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ความชุกและความสำคัญของการพบโรคอื่นนอกจากโรคหัวใจในผู้ป่วยที่ได้รับการตรวจวินิจฉัยโรคหัวใจโดยเครื่องเอกซเรย์คอมพิวเตอร์

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Prevalence and Significance of Incidental Extracardiac Findings of a Cardiac CT Angiography

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หลักการและวัตถุประสงค์: เพื่อศึกษาถึงความชุกและความสำคัญของการพบโรคอื่นนอกจากโรคหัวใจในการตรวจวินิจฉัยโดยเครื่องเอกซเรย์คอมพิวเตอร์โดยเฉพาะที่บริเวณทรวงอกและช่องท้องส่วนบนที่อาจตรวจพบร่วมกันได้

วิธีการศึกษา: ศึกษาข้อมูลย้อนหลังของผู้ป่วย 233 ราย ที่ได้รับการส่งตรวจวินิจฉัยโรคหัวใจโดยเครื่องเอกซเรย์คอมพิวเตอร์ โดยแบ่งการพบโรคอื่นนอกจากโรคหัวใจตามความสำคัญทางคลินิกเป็นความผิดปกติน้อยซึ่งมีความสำคัญทางคลินิกน้อยไม่ต้องติดตามต่อไป ปานกลางซึ่งอาจต้องติดตามต่อไปร่วมกับซักประวัติเพิ่มเติมและมากซึ่งต้องตรวจวินิจฉัยเพิ่มเติมหรือให้การรักษาทันที

ผลการศึกษา: พบโรคอื่นนอกจากโรคหัวใจในผู้ป่วย 153 ราย (ร้อยละ 66) แบ่งเป็นเพศชาย 102 รายและหญิง 51 ราย อายุเฉลี่ยประมาณ 67.2±12.5 ปี แบ่งเป็นความผิดปกติน้อยร้อยละ 71 ปานกลางร้อยละ 14 และผิดปกติมากร้อยละ 15 ซึ่งพบความผิดปกติน้อยทั้งหมด 185 ชนิดจากผู้ป่วย 115 ราย ความผิดปกติปานกลาง 37 ชนิดจากผู้ป่วย 26 ราย และความผิดปกติมาก 39 ชนิดจากผู้ป่วย 38 ราย

สรุป: จากการศึกษานี้พบว่ามีการตรวจพบโรคอื่นนอกจากโรคหัวใจในการตรวจวินิจฉัยโรคหัวใจโดยเครื่องเอกซเรย์คอมพิวเตอร์จำนวนไม่น้อย ดังนั้นแพทย์ผู้แปลผลการตรวจต้องตระหนักถึงความสำคัญและประเมินอวัยวะอื่นที่เห็นร่วมด้วยอย่างละเอียด

Background and objective: To evaluate prevalence and significance of extracardiac findings (ECF) in patients referred for cardiac CT angiography (CCTA). CCTA has the ability to depict ECF in the visualized thorax and upper abdomen. These incidental lesions can often present a challenge to physicians.

Method: We performed a retrospective review of 233 consecutive patients referred for CCTA. Extracardiac CT findings (ECF) were classified as benign, indeterminate, or of clinical significance at the time of image evaluation. Benign findings were those considered to be of little clinical significance with no follow-up needed. Indeterminate findings were those deemed of potential clinical importance, requiring correlation of the patient history or a follow-up study. Clinically significant findings were those felt to be of definite clinical importance requiring immediate evaluation or intervention.

Results: A total of 261 ECF were found in 153 patients (66%), 102males and 51 females, with a mean age of 67.2±12.5 years. Of those, 185 (71%) were considered benign, 37 (14%) indeterminate, and 39 clinically significant findings (15%). A total of 185 benign ECF were found in 115 patients. The 37 ECF indeterminate findings were present, distributed in 26 patients. The 39 clinically significant ECF were distributed in 38 patients.

