European Journal of Radiology Open 8 (2021) 100330

Contents lists available at ScienceDirect

European Journal of Radiology Open

journal homepage: www.elsevier.com/locate/ejro

Prevalence of intracardiac thrombi on cardiac computed tomography angiography: Outcome and impact on consequent management

Narumol Chaosuwannakit [a,*], Pattarapong Makarawate [b]

[a] Radiology Department, Faculty of Medicine, Khon Kaen University, Khon Kaen, 40000, Thailand
[b] Cardiology Unit, Internal medicine Department, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand

ARTICLE INFO

Keywords:
Computed tomography
Cardiac thrombus
Cardiac CTA

ABSTRACT

Objective: Intracardiac thrombi are intermittently come across on cardiac computed tomography angiography (CCTA). This study aimed to examine the prevalence, outcome, and prognosis in patients with incidental found left-sided cardiac thrombi on CCTA.
Material and Methods: The Ethics Committee approved the present study of the Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand. A retrospective review of CCTA was performed for incidental left-sided cardiac thrombi.
Results: A total of 1080 CCTAs were enrolled with the prevalence of incidental left-sided cardiac thrombi is 4.53%. Of the 49 patients with CCTA incidental left-sided cardiac thrombi, 16 had left atrial thrombi, and 33 had left ventricular thrombi. All thrombi were undetermined before the CCTA, and their identification subsequently generated anticoagulation treatment. In 10 patients, embolic complications happened, 4 of which were fatal. Patients with incidental detected left-sided intracardiac thrombi seen by CCTA had more embolic event than patients who did not discover left-sided intracardiac thrombi by CCTA (HR = 8.07; 95% CI 1.48–44.06; $p = 0.016$).
Conclusions: Incidental left-sided cardiac thrombi on CCTA guided to management adjustments and seemed to present substantial mortality and morbidity in the present study. Physicians who interpret CCTA should ensure a dedicated effort not to disregard these prospective pitfalls.

1. Introduction

Thrombus is the most common filling defect observed in cardiac chambers, with a preference for the left ventricular apex and left atrial appendage [1]. The incidence of thrombus in the left atrial appendage is substantially raised in patients with mitral valve disease and atrial fibrillation [2]. Left ventricular thrombi are at increased probability in patients with coronary artery disease, left ventricular aneurysm t or wall motion abnormality, and thus early detection with subsequent treatment is crucial [1]. Thrombi typically do not enhance cardiac computed tomography angiography (CCTA) imaging, but chronic thrombi can show heterogeneous enhance with peripheral fibrous capsule enhancement, or they could calcify [1–3]. Compared to transesophageal echocardiography (TEE), CCTA is a non-invasive technique for detecting intracardiac thrombus with high diagnostic accuracy. It can be used instead of, or along with, echocardiography in patients with contraindications for TEE, as it needs substantial sedation and could be painful [4,5].

Incidentally discovered left-sided cardiac thrombi on CCTA are sporadically come across in clinical practice. Severe complications of left-sided cardiac thrombi are predominantly associated with systemic embolization such as a limb or mesenteric ischemia or strokes [1,6,7]. The present study's objective was to evaluate the prevalence, outcome, and prognosis of incidental found left-sided cardiac thrombi on CCTA.

2. Materials and methods

2.1. Patient population

This study was a retrospective study conducted at Khon Kaen University Hospital, Khon Kaen, Thailand. The inclusion criteria were consecutive patients who underwent CCTA from various clinical

* Corresponding author.
E-mail address: narumol_chao@yahoo.com (N. Chaosuwannakit).

https://doi.org/10.1016/j.ejro.2021.100330
Received 22 December 2020; Received in revised form 4 February 2021; Accepted 8 February 2021

indications according to the Appropriate Use Criteria for Cardiac Computed Tomography guideline within five years. [7]. Exclusion criteria were those with known intracardiac thrombus, unsatisfactory CCTA quality, incomplete medical information, or contraindication for CCTA, including renal failure, pregnancy, or a history of an allergic reaction iodine-containing contrast agents. These eligible patients included 49 patients of incidentally found left-sided cardiac thrombus on CCTA (Fig. 1). These patients' medical records were retrospectively reviewed to define which patients had consequent confirmation of thrombi on echocardiography. The effect of incidental left-sided cardiac thrombi on patient treatment was also verified. In each case, the possible etiology of left-sided thrombi is left ventricular aneurysm, myocardial infarction with wall motion abnormality, mitral valvular heart disease, or atrial fibrillation.

