabetes mellitus	44 (20 %)
indications for cardiac CT	
status before PVI	220 (98 %)
status after prior PVI	4 (2 %)

PVI = pulmonary vein isolation

**Table 2** Cardiac findings.

**Tab. 2** Kardiale Befunde.

location	cardiac findings	patients	percent
atrial	left atrial dilatation <sup>1</sup>	40	5.5 %
	right atrial dilatation <sup>1</sup>	40	5.5 %
	intima flap of the atrial septum	16	2.2 %
	cardiac aneurysm right atrium	1	0.1 %
	left atrial scar	1	0.1 %
thrombus	thrombus left atrium <sup>2</sup>	13	1.8 %
	thrombus left ventricle <sup>2</sup>	1	0.1 %
ventricle	right ventricular dilatation <sup>1</sup>	11	1.5 %
	left ventricular dilatation <sup>1</sup>	3	0.4 %
	left ventricular hypertrophy <sup>1</sup>	5	0.7 %
	right ventricular hypertrophy <sup>1</sup>	1	0.1 %
	cardiac aneurysm left ventricle	1	0.1 %
pulmonary artery	pulmonary artery dilatation <sup>1</sup>	12	1.7 %
	pulmonary artery hypoplasia	1	0.1 %
	pulmonary artery stenosis	1	0.1 %
aortic	aortic arteriosclerosis (moderate or severe)	50	6.9 %
	aortic valve sclerosis	29	4.0 %
	aortic valve replacement	2	0.3 %
	aortic and pulmonary stents	3	0.4 %
	aortic stenosis > 50 % (including coarctation)	3	0.4 %
mitral	mitral valve sclerosis	19	2.6 %
	mitral valve replacement	4	0.6 %
	mitral annulus dilatation <sup>1,2</sup>	1	0.1 %
	mitral valve anuloplastia	1	0.1 %
	endocarditis <sup>2</sup>	1	0.1 %
tricuspidal	tricuspidal valve replacement	1	0.1 %
vena cava	inferior vena cava dilatation > 4 cm	2	0.3 %
	superior vena cava dilatation > 4 cm	1	0.1 %
septal	thin septum (ventricular) <sup>1</sup>	4	0.6 %
	septal hypertrophy > 2 cm (ventricular)	3	0.4 %
RCA	RCA sclerosis (1–49 % luminal reduction)	50	6.9 %
	RCA stenosis ( $\geq$ 50 % luminal reduction)	20	2.8 %
	coronary anomaly	10	1.4 %
	coronary stent	11	1.5 %
	coronary bypass	15	2.1 %
LM	LM sclerosis (1–49 % luminal reduction)	35	4.8 %
	LM stenosis ( $\geq$ 50 % luminal reduction)	4	0.6 %
LAD	LAD sclerosis (1–49 % luminal reduction)	89	12.3 %
	LAD stenosis ( $\geq$ 50 % luminal reduction)	30	4.1 %
LCX	LCX sclerosis (1–49 % luminal reduction)	54	7.5 %
	LCX stenosis ( $\geq$ 50 % luminal reduction)	17	2.3 %
pulmonary vein	common left pulmonary vein ostium	37	5.1 %
	pulmonary vein dilatation	6	0.8 %
	pulmonary vein stenosis	11	1.5 %
	common right pulmonary vein ostium	7	1.0 %
	three/accessory pulmonary veins right	12	1.7 %
pericardial	three/accessory pulmonary veins left	1	0.1 %
	pericardial effusion (clinically relevant)	13	1.8 %
	pericardial sclerosis	7	1.0 %
pericardial	pericardial lipomatosis	2	0.3 %
	status after cardiac puncture	18	2.5 %
interventional	status after dislocation of pacemaker wire	3	0.4 %
	status after perforation of pacemaker wire	1	0.1 %
findings, total		724	100 %

RCA = right coronary artery; LM = left main artery; LAD = left anterior descending;

LCX = left circumflex artery

<sup>1</sup> Adapted from Lang et al. [31].

