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A Case in Which Identification of Cardiac Scar Tissue by MDCT Was Effective in Ablation for Ventricular Tachycardia – A Secondary Publication

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Abstract: During catheterization of ventricular tachycardia, it is often found difficult to identify the origin of ventricular tachycardia when tachycardia is not induced during the procedure or hemodynamics are disrupted. Late gadolinium enhancement (LGE) in cardiac MRI and late Iodine enhancement (LIE) in cardiac CT are reportedly performed to identify myocardial scar tissue and estimate the origin of ventricular tachycardia preoperatively. However, although LGE is useful for identifying the origin of tachycardia, the slice thickness is large and imaging takes a long time, and if a premature beat occurs or the device is inserted during imaging, a good image cannot be obtained. On the other hand, LIE also has poor resolution, making it difficult to take clear images. In this case report, the origin of ventricular tachycardia was presumed preoperatively using a new image processing method called Subtraction Myocardial Image for Late Iodine Enhancement (SMILIE) using a 320-row Area Detector CT, which was useful during catheter ablation.

Keywords: Multi Detector-row CT; Delayed enhancement imaging; Ventricular tachycardia

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1. Introduction

Ventricular tachycardia (VT) is widely recognized as a life-threatening arrhythmia and is often treated with catheter ablation in recent years. However, the success rate is only about 60% [1], which is not necessarily high. One reason for this is the difficulty in identifying the origin and circuit of VT. In catheter ablation therapy, VT is generally induced, and its origin and circuit are identified during VT for treatment. However, there are many problems such as the patient's hemodynamics deteriorating during the identification of the circuit of tachycardia or tachycardia itself not being induced at all.

Therefore, there have been reports [2-5] suggesting that myocardial scars depicted by late gadolinium enhancement (LGE) in cardiac MRI or late iodine enhancement (LIE) in cardiac CT are related to the origin of VT, and attempts have been made to identify the origin of VT using them. However, there are still many challenges such as the long duration of delayed enhancement MRI or CT imaging and the resulting unclear images.

At the Japanese Red Cross Wakayama Medical Center, cases have been experienced where catheter ablation therapy for ventricular tachycardia proved useful by clearly depicting myocardial scar tissue using a new CT image processing method called Subtraction Myocardial Image for Late Iodine Enhancement (SMILIE) [6]. As far as know, there have been no case reports of successful catheter ablation therapy for VT using SMILIE in the past, and this is the first report.

2. Case presentation

The patient is a 76-year-old male with a chief complaint of palpitations. He has no significant past medical history, medications, or family history. Additionally, he has no history of smoking and no known allergies.

Present illness: The patient has been experiencing palpitations for about a week. He noticed shortness of breath when climbing stairs a few days ago and presented at the Japanese Red Cross Wakayama Medical Center.

Physical examination on admission: Height 156.2 cm, weight 58.2 kg, blood pressure 156/98 mmHg, heart rate 205 beats/min, respiratory rate 30 breaths/min, temperature 37.3°C, percutaneous oxygen saturation 92% (room air), alert and oriented, no conjunctival pallor, no scleral icterus, no cardiac murmurs, clear lung sounds, flat abdomen, no tenderness or rebound tenderness, no bilateral lower leg edema.

Laboratory findings: AST 63 U/L, ALT 69 U/L, LDH 261 U/L, Alb 3.3 g/dL, BUN 30 mg/dL, Cre 1.72 mg/dL, CK 111 U/L, serum Na 136 mEq/L, serum K 4.2 mEq/L, serum Cl 107 mEq/L, blood glucose 145 mg/dL, HbA1c 5.5%, WBC 10800/μL, RBC 4.61 million/μg, Hb 14.2 g/dL, Hct 42.7%, platelets 117,000/μL, CRP 1.58 mg/dL, PT-INR 1.65, APTT 28.7 seconds, LDL 107 mg/dL, HDL 49 mg/dL, TG 63 mg/dL, T-chol 172 mg/dL, BNP 1755.6 pg/mL, cardiac troponin 201.5 pg/mL.

12-lead electrocardiogram (**Figure 1**): Heart rate 205 beats/min, ventricular tachycardia with right bundle branch block morphology and inferior axis.

