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CASE REPORT

Superiority of photon-counting computed tomography for detecting high-risk unstable angina patients: two case reports

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Abstract

Coronary artery disease is the leading cause of death among non-communicable diseases. The management strategy prioritizes early detection and optimal treatment, with emerging roles for imaging approaches. Photon-counting computed tomography is a new non-invasive diagnostic imaging tool that can detect high-risk plaques in coronary artery disease patients. Using photon-counting computed tomography in screening and intravascular ultrasound later in verifying diagnosis and intervention guidance could be a new technique to swiftly discover unstable plaques, prepare lesions for surgery, and determine the optimal percutaneous intervention strategy. However, there is no documentation available for this new approach. We reported two acute coronary syndromes managed with a combination of two imaging methods. Despite receiving medical therapy, the first case continued to experience chest pain, leading to the detection of plaque ulceration in the left anterior descending artery. On the other hand, two PCCT screenings within 6 months revealed plaque progression in the second case. We then used IVUS to confirm the lesions and proceed to intervention. We successfully discharged both cases, and they showed no symptoms 6 months after discharge.

Keywords Photon-counting computed tomography · Intravascular ultrasound · Percutaneous coronary intervention · Hybrid · Coronary artery disease

Introduction

Unstable angina (UA) is a critical condition that accounts for nearly half of acute coronary syndrome (ACS) [1]. Unlike stable angina, which occurs with exertion, UA manifests unexpectedly and can occur at rest, often indicating a progression of coronary artery disease. Studies have demonstrated that a significant proportion of patients with unstable angina will experience a heart attack within the next few days to weeks if left untreated, with the risk of progression to myocardial infarction standing at 15–30% [2].

Factors that predict the likelihood of myocardial infarction in patients with UA include age, presence of risk factors such as hypertension, diabetes, and hyperlipidemia, as well as the severity and frequency of angina episodes [3, 4]. Computed tomography (CT) plays a significant role in the early detection and risk stratification of high-risk UA. Using advanced imaging techniques, CT can assess coronary artery disease by visualizing coronary arteries, identifying blockages, and quantifying plaque burden with a high level of sensitivity and specificity. Photon Counting Computed Tomography (PCCT) is an emerging imaging technology that shows promise in the assessment of high-risk atherosclerotic plaques, particularly in identifying high lipid content within these plaques. Unlike conventional CT, which utilizes a traditional detector system, PCCT employs photon counting detectors that offer enhanced image resolution and contrast, allowing for more precise characterization of plaque components.

On the other hand, substantial evidence supports the practicality of intravascular ultrasound (IVUS), making it the most advantageous option among existing intravascular imaging modalities [5, 6]. IVUS allows interventionists to assess the lumen and artery wall with excellent resolution. Therefore, IVUS is the gold standard in confirming

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coronary lesions. In this report, we aim to present the novel approach, using PCCT to detect high-risk coronary plaque in unstable patients, which was later confirmed by IVUS. We present two cases of acute coronary syndrome, effectively diagnosed and treated with PCCT and IVUS, along with follow-up results. All patients provided the consent form for publication.

Case 1

This is a case of a 47-year-old female patient with a history of hypertension and type 2 diabetes mellitus. She presented after a 3-week course of typical angina episodes. The episodes of severe pain initially began in the left chest, lasted for 5–10 min, spread to the left arm, and were alleviated by rest. ECG at admission was unremarkable (Fig. 1). hs-Troponin concentration was 0.1 (< 15.6 pg/mL), eGFR was 88.96 mL/min/1.73 m^2 (> 60 mL/min/1.73 m^2), HbA1C was 8.3%, and LDL-cholesterol was 2.54 mmol/L (< 3.4 mmol/L). At that time, a photon-counting computed tomography showed that the proximal left anterior descending artery (LAD) was 59.61% stenosed and had a lipid volume of 69.2 mm2, which was equal to 35.2% of the lipid core burden (Fig. 2). The diagnosis at this time was typical angina/60% stenose of LAD II – type 2 diabetes mellitus. She was then managed with clopidogrel, rosuvastatin, isosorbide mononitrate, metoprolol, and trimetazidine.