2.2. Cardiac CT angiography scanning protocol

Imaging was performed using a dual-source CT scanner (Somatom Definition; Siemens Healthcare, Forchheim, Germany). With two tubes and two detectors mounted at orthogonal orientation in the gantry, temporal resolution significantly improved. A gantry rotation time of 0.28 s thus results in a temporal resolution of 75 ms. Tube voltage for CT-angiography was 80−100 kV for both tubes, the full current between 30 and 80 % of the cardiac cycle, pitch 0.2–0.44 adapted to the high resolution. Per-rotation 128 slices are generated with collimation of 0.6 mm, leading to an isotropic voxel resolution of approximately 0.6 mm edge length and 0.2 mm. The radiation dose was adjusted not to exceed 350 mGy cm. No preparation nor beta-blockers were given before the examination. Non-contrast scan for calculation for coronary calcium score was taken from the carina to the heart's apex. A test bolus injection followed the scan to calculate the peak of contrast enhancement time. Then the final cardiac CT angiography was taken. A bolus of iodinated contrast material (350 mg/mL, Omnipaque; GE Healthcare) at a dose of 1.5 mL/kg with dual-head power injector followed by a 10−20 ml of saline flush at the same rate as that of the contrast injection. Axial images were reconstructed with 0.75 mm slice thickness and 0.5 mm increment using a medium sharp convolution kernel (B26) and retrospective ECG gating. The reconstructions were performed in 5% steps over the entire R-R cycle using a single-segment algorithm that utilizes a quarter segment of projection data from both detectors. Patients were scanned in the supine position [8].

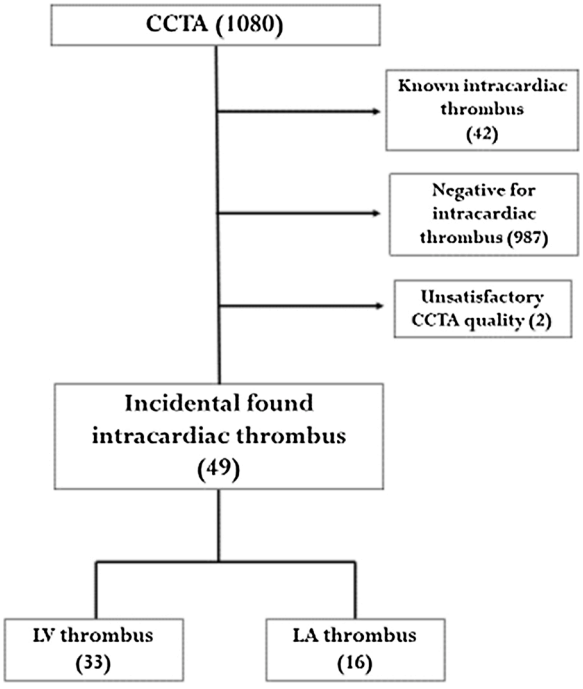

Fig. 1. Flow-chart of the patients' inclusion in the study.
(CCTA : Cardiac computed tomography angiography, LV: left ventricle, LA: left atrium)

2.3. CCTA image analysis

All acquired CCTA images were transferred to a dedicated 3D-post-processing workstation (Syngo via, Siemens Healthcare Global, Malvern, PA). CCTA image analysis was performed by cardiac imaging radiologist and cardiologist in consensus (with a respective 10 and 11 years of experience in examining cardiac CTA) and blinded to the clinical data.

2.4. Statistical analysis

Statistical analyses were performed using SPSS software version 16 (SPSS, Inc., Chicago, IL, USA). Continuous data were expressed as mean ± SD. A significance level of $p < 0.05$ was considered a statistically significant result, and all reported p-values were two-sided. Means were compared using unpaired t-test, and Mann-Whitney rank sum was used when data were not normally distributed. Hazard ratio and Kaplan-Meier curve analysis for incidental detected left-sided intracardiac thrombus by CCTA and embolic events was assessed.

