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Discrepancy in Diagnosing Coronary Artery Occluded Lesion: CT-Derived Fractional Flow Reserve (FFR_{CT}) Versus Invasive Coronary Angiography

Koroner Arter Tıkalı Lezyonlarının Teşhisinde Tutarsızlık: BT ile Elde Edilen Fraksiyonel Akış Rezervi (FFR_{CT}) ile İnvaziv Koroner Anjiyografi

CASE REPORT
OLGU SUNUMU

ABSTRACT

Coronary computed tomography angiography (CCTA) and CT-derived fractional flow reserve (FFR_{CT}) findings demonstrate high diagnostic accuracy, aligning consistently with invasive coronary angiography (ICA), the gold standard diagnostic technique for coronary artery disease. The differential diagnosis of total versus subtotal coronary occlusion is crucial in determining the appropriate treatment strategy. Subtotal coronary occlusions composed of vulnerable tissue can sometimes present as total coronary occlusions on ICA. This presentation can be inconsistent with findings from CCTA and FFR_{CT}. This case report presents discrepant findings between CCTA, which indicated subtotal coronary occlusion, and ICA, which suggested total coronary occlusion. The stenotic lesion, filled with vulnerable tissue (low-attenuation plaque volume: 20.3 mm^3 and intermediate-attenuation plaque volume: 71.6 mm^3), could be dilated with a vasodilator during maximal hyperemia. This dilation facilitated the acquisition of CCTA and FFR_{CT} images. We were able to diagnose subtotal coronary occlusion and identify the overall anatomical structure of the vessels prior to percutaneous coronary intervention (PCI). This allowed us to perform a successful and uncomplicated PCI.

Keywords: Coronary artery disease, coronary computed tomography angiography, total occlusion

ÖZET

Koroner bilgisayarlı tomografi anjiyografi (KBTA) ve BT kaynaklı fraksiyonel akım rezervi (FFR_{CT}) bulguları, koroner arter hastalığı için altın standart tanı tekniği olan invaziv koroner anjiyografi (IKA) ile tutarlı bir şekilde uyumlu olarak yüksek tanısal doğruluk göstermektedir. Total ve subtotal koroner oklüzyonun ayırıcı tanısı, uygun tedavi stratejisinin belirlenmesinde çok önemlidir. Hassas dokulardan oluşan subtotal koroner oklüzyonlar bazen İKA'da total koroner oklüzyonlar gibi görünebilir. Bu durum, KBTA ve FFR_{CT} bulguları ile tutarsız olabilir. Bu olgu sunumunda, subtotal koroner oklüzyonu gösteren KBTA ile total koroner oklüzyonu gösteren İKA arasındaki tutarsız bulgular sunulmaktadır. Hassas dokuyla dolu stenotik lezyon (düşük atenüasyonlu plak hacmi: 20,3 mm^3 ve orta atenüasyonlu plak hacmi: 71,6 mm^3), maksimal hiperemi sırasında bir vazodilatör ile dilate edilebildi. Bu dilatasyon KBTA ve FFR_{CT} görüntülerinin elde edilmesini kolaylaştırdı. Subtotal koroner oklüzyonu teşhis edebildik ve perkütan koroner girişim (PKG) öncesinde damarların genel anatomik yapısını tanımlayabildik. Bu da başarılı ve komplikasyonsuz bir PKG gerçekleştirmemizi sağladı.

Anahtar Kelimeler: Koroner arter hastalığı, koroner bilgisayarlı tomografi anjiyografi, total oklüzyon

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Total coronary occlusion remains a significant challenge, characterized by low treatment success rates in percutaneous coronary intervention (PCI) and a high incidence of restenosis or re-occlusion after PCI, compared to subtotal coronary occlusion.[1,2] Consequently, distinguishing between total and subtotal coronary occlusion is important for determining the appropriate treatment strategy. Subtotal coronary occluded lesions filled with vulnerable tissue can occasionally present as total coronary occlusions on invasive coronary angiography (ICA). For these lesions,

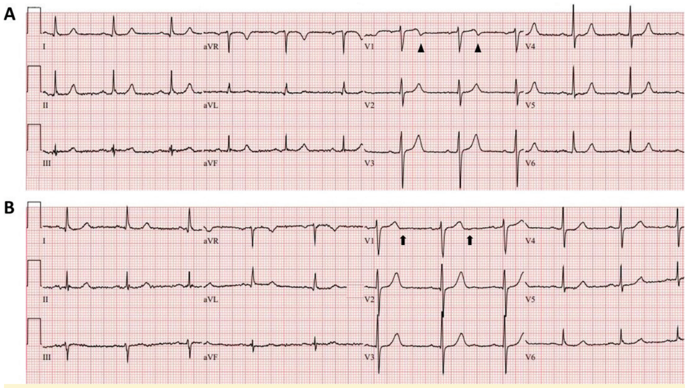

Figure 1. Electrocardiogram: (A) On admission. Terminal T wave inversion in V1 (arrowhead). (B) Before invasive coronary angiography enforcement: Flattening of the terminal T wave inversion (arrow).