After 17 days, she still experienced typical chest pain at exertion with similar characteristics lasting approximately 30 min. This led to her hospitalization. Vital signs at admission were within normal range. The physical examination was unremarkable. hs-Troponin I concentration was 0.2 (< 15.6 pg/mL), NT-proBNP was 59.6 pg/mL (< 125 pg/mL), ALT was 38.4 U/L (< 35 U/L), and AST was 33.5 U/L (< 35 U/L). The diagnosis of high-risk unstable angina was made, and she was transferred to the cath lab.

Coronary angiography (Fig. 3) showed 70% stenosis and suspected ulceration of proximal LAD; myocardial bridge caused 40% stenosis of LAD II, with 40% stenosis of the mid-left circumflex artery and 30% stenosis of the mid-right coronary artery. Intravascular ultrasound (IVUS) showed plaque ulceration in proximal LAD with a minimum lesion area of 2.6 mm^2, proximal reference diameter of 3.7 mm, distal reference diameter of 3.2 mm, and plaque burden of 76% (Fig. 4).

The intervention decision was made based on two indications: chest pain refractory to medical treatment and high-risk unstable atherosclerosis on intravascular ultrasound. We employed a 3.0 × 28 mm drug-eluting stent and conducted IVUS after the intervention to ensure optimal intervention. This revealed no edge dissection; The lumen cross-sectional area was 10.36mm^2, which was 98% of the distal lumen reference (Fig. 5).

She was then discharged after an uneventful hospital stay. 6-month follow up showed absence of angina with improvement in physical health.

Case 2

This is a 57-year-old male patient with a medical history of hypertension. He was a long-time treated patient with 5 mg of felodipine and 50 mg of metoprolol daily. 6 months before admission, he visited the cardiology clinic for routine observation. He was advised to take the photon-counting CT scan to evaluate the coronary artery system since there were angina episodes at exertion. PCCT at the time noted 30%

