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The Role of Coronary CT Angiography in Chronic Total Occlusion Coronary Intervention

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Abstract

Context: The application of coronary computed tomography angiography (CCTA) is increasingly being recognized for its role in diagnosing and ruling out coronary artery disease (CAD). This editorial letter discusses the usefulness of CCTA in planning for chronic total occlusion percutaneous coronary intervention (CTO PCI).

Evidence Acquisition: We searched for articles using Google Scholar and the PubMed Database. The keywords used were "Coronary CT Angiography (CCTA)," "Chronic Total Occlusion (CTO) intervention," "pre-procedural CTO PCI," and "post-CTO interventions." The articles included in the review were published between 2013 and 2023.

Results: Regarding pre-procedural planning for the revascularization of chronic total occlusions (CTOs), there is significant interest in the ability of CCTA to visualize and analyze coronary atherosclerotic plaque. Additionally, CCTA can provide three-dimensional coronary vessel imaging. Following post-CTO intervention, CCTA is utilized to determine whether the formation of new channels and plaque remodeling will improve the chances of future successful interventions.

Conclusions: CCTA allows for the precise assessment of anatomical features without invasive procedures, making the diagnosis of CAD easier. The technology is advancing rapidly, with new scanners offering higher resolution, better-quality images, and reduced radiation exposure.

Keywords: CCTA, CTO, pre-Procedural CTO PCI, Post-CTO Interventions

1. Context

A coronary artery chronic total occlusion (CTO) refers to a complete blockage of a coronary artery with no antegrade flow (TIMI 0 flow) and an occlusion lasting more than three months. Approximately 25% of individuals diagnosed with coronary artery disease (CAD) have CTOs when examined with coronary imaging. The likelihood of these blockages increases with age (1, 2). These lesions comprise adventitia, atheromatous plaque, and an organized, widely recanalized thrombus in an obstructed lumen. Both intracellular and extracellular calcium and lipid components are also present. Tough fibrous tissue, rich in collagen, limits the blocked lumen both proximally and distally (3).

Over 12 months, CTO lesions develop tough proximal and distal caps, become more calcified, and exhibit reduced neovascularization. The structure of coronary collateral circulation can provide sufficient oxygen supply to the vascular bed distal to a CTO. However, even with well-developed collaterals, patients might still experience symptoms, particularly during exertion, when collateral perfusion to the afflicted myocardium is insufficient, leading to ischemic myocardial areas (4). Successful revascularization with either percutaneous coronary intervention (PCI) or coronary artery bypass graft (CABG) can improve symptoms and perfusion to these ischemic areas. Compared to the best medical therapy, this can significantly improve angina and quality of life (5).

Utilizing coronary computed tomographic angiography (CCTA) before the procedure can provide additional insights into the characteristics of the CTO that might influence procedural preparation and outcomes (6). Its incorporation into the procedure through fusion with fluoroscopy could be a further step. Coronary computed tomography angiography has the potential to be used as a screening tool for patients with suspected CAD, allowing for the identification of CTOs (7).

2. Evidence Acquisition

In this mini-review article, we searched for relevant articles using Google Scholar and the PubMed Database. The keywords used were CCTA, CTO intervention, pre-procedural chronic total occlusion percutaneous coronary intervention (CTO PCI), and post-CTO interventions. The articles selected for this review were published between 2013 and 2023. Only full-text articles related to our discussion were included. All selected articles were in English and were reviewed by each author.

3. Results

3.1. Percutaneous Coronary Intervention (PCI)

Percutaneous coronary intervention is currently the most frequently used procedure for treating symptomatic CAD, in addition to appropriate medicinal therapy. New drug-eluting stent technology and improved patient outcomes have significantly reduced the prevalence of device-related problems (8). Despite these developments, patients are frequently transferred to the catheterization laboratory without prior knowledge of their precise coronary anatomy and lesion features (such as length, diameter, and amount of calcification), which might guide the procedure's strategy. This contrasts with structural heart interventions, reflecting a historical perspective because invasive coronary angiography (ICA) was developed before CCTA and has been used for a long time without any additional anatomical information (9).

Incorrect stent selection and higher rates of adverse events may result from incomplete plaque coverage caused by erroneous lesion length estimation and inadequate fluoroscopic view angle (10). In addition, low-attenuation plaques are independent predictors of abnormal translesional physiology and periprocedural myocardial infarction. Plaques with a high calcium burden can lead to inadequate stent expansion and increased chances of target artery failure during PCI. To better inform ICA on the volume and nature of atherosclerotic plaques that may affect the invasive process, CCTA offers complementary information (11).

Coronary computed tomography angiography is a non-invasive imaging technique that effectively evaluates the degree and severity of CAD by assessing plaque form, composition, and features (12). When analyzing CCTA scans, the size of the lumen filled with contrast should be noticeably smaller. Preprocedural CCTA may offer additional information on the characteristics of the CTO that could influence procedural planning and results. Its incorporation into the procedure through a fusion with fluoroscopy could be a further step (13).

