A Novel Dual-Axis Rotational Coronary Angiography Evaluation of Coronary Artery Disease — Case Presentation and Review

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Introduction

Abstract and key words on FTP. Despite tremendous advances in the invasive and noninvasive evaluation of coronary artery disease (CAD), standard coronary angiography (SA) remains the gold standard diagnostic modality to assess the severity of coronary stenoses. There are significant limitations inherent to fixed-view angiography related to its 2-dimensional (2D) nature and limited number of standard projections acquired. Intravascular ultrasound studies have verified the limited diagnostic accuracy of SA, especially in the setting of complex or eccentric atherosclerotic lesions.[1] Furthermore, 3-dimensional (3D) coronary reconstructions have demonstrated the negative impact of vessel overlap and foreshortening on diagnostic accuracy and therapeutic efficiency in screening angiograms and subsequent interventions.[2,3]

The technique of rotational angiography (RA) was developed to enhance the number of images available to more fully assess the complex coronary vasculature from numerous projections and has been found to be clinically useful in decreasing contrast dose, radiation exposure, and overall procedure time with an adequate safety profile and comparable image content to SA.[4–6] Dual-axis rotational coronary angiography (DARCA) was developed as an innovative adaptation of RA in which rotation occurs in the left anterior oblique (LAO)/right anterior oblique (RAO) and cranial/caudal orientations during 1 cine acquisition to obtain images in a trajectory specifically designed to reduce vessel foreshortening. We present 2 cases demonstrating the novel application of DARCA in optimally defining the significance of specific coronary artery lesions while reducing contrast, radiation exposure, and providing superior lesion imaging.

Case Presentations

Case 1

A 68-year-old male with history of CAD, hypertension, and hyperlipidemia was referred for coronary angiography due to exertional angina and a positive functional study. Standard angiography was first performed using a single-plane digital angiographic system (Allura Xper FD20, Philips Healthcare, Best, Netherlands) and revealed a critical 90% mid-left anterior descending (LAD) stenosis distal to the moderate-sized first diagonal artery. As part of a research protocol, the patient then underwent DARCA of the left and right coronary systems at 30 frames per second. Due to the need to maintain vessel opacification over the approximately 7 second DARCA acquisition during left coronary angiography, contrast injection was performed using an ACIST power injection system (ACIST Medical Systems Inc., Eden Prairie, MN) at a flow rate of 3 mL per second for a total contrast injection of 18 mL using a low-osmolar contrast agent. Right coronary angiography using DARCA involves a 3.5 second acquisition and thus typically requires a setting of 1.5 to 2.5 mL/sec for a total of 10 mL depending on the individual vessel size. Isosmolar or low-osmolar contrast agents were selected for these cases based on the increased risk of nausea, hypotension, and arrhythmias during prolonged injections using hyperosmolar contrast agents. The safety of the prolonged coronary injections has previously been evaluated.[5] In addition, radiation dose was measured by the x-ray system as dose area product (DAP; Gy/cm^2) for both SA and DARCA. Dosimetry was not performed as part of this protocol.

In this case, DARCA clearly highlighted the severity of the mid-LAD subtotal stenosis (Figure 1A; white arrows) in multiple projections from LAO to RAO and caudal to cranial with a single injection. DARCA evaluation of the right coronary artery (RCA) revealed non-obstructive CAD during 1 injection (Figure 1B). Thus, the application of DARCA produced a complete evaluation of the entire coronary vasculature in 2 injections resulting in a decrease in both contrast use (26.9 mL vs 43.9 mL) and radiation exposure (30.2 Gy/cm^2 vs 44.7 Gy/cm^2) as compared to SA. Despite the prolonged coronary injections, there were no significant hemodynamic perturbations. The mid-LAD lesion was subsequently treated with a 3.0 mm × 20 mm bare-metal stent (Boston Scientific Corp., Natick, MA) without complication.

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Figure 1. Dual-axis rotational coronary angiography of the left coronary system: (A) Multiple sequential (LAO to RAO and caudal to cranial) representative frames of the DARCA acquisition are displayed. (The total number of frames for a DARCA left coronary injection is approximately 180.) Clearly evident in multiple views is a critical mid-LAD lesion (white arrows). (B) Multiple representative sequential frames from a DARCA right coronary artery injection during 1 cine injection from RAO to LAO and cranial to caudal projections revealing non-obstructive coronary artery disease. (The total number of frames for a DARCA right coronary injection is approximately 90.)
Abbreviations: LAD, left anterior descending; LAO, left anterior oblique; RAO, right anterior oblique.