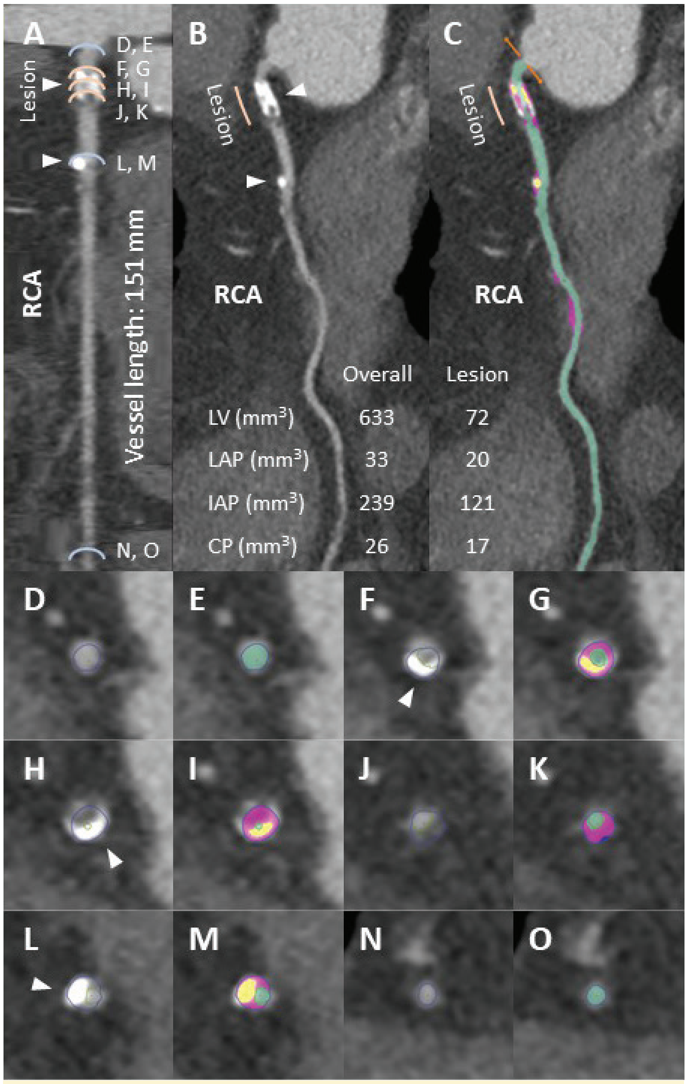

Figure 2. CCTA: (A) Stretched multiplanar reformation of RCA. (B) Curved multiplanar reformation of RCA. (C) Color-coded plaque image of RCA. (D-O) Short-axis images coinciding with stretched multiplanar reformation. (A, B, D, F, H, J, L, N) Contrast-enhanced images. CP (arrowhead). (C, E, G, I, K, M, and O) Color-coded plaque images. Green: LV, Red: IAP, Yellow: CP. CP, calcified plaque; IAP, intermediate-attenuation plaque; LAP, low-attenuation plaque; RCA, right coronary artery.

the administration of vasodilators can uncouple loosely cross-linked tissue. This allows for enhanced contrast and accurate diagnosis using coronary computed tomography angiography (CCTA) or CT-derived fractional flow reserve (FFR_{CT}). We present a case initially diagnosed as total coronary occlusion on ICA, where vasodilator-assisted CCTA and FFR_{CT} indicated a subtotal coronary occlusion. This enabled the comprehensive assessment of the vessel's anatomical structure, resulting in a successful and complication-free PCI. This case highlights the potential of transition phase lesions, from subtotal to total occlusion, containing vulnerable plaque components (low-attenuation plaque [LAP] and intermediate-attenuation plaque [IAP]) to dilate and perfuse the peripheral coronary artery during maximal hyperemia, thus facilitating CCTA and FFR_{CT} analysis.

