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EDITORIAL COMMENT

The Use of CTCA for Planning PCI

Using the 3D Coronary Tree Information*

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The expanding utility of computed tomography (CT) coronary angiography (CTCA) in the assessment of coronary artery disease (CAD) has achieved major transitions in the last decade. Detection and quantification of calcification made early CT technology a screening modality for CAD. Subsequent improvement in CT began its use for assessment of lumen size and its reduction from atherosclerosis. More recently the physiological importance of a coronary lesion has followed catheter-based methods of assessing flow restrictions such as fractional flow reserve and instantaneous wave-free ratio. Thus, CTCA technology and evidence development have challenged the dominance of invasive coronary angiography. This is not to minimize invasive x-ray technology improvements yielding higher resolution images using a lower radiation dose and radial artery access, increasing safety, and reducing the burden on the patient.

CTCA-based coronary imaging can now be used to comprehensively plan percutaneous coronary interventions (PCI). Procedure time, contrast volume, and radiation dose for the PCI could potentially be reduced using the pre-PCI CTCA.

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In this issue of *JACC: Cardiovascular Interventions,* Kočka et al. (1), from 6 different countries, describe a CTCA-based method to define C-arm or gantry-based optimal viewing angles of both coronary ostia and coronary bifurcations. Several of the senior authors from Canada have been at the forefront of using CTCA to plan structural heart disease interventions including the prediction of optimal gantry positions for adequate coplanar views of aortic root to deploy transcatheter heart valves. It is exciting to see them apply their experience and efforts to planning PCI using CTCA.

In this study, the investigators retrospectively analyzed 100 CTCA scans of consecutive patients referred for suspected CAD at the University Hospital Královské Vinohrady in Prague. An optimal view was defined as a gantry position to acquire a projection image that would have no foreshortening and overlap of structures for a specific anatomic location in the coronary artery tree. From 100 patients, they derived the mean fluoroscopic projections for all evaluated coronary structures with 95% confidence intervals. They focused their assessment on the ostia, proximal right and left coronary arteries, and common bifurcations.

They summarize the major findings of this study with 3 points: 1) Methodology feasibility: optimal fluoroscopic viewing angles for these anatomic locations can be derived from multiplanar CTCA reconstructions to predict x-ray-based optimal fluoroscopic views; 2) Gantry constraints: not all CTCA-defined fluoroscopic viewing angles are practical or achievable with existing C-arm equipment; and 3) Patient variability: optimal views are highly variable from patient to patient.

With these encouraging results, the next logical step would be to validate that predicted optimal views match those when the patient has PCI. The methodology used to demonstrate congruence needs to be defined because it will not be possible to verify that the catheter-based coronary image has no

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foreshortening of the anatomic location due to a different table-bed location and the orientation of the patient's body. Visual inspection may be sufficient to say there is no overlap. The second challenging step is to prove the clinical value the investigators describe as to "help operators better plan PCI procedures" and "the clinical impact of this approach (e.g., contrast volume, radiation exposure, procedural duration, cardiovascular event rates)."

This important publication can best be appreciated by discussing the current use of catheter-based coronary angiography to plan PCI with a focus on optimizing angiographic views of the target lesion.

The angiographic images from catheter-based coronary angiography are generally acquired by moving the C-arm or gantry of the x-ray imaging system to different locations to visualize the "flat" or 2-dimensional (2D) projections of the corresponding 3-dimensional (3D) vessel lumen. As a result, overlapped vessels and foreshortened vessel segments occur on the 2D images due to the nature of perspective projection technology as used in the x-ray imaging system. Although additional groundwork may be needed to use the results as summarized in this study, there are several considerations needed to be incorporated to practically guide PCI.

The movement of the C-arm in the 3D space is characterized by 2 degrees of freedom as left anterior oblique (LAO)-right anterior oblique (RAO) and cranial (CRAN)-caudal (CAUD) angles, which is like latitude and longitude used in geography. On the basis of the unique combination of longitude and latitude, any unique location on earth can be accurately and uniquely defined. However, the anatomy of coronary arterial tree varies in individuals, and a stenotic lesion needs to be angiographically visualized with no overlap from any other vessels and minimal length foreshortening such that the subsequent quantitative analyses (e.g., lesion length, vessel size) can be performed accurately. Although spatial geometry of coronary arteries is different from person to person, the 3D orientations of main arteries share similar spatial patterns. For example, a "spider view" or LAO-CAUD view is a favorite to examine the stenosis of proximal left anterior descending or left circumflex coronary arteries, and RAO-CAUD views are preferred to inspect the mid and distal segments of left circumflex coronary or obtuse marginal arteries.

Multiple gantry positions are used to provide a complete set of projection images for diagnostic purposes to optimize the visualization of the target lesion. Minimizing overlap with surrounding structures is a straightforward visual task but minimizing vessel segment foreshortening is not. If the lesion is seen in different projections, then a view with less foreshortening of the lesion is when the lesion appears the longest. Often the initial set of cineangiographic images are inadequate to find an optimal view for PCI, and additional acquisitions are needed. Although experience helps to efficiently find an optimal view, this is a trial-and-error approach with increased radiation dose and contrast volume.

The concept of optimal view does have other aspects and some practical constraints. First, an optimal view that minimizes foreshortening of a bifurcation has a unique gantry position rather than the optimal view(s) for a single coronary segment, which has a family of optimal views, typically in a trajectory with a pathway circling around the single segment through the RAO-LAO and CRAN-CAUD coordinate system. Second, an optimal views defined as a view with no overlap from other coronary artery segments has a unique family of views composed of a variety of gantry position scattered in the coordinate space. Third, an optimal view incorporating both parameters of no foreshortening and no overlap may or may not be achieved for a bifurcation lesion, and a compromise on the unique view minimizing foreshortening may be needed. Four, there are physical constraints of gantry position beyond 40° in CRAN-CAUD and 60° in LAO-RAO. Fifth, more angulated views result in penetration of the x-ray beams thru more tissue with potential decrements of image quality and higher radiation dose. Thus, the concept of an optimal view needs to include these technical, image quality, and safety issues in additional to solving the issues associated with foreshortening and overlap.

In the past, other advances in coronary angiography for finding the optimal view have taken different approaches (2). One approach is to acquire catheter-based coronary angiography, not in a series of fixed locations of the gantry, but by performing rotational angiography with resultant panoramic views of the coronary tree from which to choose a potential optimal view (3,4). A second approach has been to use catheter-based coronary angiographic views to perform modelling or reconstruction to produce a 3D coronary tree that then can be used for optimal view determination (5-8). Optimal view calculations and recommendations can be made for all segments of each of the coronary arteries as well as bypass grafts (9). These efforts were successful in showing feasibility, accuracy, and achievement of surrogate clinical endpoints of reduced contrast volume and radiation dose. But they were not successful in changing the practice of how catheter-based coronary angiography was being performed and did not cause a conversion of a larger number of catheterization labs to the required workstation-based software.

With the growth and expansion of CTCA, the investigators approach has the potential for widespread success of impacting clinical care, especially if further validation studies are successful and demonstrate reductions in radiation and contrast volume during PCI.

AUTHOR RELATIONSHIP WITH INDUSTRY

The authors have U.S. patents related to coronary angiography and optimal view determination that are assigned to the University of Colorado.

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