Coronary computed tomography angiography is also useful in screening for patients with suspected CAD and may detect CTO. It is important to differentiate CTOs from subtotal occlusions (STO), as the length of occlusion is usually longer in CTOs than STOs. Additionally, attenuation gradient and identifying collaterals are other features to differentiate CTO and STO (14). Using CCTA, CTOs are frequently diagnosed in cross-sectional views when there is no lumen opacification. The lumen distal to the blockage is sometimes obscured by retrograde collateral contrast flow. Because retrograde collaterals allow for opacification of the artery close to the stenosis, a CTO may not be properly detected on CCTA. On CCTA, the contrast-enhanced lumen is interrupted in both total and subtotal occlusions, and it can be challenging to distinguish between these two due to poor spatial resolution (15).

3.2. Pre-procedural Chronic Total Occlusion Percutaneous Coronary Intervention Planning Using Coronary Computed Tomography Angiography

The treatment of high-risk patients involves more clinical complexity than most cutting-edge cardiac procedures. Performing a preprocedural risk assessment is essential to identify individuals who will benefit from CTO PCI and to select those who may safely undergo the surgery (16). Various scoring systems based on angiographic parameters can predict technical success and associated difficulties. The J-CTO score is commonly used due to its proven ability to reliably predict the successful crossing of guidewires within a 30-minute timeframe and overall technical success. Coronary computed tomography angiography may be a crucial component of preprocedural planning before CTO PCI, as it currently appears to have even more discrimination (17).

Coronary computed tomography angiography thoroughly describes the coronary anatomy in three dimensions, which can aid in procedural planning. Coronary computed tomography angiography better characterizes the anatomic morphology of blocked arteries than conventional coronary angiography. It helps identify the distal vessel region and measure coronary artery calcium. This is particularly useful when coronary angiography cannot opacify the distal segments in lengthy, convoluted veins. The selection of debulking devices might be based on morphological parameters, specifically the quantity of calcium present (18). Patients undergoing CTO PCI who have poor collateral artery visualization by angiography may find it particularly helpful because fluoroscopic projection angles can be predicted based on the trajectory of the channel on CCTA (19).

Additionally, CCTA can offer precise anatomical information about the occluded section. It accurately measures the length of the blocked section, which might be difficult in conventional coronary angiography. It can provide information on the angles, proximal and distal stump or cap features, and vascular tortuosity (20). In addition to the vessel's length and anatomical path, CCTA can provide detailed information on the structural features of the blocked section and the condition of the plaque. It has the ability to both detect and characterize the extent of calcification, both of which serve as indicators of operation failure (21).

3.3. Coronary Computed Tomography Angiography in Post-chronic Total Occlusion Intervention

Failure of the CTO PCI is indicated by an unsuccessful re-entry into the distal lumen or entry into the proximal cap. Modifying plaque and establishing new routes can enhance the likelihood of future therapies being successful, regardless of their initial outcome(22) Coronary computed tomography angiography can be used to improve the detection of specific details during an interventional procedure. These details include the formation of new tracks, the direction of the dissection plane, the distance to the distal entry cap, and the likelihood of a successful antegrade dissection re-entry. By assessing the degree of calcification and identifying the area of the artery where success is most likely, CCTA can help increase the chances of a successful procedure after a failed attempt to re-enter or only ballooning of the extra-plaque space (23, 24). The success rate of CTO PCI has increased due to several factors. Technological advancements, including the creation of wires, microcatheters, calcium modification techniques, and intracoronary imaging, are crucial. Additionally, the success rate has considerably increased due to thorough pre-procedural planning, the utilization of twin injections, the introduction of advanced equipment featuring specialized wires and support catheters, and the implementation of several other procedures (25). Interventional cardiologists reportedly only commonly employ CCTA in CTO PCI for patients who have had prior CABG or for operations that have failed. This may be due to a lack of staff members who can provide the CTO operator with an explanation of the complex details of CTO anatomy, which is necessary for treatment planning. Consequently, the usefulness of CCTA in this context may be limited (26).

4. Conclusions

Coronary computed tomography angiography allows for precise anatomical feature assessment without intrusive procedures, making the diagnosis of CAD easier. The technology is developing quickly, with new scanners offering higher resolution, higher-quality images, and reduced radiation exposure. When analyzing CT images, CTO is frequently discovered. Successfully revascularizing CTO with PCI results in better left ventricular function and improved patient outcomes. Single characteristics or integrated scoring systems using CCTA can be employed to assess the complexity of the CTOs before PCI. These approaches have demonstrated the ability to accurately predict the rates of procedural success. After CTO intervention, CCTA is used to assess whether the modification of the plaque and the creation of new channels will increase the likelihood of successful future interventions.

Footnotes

Authors' Contribution: Study concept and design, SL and NMS; acquisition of data, SL and NMS; analysis and interpretation of data, SL and NMS; drafting of the manuscript, SL and NMS; critical revision of the manuscript for important intellectual content, SL and NMS; statistical analysis, SL and NMS; administrative, technical, and material support. SL and NMS; study supervision, SL.

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