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Value of Pre-procedural Multi-detector Computed Tomography Angiography in Prediction of Outcome in Recanalization for Coronary Chronic Total Occlusion

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Abstract
background: The Critical components of cardiovascular care include the detection and treatment of Coronary Artery Chronic Total Occlusion (CTO). Objective: The major purpose of this research is to evaluate coronary CT angiography (CCTA) and associated scoring systems for their use in assessing candidates for CTO-PCI prior to the actual surgery. We want to learn how these methods improve patient outcomes by making it possible to foresee the degree of difficulty and likelihood of success associated with CTO recanalization. Conclusions: Improvements in the treatment of coronary artery CTOs may be possible with the use of CCTA. Improved patient outcomes are a direct result of CCTA's ability to precisely characterise CTO lesions, facilitate the selection of optimal procedural strategies, and incorporate quantitative parameters for risk stratification, suggesting that CCTA will play a pivotal role in the future of cardiovascular imaging and intervention.

Keywords: Coronary Computed Tomography Angiography, Chronic Total Occlusion, Percutaneous Coronary Intervention, CTO-PCI, Predictive Scoring Systems.

Introduction

Among the many cardiac disorders that contribute to the global burden of death, Chronic Total Occlusion (CTO) in coronary arteries stands out as particularly daunting. When a coronary artery is completely blocked for an extended period of time, it may have devastating clinical consequences for the patient. Over time, the treatment of CTO has progressed from more intrusive methods to less invasive ones, such as percutaneous coronary intervention (PCI). While CTO-PCI has made great strides, reopening occluded arteries is still a challenging and uncertain process.

When it comes to imaging the heart, coronary computed tomography angiography (CCTA) has become a game-changer. By non-invasively and precisely visualising the coronary architecture, CCTA sheds light on the size and composition of CTO lesions. Its value goes beyond visual inspection since it permits the precise measurement of an array of characteristics, including calcification, vascular architecture, and lesion length. These skills have motivated additional research of CCTA's function in forecasting the results of CTO-PCI operations [2].

The purpose of this study is to provide a thorough examination of CCTA's function in assessing and predicting results before CTO-PCI. Potential advantages of CCTA for evaluating CTO lesions, predicting operative success, and better managing patients with CTOs are discussed.

Prior to the development of multi-detector computed tomography (MDCT), the primary hurdles in peripheral arterial disease (PAD) and coronary angiography were the slow acquisition speed and poor spatial and temporal resolution of CT angiography (CTA). First performed in 1927 by Egas Moniz, diagnostic coronary angiography was a medical breakthrough in 1958. Catheter angiography is intrusive and has dangers; nevertheless, less invasive procedures such as CTA have developed in tandem with advances in catheter arteriography, making CTA an emerging gold standard in certain circumstances. Coronary computed tomographic angiography (CCTA) is a useful anatomic test for intermediate-risk individuals in the diagnosis of cardiovascular disorders like CAD, offering prompt results [3, 4].