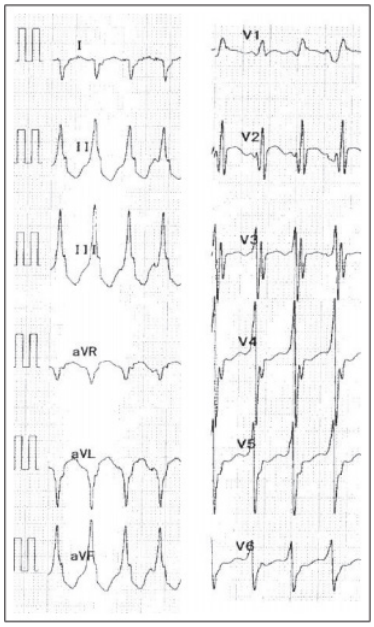

Figure 1. 12-lead electrocardiogram during tachycardia

Chest X-ray: Cardiothoracic ratio 52%, pulmonary congestion present.

Transthoracic echocardiogram on admission (performed during atrial fibrillation): Diffuse left ventricular wall motion abnormality, left ventricular ejection fraction 34%, left ventricular end-diastolic diameter 41.7 mm, left ventricular end-systolic diameter 35.0 mm, interventricular septum thickness 12.7 mm, left ventricular posterior wall thickness 10.0 mm, left atrial diameter 41.1 mm, mild mitral valve regurgitation present.

3. Clinical course

Acute heart failure due to ventricular tachycardia (VT) was diagnosed, and a plan for catheter ablation for VT was made. The obtained VT electrocardiogram (**Figure 1**) suggested an origin in the left ventricular outflow tract. Additionally, intermittent atrial fibrillation was concurrent, leading to a temporary state of heart failure requiring mechanical ventilation. However, when the heart failure symptoms stabilized, SMILIE was performed during atrial fibrillation, revealing a scar area in the left ventricular basal anterior septum (**Figure 2**).

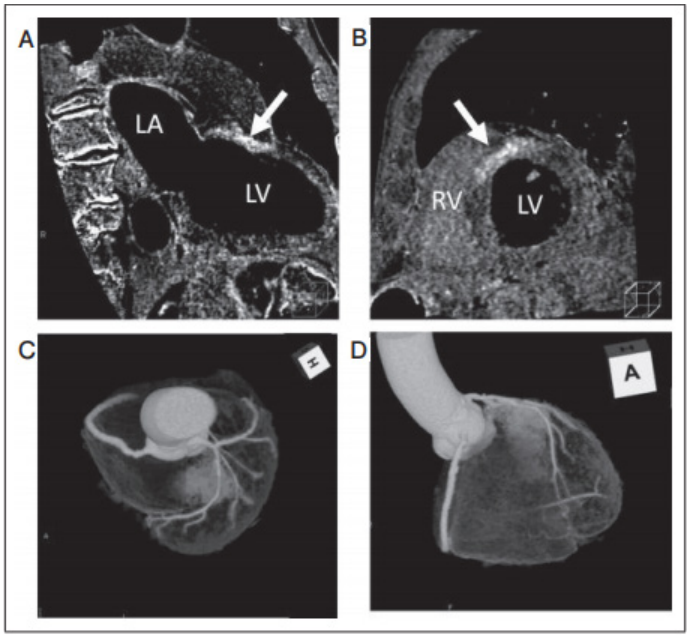

Figure 2. Cardiac CT: Late iodine enhancement (LIE) was observed in the left ventricular basal anterior septum. **(A)** Long axis; **(B)** Short axis showing LIE indicated by the arrow. Delayed enhancement is prominently observed on the ventricular septal side, suggesting the potential need for an approach from the right ventricular outflow tract; **(C)** Superior view of the 3D image of cardiac CT; **(D)** Right anterior oblique (RAO) view. LIE was observed in the left ventricular basal anterior septum.

Based on the scar area revealed by SMILIE and the electrocardiogram during tachycardia, mapping of the left ventricular outflow tract was deemed necessary. The scar area was predominantly located on the ventricular septal side, suggesting that an approach from the right ventricular side might also be necessary depending on the location of the earliest excitation site (**Figure 2**).

During catheter treatment, VT intermittently appeared and stopped from the beginning of the procedure, with a monomorphic pattern and a constant cycle length of 460 msec. Evaluating the tachycardia circuit with pace mapping or entrainment pacing was challenging due to atrial fibrillation and intermittent appearance of VT, which was expected to take time to determine whether pacing was capturing the ventricle.