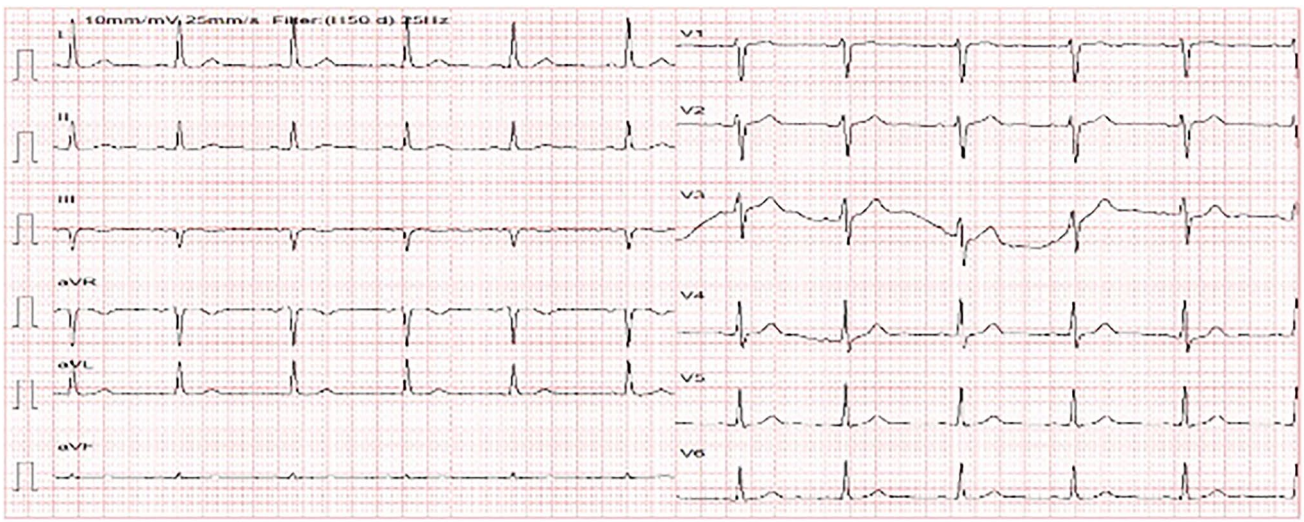

Fig. 1 Admission ECG showed no abnormalities

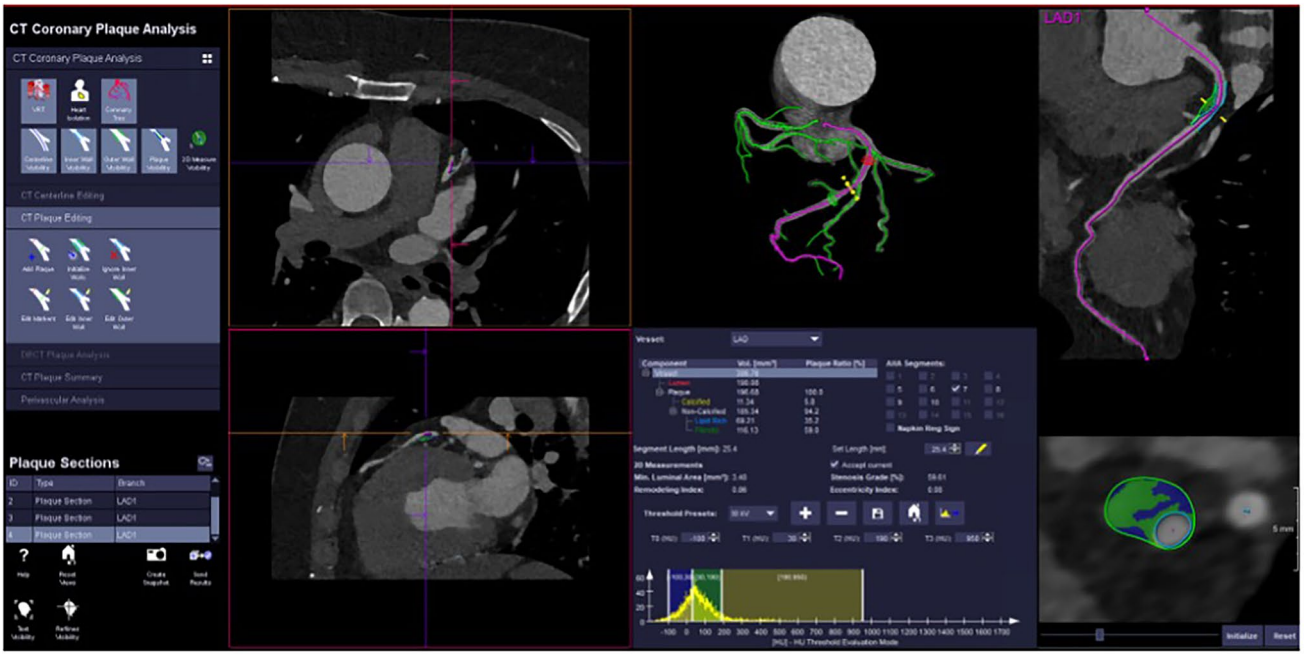

Fig. 2 Photon-counting computed tomography: 59.61% stenosis of proximal LAD with a lipid volume of 69.2 mm^2, correlated to 35.2% of lipid core burden

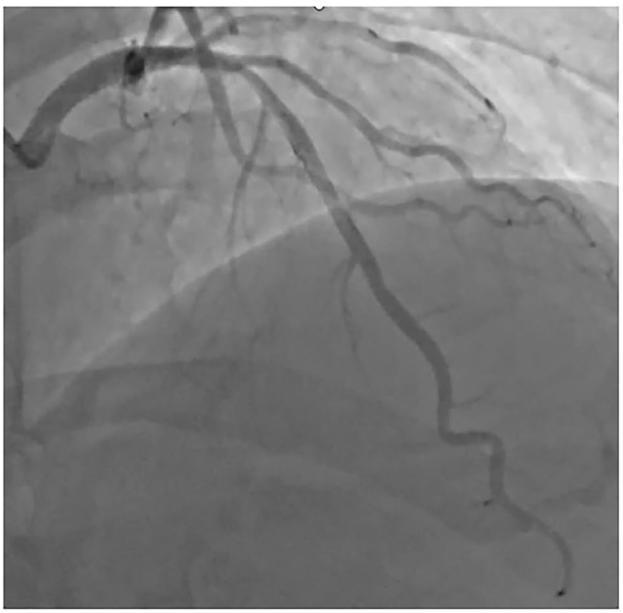

Fig. 3 Pre-intervention coronary angiography focusing on the left anterior descending artery