3. Results

Patient clinical characteristics are presented in Tables 1 and 2. A total of 1080 CCTA were enrolled in the present study. Forty-two studies were excluded due to known intracardiac thrombi from previous echocardiography. The prevalence of incidental left-sided cardiac thrombi in the present study is 4.53 %. Of the 49 patients with incidental left-sided cardiac thrombi on CCTA, 16 patients had left atrial thrombi (32.6 %), and 33 patients had left ventricular thrombi (67.4 %). Transthoracic echocardiography (TTE) was subsequently performed in all cases. The mean time interval between CCTA and TTE was 22 ± 16 days (range, 2–68 days). Eight patients with left atrial thrombi were subsequently confirmed on TTE (50 %). No LA thrombus was seen on transthoracic echocardiography (TTE) in 8 cases (50 %); hence, transesophageal echocardiography (TEE) was subsequently performed and can be demonstrated left atrial thrombus in additional 2 cases. Twenty patients with the left ventricular (LV) thrombi were consequently confirmed on transthoracic echocardiography (TTE) (60.6 %). No LV thrombus was seen on TTE in 13 cases (39.4 %). All the patients with left ventricular thrombi had evidence of wall motion abnormalities on echocardiography. All the incidental found left-sided cardiac thrombi were unknown before the CCTA, and their detection generated subsequently echocardiography and anticoagulation in most cases where the echocardiography was positive. Remarkably, one patient had right atrial thrombi in addition to left atrial thrombi (Fig. 2). Due to systemic embolization, six patients suffered an embolic stroke. Two patients had ischemic bowel from celiac and superior mesenteric artery emboli. One patient had lower extremity ischemia, and one patient had renal infarction. Patients with incidental found left-sided intracardiac thrombi detected by CCTA

Table 1
Patient characteristics and etiology of incidental left ventricular thrombi (n = 33).

Characteristic	Value
Age (years), mean ± SD (range)	60.9 ± 8 (36-80)
Men	23 (69.7 %)
Myocardial infarction with wall motion abnormality	33 (100 %)
LV pseudoaneurysm	1 (3 %)
LV true aneurysm	12 (36.4 %)

Table 2
Patient characteristics and etiology of incidental left atrial thrombi (n = 16).

Characteristic	Value
Age (years), mean ± SD (range)	59.4 ± 7 (27–77)
Men	12 (75 %)
Mitral valvular heart disease	5 (31.3 %)
Atrial fibrillation	3 (18.8 %)
Ischemic cardiomyopathy	3 (18.8 %)
Dilated cardiomyopathy	2 (12.5 %)
Infective endocarditis	2 (12.5 %)
Cortriatriatum	1 (6.3%)

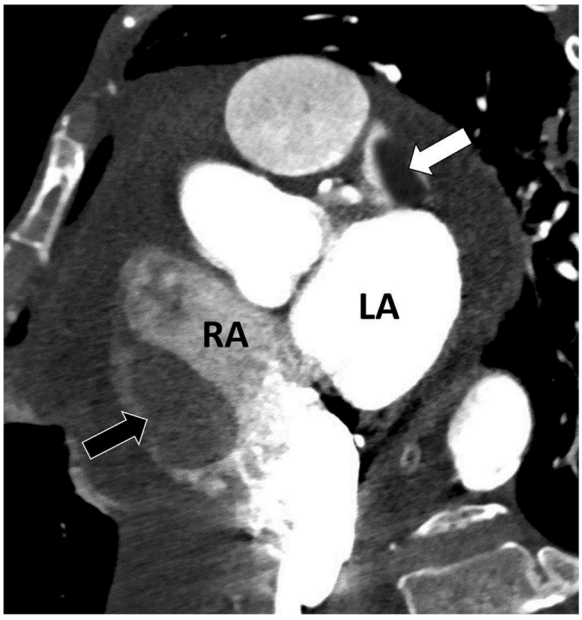

Fig. 2. CCTA of a 66-year-old woman with atrial fibrillation and post central line removal. She was referred for CCTA to evaluate coronary artery disease. Incidental found thrombus in left atrial appendage (white arrow) and right atrium (black arrow) were demonstrated. (CCTA: Cardiac computed tomography angiography, RA: Right atrium, LA: Left atrium).