With VT appearing and hemodynamics stable, a retrograde approach from the aorta was planned using

EnSite Precision™ and Advisor™ HD Grid catheters to evaluate the earliest excitation site of VT, primarily in the left ventricular outflow tract, by activation mapping within a short time. The earliest excitation site was identified in the left ventricular basal anterior septum, consistent with the scar site obtained with SMILIE (**Figure 3**). Voltage in the myocardium at the earliest excitation site was preserved. A potential preceding potential 25 ms ahead of QRS onset was observed at the earliest excitation site (**Figure 4**). Subsequently, when ablating at 40 W at the same site, VT ceased within 10 seconds of the initial ablation, and no further inducibility was observed, allowing completion of the procedure without complications with ablation only from the left ventricular side.

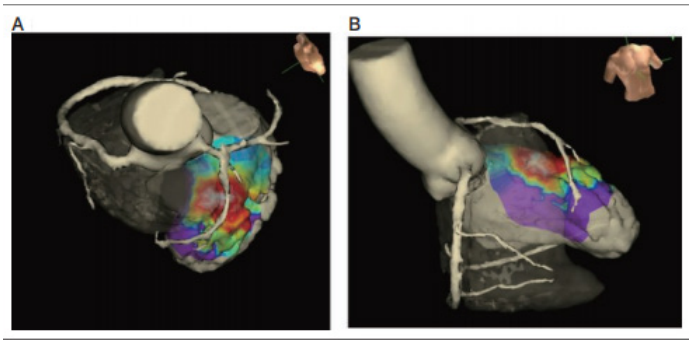

Figure 3. Activation map of ventricular tachycardia using a multi-electrode mapping catheter. **(A)** Superior view; **(B)** Right anterior oblique (RAO) view. The earliest excitation site was identified in the left ventricular basal anterior septum, consistent with the site of late iodine enhancement (LIE). The voltage at the earliest excitation site was relatively preserved.

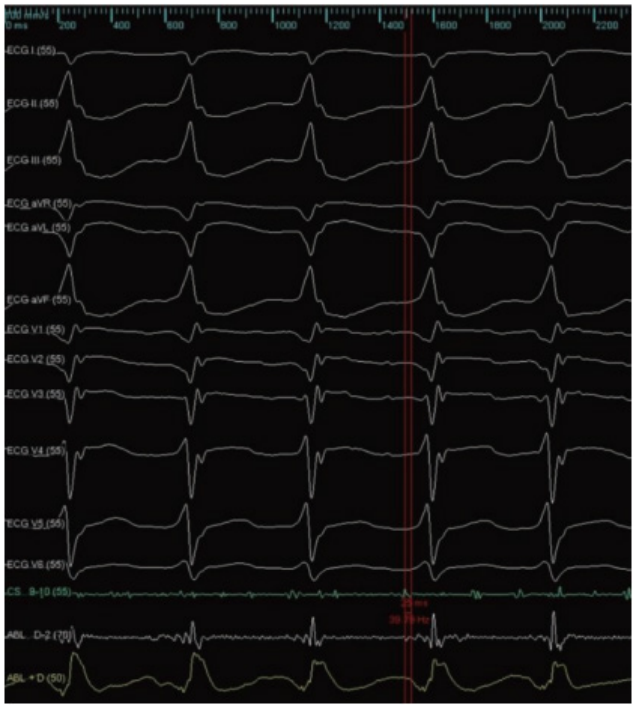

Figure 4. Intracardiac electrocardiogram during ventricular tachycardia before ablation initiation (EnSite Precision™). During ventricular tachycardia, atrial fibrillation persisted, and despite cardioversion attempts, it immediately recurred, rendering the tip potential of the ablation catheter unclear. At the earliest excitation site, a ventricular wave preceding the QRS onset by 25 ms was observed. When ablating at 40 W at the same site, ventricular tachycardia ceased within 10 seconds of the initial ablation, and no further inducibility was observed.