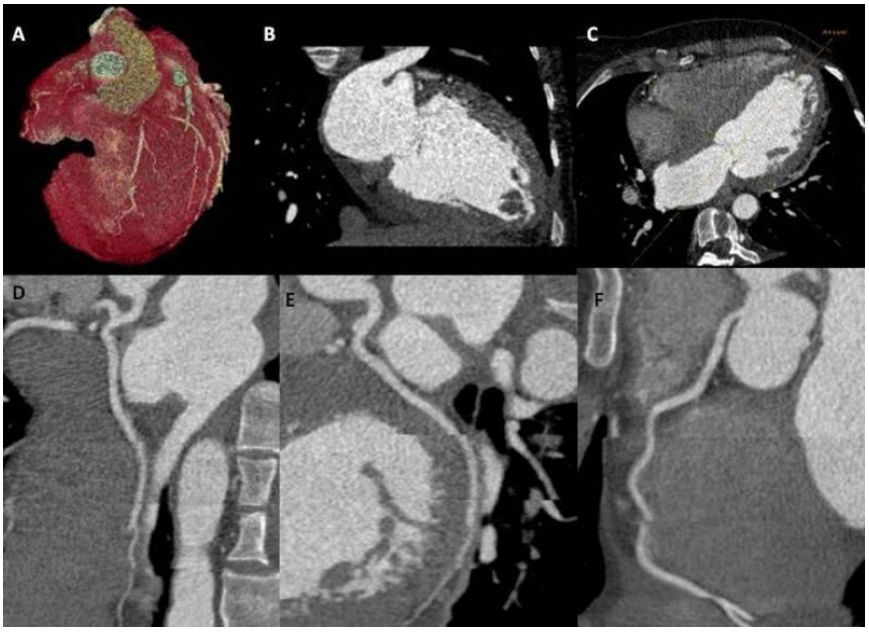

Fig. (1) CCTA imaging, (A) is a volume rendering of the heart in three dimensions, (C) are oblique planar pictures of the heart, and (B) are from the apex, which is consistent with an intracavitary thrombus. [5] is shown in (D), (E), and (F) as a multiplanar reformat.

When it comes to identifying coronary artery disease, CCTA has emerged as a non-invasive alternative to invasive coronary angiography due to its potential benefits in terms of risk avoidance, time, and cost-effectiveness. CCTA depends on both spatial and temporal resolution, which has been increased by contemporary technology such as 64-slice multi-detector CT (64-MDCT) systems, allowing for exact evaluation even of distant coronary artery segments. Despite certain patient exclusions, early investigations demonstrated good sensitivity, specificity, and predictive values for diagnosing severe coronary lesions [6].

Patients may be stratified into low, intermediate, and high risk categories for future CAD development based on their coronary artery calcium (CAC) score, which is calculated during the non-contrast phase of CCTA. Guidelines from the medical community recommend using CAC scores in certain circumstances when the patient is asymptomatic to determine whether or not they are at an intermediate risk. However, CCTA, which gives a more thorough evaluation of coronary artery morphology and plaque features, including non-calcified plaques [7], may be a more suitable diagnostic tool than CAC score alone for symptomatic individuals with moderate pre-test likelihood of CAD.

The diagnostic value of cardiac computed tomography angiography (CCTA) lies in its ability to examine the heart and its surrounding structures in great detail. Key points about CCTA are summarised here, including its anatomical and physiological uses, indications, contraindications, equipment and staff needs, preparatory stages, imaging methodologies, complications, clinical importance, and current technological advances. The ability of healthcare providers to consider CCTA as a diagnostic test for patients with cardiovascular problems necessitates an understanding of these factors [8]. Important Data from Cardiac CT Angiography (CCTA) Sections Table 1

Anatomy and Physiology	CCTA allows visualization of the heart, including various cardiac structures, coronary arteries, and adjacent structures. It can diagnose cardiac anatomical abnormalities.
Indications	CCTA is used for testing coronary artery stenosis in patients with chest pain and intermediate pre-test probability of obstructive CAD. It's also recommended for diagnosing congenital anomalous coronary arteries.
Contraindications	Contraindications include a history of severe contrast reaction, hemodynamic instability, acute myocardial infarction, and renal impairment. Relative contraindications include pregnancy, severe aortic stenosis, and certain medical conditions.
Equipment	Recommended equipment for CCTA includes at least a 64-slice CT scanner, dual-head power injection pumps, DICOM format for image storage, and a PACS system for image review.

Personnel	Trained technologists, individuals skilled in IV catheter insertion, ACLS-certified staff, and those experienced in administering beta-blockers and nitroglycerin are recommended for CCTA. The interpreting physician should be trained in CCTA.
Preparation	A review of contraindications should be performed, informed consent obtained, fasting, and specific IV access methods for contrast administration followed.
Technique	Adequate opacification and timing of the contrast bolus are crucial. Different tube potential and current settings should be optimized to minimize radiation while maintaining image quality.
Complications	Rare complications may include anaphylactic responses. Radiation exposure is a concern, especially in children and young adults. Minimizing exposure is essential.
Clinical Significance	CCTA is a cost-effective and non-invasive tool for assessing cardiovascular health. It's important to consult with a cardiologist to determine the appropriate diagnostic procedure.
Metrics for CT Angiography	Key metrics include spatial resolution, temporal resolution, and volume coverage, which affect the ability to visualize and distinguish tissues. Contrast media administration is also important **(Figure 2)**.
Image Acquisition	Various techniques such as helical CT and gating methods (retrospective, prospective) are used to acquire CTA images. Wide area detector systems and dual source CT provide advantages for CTA **(Figure 3)**.
New Developments	Modern CT scanners have improved on traditional parameters, and advancements include wide area detector scanning and dual source CT. These developments enhance CTA capabilities.
Clinical CTA	In coronary CTA, calcium scoring precedes the angiographic phase. ECG gating is essential to capture images during the appropriate cardiac phases. Radiation dose is minimized using prospective ECG gating.