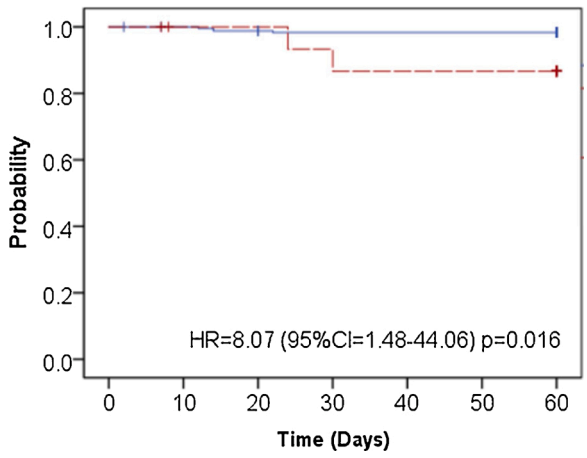

Fig. 3. Kaplan-Meier curve for embolic events for the patients with left-sided intracardiac thrombi detected by CCTA (red line) and the patients with normal CCTA (blue line). (CCTA: cardiac computed tomography angiography) (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

had more embolic event than patients who did not discovered left-sided intracardiac thrombi by CCTA (HR = 8.07; 95% CI 1.48–44.06; $p = 0.016$) (Fig. 3). There were 6 mortalities during hospitalization, 4 of which were apparently associated with embolic events (8.2 %). Of the two fatality was not correlated to embolic events, one from underlying leukemia and the other was from ruptured left ventricular pseudoaneurysm.

4. Discussion

We report a prevalence of 4.53 % for incidental left-sided cardiac thrombi among patients who underwent CCTA over five years. To our knowledge this is the first report on the prevalence of incidental left-sided cardiac thrombi among patients who underwent CCTA in Thailand. Thrombus in the left-sided cardiac chambers correspond to a crucial cause of emboli and can be incidentally identified by CCTA. Intracardiac filling defects are likely to be thrombi when there is no enhancement and where underlying cause that establishing characteristics for thrombus formation are present, such as myocardial infarction and wall motion abnormality (Fig. 4), left ventricular aneurysm (Fig. 5) or mitral valvular heart disease (Fig. 6). LV thrombi are frequently correlated with myocardial infarction, and more than 75 % develop within the first 2 weeks [9,10]. In the present study, all the patients with left ventricular thrombi had evidence of left ventricular wall motion abnormalities on subsequent echocardiography. Transthoracic echocardiography (TTE) is sensitive for the detection of LV thrombi, with sensitivities approximating 90 % in some study [11]. TTE is less sensitive for detect left atrial thrombi due to posterior location of the left atrium. Conversely, transesophageal echocardiography (TEE) is the study of choice for evaluate left atrial thrombi [12]. Left atrial thrombi usually detected in left atrial dilatation, atrial fibrillation or mitral valvular heart disease [1,2]. In the present study, patients with left-sided cardiac thrombi on CCTA had considerable mortality and morbidity associated with systemic embolic incidents. Embolic stroke was the most common complication. There was a comparatively high concordance rate between left-sided cardiac thrombi seen on CCTA and consequent confirmation on echocardiography. More significantly, in most of these cases, the referring medical team was not concerned of the cardiac thrombi, which lead to considerable changes in the therapeutic strategy mainly regarding anticoagulation therapy. There was only one case of concomitant right atrial thrombi, which is in keeping with the statistic that left-sided cardiac thrombi are more common than right-sided cardiac thrombi [13]. The present study's interesting consequence was the subset of patients with incidental left atrial thrombus on CCTA which was not visualized on subsequent transthoracic echocardiography (TTE). This might have affected the lack of concordance between CCTA and echocardiography, as previous studies have shown that TEE is superior to TTE for detecting left atrial thrombi [14,15]. Notable, two cases of LA thrombi that were not demonstrated on TTE was detected on TEE. Overall, left-sided cardiac thrombi are accurately visualized on CCTA [16–18]. Noteworthy, the subsequent echocardiography was not performed on the same day of CCTA. This time gap could have permitted dissolved or embolization of small thrombi causing disagreement between CCTA and TTE for incidental cardiac thrombi.