Case 2

A 61-year-old male with history of non-obstructive CAD was referred for coronary angiography due to atypical chest pain and a positive exercise treadmill test. Standard coronary angiography revealed severe 3-vessel disease with a 70% proximal LAD stenosis, a 90% mid-circumflex stenosis, and a 100% proximal RCA obstruction with left-to-right collaterals filling the posterior descending artery and posterolateral vessels. As part of a research study, the patient underwent DARCA which illustrated the severe 3-vessel disease from numerous projections, including the bridging left-to-right collaterals, during just 1 injection (Figure 2). At the discretion of the operator, the RCA did not undergo DARCA acquisition due to a proximal chronic total occlusion. Use of DARCA supplied a complete evaluation of the left coronary vasculature and bridging collaterals during 1 cine acquisition with a favorable safety profile as evidenced by a decline in low-osmolar contrast use (15 mL vs 39 mL) and radiation exposure (8.1 Gy/cm^2 vs 19.1 Gy/cm^2) as compared to SA. Again, there were no hemodynamic changes during the prolonged DARCA acquisition. Based on the comprehensive coronary evaluation, this patient was subsequently referred for coronary artery bypass graft surgery. Most importantly, the images derived using DARCA were judged by experienced invasive/interventional cardiologists as part of a research study to provide the necessary screening adequacy and lesion assessment required for clinical decision making in both cases.

Discussion

Since the initial fortuitous evaluation of epicardial vessels by Dr Mason Sones in 1958, standard coronary angiography has evolved as the gold standard in the diagnosis of CAD. Despite significant technological progress, limitations engendered by silhouette imaging of the coronary vasculature persist. Thus, SA can result in an inadequate assessment of the coronary lumen, especially in the setting of complex disease,[1] and may lead to insufficient data required for the accurate diagnosis of CAD.

Rotational angiography demonstrates comparable coronary lesion assessment and screening adequacy to SA while reducing contrast volume, radiation exposure, and in some studies, overall diagnostic procedure time as compared to SA.[4–6] By providing potentially 360 acquisition frames, RA may lead to a more comprehensive evaluation of the coronary tree.[2] Overall, RA demonstrates several advantages in comparison to SA by providing a mental 3D impression of the

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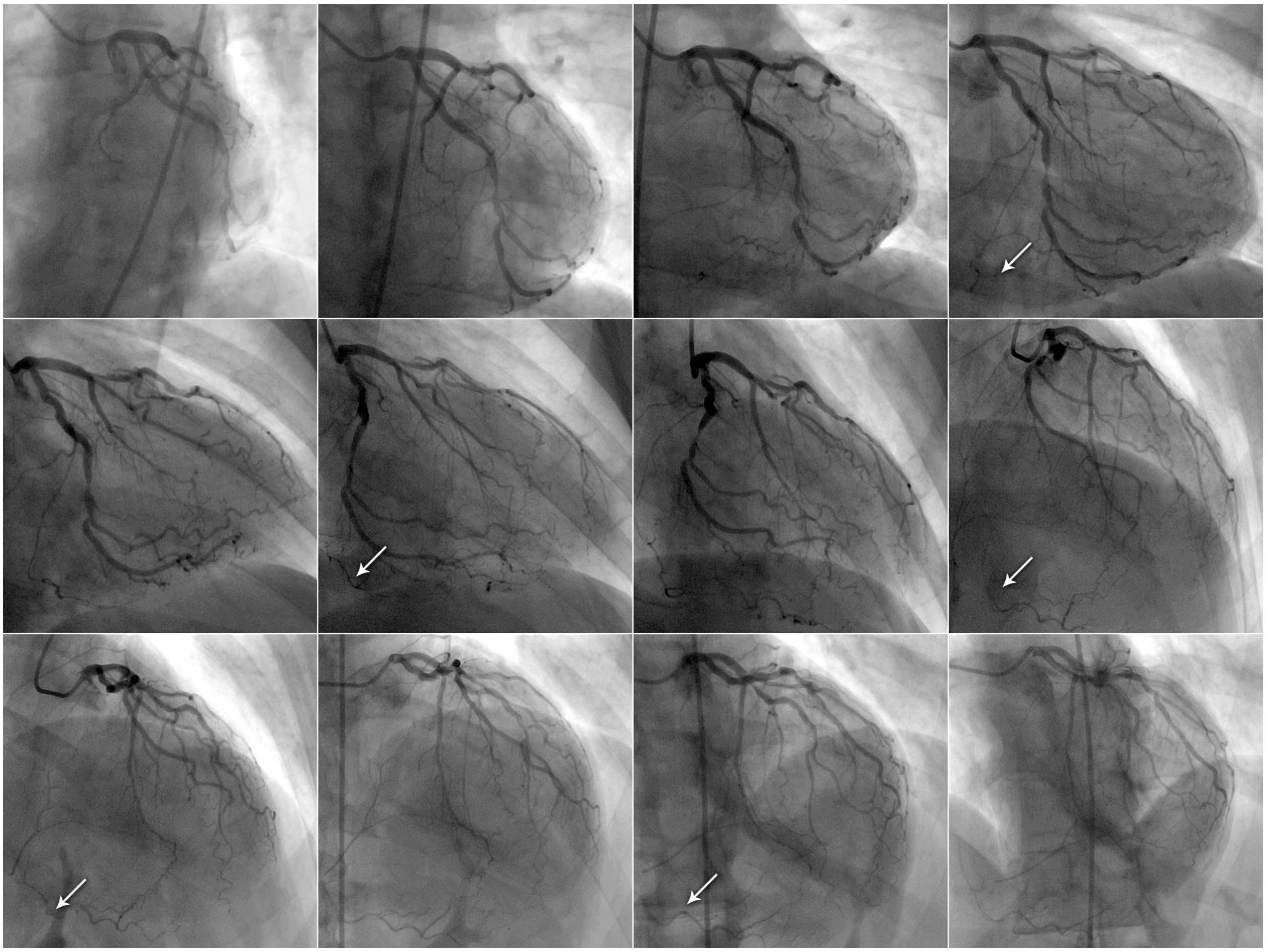

