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Brief report

AngioWave Artificial Intelligence-Assisted Analysis of Septal Collaterals for Retrograde Chronic Total Occlusion Percutaneous Coronary Intervention

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ABSTRACT

Artificial intelligence (AI) can augment coronary angiography images to enhance interpretation. We compared two blinded operators' interpretation of chronic total occlusion (CTO) angiograms obtained for retrograde percutaneous coronary intervention (PCI) standard vs. AI-enhanced (AngioWave, Concord, MA) images and assessed the association with septal collateral crossing success. We reviewed 50 retrograde CTO PCI angiograms. The most common (83.7%) target vessel was the right coronary artery and target CTOs had high complexity with high rates of proximal cap ambiguity (55.3%), blunt or no stump (79.2%), moderate or severe calcification (50.0%) and high J-CTO scores (2.96 ± 0.93). Retrograde was the first crossing strategy in 44.0% of lesions and was successful in 80%. Operators assigned lower frequency of corkscrew bends (10.2% vs 20.6%, p=0.035) and septal collateral tortuosity (31.7% vs 51.5%, p=0.004) and higher frequency of CC2 collateral size (6.5% vs 0.0%, p=0.007) to AI-enhanced compared with standard angiograms. The aggregate predicted likelihood of crossing (85% vs 70%, $p<0.001$, Wilcoxon test: $p<0.001$) and ease of interpretation (9.00 vs 7.00, $p<0.001$) were higher in the AI-enhanced angiograms. There was no difference in predictive performance for crossing success in the two groups (AUCAI-enhanced = 0.74 and AUCstandard = 0.73, De Long test: $p=0.856$). AI-enhanced angiograms were assigned a median 10.7% higher predicted likelihood of success. Compared with standard angiograms, AI-enhanced angiograms allow easier interpretation of angiograms and have similar predictive performance for collateral crossing despite showing lower collateral complexity.

The retrograde approach is an advanced chronic total occlusion (CTO) crossing technique used either upfront or after failure of antegrade crossing.[1] Septal collaterals are most commonly used for retrograde crossing due to high availability and lower risk of complications.[2] Septal collaterals may be small and hard to visualize with coronary angiography and even more so with coronary computed tomography angiography (CCTA).[3] AngioWave (AngioWave, Concord, MA) is an artificial intelligence (AI) -guided software designed to enhance coronary angiography images and augment vessel delineation. We examined AngioWave for predicting septal collateral crossing success during retrograde CTO percutaneous coronary intervention (PCI).

We retrospectively identified 50 patients who underwent CTO PCI with at least 1 retrograde wiring attempt through a septal collateral at our institution. Deidentified angiograms of these patients were enhanced using the AngioWave software. Two independent, blinded operators analyzed the angiography images of patients without AngioWave enhancement. After 30 days, operators reviewed the same angiograms with AngioWave enhancement. The reason for doing the review on a different day was to eliminate potential bias from recalling previous answers. Operators were asked to assess septal collateral morphology, likelihood of crossing for each appropriate septal collateral and a total ease of interpretation of the angiograms. Ease of interpretation was measured using a scale from 1 to 10 (1 = hardest to interpret, 10 = easiest to interpret).

Categorical variables were expressed as percentages and compared using the Pearson's chi-square test. Continuous variables are presented as mean ± standard deviation or median (interquartile range) and were compared using the independent-samples t-test

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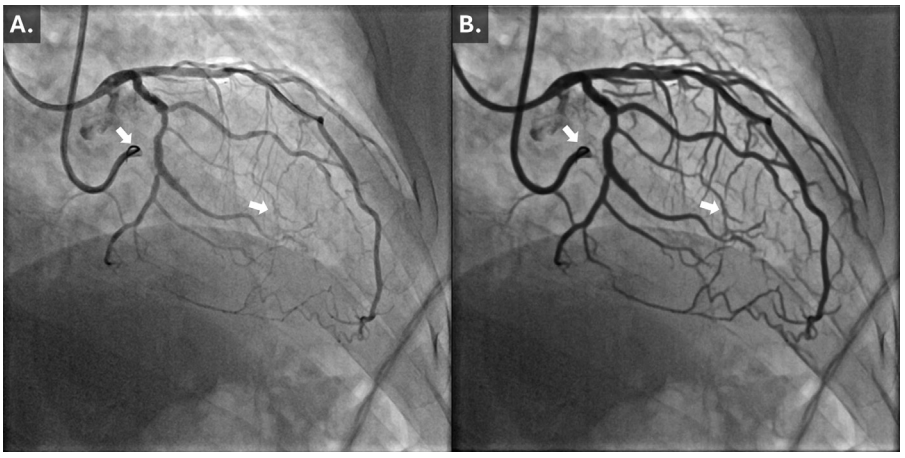

Figure 1. Nonenhanced (*A*) and AI-enhanced (*B*) angiograms (arrows point in descending order: RCA CTO, target collateral).

and the Mann-Whitney U test as appropriate. The study was approved by the institutional review board.