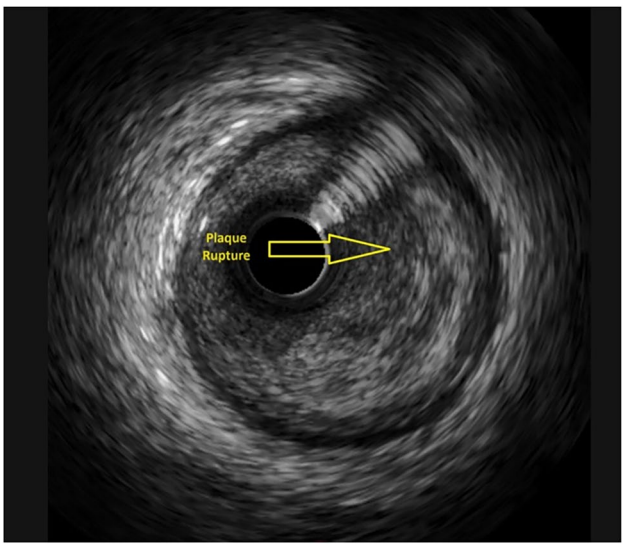

Fig. 4 Pre-intervention IVUS showed plaque ulceration in proximal LAD

stenosis of RCA I (Fig. 6). He was then prescribed 81 mg of aspirin, 20 mg of atorvastatin, 25 mg of metoprolol succinate and 5 mg of felodipin, and was observed as outpatient (Fig. 7).

He was managed all right until 2 weeks before admission, when he experienced several chest pain episodes with similar characteristics even at rest. At admission, he was alert, with a heart rate of 79 beats per minute, blood pressure of 160/100 mmHg, and a body mass index of 24.9 kg/m^2. The other physical examination was unremarkable. ECG showed sinus rhythm, no elevated ST segment, a slightly inverted T wave in V5, V6, and aVL leads (Fig. 8). hs-troponin I was 6.1 pg/mL (< 15.6 pg/mL), HbA1C of 5.8%, eGFR of 77.88 mL/min/1.73 m^2 (> 60 mL/min/1.73

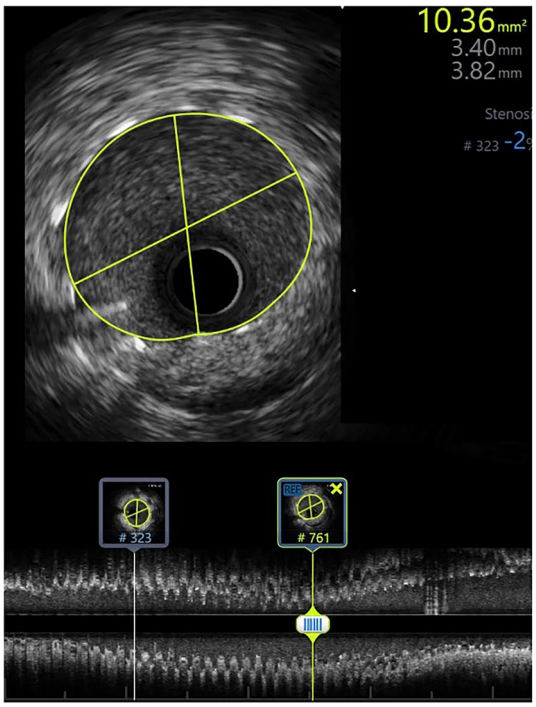

Fig. 5 Post-intervention IVUS showed no edge dissection and CSA of 10.36 mm.^{2}

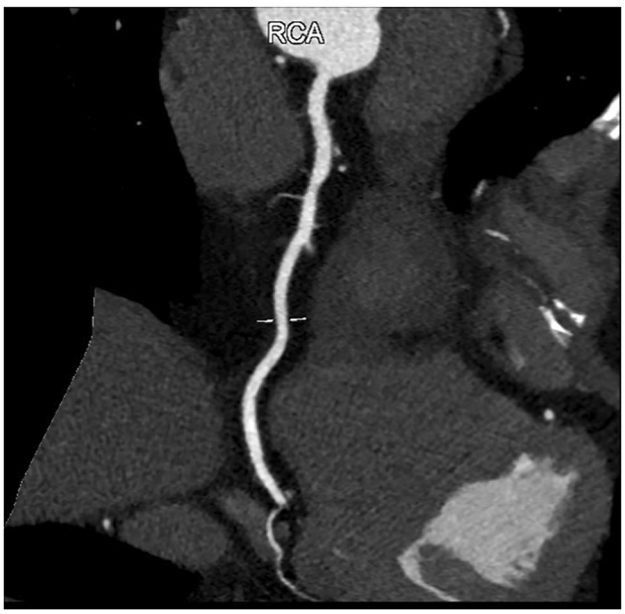

Fig. 6 Photon-counting computed tomography 6 months before admission: 30% stenosis of RCA I

