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CORRELATION OF WELL-DEVELOPED COLLATERAL CIRCULATION AS A MARKER OF VIABILITY IN CHRONIC TOTAL OCCLUSION AS EVIDENCED BY CARDIAC MRI

Dr. Rafi Ullah Jan[1], Dr. Muhammad Waleed[2*], Dr. Maryam Masood[3]

[1]Assistant Professor, MTI Peshawar Institute of Cardiology, Peshawar, Pakistan
[2*]Registrar, MTI Peshawar Institute of Cardiology, Peshawar, Pakistan
[3]Senior Registrar, MTI Peshawar Institute of Cardiology, Peshawar, Pakistan

***Corresponding author:** Muhammad Waleed,
Registrar, MTI Peshawar Institute of Cardiology, Peshawar, Email: drwaleedparacha@gmail.com

ABSTRACT

Background: The complete blockage (occlusion) of coronary arteries (CTOs) poses a challenge when considering a patient for revascularization, especially for a chronic total occlusion (CTO). Evaluating myocardial viability is crucial in determining which patients will most likely benefit from the procedure. Angiographic collateral circulation can, perhaps, provide a marker of viability without needing a potentially invasive procedure. To evaluate the correlation between collateral vessel development and myocardial viability in patients with coronary CTO, using cardiac magnetic resonance imaging (CMR) as the reference standard.

Methods: This retrospective study reviewed 65 patients with angiographically confirmed CTO of the left anterior descending (LAD) or dominant right coronary artery (RCA), who underwent cardiac MRI within two weeks of angiography. Rentrop grading was used to classify collateral development. Viability was assessed on CMR using late gadolinium enhancement (LGE). The association between collateral grade and myocardial viability was analyzed statistically.

Results: Of the 65 patients, 55.4% had viable myocardium on CMR. Well-developed (Rentrop grade 2) and complete collaterals (grade 3) were significantly more common among patients with viable tissue ($p = 0.003$). Poor or absent collaterals correlated with non-viable segments.

Conclusion: Well-formed collateral circulation is strongly associated with myocardial viability in patients with chronic coronary occlusion. Rentrop grading may serve as a useful adjunct to guide revascularization decisions when advanced imaging is unavailable.

Keywords: Chronic total occlusion, myocardial viability, cardiac MRI, Rentrop classification, coronary collaterals, late gadolinium enhancement, revascularization

INTRODUCTION

Advanced coronary artery disease is often associated with chronic total occlusions (CTO) of the coronary arteries, which refers to a complete blockage of a coronary vessel for more than 3 months. The decision to revascularize CTO lesions is still quite challenging, especially with the presence of percutaneous coronary intervention (PCI) due to the need of determining if the myocardium is viable. Revascularization will improve functionality and prognosis which suggests viability indeed [1-3].

In clinical practice, 'cardiac magnetic resonance imaging (CMR) with late gadolinium enhancement (LGE) is considered the best non-invasive method for discerning myocardial viability'. It captures

intricate details of scar burden and tissue preservation. Still, CMR is not available everywhere, particularly in lower-resourced regions. In these scenarios, assessing collateral circulation noted during coronary angiography might aid, even if indirectly, in estimating myocardial viability [4, 5].
Coronary collaterals are the naturally developed bypass vessels that offer supplementary perfusion to the ischemic myocardium. These vessels are rather heterogeneous in their form and function, and their clinical importance has been controversially discussed. According to some studies, developed collaterals aid in the maintenance of myocardial tissue during prolonged ischemia, therefore diminishing the infarct size and aiding in recovery [6-8]. The relation between graded collateral supply and objective assessable viability evaluated with CMR still poses numerous unanswered questions.
This study aims to investigate the correlation between the degree of collateral circulation, as assessed by the Rentrop classification, and myocardial viability determined by cardiac MRI. By exploring this relationship, the study seeks to identify whether angiographic collaterals can serve as a reliable surrogate marker for viability in patients with CTO.

METHODOLOGY

This retrospective observational study was conducted at Peshawar Institute of Cardiology within a one year span from 01/03/2023 to 29/02/2024. The goal of the study was to assess the relationship between the development of coronary collateral circulation and myocardial viability among patients with chronic total occlusion (CTO) of major coronary arteries as evaluated through Cardiac Magnetic Resonance Imaging (CMR).
Patients who went through diagnostic coronary angiography and had a CTO of an LAD artery or a dominant RCA were reviewed. In the final analysis, 65 patients had CMR done for viability assessment within two weeks of their angiogram.

Inclusion Criteria

- Adult patients with CTO of the LAD or dominant RCA documented on angiography.
- CMR performed within two weeks of angiographic diagnosis.
- Patients with adequate image quality for viability assessment.

