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EDITORIAL COMMENT

How Accurate Is Optical Coherence Tomography?*

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The paper by Lutter et al. (1), in this issue of *JACC: Cardiovascular Interventions*, which compares histological cross sections and optical coherence tomography (OCT) images for anatomic accuracy and tissue characterization, is an important study for several reasons. It is noteworthy for the meticulous care in design and amount of labor that was required to perform such an exhaustive study. Part of this research group is well-known for other insights obtained by comparing histological arterial anatomy with clinical events to help us understand the pathophysiology of disease as well as the mechanism of action of coronary artery stenting. The current study focuses on OCT imaging in patients from the CVPath stent registry who died from variable causes sometime after receiving a coronary artery stent. The observations from this study also provide a lesson in the process of scientific discovery and how we have the potential to mislead ourselves into making assumptions not supported by rigorously vetted data. That is the more profound message of this paper and goes beyond the specifics of the accuracy of OCT imaging.

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For the past 10 years, there has been controversy over the benefits and differential capabilities of OCT versus intravascular ultrasound (IVUS) imaging. The resolution of OCT, defined as the ability to distinguish 2 points, is 10 microns, which is superior to IVUS imaging at 100 microns. The OCT images in the near field can resolve stent struts, tissue protrusion, or tears, and can distinguish thrombus formation more easily than can be seen or interpreted with IVUS. Although these OCT pictures are impressive, there is no evidence that any of the finer anatomic observations makes any difference to clinical outcomes. The few outcome studies that have been done demonstrate that the greater resolving power of OCT for structural details does not portend adverse clinical events; therefore, the recommendation has been not to intervene by treating them with more stents (2).

One of the major limitations of OCT is the lack of power for tissue penetration. Because OCT uses an optical wavelength of light, the power of the infrared light is unable to penetrate and reflect enough information about plaque in the far field, defined as >2 mm from the probe source. This is evident when measuring plaque area in cardiac transplant studies (3). The OCT images have significant dropout of information in the far field so that the external elastic membrane cannot be distinguished if the plaque is >2 mm thick. This means that OCT cannot measure plaque size or plaque burden accurately.

It is also controversial as to whether OCT has the ability to correctly identify tissue characteristics within the plaque. When IVUS devices were developed initially, there were extensive comparison studies performed with histological cross sections of human atherosclerotic arteries so that the grayscale images of IVUS could be interpreted against high quality histology. Although it was not fully validated, frequency backscatter images were compared with OCT in identifying intravascular pathology (4). Beginning in 2002, ex vivo validation studies of OCT and histology established criteria for fibrous plaque (homogeneous signal-rich regions), fibrocalcific plaque (signal-poor regions with sharp borders), and lipid rich plaque (signal-poor regions with diffuse

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borders) (5-7). However, the low penetration of OCT limited the full assessment of these plaques, particularly in the differentiation of lipid from calcific plaque components (6,8).

In 2009, Gonzalo et al. (9) established the initial classification scheme for evaluation of in-stent restenosis with OCT, based on optical pattern characteristics (homogeneous, heterogeneous, or layered), signal backscatter (high or low), and presence of microvessels (peristrut or intra-intimal). The accompanying article by Lutter et al. (1) is the first major study to correlate these OCT findings with histology. They found that, for each predefined OCT imaging category, there was a wide histological differential, particularly for layered neointimal pattern and peristrut low-intensity patterns. Despite a controlled post mortem experimental setting, OCT imaging was not reliable in differentiating lipid pools, calcium, or macrophages. The best histological correlation was with the "honeycomb" appearance (corresponding with organized thrombus with channels) and irregular intraluminal protruding masses (corresponding with thrombus). But "honeycombing" is not a tissue characteristic; it is recognition of a geometric shape on imaging. However, OCT has very good spatial resolution and produces clear anatomic representations of the arterial cross section. It remains useful for measuring the lumen of the artery and the stent size or apposition; OCT is not reliable in interpreting tissue composition.

The OCT images in this article show a continuous drop-off of reflected light signal amplitude. This manifests itself as showing the highest intensity around the inner circle of the lumen with gradual decrease in intensity of the image as you move peripherally in a radial direction. This continuous dropout of data produces the so-called "layering effect" demonstrated in the OCT figures of the Lutter et al. article. It is not a manifestation of any tissue characteristic, but rather a representation of the physics of OCT, that is, continuous dropout of data that makes it appear as if the tissue is gradually changing its composition. For example, in Figure 2-B1, OCT shows large plaque burden that is signal-poor with diffuse borders and a high-attenuation surface. Traditional interpretation of these findings would be superficial foam cells covering lipid-rich plaque. The corresponding histology in Figure 2B3 shows fibrous plaque with neovascularization, calcium deposits, the remainder of the stent struts that were not seen on OCT, and an absence of foamy macrophages.