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คำสำคัญ: โรคอื่นนอกจากโรคหัวใจ, โรคที่พบร่วมด้วยโดยบังเอิญ, การตรวจวินิจฉัยโรคหัวใจโดยเครื่องเอกซเรย์คอมพิวเตอร์, เครื่องเอกซเรย์คอมพิวเตอร์ชนิดมัลติดีเทคเตอร์

Conclusion: There were a significant number of extracardiac findings in CCTA. Physicians who analyze CCTA should carefully evaluate all organs in the scan.

Keywords: Extracardiac findings, incidental findings, cardiac CTA, multidetector computed tomography (MDCT)

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Introduction

Multidetector computed tomography (MDCT) with high temporal and spatial resolution is emerging as a noninvasive diagnostic technique to visualize the heart[1-10]. It is now accepted as a useful modality to detect coronary stenoses, coronary plaques, to assess calcification of the coronary arteries, remodeling of coronary atherosclerotic lesions, anatomy of the pericardium, and size and function of the ventricles[1-10]. Because of the growing number of scanners, these examinations will be performed with increasing frequency. This versatile modality is expected to diagnose not only coronary artery disease but also other diseases causing chest pain such as aortic dissection[11] and pulmonary embolism[12].

Although a cardiac computed CT angiography (CCTA) is mainly focused on the assessment of the coronary, aortic, and cardiac structures, portions of the non-cardiac structures are visible on the scan as well[13-15]. Lesions depicted incidentally during CCTA can often be clinically significant and present a challenge to physicians. The study of the coronary arteries requires a small field of view (FOV) in order to ensure optimal spatial resolution. However, for the evaluation of non-cardiac structures, reconstructions with a larger FOV can additionally be acquired to encompass the entire thorax.

In the present study, we retrospectively assess the spectrum, prevalence, and significance of extracardiac findings in a series of patients undergoing cardiac MDCT using a 128-slice MDCT scanner.

Materials and Methods

Patients

This retrospective study included 233 patients (149 males and 84 females) referred for CCTA, between November 2009 to December 2011. The indications for CCTA were an abnormal, equivocal or non-diagnostic stress test, chest pain, evaluation of cardiomegaly and congestive heart failure, as well as the evaluation of cardiac etiology of syncope. Patients with a intermediate probability of coronary artery disease (CAD) were also referred for a CCTA as a first test. The above are considered appropriate indications for CCTA, based on the criteria of the American College of Cardiology (ACC)[10] and the recent American Heart Association Scientific Statement on Cardiac CT[10]. Exclusion criteria for CCTA included the presence of multiple ectopic beats, atrial fibrillation, renal failure, pregnancy and a history of allergic reaction to iodine-containing contrast agents. The study protocol was approved by the Office of Human Research Ethics, Khon Kaen University, Thailand, and informed consent was obtained from all patients.

Cardiac CT Angiography Protocol

CCTA examinations were performed on a 128-slice MDCT (Brilliance 128, Philips Healthcare, Netherland) using prospective or retrospective electrocardiographic (ECG) gating with the following parameters: 128 × 0.6 collimation, 0.3 sec rotation time, pitch of 0.32, 120 kV tube voltage and 185 reference mAs. Patients with heart rates over 75 bpm with no contraindications to the use of beta-blockers received metoprolol orally 1 hour before the examination to reduce heart rate (n=11). However, in the presence of contraindications for a beta-blocker or an unsatisfactory lowering of the heart rate, the scan was still performed, even at higher heart rates. Image acquisition was performed during inspiratory breath-hold. To familiarize the patient with the protocol, breath-holding was practiced before the examination. A contrast agent bolus of 80-100 ml was injected with a mean flow rate of 5 ml/s followed by a 50-ml saline flush. For timing purposes, an automated bolus-tracking software was used, starting the scan automatically 6 seconds after contrast agent density in the descending aorta reached a predefined threshold of 130 HU. The entire volume of the heart was covered during one breath-hold in approximately 5 seconds with simultaneous recording of the ECG trace. Patients were scanned in the supine position twice, first without contrast medium to calculate the calcium score and secondly after contrast medium injection. Studies were acquired in the cranio-caudal direction from the level of the carina to just below the diaphragm. For optimal motion-free image quality, data sets were reconstructed in mid diastole (mean interval, 614±175 ms after the R wave). All scans were performed with either ECG triggering using 60% to 100% phase window or, in patients with an indication for evaluation of cardiac function, full-beat retrospective ECG triggering using tube current modulation. Electrocardiographically gated datasets were reconstructed automatically to overlapping 0.5-mm slices in 0.25-mm intervals at 75% of the RR cycle length. Additional reconstruction windows were constructed after examination of initial datasets if motion or noise artifacts were present.

