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## Role of FFR-CT for the Evaluation of Patients With Anomalous Aortic Origin of Coronary Artery

Interarterial course of anomalous aortic origin of coronary artery (AAOCA) is the most frequent form found on autopsy of young patients who experienced sudden cardiac death. Patients dying of AAOCA often have an intramural coronary segment crossing the aortic wall with elliptic luminal narrowing (1). Fractional flow reserve-computed tomography (FFR-CT) imaging offers evaluation of the hemodynamic impact of coronary stenosis by modeling stress blood flow (2) and might represent an interesting imaging approach in AAOCA.

Among 496 patients included in the observational multicentric Anomalous Connections of the Coronary Arteries (ANOCOR) registry (3), a total of 107 patients were imaged with a dedicated coronary CT angiography (CTA) protocol, but only 62 scans were deemed of sufficient image quality for FFR-CT analysis (severe motion artifacts in 14, image quality not sufficient in 29, and former coronary revascularization in 2). The ANOCOR registry has been approved by the Institutional Review Board of Bichat University Hospital (IRB00006477), and all patients have signed a consent form for the use of their clinical and imaging data for research purposes.

Morphological analysis of coronary CTA scans included: 1) luminal surface narrowing; 2) luminal eccentricity; and 3) takeoff angle. Intramural path was defined by the presence of 3 morphological criteria: takeoff angle $<30^{\circ}$, luminal surface narrowing >50%, and eccentricity degree >1.5. For FFR-CT measurements, coronary CTA data were transmitted to a central core laboratory (HeartFlow Inc., Redwood City, California). FFR-CT values were computed by selecting regions of interest proximally immediately at the end of the ectopic segment, defined as the point where AAOCA reaches its usual path and 3 cm after the ostium of non-AAOCA arteries, and in most distal segments of coronary arteries. To test the interobserver reproducibility, coronary CTA and FFR-CT analyses were performed by operators with long and only limited experience in AAOCA evaluation.

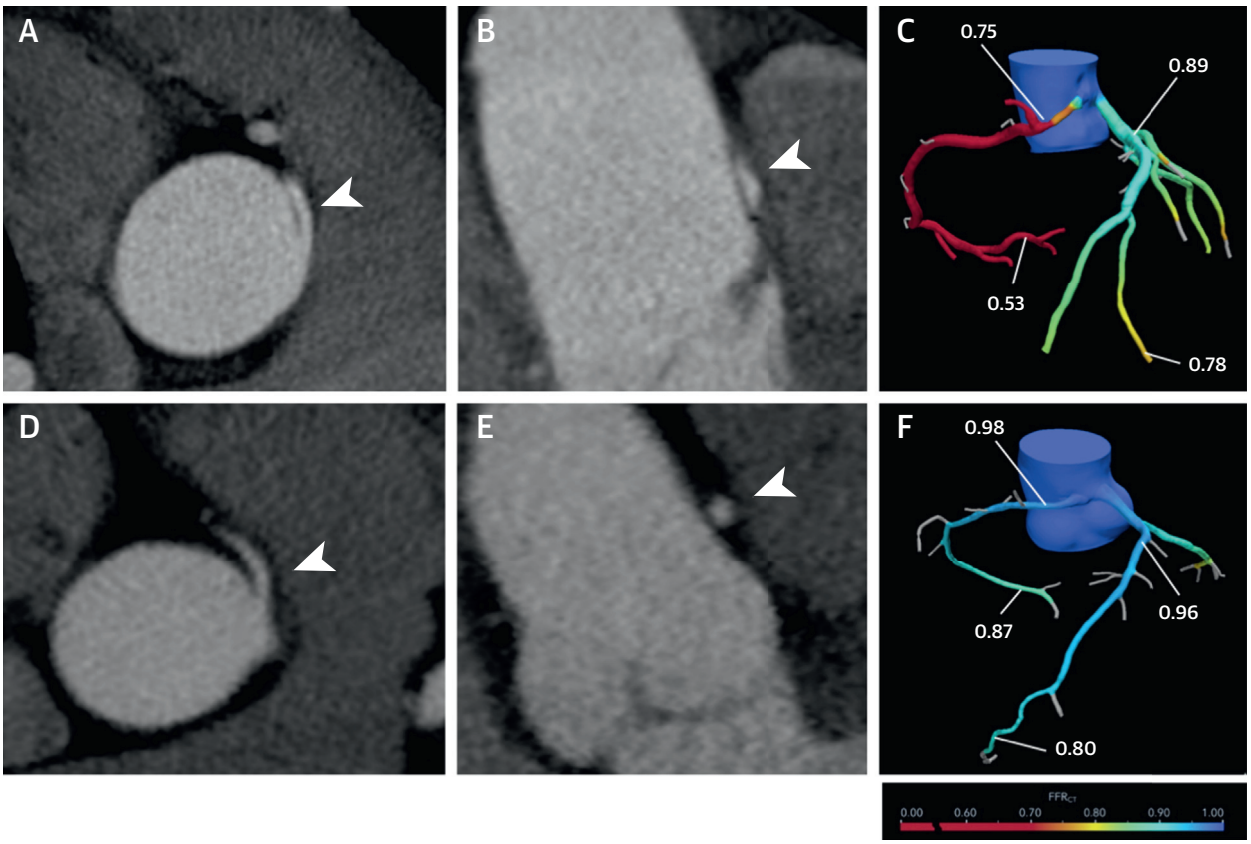
Sixty-two patients (mean age 59.5 ± 12.8 years; 79% male) were included, with 63 AAOCA involving left main (n =10), right coronary (n = 37), left anterior descending a (n = 2), and left circumflex (n = 14) arteries. AAOCA course was interarterial (n = 37, including 9 with intramural path), retroaortic (n = 17), retropulmonic (n = 6), and pre-pulmonic (n = 3). Distal FFR-CT values <0.80 were more prevalent in AAOCA with surface narrowing >50% (odds ratio [OR]: 4.2; 95% confidence interval [CI]: 1.3 to 13.7; p = 0.01), eccentricity degree >1.5 (OR: 2.6; 95% CI: 0.8 to 8.4; p = 0.11), angle $<30^{\circ}$ (OR: 3.5; 95% CI: 1.1 to 11.9; p = 0.05), and with all 3 criteria of intramural path on coronary CTA (OR: 9.2; 95% CI: 1.7 to 49.9; p = 0.01) but not specifically in AAOCA with interarterial course (OR: 1.2; 95% CI: 0.4 to 3.7; p = 0.74). FFR-CT values calculated proximally and distally to the ectopic segment were significantly lower in interarterial AAOCA with all 3 versus fewer than the 3 morphological criteria of intramural path on coronary CTA (proximal FFR-CT values: 0.80 [0.74 to 0.88] vs. 0.96 [0.93 to 0.98]; distal FFR-CT values: 0.77 [0.54 to 0.80] vs. 0.86 [0.80 to 0.90], respectively [median and interquartile Q1 to Q3 range]; p < 0.05 with Wilcoxon tests) (**Figure 1**). A cutoff value of proximal FFR-CT ≤0.83 provided sensitivity of 96% and specificity of 100% for identification of ANOCOR with intramural path on coronary CTA (area under the curve: 0.89).