The conclusions of this paper provide important results that contradict previous papers about OCT. The authors demonstrate that there is significant variation between OCT images and tissue composition in the chronic phase after stent implantation. Early studies recognized that there were misinterpretations of the images compared with histology, especially when the plaque was thick (8). Papers about OCT in the clinical setting, when histology is not available, assume that the images accurately correspond with different tissue types. Claims are made about "this calcified plaque" or "this lipid pool" or "the presence of macrophages" when there is no clear image on OCT of the distal part of the plaque due to dropout of information. When there is dropout of data, the interpreter can say whatever they want, because there is no way to verify the interpretation in the absence of histology.

With this lesson about OCT as a background, the same concerns can be made about so-called virtual histology image interpretation. These images use the backscatter frequency domain of IVUS, but the information is interpreted by a computer algorithm to tell the operator about plaque composition. Unfortunately, this technology also has a poor correlation with histology. The resulting computer interpretations often do not correlate anatomically, filling in data that are just not there due to shifts or dropout of the signal (10). The lessons from OCT and frequency backscatter images is that we should be more skeptical of claims about imaging technology unless there are rigorous histological comparisons to verify the interpretations about plaque composition. In comparison, there have been extensive histological correlations with near-infrared spectroscopy, which more accurately reveals the concentration of lipid within a plaque (11).

The meticulous analysis from this paper should stimulate a reappraisal of what OCT is capable of showing us and what it cannot. If there is high plaque burden, there will be image attenuation, and the dropout of information results in a poor correlation with tissue characteristics. Although OCT imaging remains useful for detailed anatomic imaging of coronary arteries and stents in the immediate procedural setting, one should be cautious about any attempt to describe plaque characteristics with OCT. Histopathological validation studies such as this paper are important in forming the basis for future clinical trials to define the role of intravascular imaging.

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REFERENCES

1. Lutter C, Mori H, Yahagi K, et al. Histopathological differential diagnosis of optical coherence tomographic image interpretation after stenting. J Am Coll Cardiol Intv 2016;9:2511–23.

2. Prati F, Romagnoli E, Burzotta F, et al. Clinical impact of OCT findings during PCI: The Cli-OPCI II Study. J Am Coll Cardiol Img 2015;8:1297–305.

3. Guddeti R, Matsuo Y, Matsuzawa Y, et al. Clinical implications of intracoronary imaging in cardiac allograft vasculopathy. Circ Cardiovasc Imaging 2015;8:e002636.

4. Brown A, Obaid D, Costopoulos C, et al. Direct comparison of virtual-histology intravascular ultrasound and optical coherence tomography imaging for identification of thin-cap fibroatheroma. Circ Cardiovasc Imaging 2015;8:e003487.

5. Yabushita H, Bouma BE, Houser SL, et al. Characterization of human atherosclerosis by optical coherence tomography. Circulation 2002;106:640–5.

6. Kawasaki M, Bouma BE, Bressner J, et al. Diagnostic accuracy of optical coherence tomography and integrated backscatter intravascular ultrasound images for tissue characterization of human coronary plaques. J Am Coll Cardiol 2006;48:81–8.

7. Rieber J, Meissner O, Babaryka G, et al. Diagnostic accuracy of optical coherence tomography and intravascular ultrasound for the detection and characterization of atherosclerotic plaque composition in ex-vivo coronary specimens: a comparison with histology. Coron Artery Dis 2006;17:425–30.

8. Manfrini O, Mont E, Leone O, et al. Sources of error and interpretation of plaque morphology by optical coherence tomography. Am J Cardiol 2006;98:156–9.

9. Gonzalo N, Serruys PW, Okamura T, et al. Optical coherence tomography patterns of stent restenosis. Am Heart J 2009;158:284–93.

10. Thim T, Hagensen MK, Wallace-Bradley D, et al. Unreliable assessment of necrotic core by virtual histology intravascular ultrasound in porcine coronary artery disease. Circ Cardiovasc Imaging 2010;3:384–91.

11. Kilic ID, Caiazzo G, Fabris E, et al. Near-infrared spectroscopy-intravascular ultrasound: scientific basis and clinical applications. Eur Heart J Cardiovasc Imaging 2015;16:1299–306.

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