<sup>2</sup> Consistent with findings from echocardiography.

sclerosis with 1–49% luminal reduction (<50% = sclerosis) of the LAD (left anterior descending coronary artery) in 89 cases (12.3%), of the LCX (left circumflex artery) in 54 cases (7.5%), of the RCA (right coronary artery) in 50 cases (6.9%), and of the LM (left main coronary artery) in 35 cases (4.8%). Coronary stenosis with  $\geq 50\%$  luminal reduction was found in the RCA (20 cases; 2.8%), LM (4 cases; 0.6%), LAD (30 cases; 4.1%), and LCX (17 cases; 2.3%). On average there were 3.2 cardiac findings per patient.

### Extra-cardiac findings

In 80% of patients (179 of 224) a total of 619 extra-cardiac findings were identified. Among them, 32% (196 of 619) were classified as “significant” (Table 3) and 68% (423 of 619) as “non-significant” (Table 4).

The most frequent “significant” extra-cardiac findings were: 7.3% (45 of 619 cases) with clinically symptomatic extensive degenerative spine disease, 5.8% (36 of 619 cases with additional follow-up such as X-ray) with enlarged mediastinal/hilar lymph nodes sizing > 10 mm, and 4.2% (26 of 619 cases) with moderate to severe lung emphysema (follow-up for this disease with chest-CT). Among the less frequent but clinically important “significant” extra-cardiac findings were: aortic ectasia or aneurysm of > 4 cm diameter (10 patients), primary diagnosis of pneumonia (2 patients), primary diagnosis of pulmonary embolism (1 patient), primary diagnosis of aortic dissection (1 patient), previously unknown esophageal cancer (1 patient), and previously unknown lung cancer (1 patient).

The most frequent “non-significant” extra-cardiac findings were: 19.1% (118 of 619 cases) with asymptomatic mild degenerative spine diseases, 13.1% (81 of 619) with pulmonary scars, and 5.5% (34 of 619 cases) with prominent mediastinal or hilar lymph nodes sizing 8–10 mm (but not exceeding 10 mm diameter).

**Table 3** Significant extra-cardiac findings.

**Tab. 3** Signifikante extra-kardiale Befunde.

location	significant extra-cardiac findings	count	percent
vascular	aortic ectasia or aneurysm > 4 cm	10	1.6 %
	aortic dissection	1	0.2 %
mediastinal	mediastinal/hilar lymph nodes > 10 mm	36	5.8 %
pulmonary	moderate/severe lung emphysema	26	4.2 %
	pulmonary fibrosis	17	2.7 %
	pulmonary nodule > 10 mm	20	3.2 %
	pneumonia	4	0.6 %
	ground glass attenuation	4	0.6 %
	pneumokoniosis or asbestosis	2	0.3 %
	lung cancer	1	0.2 %
	pulmonary embolism	1	0.2 %
	pulmonary cavern (or bulla)	1	0.2 %
	air space opacity	1	0.2 %
osseous	extensive degenerative spine disease	45	7.3 %
	rib lesion	5	0.8 %
	fracture of thoracic vertebra	1	0.2 %
diaphragmal	diaphragmatic hernia > 2 cm	14	2.3 %
	esophageal cancer	1	0.2 %
abdominal	epigastric lymph nodes	3	0.5 %
	unclear liver lesion	2	0.3 %
	splenomegaly	1	0.2 %
findings, total		196	31.7 % of n = 619

### Examples and Summary of Findings

Fig. 1–4 show some typical examples of significant and non-significant extra-cardiac and cardiac findings. On average there were 3.2 cardiac and 2.8 extra-cardiac findings per patient, with 32% of all extra-cardiac findings classified as potentially “significant” for patient management (Table 5). There were significantly more extra-cardiac findings in patients with a pathological cardiac finding, in patients over 60 years of age, and in patients with a history of smoking ( $P < 0.05$ ). Smokers also had significantly more pathological cardiac findings than non-smokers ( $P < 0.05$ ).