m^2), LDL-C of 1.8 mmol/L (was 2.35 mmol/L 6 months before), AST of 31 U/L, ALT of 41 U/L. Echocardiography showed a preserved left ventricular ejection fraction of

Fig. 8 PCCT at admission showed 30% stenosis of RCA I and 80% stenosis of RCA III

62%, no sign of dilatation or thick wall, and no abnormal regional wall motion.

PCCT at this time showed 35% stenosis of LAD II (not significant changed compared to 6 months), 30% stenosis of RCA I and 80% stenosis of RCA III (Fig. 7, 9).

A GRACE score of 64 points led to the diagnosis of non-high-risk unstable angina. We then indicated that he should undergo invasive coronary angiography. IVUS at the time showed showed 90 degree of endothelial dissection from 0 to 3 h position along RCA III (Fig. 10), with a maximum plaque burden of 81% with a MSA of 2.84 mm^2 (Fig. 11).

The intervention was made based on the indication of unstable angina refractory to medical treatment and a dissected lesion in RCA III on IVUS (Fig. 10). We placed a 3.0 × 18 mm drug-eluting stent with an NC balloon 3.0 × 15 mm, and IVUS was conducted after intervention to ensure optimal intervention, which revealed no edge dissection. The lumen cross-sectional area was 6.91 mm^2 and was 93% of the distal lumen reference (Fig. 12).

He had an uneventful hospital stay and was discharged with 81 mg of aspirin, 180 mg of ticagrelor, 20 mg of rosuvastatin, 25 mg of metoprolol, 50 mg of losartan, 70 mg of trimetazidine. 4-month follow up showed no angina episode and good clinical health.

Discussion

Although both IVUS and PCCT were developed to be useful imaging modalities, they are different in both technology aspects and adaptation settings. IVUS, with a history