Case Report

A 65-year-old man presented to his general practitioner one week prior with complaints of chest discomfort. An electrocardiographic examination indicated non-specific changes, with terminal T wave inversion in V1, leading to a referral to our hospital. Upon his hospital visit, he exhibited no chest symptoms. However, an electrocardiogram revealed identical findings to those noted by the general practitioner (Figure 1A: arrowhead), prompting his admission for further evaluation. He had hypertension as a cardiovascular risk factor, which had been clinically managed with Lisinopril 5 mg/day. Other cardiovascular risk factors, such as dyslipidemia, diabetes mellitus, and smoking, were not present. His vital signs were stable, with a blood pressure of 122/73 mmHg and a heart rate of 77 beats/minute. Cardiac biomarkers, including creatine kinase and troponin T, were measured at 59 IU/L (normal range: 15-130 IU/L) and 0.052 μg/L (normal range: 0-0.04 μg/L), respectively. Transthoracic echocardiography (TTE) showed normal left ventricular (LV) systolic function with no regional wall motion abnormalities, no significant valvular disease, and no pericardial effusion. CCTA was performed on the day of admission. Vessel morphology and components of each segment were assessed using GE AW server 3.2 software and Color Code Plaque (General Electric Healthcare, Chicago, Illinois, USA). Vessel components were characterized based on Hounsfield units (HU) into low-attenuation plaque (LAP) (< 30 HU), intermediate-attenuation plaque (IAP) (30-150 HU), and calcified plaque (CP) (> 150 HU).[3-7] FFR_{CT} (HeartFlow Inc., Redwood City, California,

ABBREVIATIONS

CCTA	Coronary computed tomography angiography
FFR_{CT}	CT-derived fractional flow reserve
HU	Hounsfield units
IAP	Intermediate-attenuation plaque
ICA	Invasive coronary angiography
LAP	Low-attenuation plaque
LCX	Left circumflex artery
LV	Left ventricular
PCI	Percutaneous coronary intervention
RCA	Right coronary artery
TTE	Transthoracic echocardiography

USA) was calculated based on a 3-dimensional anatomical model synthesized from Computed Tomography (CT) angiographic data.[3-7] As the heart rate achieved was < 60 beats/minute, beta-blockers were not administered. According to the guidelines of the Society of Cardiovascular Computed Tomography,[8] sublingual nitrates (two sprays of 0.8 mg each) were administered five minutes before scanning. The CCTA revealed severe stenosis with calcification in the proximal segment of the right coronary artery (RCA) (Figures 2A-2C) and in the proximal segment of the left anterior descending artery (LAD) (Supplementary Figures 1A-1C). The left circumflex artery (LCX) appeared almost normal (Supplementary Figures 1D-1F). In the RCA, the total vessel length, total luminal volume, total low-attenuation plaque (LAP) volume, total intermediate-attenuation plaque (IAP) volume, and total calcified plaque (CP) volume were 151.2 mm, 633.2 mm^3, 32.5 mm^3, 230.2 mm^3, and 25.7 mm^3, respectively. The stenotic lesion's blooming artifacts, due to severe calcification, interfered with the assessment of vessel lumen (Figures 2A-2C). Color Code Plaque images from the short-axis view indicated very low coronary flow perfusion in the middle of the stenotic lesion (Figure 2I). The lesion's vessel length, luminal volume, LAP volume, IAP volume, and CP volume were 16.2 mm, 71.6 mm^3, 20.3 mm^3, 121.3 mm^3, and 16.7 mm^3, respectively (Figures 2A-2C). The FFR_{CT} was 0.98 at the proximal part of the stenotic lesion and decreased steeply to 0.57 at the distal end. FFR_{CT} further dropped to 0.54 at the end of the RCA (Figures 3A-3B). He was diagnosed with non-ST-segment elevation myocardial infarction and was prescribed aspirin 80 mg. No significant changes were observed in creatine kinase (37 IU/L), troponin T (0.053 ng/L), or the electrocardiogram (where terminal T inversion was slightly flattened) (Figure 1B: arrow) until the enforcement of invasive coronary angiography (ICA). Several hours later, ICA was performed, revealing total coronary occlusion at the proximal segment of the RCA (Figure 4A and Video 1: arrowhead). Additionally, underdeveloped and narrow collateral circulations, supplied from the LAD (Rentrop classification: grade 1), were observed (Figures 4A-B and Videos 1-2: arrow). Severe stenosis was also noted in the LAD (Figures 4C-D and Videos 3-4: arrowhead). Immediate PCI was performed