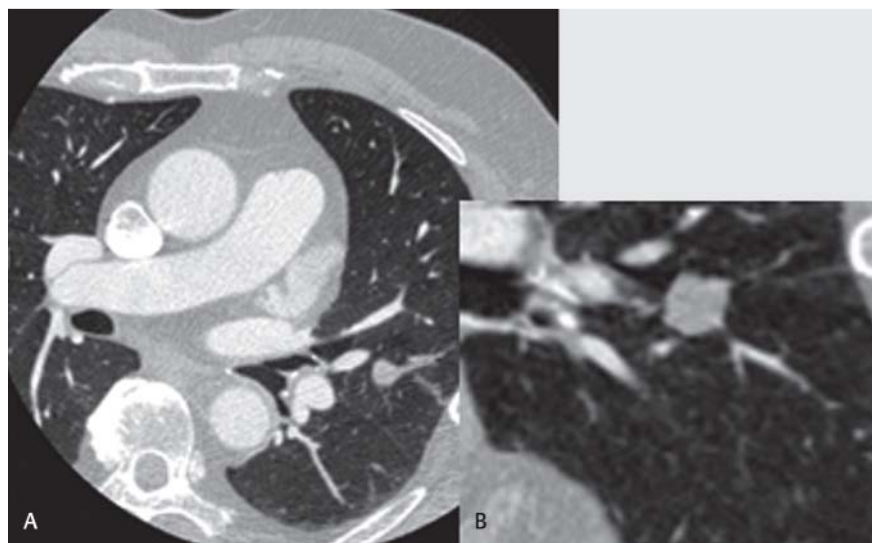
### Additional diagnostics and costs

Many patients received follow-up diagnostics for evaluating incidental “significant” extra-cardiac findings, causing subsequent costs. In the German public healthcare system, a CT scan costs

**Table 4** Non-significant extra-cardiac findings.

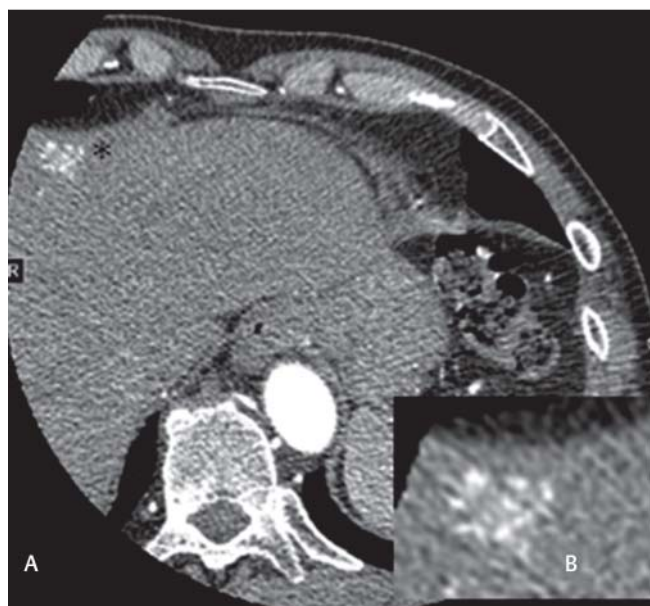
**Tab. 4** Nicht-signifikante extra-kardiale Befunde.