Despite promising initial results, the present study has potential limitations. First, the sample size of the present study was relatively small, but this underscored the significance of our findings. There was substantial morbidity and mortality associated with incidental left-sided cardiac thrombi despite the small sample size. Secondly, the present study had limitations similar to the other retrospective studies. We were merely capable of acquire data on patients who returned to our health care system for consequent treatment and no data on outcome was accessible for a group of patients who loss follow-up. Thirdly, It is known that further assessment with delayed imaging of the CCTA after 1 to 2 minutes of contrast administration can improve the specificity for distinguishing circulatory stasis from thrombus [19]. However,

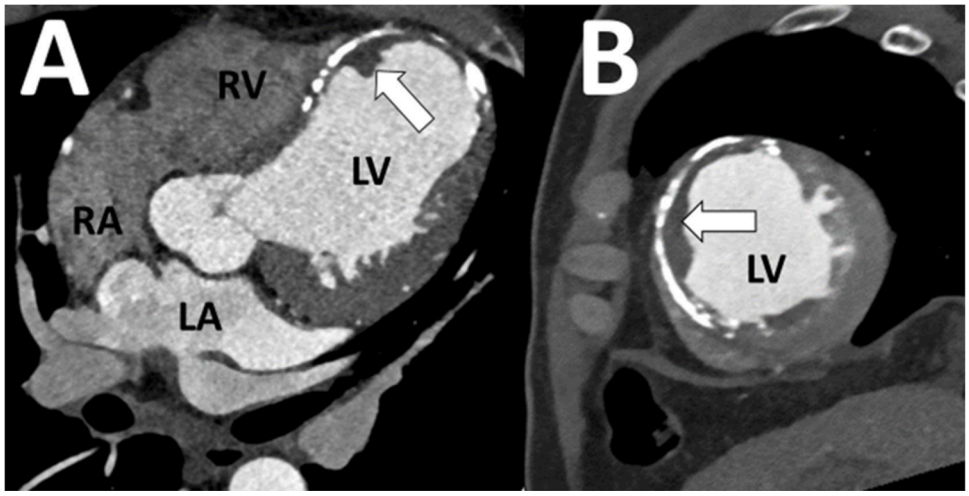

Fig. 4. A 63-year-old man was referred for CCTA to evaluate coronary artery bypass graft patency. Four chamber view (A) and short axis view (B) CCTA demonstrated incidental found left ventricular thrombus (arrows) adhere to the thin calcified left ventricular myocardium. (CCTA : Cardiac computed tomography angiography, RA : Right atrium, LA : Left atrium, RV : Right ventricle, LV : Left ventricle).

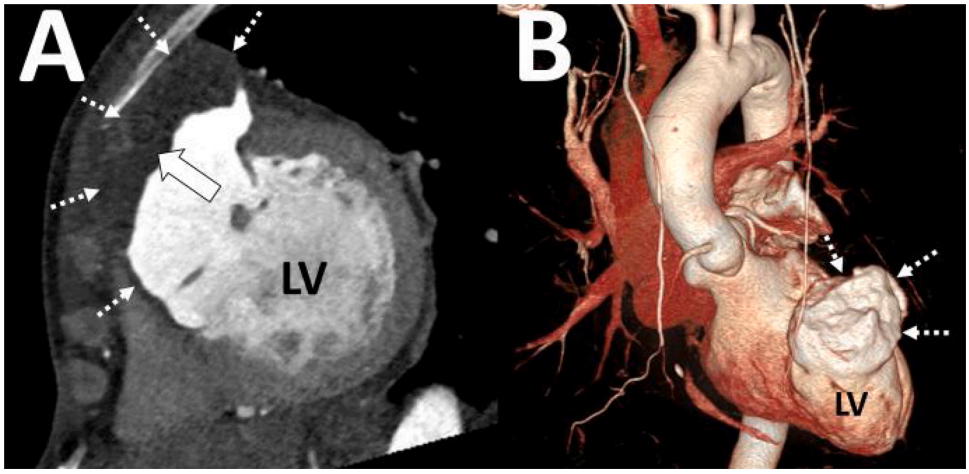

Fig. 5. A 69-year-old man was referred for CCTA to plan percutaneous coronary interventions (PCI) of left anterior descending artery occlusion. Short axis view (A) and 3D volume rendering technique image (B) CCTA reveals left ventricular aneurysm (dashed arrows) with mural thrombus (arrow). (CCTA : Cardiac computed tomography angiography, LV : Left ventricle).

radiation exposure to patients increased with this 2-phase technique, so the current study did not routinely implement the delayed phase. Finally, our results represent a single-center experience, the generalizability of the present results is limited.