Exclusion Criteria

- History of prior coronary artery bypass graft (CABG) surgery.
- Patients with chronic kidney disease (CKD) contraindicating the use of gadolinium contrast.
- Patients unable to undergo or complete CMR due to clinical or technical limitations.

Coronary collaterals were assessed using the Rentrop classification based on angiographic images:

- Grade 0: Absence of distinct collateral vessels
- Grade 1: Infusion of the limb stems of the artery through collateral pathways without sight of the epicardial portion
- Grade 2: Incomplete infusion of the epicardial segment through collateral pathways
- Grade 3: Full infusion of the epicardial segment of the blocked artery through collaterals

For this study, well-developed collaterals were defined as Rentrop grade 2, and complete collaterals as grade 3.
CMR studies were performed using standard viability imaging sequences, including late gadolinium enhancement (LGE). The scans were reviewed independently by an experienced radiologist who was blinded to the angiographic findings and collateral grading to minimize bias.
Myocardial viability was assessed based on the extent and transmurality of late gadolinium enhancement:

- Segments with >50% viability (i.e., scar tissue ≤50% thickness) were considered viable.
- Segments with partial thickness scar (25–50% LGE) were labeled as partially viable, and those with >50% transmural LGE were considered non-viable.
- Segments with no enhancement were interpreted as fully viable.

Demographic and clinical variables were collected from hospital records, including age, gender, comorbidities, and indication for angiography and CMR. The extent of collateral circulation and MRI-determined viability were recorded and correlated.

Statistical analysis was performed using appropriate software. Categorical variables (Rentrop grade and presence of viability) were analyzed using chi-square or Fisher's exact test where applicable. A p-value < 0.05 was considered statistically significant.

RESULT

The study population consisted predominantly of middle-aged males, with a mean age of approximately 59 years. Nearly three-fourths of the patients were male, indicating a higher burden of CTO in men. Hypertension and diabetes mellitus were the most frequent comorbidities, found in over half and about 43% of the patients, respectively. One-third had a history of smoking, and around 38% were diagnosed with dyslipidemia. Regarding the distribution of occluded vessels, the majority had CTO involving the LAD artery, while the remaining cases involved a dominant RCA.

Table 1: Baseline Demographic and Clinical Characteristics (n = 65)

Variable	Frequency (n)	Percentage (%)
Mean Age (years)	59.4 ± 8.6	—
Gender (Male)	48	73.8%
Diabetes Mellitus	28	43.1%
Hypertension	36	55.4%
Dyslipidemia	25	38.5%
Smoking History	22	33.8%
CTO Location – LAD	39	60.0%
CTO Location – Dominant RCA	26	40.0%

Evaluation of coronary collaterals using the Rentrop classification revealed that most patients had developed some degree of collateral circulation. About one-third showed well-developed collaterals (Grade 2), and nearly 30% exhibited complete filling of the distal vessel through collateral channels (Grade 3). On the other hand, 37% of patients had either no visible collaterals or only minimal collateral supply. These findings suggest a significant variation in collateral development among patients with chronic occlusions.

Table 2: Collateral Circulation Grading (Rentrop Classification)

Rentrop Grade	Number of Patients (n)	Percentage (%)
Grade 0 (None)	11	16.9%
Grade 1 (Minimal)	13	20.0%
Grade 2 (Well-Developed)	22	33.8%
Grade 3 (Complete)	19	29.2%

The cardiac MRI results indicated that over half of the patients had viable myocardium in the affected territory, implying a potential benefit from revascularization. Approximately 28% had partial scarring, showing a mix of viable and non-viable tissue. Full-thickness scar, representing irreversible damage, was observed in about 17% of the cohort. This pattern underlines the heterogeneity in myocardial response to chronic ischemia and emphasizes the value of viability imaging in guiding management decisions.

Table 3: Myocardial Viability on Cardiac MRI

Viability Classification	Number of Patients (n)	Percentage (%)
Fully Viable (>50% viable)	36	55.4%
Partial Thickness Scar (25–50%)	18	27.7%
Full Thickness Scar (>50%)	11	16.9%

A strong relationship was noted between the degree of collateral circulation and myocardial viability. Among those with viable myocardium, the majority had Rentrop Grade 2 or 3 collaterals, suggesting that well-developed or complete collaterals contribute significantly to maintaining myocardial health in the setting of chronic occlusion. Conversely, non-viable myocardium was predominantly observed in patients with poor or absent collaterals. The association was statistically significant ($p = 0.003$), reinforcing the hypothesis that collateral development may serve as a surrogate marker for viability.