location	non-significant extra-cardiac findings	count	percent
vascular	aortic ectasis < 4 cm	5	0.8 %
	lusoria artery	1	0.2 %
	accessory hepatic artery	1	0.2 %
	common ostium of left subclavian and vertebral artery	1	0.2 %
mediastinal	mediastinal/hilar lymph nodes sizing 8–10 mm	34	5.5 %
pulmonary	pulmonary scar	81	13.1 %
	bronchial thickening	21	3.4 %
	pulmonary bulla	15	2.4 %
	asymptomatic lung emphysema	11	1.8 %
	atelectasis	11	1.8 %
	focal bronchitis with tree-in-bud	8	1.3 %
	bronchiectasis	8	1.3 %
	pulmonary granuloma < 10 mm	6	1.0 %
	pulmonary nodule < 10 mm (e. g. calcification)	3	0.5 %
	small and linear lung opacity	1	0.2 %
pleural	pleural sclerosis	9	1.5 %
	pleural effusion	7	1.1 %
	pleural thickening	2	0.3 %
chest wall	cardiac devices other than pacemakers (intracardiac defibrillator, event recorder)	31	5.0 %
	status after sternotomy	13	2.1 %
	cardiac pacemaker	3	0.5 %
	lipoma	1	0.2 %
	pectus excavatum	1	0.2 %
	ablation of the breasts	1	0.2 %
	extended relaxed diaphragm	1	0.2 %
	thoracic collateral veins dilatation	1	0.2 %
osseous	asymptomatic mild degenerative spine disease	118	19.1 %
	thoracic spine hemangioma	2	0.3 %
	rib osteoma	1	0.2 %
	rib cysts	1	0.2 %
abdominal	hepatic cysts	14	2.3 %
	hepatic hemangioma	5	0.8 %
	ascites	3	0.5 %
	accessory spleen	1	0.2 %
	hepatic steatosis	1	0.2 %
total	all	423	68.3 % of n = 619



**Fig. 1** Pulmonary granuloma in a 60-year-old patient of the left upper lung (>4 mm diameter). After the primary cardiac CT scan, the diagnosis was not clear, and therefore we considered this finding as "significant" extra-cardiac structure and recommended follow-up and further diagnostics. The final diagnosis of granuloma was based on follow-up CT and bronchoscopy (A axial view, contrast-enhanced 64-slice MDCT; B magnification of A).

**Abb. 1** Pulmonales Granulom bei einem 60-jährigen Patienten, welches im Cardio-CT zufällig im linken Oberlappen gefunden wurde (>4 mm). Nach dem ersten CT war der Befund nicht eindeutig, sodass zusätzliche Untersuchungen empfohlen wurden. Somit wurde der Befund als „signifikant“ bezeichnet. Die finale Diagnose wurde mit der Hilfe einer Bronchoskopie gestellt (A axial, kontrastmittelgestützte 64-Zeilen MDCT; B Vergrößerung von A).



**Fig. 2** A 72-year-old male with atrial fibrillation and coronary artery disease was seen with a subcapsular hepatic hemangioma of the right hepatic lobe at the border of the FOV. The diagnosis was made by the first CT scan and there was no recommendation for further diagnostics (A axial view; B magnification; both with contrast medium, 64-slice MDCT). This extra-cardiac finding was previously unknown, but with no consequence in the patient's management or additional diagnostics and therefore defined as "non-significant".

**Abb. 2** Bei einem 72-jährigen Patienten mit Vorhofflimmern und Koronarer Herzkrankheit fanden wir ein subkapsuläres Hämangiom im rechten Leberlappen am Rand des FOVs. Die Diagnose war nach dem ersten CT eindeutig und es gab keine Indikation für weitere Untersuchungen (A axial; B Vergrößerung; kontrastmittelgestützte 64-Zeilen MDCT). Dieser Befund war vorher unbekannt, hatte keine Konsequenzen für die Therapie des Patienten bzw. weiterführende Diagnostik und wurde somit als „nicht-signifikant“ definiert.

151.55 Euros (additional costs were 46.63 Euros for 3D reconstruction and 29.14 Euros for additional series) [16]. The costs for contrast medium in CT were 5.95 in one patient. Within the study

group there were additional total costs for CT of 28 925.48 Euros (approximately 38 314.69 US dollars) in a total of 124 patients. Ultrasound costs 11.66 Euros for one organ, and ultrasound of three more organs costs an additional 4.66 Euros. The total costs for all ultrasound examinations in 19 patients were 310.08 Euros (approximately 410.73 US dollars).