Figure 2. Dual-axis rotational coronary angiography of the left coronary system demonstrated severe 3-vessel coronary artery disease. Left coronary artery injection during 1 cine injection from LAO to RAO and caudal to cranial projections revealing severe 3-vessel disease, including a chronic total occlusion of the right coronary artery evidenced by the significant bridging left-to-right collaterals (white arrows) supplying the PDA and posterolateral vessels. Abbreviations: LAO, left anterior oblique; PDA, posterior descending artery; RAO, right anterior oblique.

coronary tree with an adequate safety profile, although the trajectory of standard RA engenders a significant amount of vessel foreshortening based on 3D coronary reconstruction analysis.[3]

The concept of dual-axis rotational coronary angiography is a natural extension of RA with the addition of a cranial/caudal acquisition to the already present LAO/RAO acquisition in a trajectory designed to decrease foreshortening. DARCA has evolved from the generation of optimal view maps (OVMs) that demonstrate the angiographic projections in which various coronary segments are optimally visualized.[2] More specifically, these OVMs per vessel segment were generated from 3D coronary reconstruction analysis of the angiographic images in an effort to delineate gantry positions that exhibit the greatest to the least amount of vessel foreshortening and overlap (Figure 3). Using these OVMs, computer-generated or facilitated views of coronary vessels have been found to be superior to operator-derived images further highlighting the limitations of SA.[7] Thus, DARCA supplies a variety of angiographic images following a specific trajectory designed to reduce foreshortening during 1 cine acquisition using a limited amount of contrast and radiation in comparison to SA.

There are, however, several limitations of this innovative angiographic technique. First, is the learning curve associated with acquisition technique, as well as a requirement for a prolonged coronary injection, the safety of which has been previously demonstrated.[5] Second, long coronary injections could potentially be deleterious in the setting of pressure waveform dampening due to ostial lesions or in acute coronary syndromes. Third, there

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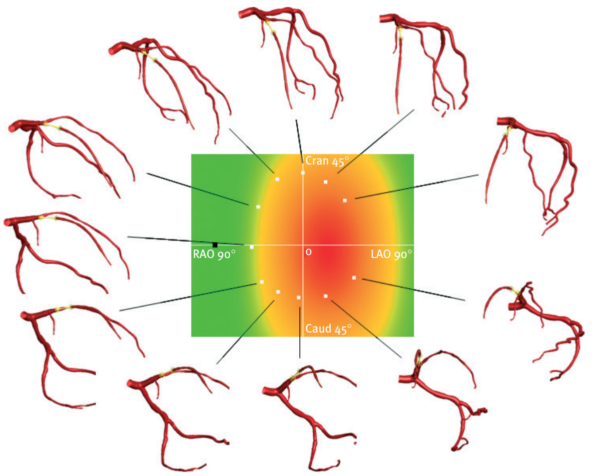

Figure 3. Optimal view map of the mid LAD with multiple 3D projections obtained during 1 acquisition of the left coronary system. Shown are the 3D model reconstructions of the left coronary system during a dual-axis rotational coronary angiographic acquisition revealing the 90% mid-LAD stenosis (yellow segment). The 3D models led to the development of a patient-specific optimal view map (middle box) allowing for the quantitative assessment of the degree of vessel foreshortening (most foreshortened: red; least foreshortened: green).
Abbreviations: LAD, left anterior descending.

Table 1. Comparative Analysis of Several Angiographic Techniques

	SA	RA	DARCA
Contrast volume	+	+++	+++
Radiation exposure	+	+++	+++
Procedural time	++	++	+
Image content	+	++	+++
Ease of use	+++	++	++

Abbreviations: DARCA, dual-axis rotational coronary angiography; RA, rotational angiography; SA, standard angiography.
+ Least favorable. ++ Similar. +++ Most favorable.

is additional software required for acquiring images and to date only 1 vendor will be offering this technology. Despite these potential limitations, our cases demonstrate the novel application of DARCA in the evaluation of CAD without untoward hemodynamic effects. In addition, lesion assessment was optimized in multiple images which could potentially improve clinical decision making. Currently, we are comparing the safety and image content profile of DARCA vs SA (see Table).[8] Overall, this innovative technology demonstrates significant potential in enhancing the number of angiographic projections obtainable with superior imaging results while reducing safety concerns related to contrast volume and radiation exposure.

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