Table 4: Association between Collateral Grade and Myocardial Viability

Collateral Grade	Viable (n=36)	Non-Viable (n=29)	p-value
Grade 0	2	9	0.003
Grade 1	4	9	
Grade 2	16	6	
Grade 3	14	5	

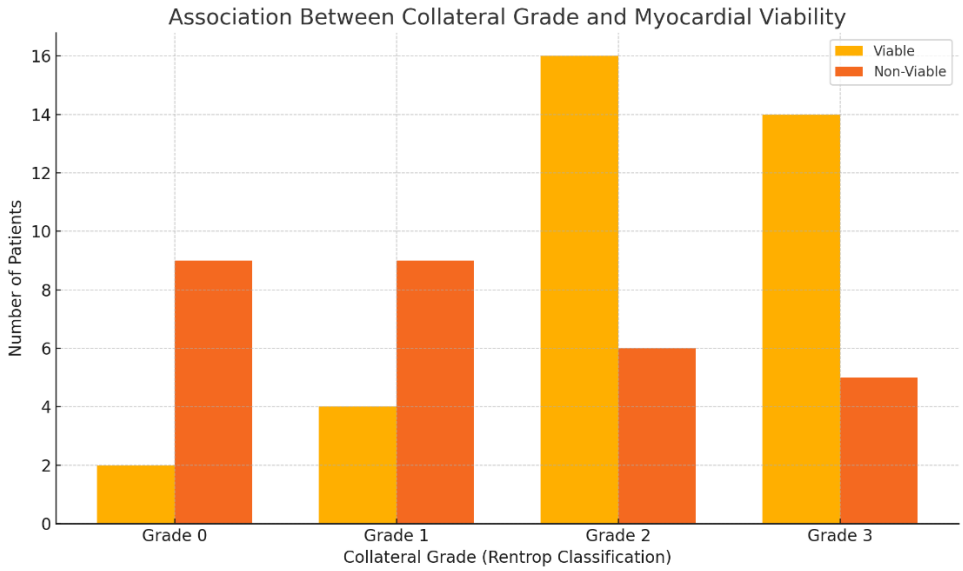

Figure 1: Graph showing the relationship between collateral grade and myocardial viability. It clearly demonstrates that higher Rentrop grades (Grade 2 and 3) are associated with a greater number of viable myocardial segments, supporting the clinical value of collateral assessment as a predictor of viability.

DISCUSSION

This study provides meaningful insight into the relationship between the degree of coronary collateral circulation and myocardial viability in patients with CTO. The data show a significant association, where patients with Rentrop grade 2 or 3 collaterals were substantially more likely to have preserved myocardial viability on cardiac MRI, compared to those with poor or absent collaterals. These findings highlight the functional role of well-developed collaterals in maintaining perfusion to ischemic myocardium [9, 10].

Previous literature supports the concept that collateral circulation plays a protective role against myocardial necrosis in the setting of occluded coronary arteries. Studies demonstrated that well-formed collaterals are associated with preserved left ventricular function, and that the presence of

such channels can mitigate the extent of infarction [11-13]. Similarly, studies emphasized the prognostic importance of collaterals in both acute and chronic coronary syndromes, with better outcomes seen in patients who had functional collaterals at the time of occlusion [14-16].

Our results were consistent with studies reported that cardiac MRI, particularly late gadolinium enhancement (LGE), provides highly accurate differentiation between viable and non-viable myocardium [17-19]. In their work, viability detected on CMR strongly correlated with recovery of function post-revascularization [20]. This further validates the use of CMR as a standard tool in viability assessment, especially in CTO patients where the decision to proceed with complex interventions depends heavily on myocardial viability.

Furthermore, the correlation between Rentrop grading and CMR viability seen in our data highlights the utility of angiographic collateral assessment as a predictive marker. Although not a substitute for direct tissue imaging, collateral grading provides an accessible and cost-effective means of risk stratification, especially in settings where advanced imaging like MRI is limited.

However, it is important to interpret Rentrop grading cautiously, as it is subject to interobserver variability and reflects anatomical flow rather than direct tissue perfusion. Despite this limitation, the concordance with MRI viability in our cohort strengthens the case for its clinical relevance.

CONCLUSION

In conclusion, this study reinforces the notion that well-developed coronary collateral circulation is a strong indicator of myocardial viability in patients with CTO. Cardiac MRI remains the gold standard for assessing viability, but the presence of Rentrop grade 2 or 3 collaterals on angiography can serve as a reliable surrogate marker when MRI is unavailable. These findings support incorporating collateral assessment into clinical decision-making, especially in evaluating the potential benefit of revascularization in CTO patients. Future studies should explore prospective validation and the impact of collateral-driven decisions on long-term outcomes.

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