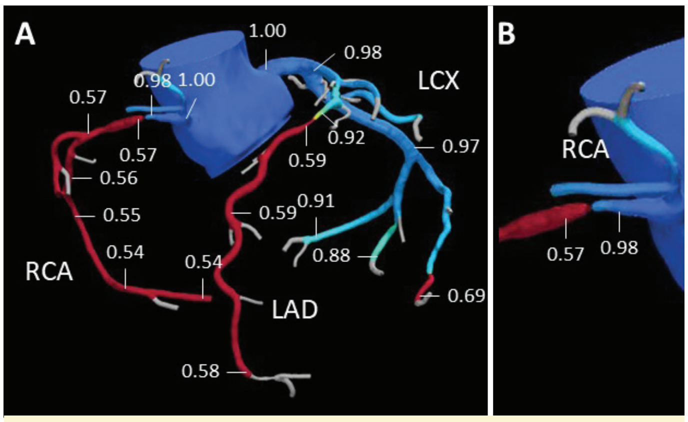

Figure 3. FFR_{CT}: (A) Overall view. (B) Magnified view. LAD, left anterior descending artery; LCX, left circumflex artery; RCA, right coronary artery.

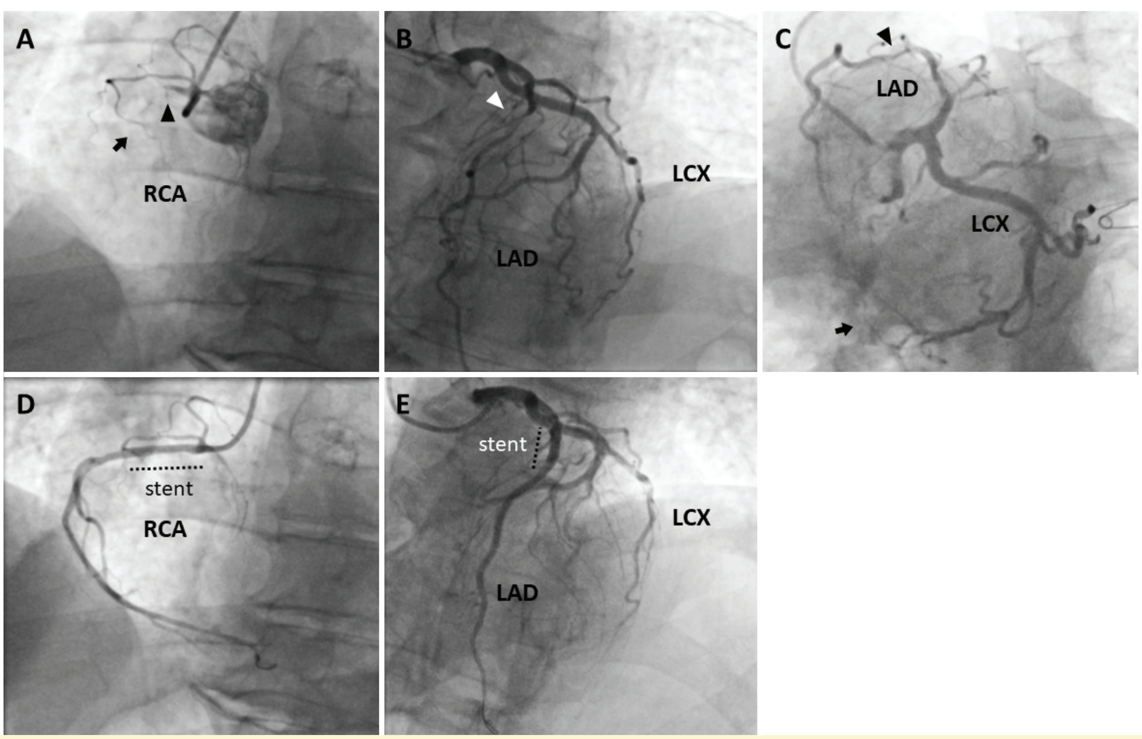

Figure 4. Invasive coronary angiography: (A) Total occlusion (arrowhead) at the proximal segment of the RCA. Collateral circulation (arrow). (B) Collateral circulation from the proximal of the LAD to the RCA. (C–D) Severe stenosis (arrow) in the proximal segment of the LAD. (E) Post-drug-eluting stent (dotted line) implantation at the proximal segment of the RCA. (F) Post-drug-eluting stent (dotted line) implantation at the proximal segment of the LAD. CRA, cranial; LAD, left anterior descending artery; LAO, left anterior oblique; LCX, left circumflex artery; RAO, right anterior oblique; RCA, right coronary artery.

for both the RCA (Figure 4E and Videos 5-6) and LAD (Figure 4F and Videos 7-8). After PCI, creatine kinase and troponin T levels were 333 IU/L and 0.289 ng/L, respectively. TTE results remained similar to those at admission. A summary of the process from the initial chest symptoms to discharge is presented in Supplementary Figure 2. During the year following the PCI, the patient had an uneventful clinical course and did not develop any cardiovascular symptoms.