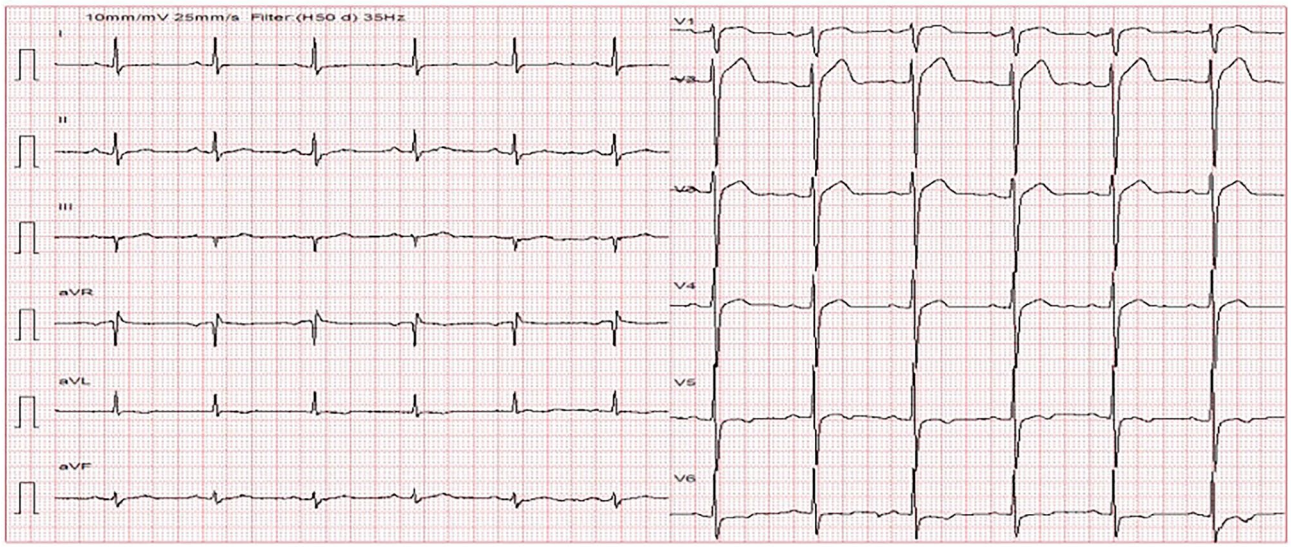

Fig. 7 Admission ECG showed slightly inverted T wave in V5, V6 and aVL leads

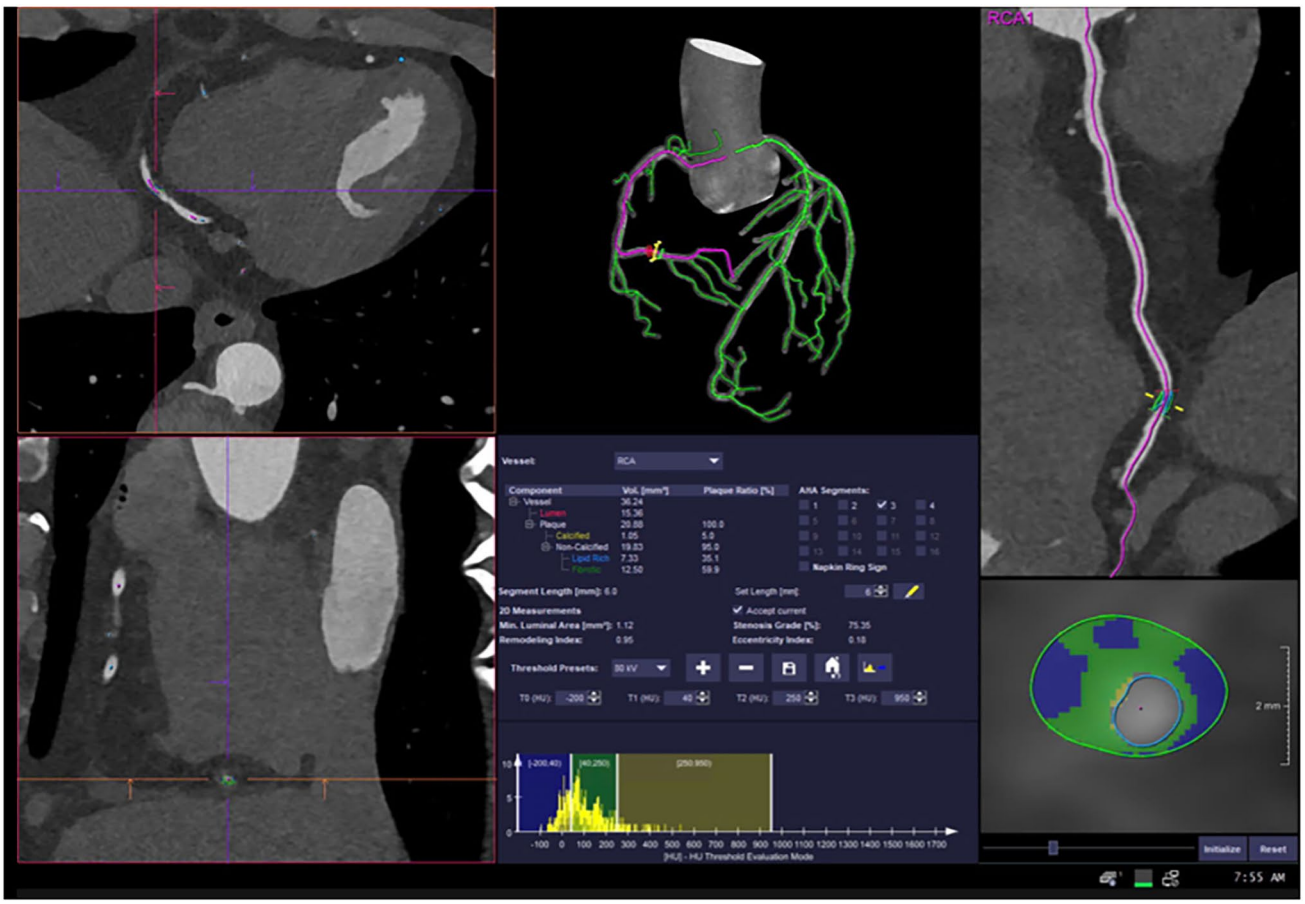

Fig. 9 Admission PCCT analysis of the right coronary artery

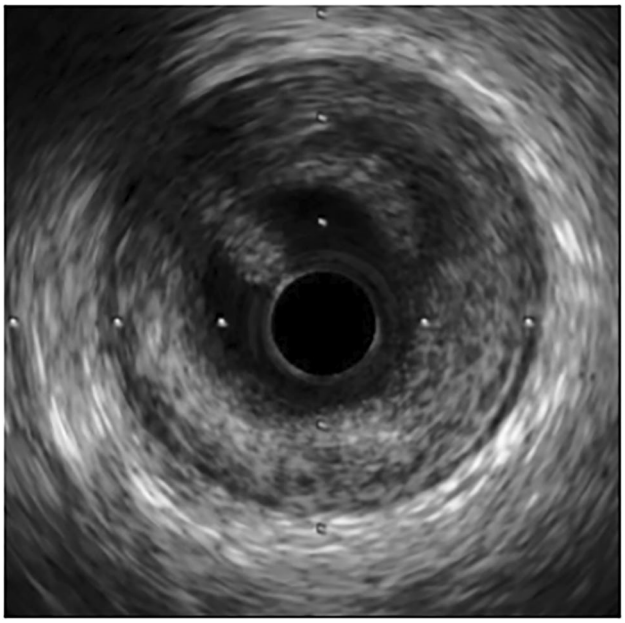

Fig. 10 IVUS of RCA III showed 90 degree of endothelial dissection from 0 to 3 h position

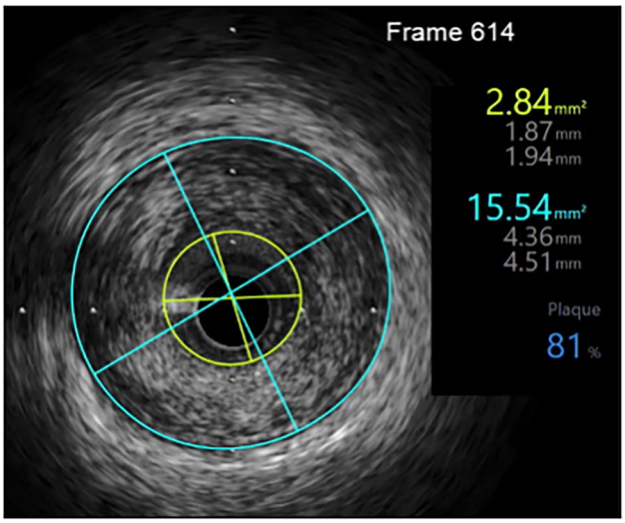

Fig. 11 Pre-intervention IVUS of RCA III showed maximum plaque burden of 81% with a MSA of 2.84 mm.^{2}