5. Conclusion

For patients undergoing cardiac computed tomography angiography (CCTA), an incidental left-sided cardiac thrombus is not unusual and providing important prognostic information. A dedicated effort not to neglect these prospective pitfalls should be made by physicians interpreting CCTA.

Funding

No funding was received for this work.

Intellectual property

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual

Research ethics

We further confirm that any aspect of the work covered in this manuscript that has involved human patients has been conducted with the ethical approval of all relevant bodies. This study was reviewed and approved by the local Ethics Committee of Khon Kaen University, Thailand and was registered under reference number HE 601181. All methods were performed in accordance with the relevant guidelines and regulations. The local Ethics Committee of Khon Kaen University also approved our study with a waiver of informed consent due to retrospective study design.

Authorship

We confirm that the manuscript has been read and approved by all named authors.

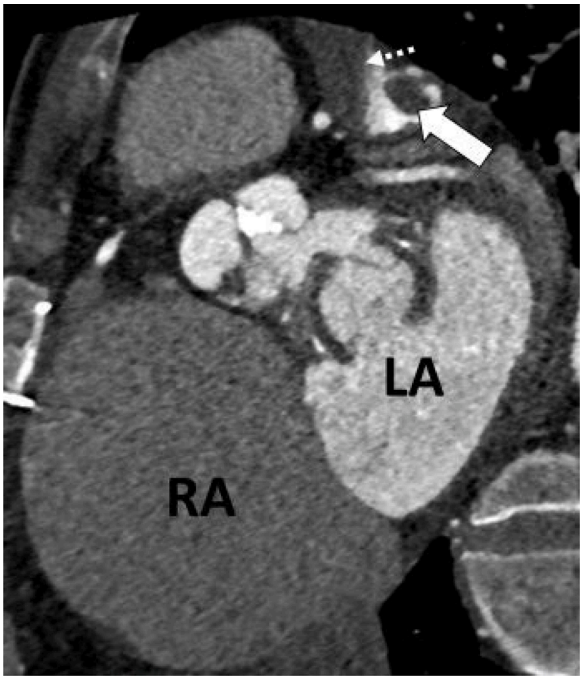

Fig. 6. A rheumatic heart disease patient was sent for CCTA to diagnosis of anomalous coronary artery. Left atrial appendage thrombus was incidentally detected (arrow) and slow flow artifact within left atrial appendage also demonstrated (dashed arrow). (CCTA : Cardiac computed tomography angiography, RA : Right atrium, LA : Left atrium).

CRediT authorship contribution statement

Narumol Chaosuwannakit: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Supervision. **Pattarapong Makarawate:** Resources, Writing - review & editing.

Declaration of Competing Interest

The authors declare no conflict of interest.

Acknowledgment

The authors thank the Faculty of Medicine for its support. We would like to acknowledge Prof. Yukifumi Nawa for editing the MS via Publication Clinic KKU, Thailand.