Discussion

In this case, there was a discrepancy in the assessment of the severity of coronary stenosis between CCTA and FFR_{CT} (indicating subtotal coronary occlusion) and ICA (indicating total coronary occlusion). The guiding catheter did not engage coaxially with the RCA, and insufficient contrast medium filling may have overestimated the severity of coronary stenosis, appearing as a total occlusion. However, several not fully developed collateral circulations (Videos 1, 2) likely provide evidence of a transition from subtotal to total occlusion. It cannot be ruled out that total coronary occlusion occurred after the CCTA. However, this is unlikely as significant changes in electrocardiograms or serum cardiac enzyme levels were not observed between CCTA and ICA. The stenotic lesion, located in the RCA and subject to high motion due to the heartbeat, contained severe calcification and was affected by several artifacts, including motion artifact and beam hardening. Despite these challenges, subtotal coronary occlusion could be diagnosed by CCTA and FFR_{CT}. If vasodilators were not used, it is likely that CCTA and FFR_{CT} might have shown findings of total coronary occlusion similar to those seen in ICA.

The distinction between total and subtotal coronary occlusion plays an important role in determining the treatment strategy. Total coronary occlusion, a common finding,[9] inherently presents challenges with lower PCI success rates and a higher incidence of restenosis or re-occlusion compared to subtotal coronary occlusion.[1,2] The presence of loose fibrous tissue spanning the sub-occluded lesion might facilitate guidewire passage for PCI.[1] Subtotal coronary occlusion, often composed of such loose fibrous tissue, occasionally appears as total coronary occlusion on ICA, complicating accurate diagnosis. Srivatsa et. al.[10] reported cases where ICA indicated total coronary occlusion, but histological findings suggested subtotal coronary occlusion. Two factors were proposed to contribute to this phenomenon: (1) the presence of neovascularization undetectable on ICA; and (2) vessels filled with vulnerable plaques (CP, 64%; non-calcified plaque [LAP and IAP], 11%; mixed plaque, 25%) that could be dilated with a vasodilator. Holmes et al.[11] observed that the use of nitroglycerin as a vasodilator increased vessel flow and luminal volume, resulting in elevated FFR_{CT}. Our previous studies[12] have shown that the different proportions of plaque components between stenotic and peri-stenotic lesions lead to different diastolic functions during maximal hyperemia with a vasodilator, altering FFR_{CT} kinetics. Thus, a stenotic lesion filled with vulnerable tissues could be dilated with a vasodilator, resulting in transient luminal enlargement and increased vessel flow. The presence of collateral circulation also influences FFR_{CT} dynamics. In a previous report,[13] we noted a coronary steal phenomenon in the donor artery due to the supply of well-developed collateral circulation (Rentrop classification: grade 3) from the donor artery, causing a decline in FFR_{CT} in the donor artery. In the current case, the impact of collateral circulation might be negligible because it was not large enough to affect FFR_{CT} hemodynamics. Although the success rate of PCI for total coronary occlusion has improved with rapid advancements in PCI-related devices, PCI is still less successful for total coronary occlusion than for subtotal coronary occlusion,[1,2] and total coronary occlusion remains the strongest independent predictor of unsuccessful revascularization.[9] In the present case, ICA revealed total occlusion, while CCTA and FFR_{CT} findings suggested subtotal coronary occlusion. The clarification of vessel anatomy before PCI enabled a successful and uncomplicated PCI procedure.

In this case, the occluded lesion consisted of non-calcified and vulnerable plaque-rich tissue (LAP and IAP), comprising 61.3% of the stenotic lesion (Figure 2). Additionally, several collateral vessels were underdeveloped and narrow. These factors might indicate that the occluded lesion was not obsolete, but rather in a transitional phase from subtotal to total occlusion (Supplementary Figure 3). This case raises the possibility that a lesion in transition from subtotal to total occlusion might have the potential to dilate and perfuse the peripheral coronary artery during maximal hyperemia, allowing for FFR_{CT} analysis.

Conclusion

The transitional phase lesion, moving from subtotal to total occlusion and consisting of vulnerable plaque components (LAP and IAP), may have the potential to dilate and perfuse coronary arteries during maximal hyperemia, facilitating CCTA and FFR_{CT} analysis.