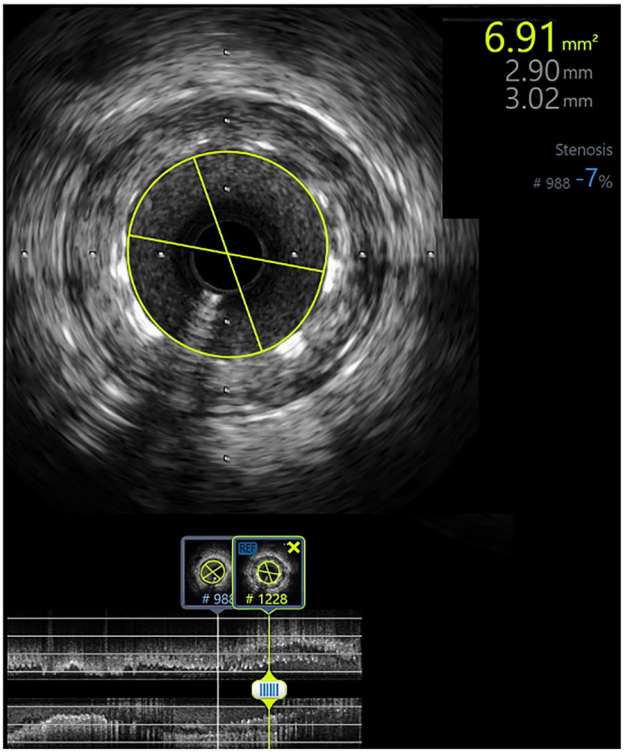

Fig. 12 IVUS post intervention showed no egde dissection, lumen cross sectional area was 6.91 mm^2 and was 93% of distal lumen reference

of long-term modifications and a great deal of evidence, has been used in confirming diagnosis and guidance in intervention. On the other hand, PCCT, despite the promising features, is still a novel tool with little evidence to date. In this paper, we want to explore the potential approach of PCCT in the management of high-risk UA patients.