The costs for a single abdominal MRI were 256.46 Euros (additional costs were 17.49 Euros for injections of contrast medium, 58.49 Euros for additional series or 1.75 Euros for placing of an intravenous line). The costs for contrast medium were about 25.70 Euros for abdominal MRI, e.g. using 10 ml gadobutrol. The total costs for additional MRI in 4 patients were 1439.56 Euros (approximately 1906.84 US dollars).

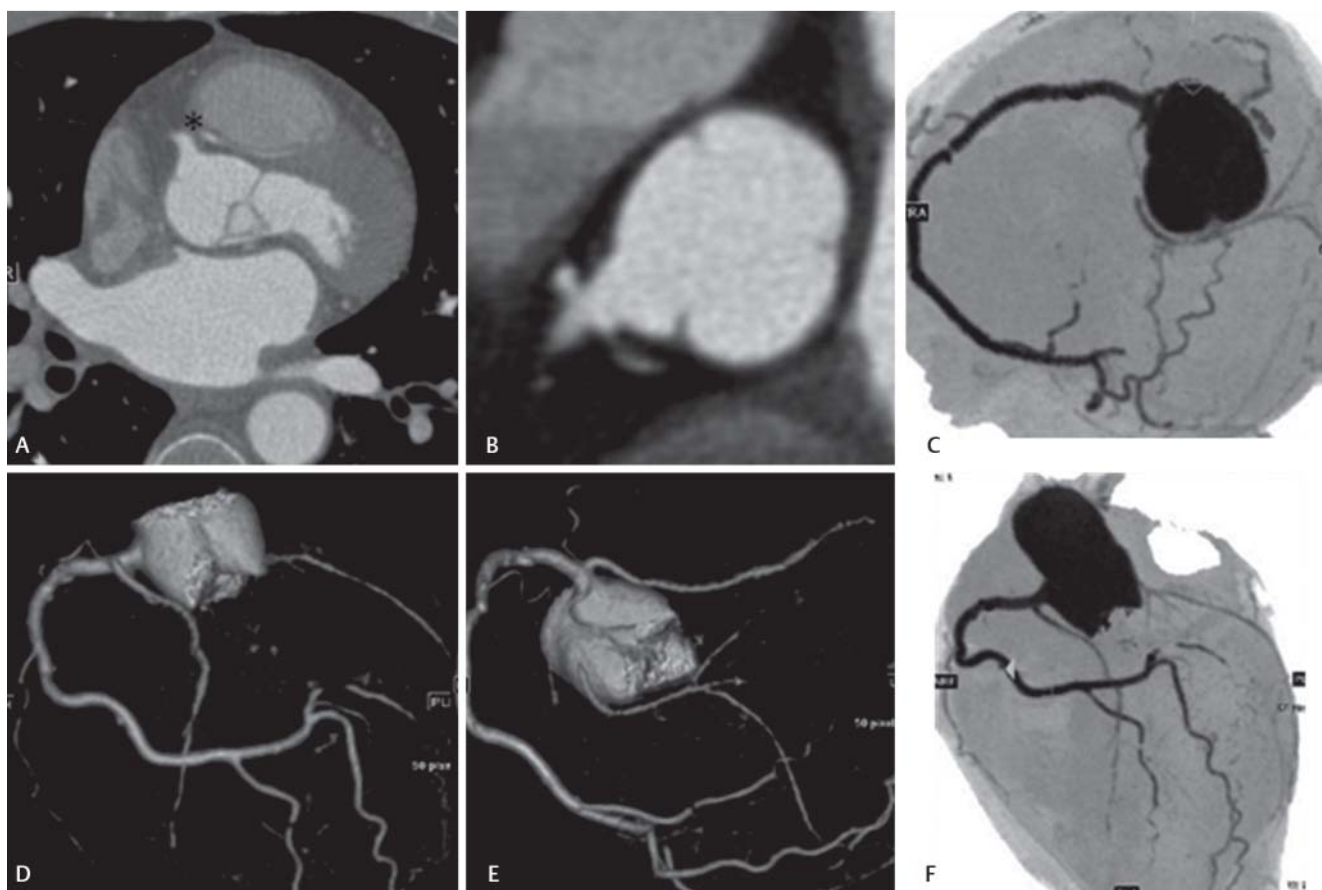
A chest X-ray costs 26.23 Euros for different planes (e.g. posterior-anterior and lateral plane). The total costs for an additional chest X-ray in 55 patients were 1442.65 Euros (about 1910.93 US dollars).