Interobserver agreement for defining acute takeoff angle, luminal narrowing >50%, or eccentricity degree >1.5 on coronary CTA were measured at 75% (K = 0.40), 75% (K = 0.45), and 84% (K = 0.68), respectively. Agreement between expert and non-expert readers was 86% (K = 0.45) for the identification of AAOCA with all 3 morphological criteria of intramural path, and at 98% (K = 0.90) and 94% (K = 0.84) for proximal and distal FFR-CT.

The presence of intramural path of AAOCA can be observed during cardiac surgery but is difficult to identify with invasive or noninvasive imaging techniques. Morphological CT imaging criteria have been proposed empirically based on per-operative and forensic observations. An important limitation of these criteria is that they are based on cutoff values, which exhibit significant interobserver variability as shown by weak concordance rates observed between expert and non-expert observers. In contrast, FFR-CT offers a high agreement rate between expert and non-expert readers as a result of automated detection and analysis of coronary arteries.

The threshold identified for AAOCA (FFR-CT ≤0.83) is higher than the usual 0.75 to 0.80 value

**FIGURE 1** **Coronary CTA and FFR-CT Images of Right Coronary Arteries With Anomalous Aortic Origin in Presence and Absence of Intramural Path**




Right coronary arteries with interarterial course and presence **(A to C)** or absence **(D to F)** of intramural path on coronary computed tomography angiography (CTA). Note typical aspects of intramural path on coronary CTA with a takeoff angle <30° **(A, white arrowhead)** and elliptic coronary luminal narrowing >50% **(B, white arrowhead)** of anomalous aortic origin of coronary artery with fractional flow reserve–computed tomography values measured at 0.75 proximally and 0.53 **(C)**. In the absence of an intramural path, the takeoff angle was >30° **(D, white arrowhead)** and luminal narrowing <50% **(E, white arrowhead)** on coronary CTA, and fractional flow reserve–computed tomography values were measured at 0.98 proximally and at 0.87 distally **(F)**.

validated for atherosclerotic coronary stenosis. FFR-CT can only help to quantify the severity of the "fixed" obstacle in AAOCA at rest. This information might, however, prove relevant for the evaluation of the risk to develop ischemic events when dynamic changes are added to this obstacle during intense exercise.

This study has a few limitations. First, FFR-CT analyses were not validated against invasive FFR. Second, the morphological criteria used to define the presence of intramural path on coronary CTA have not been validated against per-operative analysis.

In conclusion, FFR-CT provides good diagnostic performance for the identification of AAOCA with intramural path and appears as more reproducible than morphological criteria extracted from coronary CTA, in particular for imagers with limited expertise in AAOCA evaluation.

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The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the *JACC: Cardiovascular Imaging* author instructions page.

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