Informed Consent: Written informed consent was obtained from the patient for the publication of this case report and the accompanying images.

Author Contributions: Concept – T.T.; Design – T.T.; Supervision – K.T., Y.N., M. DM., J. DM., Data Collection – T.T.; Writing – T.T., Y.N.; Critical Review – T.T., K.T.

Usage of AI in Writing: Author declare that AI-assited technologies were not used in this manuscript.

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Video 1. 20° LAO, 0° CRA view. Total occlusion (arrowhead) at the proximal segment of the RCA. Collateral circulation (arrow). CRA, cranial; LAO, left anterior oblique; RCA, right coronary artery.

Video 2. 0° RAO, 30° CRA view. Several collateral circulations form the LAD. Abbreviations are shown in Videos 1 and 2.

Video 3. 20° LAO, 20° CRA view. Severe stenosis of the proximal segment of the LAD. Left anterior oblique cranial image. LAD, left anterior descending artery; LCX, left circumflex. Other abbreviations are shown in Video 1.

Video 4. 20° LAO, 20° CRA view. Severe stenosis of the proximal segment of the LAD. Abbreviations are shown in Videos 1 and 2.

Video 5. 20° LAO, 40° CRA view. Drug-eluting stent implantation in the proximal segment of the RCA. Abbreviations are shown in Videos 1 and 2.

Video 6. 20° LAO, 40° CRA view. Post-drug-eluting stent implantation at the proximal segment of the RCA. Abbreviations are shown in Videos 1 and 2.

Video 7. 0° LAO, 30° CRA view. Drug-eluting stent implantation in the proximal segment of the LAD. Abbreviations are shown in Videos 1 and 2.

Video 8. 0° LAO, 30° CRA view. Post-drug-eluting stent implantation at the proximal segment of the LAD. Abbreviations are shown in Videos 1 and 2.