4. Discussion

In recent years, various innovations have been made to estimate the circuits of ventricular tachycardia (VT) with the advancement of technology. Verma et al. reported that the circuit of VT is often located at the border of scarred myocardium [7,8]. However, to delineate the scar border, mapping the entire left ventricle is necessary, which can prolong procedural time. Prolonged procedures in patients with reduced cardiac function are not recommended due to the risk of complications.

Additionally, the origin and circuits of VT are not confined solely to the endocardial or epicardial sides but may also involve the myocardial interior. However, current technologies do not allow mapping of the myocardial interior. Therefore, methods have been reported for extrapolating ablation based on VT maps [9]. Identifying the complex origins and circuits of VT within the patient's overall condition and limited treatment time is extremely challenging. Hence, attempts have been made to estimate VT circuits through imaging diagnostics pre-catheter ablation.

Currently, late gadolinium enhancement (LGE) in cardiac MRI is the standard method for delineating myocardial fibrosis and scar lesions, as mentioned in the "2016 Guidelines for the Diagnosis and Treatment of Cardiac Sarcoidosis" by the Japanese Circulation Society [10]. However, LGE has various limitations, including long imaging durations, low spatial resolution compared to CT, and difficulty in using the obtained images with 3D mapping systems for arrhythmia treatment. Late iodine enhancement (LIE) in cardiac CT also reflects myocardial fibrosis lesions [11,12], with reports suggesting its correlation with the origin of VT [13,14]. However, images obtained using this method often lack contrast and clarity, making it difficult to identify the origin and circuits of VT.

In this regard, a technique called Subtraction Myocardial Image for Late Iodine Enhancement (SMILIE) was utilized in this study. This novel method involves subtracting coronary phase images from delayed phase images to obtain delayed enhancement images (**Figure 5**). While previous reports have compared LIE-CT subtraction images with LGE images for myocardial ischemia assessment [15], the Japanese Red Cross Wakayama Medical Center's use of SMILIE with computed tomography angiography (CTA) potentially reduces radiation exposure and examination time compared to CT perfusion imaging, making it a more versatile imaging technique. With the advent of this method and 320-row Area Detector CT (Aquilion ONE/GENESIS Edition, Canon®), imaging the entire heart in one heartbeat has become possible regardless of arrhythmias or device presence, resulting in clearer contrast images compared to conventional LIE. Additionally, due to the clear contrast, information such as myocardial scarring in the myocardial interior, which was previously difficult to determine with catheter mapping, can now be discerned. This allows for pre-procedural planning of the approach method, contributing to the consideration of VT catheter treatment strategies.

Moreover, since the location of scar lesions can be predicted, it is possible to map only the area surrounding the scar lesions during catheter treatment. Furthermore, preoperative evaluation of coronary artery information and structures around the heart is also possible, contributing to the prevention of complications and reduction of procedural time. A comparison of features between delayed enhancement images obtained with SMILIE and those obtained with MRI is shown in **Table 1**. In this case, by estimating the approximate origin of VT from the 12-lead electrocardiogram during tachycardia and delayed enhancement sites obtained with SMILIE, successful elimination of VT was achieved with minimal mapping and ablation. As many VT cases occur in patients with reduced cardiac function, minimally invasive catheter treatment is required. This technique is extremely useful for VT catheter treatment as it allows pre-procedural clarification of information regarding myocardial fibrosis deep inside the heart. Furthermore, as it is an imaging technique, it is highly versatile and can be utilized in any facility with multi-row Area Detector CT.