Coronary Artery Total Occlusion: A Chronic Condition Overview

When an angiographic assessment reveals that a coronary artery has been completely blocked for three months or more, we say that an individual suffers from coronary chronic total occlusion (CTO). During coronary angiography, blood flow is graded using a four-point scale developed by the thrombolysis in myocardial infarction (TIMI) study. There is no perfusion at the TIMI 0 level, indicating complete occlusion; penetration without perfusion at the TIMI 1 level, indicating incomplete filling of the distal coronary bed; partial reperfusion at the TIMI 2 level, indicating delayed forward flow and full filling of the distal coronary bed; and full perfusion at the TIMI 3 level, indicating normal flow in the distal coronary bed. Clinical information relating to the event producing the occlusion, such as a prior myocardial infarction or changes in anginal symptoms, might make it difficult to determine the precise length of a CTO lesion. A CTO's age may be a mystery in certain situations [9].

Etiology

Multiple variables put individuals at higher risk for developing coronary chronic total occlusion (CTO) lesions. Tobacco use in excess, having high LDL cholesterol levels in combination with low HDL cholesterol levels, having diabetes, leading a sedentary lifestyle, being overweight, having high blood pressure, having a family history of premature disease, having end-stage kidney disease, and being postmenopausal are all risk factors [10].

Epidemiology

The prevalence of CTOs in individuals with coronary artery disease is age-related, ranging from 18.4% to 20%. Because some people with CTOs exhibit no symptoms, their actual incidence among the general population is unclear. Patients having a prior CABG procedure are at increased risk for CTOs (50 percent to 55 percent). CTOs are less common in individuals who report with ST-elevation myocardial infarction (STEMI) (9 percent to 11 percent). The right coronary artery is the most prevalent site for CTOs, whereas the left circumflex artery is the least common. Older patients are more likely to have at least one CTO, with a 37 percent frequency in those under 65 years, 40 percent in patients aged 65 to 79, and 41 percent in those over 85 years [11].

Pathophysiology

Upregulation of immunologic and inflammatory markers (cytokines, leukocytes, high sensitivity C-reactive protein), endothelial dysfunction, and cholesterol buildup all play roles in the pathogenesis of coronary artery disease, which may develop to CTO lesions. Pathologic intimal thickening and lesion development often begin with the accumulation of smooth muscle cells inside the

intima, followed by the accumulation of macrophages [12].

Histopathology

Calcium, intracellular and extracellular lipids, smooth muscle cells, extracellular matrix, and neovascularization are often seen histopathologically in CTO lesions. Columnar lesions of calcified, resistant fibrous tissue surround a softer core of structured thrombus and lipids in most occlusions, with a high concentration of collagen-rich fibrous tissue at the proximal and distal ends. Soft, hard, or mixed lesions may be identified. Soft plaques, which are made up of cholesterol-laden cells and foam cells, are more common in occlusions in patients younger than 12 months. Dense fibrous tissue with fibrocalcific patches lacking neovascular channels characterises hard plaques, which are more common in occlusions older than 12 months [13].

Evaluation A thorough history and physical examination, including vital signs, a review of medications, and an ECG, is an essential aspect in assessing a patient with suspected ischemic heart disease. Heart failure and valvular heart disease are additional considerations that should be explored throughout the examination. Healthcare professionals should evaluate thyroid and pulmonary function tests, regular blood work, cardiac enzymes, chest X-ray, and echocardiography during the first examination. Urgent care patients may benefit from the use of aspirin (162 to 325 mg) and nitrates. Patients may benefit from cardiac monitoring and pulse oximetry to identify the requirement for supplementary oxygen [14].