We did not calculate the costs for additional interventions such as catheter-based angiography or biopsy under CT or ultrasound guidance. When including these diagnostics, the total costs for follow-up imaging of "significant" extra-cardiac findings are accordingly higher. Such additional costs comprise anesthesia, consumption of further material, room/staff costs, or a patient's hospital stay (basic single rates for patients of the medical fee schedule in Germany 2012) [16]. Altogether, the additional costs for these subsequent diagnostics in our study (without intervention or biopsy) were about 32 117.77 Euros (about 42 543.19 US dollars, based on the exchange rate on July 25, 2013).

## Discussion

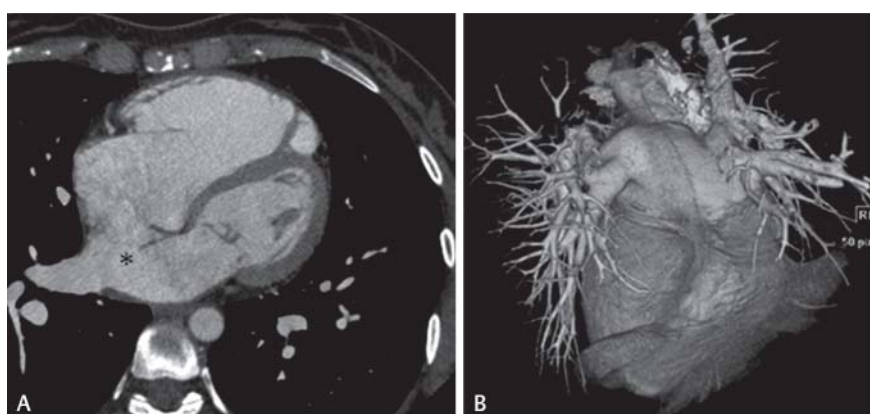
### Statement of principal findings

This study showed that extra-cardiac incidental findings are common in clinically indicated cardiac CT before pulmonary vein isolation. On average there were 3.2 cardiac and 2.8 extra-cardiac findings per patient, with 32 % of all extra-cardiac findings classified as potentially "significant" for patient management. These findings included two patients with primarily detected cancer, who were treated accordingly, 10 patients with aortic aneurysm/ectasia, and one patient with primarily detected aortic dissection.



**Fig. 3** In a 60-year-old female, we detected an ectopic pathway of the LAD originating from the RCA **A\***. The LAD route passed between the ascending aorta and pulmonary trunk **B–F**. Thus, this cardiac status was defined as a malignant coronary anomaly (**A, B** axial views; both contrast-enhanced 64-slice MDCT; **D, E** were 3 D reconstructions and **C, F** subtraction images) and defined as a “significant” cardiac finding that was previously unknown and detected on the cardiac CT scan.

**Abb. 3** Bei einer 60-jährigen Patientin zeigte sich ein ektopter Verlauf des Ramus interventricularis anterior (RIVA) aus der rechten Koronararterie **A\***. Der RIVA verläuft zwischen der Aorta ascendens und dem Truncus pulmonalis **B–F**. Dieser kardiovaskuläre Befund wurde als maligne Koronar-anomalie bezeichnet (**A, B** axial; kontrastmittelgestützte 64-Zeilen MDCT; **D, E** 3D-Rekonstruktionen und **C, F** Subtraktionsbilder) und wurde als ein „signifikanter“ Befund definiert, der vorher nicht bekannt war und im CT erstmalig festgestellt wurde.