As we have known, coronary computed tomography angiography (CCTA) currently has a Class I indication for assessment in low-intermediate coronary risk patients [7]. CCTA is helpful in mapping the coronary artery system and detecting coronary lesion severity. PCCT is an integrating system of CCTA, with the advantages of reduced radiation dosage, a higher proportion of artifact-free results, and reduced image acquisition time, which have led to improved diagnostic accuracy and a more flexible management strategy [8]. Polacin et al. in 2022 [9] reported a case of myocardial infarction with non-obstructive coronary artery disease managed with PCCT. This report proved that PCCT is useful in detecting not only intravascular plaques but also features of high-risk plaques. Since then, several papers have addressed the technical innovations and their clinical applications in cardiovascular diseases [8, 10, 11]. CCTA might be a reasonable choice in low-intermediate cardiac risk patients who are not fit to undertake coronary angiography or IVUS due to low cost [12], local expertise, or the patient's preferences with non-invasive methods. Serial CCTA can also provide valuable information on lesion progression and intervention planning. The current guideline gives a class IIa recommendation for using CCTA in patients with suspected acute coronary syndrome with non-elevated hs-cTn levels, no ECG changes, and no recurrence of pain [13]. In a chronic coronary setting, ESC even gives a class I recommendation in ordering CCTA in patients with suspected CCS and low-moderate likelihood of obstructive CAD [14].

IVUS, on the other hand, has been developed since the 1980s [15]. It has grown to have the most significant amount of evidence in efficacy and safety among imaging modalities [5, 6, 16]. With a diagnostic objective, IVUS is utilized in ambiguous angiography results [17], intermediate lesions [18], left main coronary artery undefined lesions [19, 20], and implantation vessel evaluation [21, 22]. In daily clinical practice, physicians can combine PCCT and IVUS in various ways. IVUS has been shown to detect high-risk plaques in several studies. Recently, Seung-Jung Park, Jung-Min Ahn et al. [23] presented a multicentre, randomised controlled trial that investigated preventive intervention in vulnerable atherosclerotic coronary plaques. The definitions of vulnerable plaque via intravascular imaging were at least 2 of the following four features: a minimal lumen area < 4.0 mm^2 via IVUS or optical coherence tomography; a plaque burden > 70% via IVUS; a lipid-rich plaque vie near-infrared spectroscopy; or a thin-cap fibroatheroma via radiofrequency IVUS or optical coherence tomography. In our experiences, PCCT can be used to screen for significant coronary artery disease and critical stenosed lesions before sending patients to the cath lab. With advantages in better spectral imaging and superior visibility of plaques, PCCT can identify high-risk lesions that need to undergo intervention. PCCT can also play a role in closely monitoring the plaque development in chronic chest pain patients. IVUS will then be used for lesion confirmation and intervention guidance. We believe this approach will result in a gain in net specificity and work in patients's favor.

In summary, PCCT is useful and non-invasive in unstable angina detection. PCCT is a new, essential tool and easy for training in the imaging diagnostic department. IVUS is a part of the training program for interventionists around the world and remains the most common and amicable in coronary intervention guidance. Physicians can combine photon-counting computed tomography and intravascular ultrasound daily. This combination will improve diagnostic accuracy, provide a practical way for intervention guidance, and check for optimal intervention results. This approach can solve the disadvantages of traditional computed tomography and coronary angiography.

Conclusion

The combination of photon-counting computed tomography and intravascular ultrasound is new and promising. Early detection of unstable lesions in photon-counting computed tomography and proceeding to intravascular ultrasound-based coronary intervention can improve diagnosis accuracy and bring optimal results to both procedural and clinical prospects.

Author contributions C.N and A.N wrote the main manuscript text and H.T and D.M prepared Figs. 1–12. C.N and D.H previewed the final version. All authors reviewed the manuscript.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Competing Interests The authors declare no competing interests.

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