How to Handle It Medically

Because of improvements in technology, drug-eluting stents, antithrombotic medication management, and interventional know-how, PCI for CTO has been on the increase. Long-term therapeutic advantages have resulted from the increased success rates of CTO-PCI operations made possible by these cutting-edge tactics, which include specialised techniques, sophisticated stents, and personalised antithrombotic treatment. Operators often utilise scoring systems like the J-CTO score to predict technical success before a CTO-PCI based on parameters such stump appearance, occlusion duration, calcification, bend severity, and previous unsuccessful efforts. The likelihood of successfully traversing the CTO in under 30 minutes is affected by a number of factors, each of which is assigned a point value [15, 16].

In addition to presenting with symptoms, CTOs are associated with a poorer prognosis, including increased mortality and morbidity from cardiovascular causes in a variety of patient demographics. CTO patients are older, sicker, and have more severe left ventricular dysfunction than the general population. Furthermore, patients with non-revascularized CTOs had increased mortality and a higher risk of significant adverse cardiovascular events in contrast to patients with multivessel coronary artery disease who are totally revascularized [18].

Complications

CTO PCI is more difficult than non-CTO PCI because it requires more fluoroscopy time, more contrast volume, and lower success rates. Myocardial infarction, stroke, vascular perforation, and death are all possible outcomes. However, much as with conventional PCIs, difficulties at the vascular access site might arise. These problems can include bleeding, hematoma, thrombosis, embolization, and more. There was an 86% success rate for CTO-PCI, with complications including coronary perforations, significant adverse cardiovascular events, myocardial infarction, acute renal damage, and stroke recorded in a multicenter registry (OPEN-CTO) [19]. is crucial in preventing and controlling coronary artery disease and CTO lesions. Multimedia tools and printed brochures on topics like quitting smoking and maintaining a healthy blood pressure are included. Better results may be achieved by teamwork and the early detection of predictors of revascularization failure [20].

How Effective Is CTO Revascularization Clinically?

CTO revascularization and its potential advantages are still up for discussion. There is a decreased risk of fatal arrhythmias and an improved tolerance for prospective cardiac events, as well as a higher quality of life. Evidence of these advantages has been presented by observational studies and registries, however these studies have limitations due to bias and confounders. There is still space for debate since most current randomized clinical studies are small and concentrate on surrogate outcomes or non-inferiority analyses [21].

Despite contradictory findings from randomised studies, the advantages of CTO-PCI on survival are now the subject of discussion. Refractory angina despite appropriate treatment or the presence of significant ischemia regions warrants consideration of CTO-PCI, according to guidelines. Patients with ischemic heart failure and coronary artery disease may benefit from the use of viability imaging to distinguish

between viable and non-viable myocardium [22].

Coronary revascularization, which often includes percutaneous intervention of chronic occlusion, is a complex puzzle piece.

When dealing with chronic complete occlusion (CTO) in the setting of multivessel coronary artery disease, percutaneous revascularization of CTO plays a critical role. Complete coronary revascularization, performed with CTO-PCI, dramatically lowers long-term cardiac mortality in situations of multivessel atherosclerotic disease. Complete revascularization improves 2-year survival even in individuals with multiple CTOs. Major adverse cardiac and cerebrovascular events (MACCE) and mortality are both higher at 4-year follow-up if revascularization was incomplete, which is affected by coronary complexity and comorbidities. Patients undergoing percutaneous coronary intervention (PCI) are particularly at risk for incomplete percutaneous revascularization since the presence of CTO is the strongest predictor of such failure [23].

Myocardial Infarction Occurring Rapidly Due to Chronic Blockage

The prognosis in patients with acute coronary syndrome who also have multivessel coronary disease and a chronic total occlusion (CTO) is poor. Between half of those hospitalised with a STEMI had multivessel coronary artery disease, and of those, about 13% - 20% also have a CTO. Percutaneous recanalization of the CTO has a high success rate, but is only done in a minority of patients. The short-term and long-term survival prognosis of STEMI patients with multivessel coronary artery disease and CTO is worse, according to studies. Collateral circulation is restricted to the severely occluded channel when a CTO is present, and a rapid decline in collaterals supplying the region beneath the CTO might put at risk a sizable portion of myocardium [23].