References

[1] U.O. Egolum, D.G. Stover, R. Anthony, A.M. Wasserman, D. Lenihan, J.B. Damp, Intracardiac thrombus: diagnosis, complications and management, Am. J. Med. Sci. 345 (2013) 391–395.
[2] H. Scheffel, S. Baumueller, P. Stolzmann, S. Leschka, A. Plass, H. Alkadhi, T. Schertler, Atril myxomas and thrombi : comparison of imaging features on CT, AJR Am. J. Roentgenol. 192 (3) (2009) 639–645.
[3] K.H. Mortensen, D. Gopalan, A. Balan, Atrial masses on multidetector computed tomography, Clin. Radiol. 68 (2013) e164–e175.
[4] N.K. Singh, N. Nallamothu, V.P. Zuck, Z.F. Issa, Left atrial appendage filling defects on 64-slice multidetector computed tomography in patients under-going pulmonary vein isolation: predictors and comparison to transesophageal echocardiography, J. Comput. Assist. Tomogr. 33 (2009) 946–951.
[5] C. Teunnissen, J. Habets, B.K. Velthuis, M.J. Cramer, P. Loh, Double-contrast, single-phase computed tomography angiography for ruling out left atrial appendage thrombus prior to atrial fibrillation ablation, Int. J. Cardiovasc. Imaging 33 (1) (2017) 121–128.
[6] P. Foley, A. Hamaad, Leyva F. El-Gendi, Incidental cardiac findings on CT imaging of the thorax, BMC Res 3 (2010) 326.
[7] A.J. Taylor, M. Cerqueira, J.M. Hodgson, D. Mark, J. Min, P. O'Gara, et al., ACCF/SCCT/ACR/AHA/ASE/ASNC 2010 Appropriate Use Criteria for Cardiac Computed Tomography: a report of the American College of Cardiology/ Foundation Appropriate Use Criteria Task Force Society of Cardiovascular Computed Tomography/American College of Radiology/ American Heart Association/ American Society of Echocardiography/ American Society of Nuclear Cardiology/ Society for Cardiovascular Angiography and Interventions/Society for Cardiovascular Magnetic Resonance, J. Am. Coll. Cardiol. 56 (2010) 1864–1894.
[8] I. Tsiflikas, H. Brodoefel, A.J. Reimann, C.D. Claussen, C. Burgstahler, M. Heuschmid, et al., Coronary CT angiography with dual source computed tomography in 170 patients, Eur. J. Radiol. 74 (1) (2010) 161–165.
[9] C.P. McCarthy, M. Vaduganathan, K. McCarthy, J.L. Januzzi, D.L. Bhatt, J. W. McEvoy, Left ventricular thrombus after acute myocardial infarction : screening, prevention and treatment, JAMA Cardiol. 3 (7) (2018) 642–649.
[10] R. Delewi, F. Ziljstra, J. Piek, Left ventricular thrombus after acute myocardial infarction, Heart 98 (2012) 1743–1749.
[11] J.W. Weinsaft, H.W. Kim, A.L. Crowley, I. Klem, C. Shenoy, L.V. Assceh, et al., LV thrombus detection by routine echocardiography: insights into performance characteristics using delayed enhancement CMR, J. Am. Coll Cardiol. Cardiovasc Imaging. 4 (7) (2011) 702–712.
[12] L.M. Tsai, J.H. Lin, Y.J. Yang, Role of transesophageal echocardiography in detecting left atrial thrombus and spontaneous echo contrast in patients with mitral valve disease or non-rheumatic atrial fibrillation, J. Formos. Med. Assoc. 89 (4) (1990) 270–274.
[13] A. Cresti, M. Garcia-Fernandez, G. Miracapillo, A. Picchi, F. Cesareo, F. Gurerrini, et al., Frequency and significance of right atrial appendage thrombi in patients with persistent atrial fibrillation or atrial flutter, J. Am. Soc. Echocardiogr. 27 (2014) 1200–1207.
[14] S. De Bruijn, W. Agema, G. Lammers, E.E. van der Wall, R. Wolterbeek, E. R. Holman, et al., Transesophageal echocardiography is superior to transthoracic echocardiography in management of patients of any age with transient ischemic attack or stroke, Stroke 37 (2006) 2531–2534.
[15] M. Saric, A. Armour, M.S. Arnaout, F.A. Chaudhry, R.A. Grimm, I. Kronzon, et al., Guidelines for the use of echocardiography in the evaluation of a cardiac source of embolism, J. Am. Soc. Echocardiogr. 29 (1) (2016) 1–42.
[16] J. Romero, S.A. Husain, I. Kelesidis, J. Sanz, H.M. Medina, M.J. Garcia, Detection of left atrial appendage thrombus by cardiac computed tomography in patients with atrial fibrillation: a meta-analysis, Circ. Cardiovasc. Imaging 6 (2013) 185–194.
[17] M.J. Budoff, A. Shittu, Y. Hacioglu, E. Gang, D. Li, H. Bhatia, et al., Comparison of transesophageal echocardiography versus computed tomography for detection of left atrial appendage filling defect (thrombus), Am. J. Cardiol. 113 (2014) 173–177.
[18] F.T. Sultan, S.W. Ahmed, Cardiac magnetic resonance evaluation of cardiac masses in patients with suspicion of cardiac masses on echo or computed tomography, J. Clin. Imaging Sci. 10 (2020) 57.
[19] J. Hur, Y.J. Kim, J.E. Nam, K.O. Choe, E.Y. Choi, C.Y. Shim, et al., Thrombus in the left atrial appendage in stroke patients: detection with cardiac CT angiography—a preliminary report, Radiology 249 (2008) 81–87.