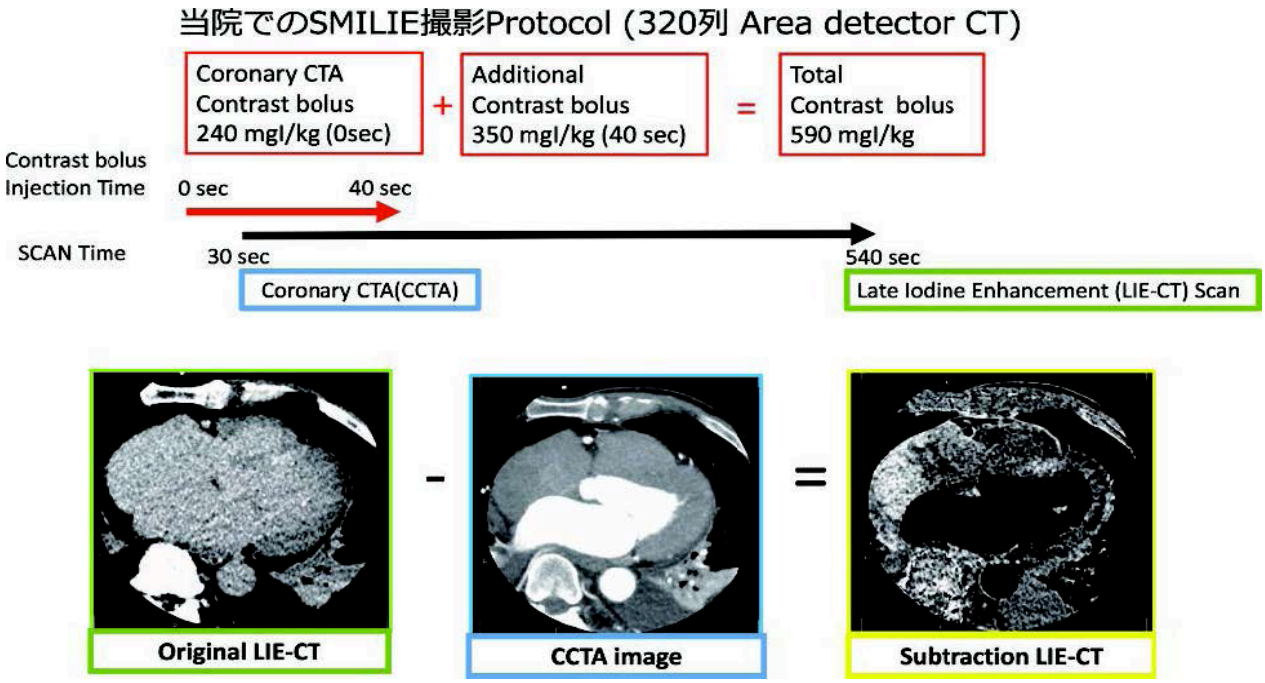

Figure 5. Imaging protocol for SMILIE at the Japanese Red Cross Wakayama Medical Center. The contrast agent is administered, and 30 seconds later, computed tomography angiography (CTA) of the coronary arteries and left atrium is performed. Approximately 9 minutes after contrast agent administration, delayed phase images of the left atrium are captured. SMILIE images are created by subtracting the CTA images from the delayed enhancement images.

Table 1. Comparison of features between SMILIE and LGE

	MRI (LGE)	CT (SMILIE)
Slice thickness	8–10 mm	0.5–1.0 mm
Examination time	Approximately 40–80 mins	Approximately 10 mins
Impact on renal function	Yes	Yes
3D-mapping system	Partial	Yes
Affected by arrhythmias	No	Yes
Feasible post-device insertion	No	Yes

Features of SMILIE

(1) Imaging with 320 rows allows for an extremely thin slice thickness of 0.5–1.0 mm, providing excellent spatial resolution.

(2) Short imaging time minimizes patient burden.

(3) Gadolinium cannot be used in dialysis patients, but iodine can be used.

(4) Obtained CT images can be directly incorporated into 3D-mapping systems for use.

(5) Imaging the entire heart in one heartbeat minimizes the influence of arrhythmias such as premature beats or atrial fibrillation.

(6) Imaging is easily feasible even in patients with inserted devices.

5. Conclusion

In this case, the delineation of scar sites obtained with SMILIE correlated very well with the earliest excitation sites of VT identified by the 3D mapping system. As a result, catheter treatment of VT was concluded in a short time without complications. The use of SMILIE in catheter treatment of VT is considered highly valuable for preoperative treatment strategy planning, higher success rate of procedures, reduction of procedural time, and complication prevention.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Marchlinski FE, Haffajee CI, Beshai JF, et al., 2016, Long-Term Success of Irrigated Radiofrequency Catheter Ablation of Sustained Ventricular Tachycardia: Post-Approval THERMOCOOL VT Trial. J Am Coll Cardiol, 67(6): 674–683. https://doi.org/10.1016/j.jacc.2015.11.041

[2] Andreu D, Ortiz-Pérez JT, Boussy T, et al., 2014, Usefulness of Contrast-Enhanced Cardiac Magnetic Resonance in Identifying the Ventricular Arrhythmia Substrate and the Approach Needed for Ablation. Eur Heart J, 35(20): 1316–1326. https://doi.org/10.1093/eurheartj/eht510