There are many applications for scoring methods. It aids in clinical decision-making and communication with the patient by providing a quantitative evaluation of the probability of success and problems. Second, CTO scores allow for better case selection by providing a more objective means of assessing anatomic and clinical complexity; while experienced operators can take on even the toughest of cases with high success rates, operators early in the CTO PCI learning curve can choose "simpler" cases, referring the more unfavourable cases to specialised centres or performing them under the supervision of a proctor. The objective chance of attaining technical/angiographic success with PCI may be taken into consideration within the cardiac team to make individualised decisions about revascularization and the appropriate method. Finally, CTO ratings serve as a helpful guide for evaluating a coronary angiography [10].

At least 15 minutes of comprehensive analysis and assessment are necessary to evaluate the lesion and design a "plan of attack" (main retrograde vs. antegrade approach, intimal or sub-intimal and wire or crossing device-based techniques). The fourth benefit of a consistent categorization of CTO lesion complexity is that it facilitates quality improvement and clinical research by allowing comparison of results with various treatments among operators, facilities, nations, and even continents. The J-CTO score, named after the multicenter CTO registry in Japan where it was developed, was the first CTO scoring system developed to predict successful guidewire crossing within 30 minutes. The J-CTO score is the current gold standard, and its development prompted a flurry of other scoring systems for predicting outcomes including technical success, contrast-induced nephropathy, and complications. Different clinical, imaging, and laboratory factors are used in more recent ratings. But is it required and helpful to make many scores? Certainly, and I'll explain why [23].

To begin, the validation of previously published scores is aided by the creation of new scoring systems. Proximal cap morphology, coronary calcification, and tortuosity are all included in the J-CTO score and other similar scores, highlighting their significance in determining CTO PCI success. Multiple studies have verified the J-CTO score's capacity to forecast the necessity for rapid guidewire crossing, but its ability to predict technical success has been less consistent. Despite some overlap, various methods to CTO PCI [22] typically use new criteria not included in older ratings or proved to be unreliable predictors of outcome.

For example, the ORA (ostial location, Rentrop grade <2, age ≥ 75 years) score by Galassi et al. reflects the creator's significant expertise with retrograde approaches and may therefore be more appropriate for hybrid or retrograde operators. The hybrid approach for CTO PCI is consistent with the PROGRESS CTO (Prospective Global Registry for the Study of Chronic Total Occlusion Intervention) score factors. CT-based assessments, such as the CT-RECTOR (Computed Tomography Registry of Chronic Total Occlusion Revascularization) score, may be particularly useful in locations with

significant usage of computed tomography angiography. A common misperception about scoring systems is that a high score (often correlating to complicated coronary architecture) equals failure. This is false, since international centres of expertise have recorded very high success rates, even with extremely difficult CTOs. Ultimately, CTO PCI scoring systems may be a great asset for both the inexperienced and the seasoned CTO operator, helping with case and strategy selection and predicting procedural efficiency, success, and even problems. It is recommended that new ratings be developed to accommodate various CTO Practices, and that current scoring methods be verified [10].

Coronary computed tomography's place Predicting the Difficulty and Outcome of Chronic Total Occlusion Using the Angiography-derived RECTOR Score Interventional Cardiology Percutaneously

Based on prior angiography or a history of acute chest discomfort or myocardial infarction compatible with the site of CTO, all patients had a native vascular or bypass graft occlusion of 2.5 mm estimated to be of 3 months' duration. The CTO was of to in-stent restenosis or new stenosis formation. According to the recommendations of the EuroCTO Club, all PCIs were carried out by operators with a minimum of 50 CTO cases under their belts annually. Dedicated wires were utilised in a gradual progression from flexible polymeric wires to more rigid flat or tapered wires. The retrograde wire approach, the subintimal tracking method, and the parallel wire technique were all used. It was up to the surgeon to decide how to intervene [24].

Lower procedural success rates (CTO vs. non-CTO, 55-80 percent vs. 90-99 percent) and higher complication rates (CTO vs. non-CTO, 1.6 percent vs. 0.8 percent) are related with coronary chronic total occlusion (CTO) percutaneous coronary intervention (PCI) than non-CTO-PCI. Improvements in angina, left ventricular function, and mortality have all been linked to successful PCI in comparison to CTO-PCI that was unsuccessful. Several physical aspects of the CTO lesion and surgeon expertise are linked to a successful outcome. Clinical decision making and procedure planning based on a more thorough understanding of CTO lesion characteristics may improve the overall success rate of CTO-PCI [25].