Cardiac CT Angiography Image Reconstruction

All CT datasets were transferred to a dedicated workstation. To evaluate the coronary arteries, the images were reconstructed with a small FOV (120-190 mm), which was restricted to the heart region. Additionally, for the evaluation of incidental extracardiac findings, images were reconstructed with a large FOV (> 300 mm) at an effective slice thickness of 0.6 mm, from the outer rib to outer rib covering the entire thorax. The images were reviewed in the axial, coronal, and sagittal planes, using a mediastinal window (width: 450, level: 35), lung window (width: 1,500, level: -700), and bone window (width: 1,500, level: 450) for all examinations.

Cardiac CT Angiography Image Interpretation

Each CT examination was retrospectively reviewed by experienced radiologist and cardiologist in consensus and the incidental extracardiac findings (ECFs) were reported. ECFs were classified as thoracic, when located above the diaphragm and abdominal, when located below the diaphragm. ECFs were also classified according to their clinical significance as severe, indeterminate, and mild. A similar classification system was used by Kirsch et al.[16]. Severe findings were those of definite clinical importance, requiring immediate evaluation or intervention. Indeterminate findings were those of potential clinical importance, requiring a follow-up study or correlation with the patient's history. Finally, mild findings were those considered to be of little clinical significance with no further need of follow-up. For abdominal findings, steatosis was used to describe diffuse low attenuation of the liver parenchyma. Smooth non-enhancing water attenuation lesions of the liver were described as liver cysts. Nodular peripheral arterial enhancement with centripedal filled-in liver lesions were characterized as hemangiomas. For the thoracic findings, pulmonary nodules were characterized based on their size, according to the current Fleischner criteria[17]. However, if the nodules were found to be smaller than 8 mm, but with other imaging characteristics to suggest malignancy, they were classified as severe. Areas with increased attenuation in lung parenchyma were characterized as consolidations or ground glass opacities, and low attenuation areas as emphysema. A diagnosis of interstitial lung disease was given when interlobular septal thickening was present in the absence of findings of congestive heart failure. An aortic diameter at the level of the ascending aorta of > 5 cm was considered aneurysm, while for the abdominal aorta a diameter of > 3 cm was considered aneurysm. The diagnosis of pulmonary embolization was based on the presence of filling defects in the pulmonary arteries and the diagnosis of pulmonary hypertension on the presence of dilated pulmonary arteries. For the lymphadenopathy, the criterion was a diameter of the short axis > 1 cm.

Results

Clinical characteristics of the patients are summarized in Table 1. In the cardiac analysis, 195 patients (84%) had a positive result for cardiac disease. The additional reconstructions performed for incidental extracardiac findings detection with a large FOV, at three planes and three windows significantly increased the total time for reviewing each CCTA examination. Incidental ECFs were detected in 153 patients (66%); 102 males and 51 females (mean age of of 67.2±12.5 years). In 26 patients (11%) multiple ECFs were depicted. A total of 261 ECFs were found: 185 (71%) were classified as mild, 37 (14%) as indeterminate and 39 (15%) as severe. The mild findings were 60% (111 of 185) thoracic and 40% (74 of 185) abdominal, while indeterminate findings were 94.6% (35 of 37) thoracic and 5.4% (2 of 37) abdominal. Lastly, the severe findings were 79.5% (31 of 39) thoracic and 20.5% (8 of 39) abdominal. Mild abdominal findings included hepatic steatosis, liver cyst, liver hemangioma, calcified liver granuloma and calcified splenic granuloma (Table 2). Mild thoracic findings included emphysema, calcified lung granuloma, bone hemangioma, bronchiectasis, calcified lymph nodes, and healed rib fracture (Table 3). The only indeterminate abdominal finding was ascites (Table 3). Indeterminate thoracic findings included pulmonary nodules > 0.8 cm and < 3 cm, consolidation or ground glass opacities, pleural effusion, atelectasis, interstitial lung disease, pleural thickening, mediastinal mass lesions, and thoracic adenopathy. Severe abdominal findings included renal mass, liver masses and abdominal aortic aneurysms (Table 4). Severe thoracic findings included pulmonary nodules > 3 cm (Figure 1), an ascending aortic aneurysm (Figure 1), aortic dissection (Figure 2), pulmonary embolism (figure 3), and pulmonary nodules of any size with malignant characteristics (Table 4).