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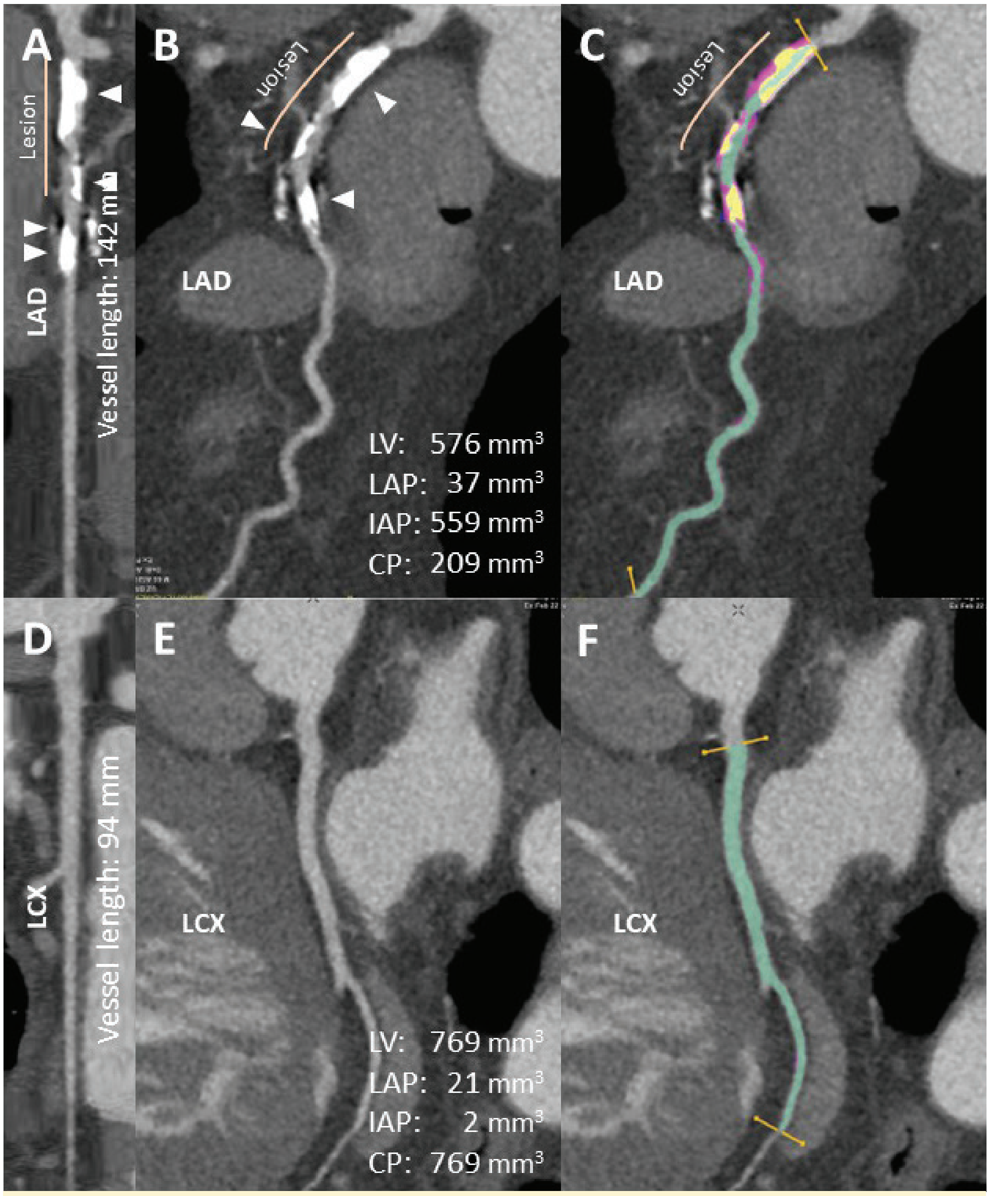
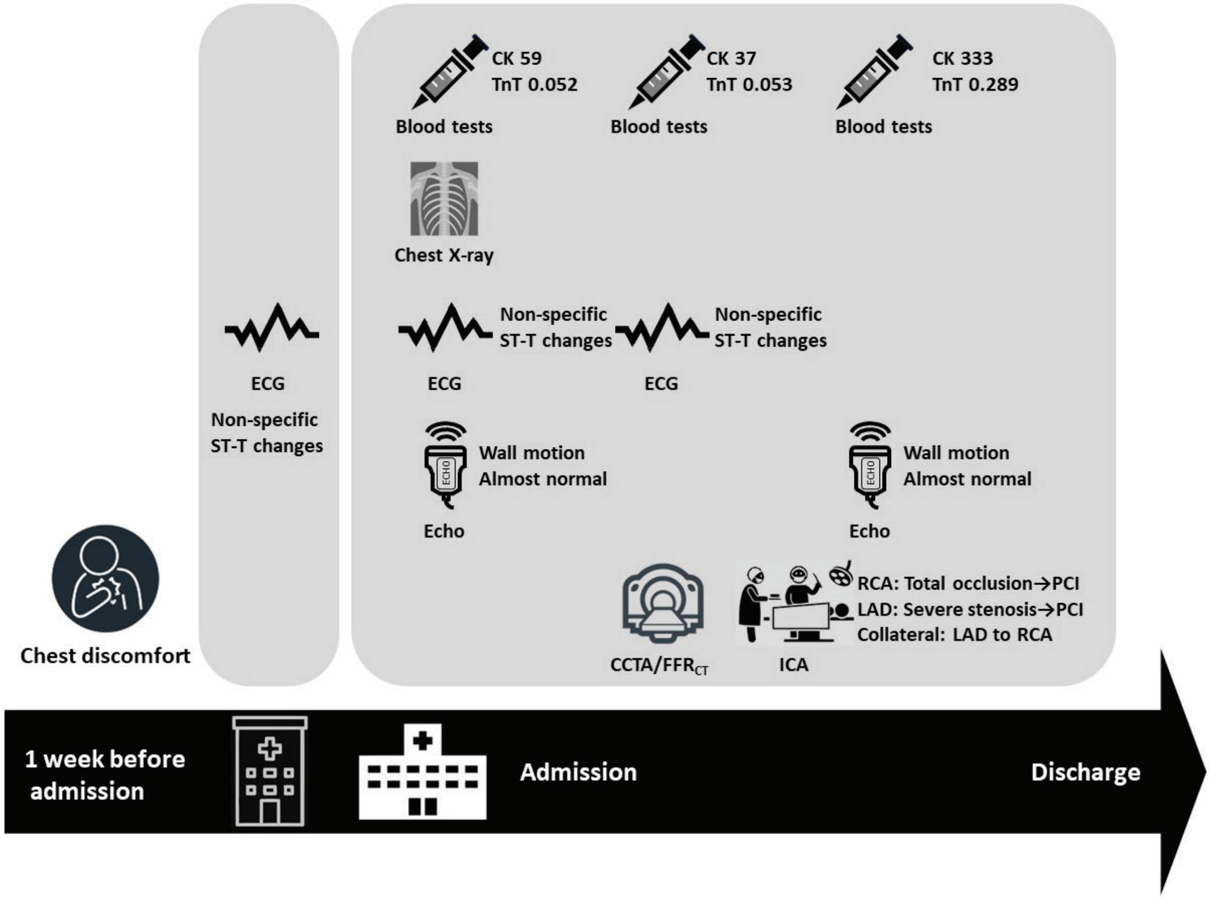
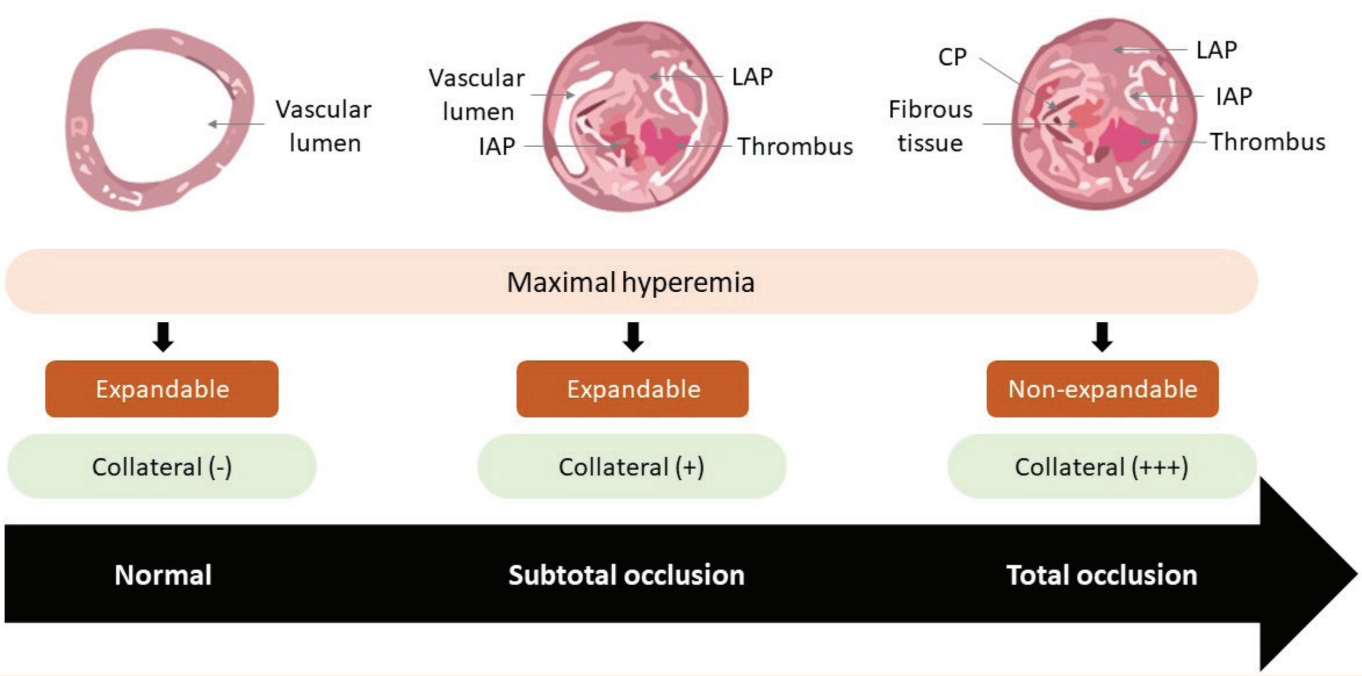


Supplementary Figure 1. CCTA: (A) Stretched multiplanar reformation of LAD. (B) Curved multiplanar reformation of LAD. (C) Color-coded plaque image of LAD. (D) Stretched multiplanar reformation of LCX. (E) Curved multiplanar reformation of LCX. (F) Color-coded plaque image of LCX. Green: LV, Red: IAP, Yellow: CP. CP, calcified plaque; IAP, intermediate-attenuation plaque; LAD, left anterior descending artery; LCX, left circumflex artery.



Supplementary Figure 2. Summary of the process from initial chest symptoms to discharge. CCTA/FFR_{CT}, coronary CT angiography/ CT-derived fractional flow reserve; CK, creatine kinase; ECG, electrocardiogram; ICA, invasive coronary angiography; LAD, left anterior descending artery; RCA, right coronary artery; TnT, troponin T.



Supplementary Figure 3. Scheme of the effects of extravascular calcification on the assessment of coronary stenosis severity with CCTA and FFR_{CT}. CP, calcified plaque; IAP, intermediate-attenuation plaque; LAP, low-attenuation plaque.