A significant benefit of coronary computed tomography angiography (CCTA) over coronary angiography (CA) in the evaluation of longer and more tortuous CTO lesions, as well as segments distal to a CTO lesion, is that CCTA can define the properties of the CTO segment. In addition, it has been studied as a potential replacement pre-procedural imaging approach for CTO-PCI [26], and it can give prognostic information beyond CA.

More accurate predictions of rapid guidewire crossing times may now be made with the use of innovative CCTA-based prediction algorithms. The CT-RECTOR score, based on 6 variables, is a more accurate predictor than the J-CTO score, which is based on CA. Moreover, these investigations demonstrated that with a rising CT-RECTOR, procedure success or the guidewire crossing time reduced [26].

An improvement in the success rate of CTO-PCIs may be possible if pre-procedural CCTA is used to identify the morphologic aspects of CTO. Negative remodelling, lesion lengths > 31.89 mm on CCTA, and ostial/bifurcation lesions on CA imaging are all markers of failed antegrade PCIs that, in suitable patients, may trigger a switch to an early retrograde approach and increase the likelihood of successful revascularization from 74% to 87%. Although this study only included a limited number of patients, pre-procedural CCTA was shown to dramatically boost the success rate of CTO-PCI from 64% to 88%. (30 patients with CCTA). Severe calcification covering 50% of the vascular cross-sectional area has been shown to be a reliable predictor of CTO-PCI failure in several CT-based investigations [27].

In terms of pre-procedural evaluation, several studies have showed a good diagnostic accuracy of CCTA for the assessment of CTOs. The J-CTOCT score from coronary CCTA corresponds well with the J-CTO score from angiography. clinical (prior attempt, occlusion length 12 months or unknown) and CCTA (multiple occlusions, blunt stump, calcification 50% of CTO cross-sectional area, and bending 45°) characteristics are included in the Computed Tomography Registry of Chronic Total Occlusion Revascularization (CT-RECTOR) score. The established CT-RECTOR score was able to significantly predict the chance of GW crossing within 30 min by awarding 1 point for each variable and adding all points accumulated. Procedural success may be predicted using other factors of the CCTA as well. Predictive value for PCI outcomes was shown for CCTA measures of attenuation of the proximal region of CTO lesions, occlusion length, and total coronary calcium score [28].

In a Japanese multicenter investigation, researchers identified the following invasive coronary angiography (ICA) features as risk factors of failure to accomplish guidewire

crossing 30 min: blunt stump, lesion length >20 mm, calcification, and bending >45°. (J-CTO). It is now recommended that CCTA be performed prior to the start of CTO PCI because this non-invasive modality has proven to be an accurate tool for grading the difficulty of PCI of CTO in scoring systems like the Computed Tomography Registry of Chronic Total Occlusion Revascularization (CT-RECTOR) and the CCTA-derived J-CTO scoring systems. More recent research has shown that pre-procedural CCTA-guided CTO PCI had better success and complication rates than angiography guidance alone. With quantitative CCTA, you may evaluate more than just morphological details with precision. The promise of quantitative CCTA was established in the risk classification and evaluation of therapy effects for coronary artery disease (CAD) patients [29].

Perspectives and suggestions for the future:

Incorporating CCTA as a routine pre-procedural planning tool, ensuring interventional cardiologists receive specialised training in interpreting CCTA images and utilising scoring systems, fostering multidisciplinary collaboration among healthcare professionals, and continuously refining and validating CCTA-derived scoring systems for enhanced predictive accuracy are all recommendations for integrating CCTA into the management of CTO. Future prospects in this field involve advancements in CCTA technology, the application of artificial intelligence for image analysis, research focusing on long-term clinical outcomes, the global standardisation of CCTA utilisation, and cost-effectiveness studies to assess the economic implications of adopting CCTA in CTO management. These suggestions and potential developments are meant to improve patient care and procedure results in the context of CTO management by using CCTA.

Conclusions:

The use of CCTA is an exciting new direction for improving the treatment of coronary artery CTOs. CCTA has the potential to play a pivotal role in the development of cardiovascular imaging and intervention because of its ability to precisely characterise CTO lesions, assist in the selection of suitable procedural techniques, and include quantitative characteristics for risk stratification.

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