In 4 patients, pulmonary nodules classified as indeterminate were known from previous thorax CT examinations. No change in size was detected within 2 or more years and the nodules were considered mild. For the indeterminate and severe pulmonary nodules, either a follow-up with CT or further evaluation by biopsy was recommended. A pathological verification was available for 7 of the 11 pulmonary nodules > 3 cm, which proved to be malignant (Figure 1). All three patients with consolidation or ground glass opacities had mediastinal lymphadenopathy and received antibiotic therapy. A follow-up with CXR showed regression of the lung lesions. Two patients with pleural effusions had a known history of congestive heart failure and the effusions existed in recent previous CXR. All four patients with pulmonary emboli received anticoagulant therapy.

Table 1 Patient characteristics (n=233)

Characteristic	Value
Age (years), mean ± SD (range)	60.2±11.5 (20-91)
Men	149 (64%)
Height (cm), mean ± SD	160.1 ± 13
Weight (kg), mean ± SD	58.2± 10
Body mass index (kg/m²), mean ± SD (range)	23.0± 6 (15-35)
Diabetes mellitus	100 (43%)
Hypertension*	181 (77%)
Hypercholesterolemia†	137 (59%)
Current smoker	118 (51%)
Obesity ‡	8 (3%)

*Blood pressure > 140/90 mmHg or treatment for hypertension.

‡Total cholesterol > 180 mg/dl or treatment for hypercholesterolemia.

†Body mass index > 30 kg/m².

Table 2 Classification of Mild Incidental Non-Cardiac Abnormal Findings According to Location

Finding	Number (%)
Abdomen	74 (40)
Hepatic Steatosis	48 (25.9)
Liver cyst	21 (11.3)
Liver hemangioma	2 (1.0)
Calcified liver granuloma	3 (1.8)
Thorax	111 (60%)
Emphysema	29 (15.7)
Calcified lung granuloma	40 (21.6)
Calcified lymph nodes	32 (17.3)
Bronchiectasis	5 (2.7)
Healed fracture	5 (2.7)

Table 3 Classification of Indeterminate Incidental Non-Cardiac Abnormal Findings According to Location

Finding	Number (%)
Abdomen	2 (5.4)
Ascites	2 (5.4)
Thorax	35 (94.6)
Pulmonary nodule >0.8 cm and < 3 cm	11 (29.7)
Lymphadenopathy	12 (32.4)
Pleural effusion	2 (5.4)
Atelectasis	4 (10.8)
Consolidation/GGO	3 (8.2)
Pleural thickening	1 (2.7)
Interstitial lung disease	2 (5.4)

GGO: ground glass opacity

Table 4 Classification of Severe Incidental Non-Cardiac Abnormal Findings According to Location

Finding	Number (%)
Abdomen	8 (20.5)
Abdominal aortic aneurysm	3 (7.7)
Liver mass	4 (10.3)
Renal mass	1 (2.5)
Thorax	31 (79.5)
Pulmonary nodule >3 cm	11 (28.3)
Pulmonary nodule of any size with malignant characteristics	1 (2.5)
Pulmonary embolism	4 (10.4)
Aortic dissection	2 (5)
Ascending thoracic aortic aneurysm	13 (33.3)