The right coronary artery (RCA) was the most common CTO target vessel (83.7%) and lesions were complex with high lesion length (35 ± 22 mm), proximal cap ambiguity (55%), side branch at the proximal cap (77%), blunt or no stump (79%), moderate or severe calcification (50%) and J-CTO scores (2.96 ± 0.93). Of the 50 patients in our cohort, 2 suffered a MACE (1 death and 1 myocardial infarction) and 6 had angiographic evidence of perforation.

Compared with nonenhanced angiograms, enhanced angiograms had lower J-channel scores (77.8% vs 58.5% were J-channel 1; 19.4% vs 37.7% were J-channel 2, p = 0.007), lower corkscrew bends (10% vs 21%, p = 0.035) and septal collateral tortuosity (32% vs 52%, p = 0.004) but higher Werner scores (6.5% vs 0.0%, p = 0.004 for CC2), higher predicted likelihood of crossing (85% vs 70%, p <0.001) and ease of interpretation (9 vs 7, p <0.001). The median difference in ease of interpretation was 2. The predictive performance for septal collateral crossing was similar ($AUC_{AI\text{-}enhanced}$ = 0.74 and $AUC_{standard}$ = 0.73, De Long test: p = 0.856). Operators tended to assign higher predicted likelihood of success to enhanced angiograms (Wilcoxon signed-rank test p <0.001) with a median difference of 10.7%.

Due to the technical difficulty of retrograde CTO PCI, septal collateral morphology is crucial. In our study, the operators found septal collaterals in enhanced angiograms to be bigger and less complex and assigned higher Werner scores and lower J-Channel scores compared with nonenhanced angiograms. Corkscrew bends and tortuosity were also less frequently seen in the enhanced angiograms, suggesting lower overall septal collateral complexity. This likely led operators to assign higher likelihood of septal collateral crossing success, however, this did not impact the predictive value of AI-enhanced angiograms and their performance was similar to review of standard angiograms. Operators reported higher ease of interpretation with AI-enhanced angiograms. However, AI-enhancement decreases the perceived complexity of the septal collaterals and can bias the assessment of collaterals towards lower complexity when used with scoring systems developed on unenhanced angiograms. A new iteration of the AngioWave software being developed offers greater sensitivity and specificity for vessel pixels, selective enhancement of additional angiographic features, dynamic control of AI-enhancement using a slider, and assistive retrograde route selection.

Our study has limitations. The sample size was relatively small. The angiographic images were not adjudicated by a core laboratory and there was no event adjudication by an independent committee. Our center has expertise in CTO PCI which may limit the generalizability of our results.

AI-enhanced angiograms improve ease of interpretation and have similar predictive value for collateral crossing success but underestimate collateral complexity compared with standard angiograms (Figure 1).

Declaration of competing interest

Dr. Sandoval: Abbott (consultant, advisory board), Roche Diagnostics (consultant, advisory board, speaker), Philips (consultant, advisory board, speaker), Zoll (advisory board), GE Healthcare (consultant, advisory board), CathWorks (consultant), HeartFlow (speaker), Cleerly (speaker, research grant). He is an Associate Editor for JACC Advances. He and others hold patent 20210401347.

Dr. Brilakis: consulting/speaker honoraria from Abbott Vascular, American Heart Association (associate editor Circulation), Boston Scientific, Cardiovascular Innovations Foundation (Board of Directors), Cordis, Elsevier, GE Healthcare, IMDS, Medtronic, SIS Medical, Teleflex, and Terumo; research support: Boston Scientific, GE Healthcare; owner, Hippocrates LLC; shareholder: Cleerly Health, LifeLens Technologies, Inc, MHI Ventures, Stallion Medical, TrueVue Inc.

CRediT authorship contribution statement

Dimitrios Strepkos: Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sandeep Jalli:** Writing – review & editing, Resources, Project administration, Methodology, Investigation, Conceptualization. **Michaella Alexandrou:** Writing – review & editing, Resources, Project administration, Methodology, Investigation, Conceptualization. **Pedro E.P. Carvalho:** Writing – review & editing, Resources, Project administration, Methodology, Investigation, Conceptualization. **Eleni Kladou:** Writing – review & editing, Resources, Project administration, Methodology, Investigation, Conceptualization. **Nick Williford:** Writing – review & editing, Resources, Project administration, Methodology, Investigation, Conceptualization. **Bavana V. Rangan:** Writing – review & editing, Resources, Project administration, Methodology, Investigation, Conceptualization. **Konstantinos Voudris:** Writing – review & editing, Resources, Project administration, Methodology, Investigation, Conceptualization. **Yader Sandoval:** Writing – review & editing, Resources, Project administration, Methodology, Investigation, Conceptualization.

Emmanouil S. Brilakis: Writing – review & editing, Resources, Project administration, Methodology, Investigation, Conceptualization.

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