**Fig. 4** In a 37-year-old female, we primarily observed an atrial septal defect (**\*A** axial view, contrast-enhanced 64-slice MDCT, confirmed by echocardiography). Besides, the right upper pulmonary drained into the right atrium (isolated partial anomalous pulmonary venous return). Due to the associated increased pulmonary flow, the right heart was dilated. The 3 D reconstruction and dorsal heart view demonstrated a common pulmonary venous ostium on the right side into the atrium (**B** 3 D 64-slice MDCT). These findings were defined as “significant” cardiac findings and were confirmed by echocardiography.

**Abb. 4** Bei einer 37-jährigen Patientin zeigte sich ein atrialer Septumdefekt (**\*A** axial, kontrastmittelgestützte 64-Zeilen MDCT, mit Echokardiografie bestätigt). Zusätzlich mündete die rechte obere Pulmonalvene in den rechten Vorhof (partielle Lungenvenenfehlmündung vom kardialen Typ). Bei entsprechend vermehrter Perfusion im Lungenkreislauf bestand eine Rechtsherzvergrößerung. Die 3D-Rekonstruktion und dorsale Herzansicht zeigte ein gemeinsames Pulmonalvenenostium auf der rechten Seite in den Vorhof (**B** 3 D 64-Zeilen MDCT). Diese Befunde wurden als “signifikanter” bezeichnet und mit der Echokardiografie bestätigt.

**Table 5** Summary of cardiac and extra-cardiac findings.**Tab. 5** Zusammenfassung der kardialen und extra-kardialen Befunde.

	count	percent
patients, total	224	100 %
patients with cardiac findings	203	91 %
patients without cardiac findings	21	9 %
patients with extra-cardiac findings	179	80 %
patients without extra-cardiac findings	45	20 %
cardiac findings, total	724	100 %
extra-cardiac findings, total	619	100 %
significant extra-cardiac findings	196	32 %
non-significant extra-cardiac findings	423	68 %

### Relevance of the study findings with comparison to the literature

In addition to the evaluation of cardiac anatomy and pulmonary vein status, surrounding cardiac and extra-cardiac structures could be included in examinations after the first scan due to the wide field-of-view surrounding the heart [17–19]. Several cardiac and extra-cardiac findings were described after cardiac-specific CT examination studies and were subdivided into significant or non-significant [11, 14, 15]. In 179 of the 224 patients (80%), one or more incidental extra-cardiac findings were noted per patient. This is consistent with the literature in which the percentage of extra-cardiac findings at cardiac CT ranges from 8% in asymptomatic patients [10] to 69% in symptomatic patients [12] with known or suspected CAD.

In our study we observed a relatively high incidence of extra-cardiac and cardiac findings, which may be due to the detailed image and the advanced mean age of our patients. We did not scan healthy patients, patients from the emergency room or “outpatients”. Our patients were pre-therapeutic “inpatients” with a specific disease (atrial fibrillation prior to PVI).

Many of our extra-cardiac findings did not cause a change in patient management. However, a considerable number of “significant” extra-cardiac findings were potentially relevant from a prospective perspective, or definitely caused a change of therapy. In more detail, 32% of all incidental extra-cardiac findings in our study were of clinical or therapeutic relevance and required additional diagnostics or further diagnostics. For comparison, in the study of Onuma et al. 22% of findings required follow-up and were therefore defined as “significant” findings [11].

In cardiac CT it is important to have a large field-of-view (FOV) to detect potential malignant findings that could potentially be treated at an early stage, such as peripheral lung cancer. Otherwise, with a small FOV focused on the heart, such findings could be missed with a severe impact on the patient's health [20, 21]. However, additional findings result in additional diagnostics, work-up, and costs for the healthcare system [22]. Lee et al. demonstrated the prevalence of extra-cardiac findings in one-third of 151 patients with cardiac CT and calculated 438 US dollars per patient with follow-up diagnostics and an average of 17 US dollars per patient in the whole screening group [22]. In our study the average costs for follow-up diagnostics “significant” extra-cardiac findings were about 190 US dollars per patient for the whole study group (224 patients). The discussion about extra-focal findings next to the primarily focused region-of-interest is widespread and is not limited to the cardiac-thoracic region. For instance, many incidental findings are in the abdominal pelvic re-

gion, as seen in a group of 1426 imaging studies by Orme et al. [23]. 576 (39%) had an incidental finding, more often seen in elderly patients similar to our study results. A clear medical benefit was only seen in 1.1% of cases, i.e. in 6 of 567 patients. There was also a high incidence of unclear benefit, limited follow-up period and different imaging methods applied [23].