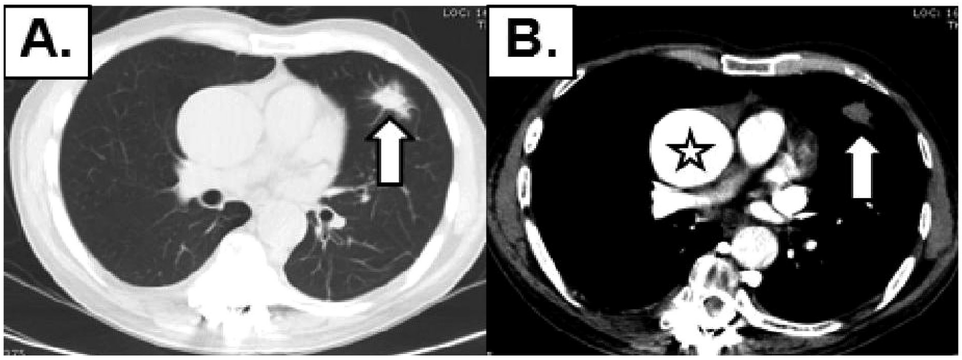

Figure 1 Incidentally detected bronchogenic carcinoma and ascending thoracic aortic aneurysm in 68-year-old man. Axial plane lung window (A) and soft tissue window CT (B) showed spiculated mass measuring 3.3 cm in diameter at lingular segment of left upper lobe (arrow) and ascending thoracic aortic aneurysm (star). The mass was pathologically proved to be adenocarcinoma.

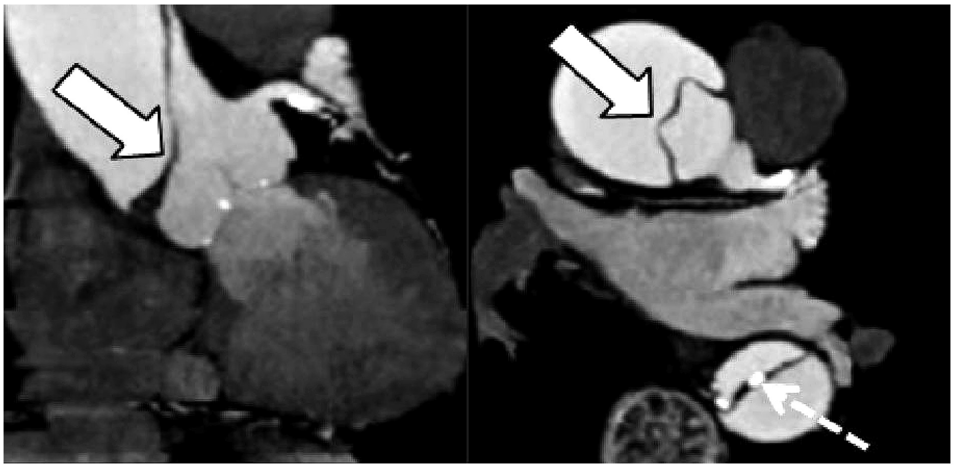

Figure 2 Aortic dissection Stanford type A of a 75-year-old woman with chest pain who underwent a 128-slice coronary CT angiography. Dissection flap (arrows) originating in the ascending thoracic aorta and extending throughout the aortic arch and descending thoracic aorta (dashed arrow).

Figure 3 Acute pulmonary embolism (arrows) incidentally found in 58-year-old-woman who was referred for coronary CT angiography for atypical chest pain.