[3] Andreu A, Penela D, Acosta J, et al., 2017, Cardiac Magnetic Resonance-Aided Scar Dechanneling: Influence on Acute and Long-Term Outcomes. Heart Rhythm, 14(8): 1121–1128. https://doi.org/10.1016/j.hrthm.2017.05.018

[4] Siontis KC, Kim HM, Dabbagh GS, et al., 2017, Association of Preprocedural Cardiac Magnetic Resonance Imaging with Outcomes of Ventricular Tachycardia Ablation in Patients with Idiopathic Dilated Cardiomyopathy. Heart Rhythm, 14(10): 1487–1493. https://doi.org/10.1016/j.hrthm.2017.06.003

[5] Esposito A, Palmisano A, Antunes S, et al., 2016, Cardiac CT with Delayed Enhancement in the Characterization of Ventricular Tachycardia Structural Substrate: Relationship Between CT-Segmented Scar and Electro-Anatomic Mapping. JACC Cardiovasc Imaging, 9(7): 822–832. https://doi.org/10.1016/j.jcmg.2015.10.024

[6] Yamaguchi T, 2019, [Evaluation of Myocardial Characteristics Using Subtraction Technique]. INNERSION, 34(10): 40–44.

[7] Marchlinski FE, Callans DJ, Gottlieb CD, et al., 2000, Linear Ablation Lesions for Control of Unmappable Ventricular Tachycardia in Patients with Ischemic and Nonischemic Cardiomyopathy. Circulation, 101(11): 1288–1296. https://doi.org/10.1161/01.cir.101.11.1288

[8] Verma A, Marrouche NF, Schweikert RA, et al., 2005, Relationship Between Successful Ablation Sites and the Scar Border Zone Defined by Substrate Mapping for Ventricular Tachycardia Post-Myocardial Infarction. J Cardiovasc Electrophysiol, 16(5): 465–471. https://doi.org/10.1046/j.1540-8167.2005.40443.x

[9] Tung R, Raiman M, Liao H, et al., 2020, Simultaneous Endocardial and Epicardial Delineation of 3D Reentrant Ventricular Tachycardia. J Am Coll Cardiol, 75(8): 884–897. https://doi.org/10.1016/j.jacc.2019.12.044

[10] Japanese Circulation Society (JCS), 2016, Guidelines for Diagnosis and Treatment of Cardiac Sarcoidosis, viewed December 1, 2022, http://www.j-irc.or.jp/guideline/pdf/JCS2016_terasaki_h.pdf

[11] Gerber BL, Belge B, Legros GJ, et al., 2006, Characterization of Acute and Chronic Myocardial Infarcts by Multidetector Computed Tomography: Comparison with Contrast-Enhanced Magnetic Resonance. Circulation, 113(6): 823–833. https://doi.org/10.1161/CIRCULATIONAHA.104.529511

[12] Nieman K, Shapiro MD, Ferencik M, et al., 2008, Reperfused Myocardial Infarction: Contrast-Enhanced 64-Section CT in Comparison to MR Imaging. Radiology, 247(1): 49–56. https://doi.org/10.1148/radiol.2471070332

[13] Ustunkaya T, Desjardins B, Liu B, et al., 2019, Association of Regional Myocardial Conduction Velocity with the Distribution of Hypoattenuation on Contrast-Enhanced Perfusion Computed Tomography in Patients with Postinfarct Ventricular Tachycardia. Heart Rhythm, 16(4): 588–594. https://doi.org/10.1016/j.hrthm.2018.10.029

[14] Ustunkaya T, Desjardins B, Wedan R, et al., 2019, Epicardial Conduction Speed, Electrogram Abnormality, and Computed Tomography Attenuation Associations in Arrhythmogenic Right Ventricular Cardiomyopathy. JACC Clin Electrophysiol, 5(10): 1158–1167. https://doi.org/10.1016/j.jacep.2019.06.017

[15] Tanabe Y, Kido T, Kurata A, et al., 2018, Late Iodine Enhancement Computed Tomography with Image Subtraction for Assessment of Myocardial Infarction. Eur Radiol, 28(3): 1285–1292. https://doi.org/10.1007/s00330-017-5048-9