The cardiac CT imaging protocol usually includes parts of the lungs, spine and upper abdomen. It could be a risk not to evaluate them, when considering potential malignant findings: We found one lung cancer and one esophagus cancer that were confirmed by subsequent diagnostics (no metastasis, local stage). These cancers were seen in two patients of 224 (0.89%) and were unknown before CT. For comparison, Hunold et al. found three lung cancers among 1812 patients [13] and Kanawo et al. detected four lung cancers, two thyroid cancers and one hepatic cancer among 625 patients [24]. Kim et al. found a prevalence of lung cancer after cardiac CT of 0.31%, 68% of these malignancies were at a resectable stage [25].

Three studies analyzed the incidence of incidental findings before pulmonary vein isolation during the last years [12, 15, 26]. Schietinger et al. found 69%, Wissner 53% and Martins 23.2% incidental findings in their patient cohort [12, 15, 26]. These values are in the range of former CT studies for CAD detection as described before [10, 11]. All those studies differ with respect to patient number and median age. There are also differences regarding patient history and characteristics. In general, findings with a major impact on life quality and life expectancy are relatively rare, but in the affected patients the impact of such findings is strong, so that their detection is relevant.

The detection of such findings requires specific education in cardio-thoracic imaging pathology beyond the image interpretation of the heart in order to interpret cardiac CT images comprehensively. Clinical experience plays a further role. For example, long-term experienced cardio-thoracic radiologists detect and interpret incidental findings more precisely than less experienced colleagues [27]. A further question is how to cope with potentially malignant findings that are unexpected and require further diagnostics for confirming or excluding malignancy. In the patient's interest such findings should be reported for performing further diagnostic work-up [28]. On the one hand precise diagnostics, on the other hand balanced communication with the patient are necessary.

### Study limitations

Our study is limited by the fact that it was performed retrospectively in a single center. The follow-up period should actually comprise a longer time span and more patients should be analyzed in a multi-center study. The study was performed in patients with atrial fibrillation before PVI and is therefore representative for such patients. However, studies with other patient characteristics may show somewhat different results. This study did not compare the success rate of cardiologists versus radiologists in detecting and interpreting cardiac and extra-cardiac CT findings. Instead we applied the consensus decision of two radiologists and one cardiologist in an interdisciplinary approach to cardiovascular imaging.

### Conclusion

▼ This study has analyzed both cardiac and extra-cardiac findings in patients with atrial fibrillation and indication for pulmonary

vein isolation. On the one hand there were 3.2 cardiac findings per patient. On the other hand there were even 2.8 extra-cardiac findings which had to be analyzed comprehensively and occur significantly more often in patients over 60 years old, in smokers and in patients with a history of cardiac findings ( $p < .05$ ). Cardiac findings on CT are common in patients referred to CT with the mentioned risk factors (38% smokers, 98% before pulmonary vein isolation and 2% after). Most findings can be diagnosed after the first examination, and others require further interdisciplinary diagnostics with consecutive costs (about 190 US dollars per patient). Radiologists and cardiologists have to be aware of relevant cardiac findings that need additional diagnostics or treatment as well as of extra-cardiac findings that might be relevant (32%), require further diagnostics, and may change the individual outcome. We support the comprehensive integration of extra-cardiac findings into approved guidelines and into the teaching of cardiovascular imaging [29–34]. The evaluation of extra-cardiac findings on cardiac CT has important implications and cardiac anatomy is becoming an increasingly common indication for CT. Protocols and image analysis should be optimized for the identification of important incidental findings.

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