Discussion

In this study, we found that 66% (153 of 233) of the patients referred for CCTA had ECFs, 16.3 % (38 of 233) of the patients which were required to have clinically significant findings which were required immediate evaluation. Additional pothological work up or intervention. Routine CCTA is performed by scanning the heart from bifurcation of the pulmonary artery to the left ventricular apex with or without a non-enhanced scan for assessment of calcification. Consequently, images are reconstructed to focus on the heart in synchronization with the diastolic phase. In the process, we can freely adjust the field of view (FOV) without additional radiation exposure because the entire content within the boundaries of the gantry is scanned and available. For cardiac imaging, FOV was confined to be as small as possible to achieve best resolution. Besides images for cardiac analysis, we made another set of images with a large FOV to evaluate the chest. This method is not universal, but we think it could be beneficial to evaluate all organs in the scan. For patients with lung, pleural or aortic diseases could be differentiated in the same scan. Of 190 symptomatic patients in whom coronary artery disease was ruled out, 19 patients were diagnosed to have ECGs which could cause anginal symptoms including pulmonary embolism, aortic dissection and ascending thoracic aortic aneurysm. In these patients, further diagnostic imaging workup was not necessary. In addition, asymptomatic malignancies could be detected. In this study, 12 cases of malignancies were revealed (7 lung cancer, 1 renal cell carcinoma, 3 cholangiocarcinoma, and 1 hepatocellular carcinoma). Evaluating ECFs may be important to prevent significant morbidity and mortality. Several studies of electron-beam computed tomography (EBCT) cardiac scans have been published on the prevalence of ECFs in cardiac CT[18,19]. Hunold et al.[19] investigated 1,812 patients undergoing EBCT and demonstrated about the same frequency of ECFs (63%) as the present study (66%). In a study by Horton et al.[18], of 1,326 consecutive patients with EBCT, significant ECFs that required clinical or radiological follow-up were observed in 7.8%. In contrast, the present study identified significant ECFs in 15%, in which pulmonary nodules and aortic disease were observed more frequently. The higher incidence of pulmonary nodules in our study is partly related to a larger number of former or current smokers. Fifty-one percent of the patients were former or current smokers in our study, while only 25% were former or current smokers in the study by Horton et al.[18] and Mueller et al.[20] who scanned patients with a 16-MDCT scanner from the subclavian artery level, through the apex of the heart to assess graft patency after coronary artery bypass graft (CABG) surgery, found that 34 of 259 patients (13%) had ECFs, including pulmonary embolisms, lung incidence of 5% for clinically significant findings, and only 10% for non-significant findings in a cohort of 108 patients scanned with a 16-row MDCT. The significance of using a large FOV, encompassing the entire thorax, versus a small FOV, encompassing only the heart, during image reconstruction for evaluation of extracardiac structures, has been documented in previous reports. Aglan et al.[21] studied the prevalence of extracoronary findings using both a full "thoracic" FOV and a small "cardiac" FOV and found a higher detection rate of clinically significant findings by using the former compared to the latter (26% versus 15%) ($p < 0.001$). Northam et al.[22] compared the frequency of detection of pulmonary nodules on cardiac CT scans acquired with a limited and a full FOV, and concluded that viewing cardiac CT scans at a limited FOV only can result in missing more than 67% of the nodules larger than 1 cm and more than 80% of nodules smaller than 1 cm. In our study, a small FOV, restricted to the heart, was used for the evaluation of the coronary arteries and additional reconstruction of images with a large FOV to encompass the entire thorax was performed in order to evaluate the presence of ECFs. Many studies suggest that CCTA can reveal important abnormalities in extracardiac structures contained in the scanned volume and therefore, the entire examination should be reconstructed with the maximum field of view and should be reviewed by qualified radiologists or cardiologists for the presence of incidental extracardiac findings[13-16].

We consider that the best approach is to view all available data in each CCTA study, report all non-cardiac findings estimating their clinical significance, and consult each patient appropriately. Specifically, the early detection of lung cancer is an issue of great importance; in our study, seven patients were diagnosed with lung cancer. Accordingly, specialists who interpret CCTA should be trained and qualified enough to recognize and evaluate extra-cardiac pathologies. The limitations of our study are as follows. The presence of limited follow-up data, as well as the absence of histopathological verification of indeterminate incidental extracardiac findings. We might have underestimated the significance of the noncardiac findings. A cost/ efficacy analysis was not performed in the present study. A prospective, controlled study is necessary to elucidate cost/efficacy of evaluating ECFs in CCTA.

Conclusion

A number of clinically significant extracardiac findings (ECFs) might have been missed in conventional coronary CT angiography. Although a small percent of the findings resulted in therapeutic consequences, some were important, including asymptomatic malignancies. The lungs, mediastinum, bones, and upper abdomen should be reviewed using appropriate mediastinal, bone, and lung windows and a large FOV to include the entire thorax. Physicians who analyze coronary CT angiography either radiologists or cardiologists should carefully evaluate all the organs in the scan.

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