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INNOVATIVE TECHNIQUES SECTION

RESEARCH ARTICLE

First in vivo Real-Time Imaging of Endocardial Radiofrequency Ablation by Optical Coherence Tomography: Implications on Safety and The Birth of ''Electro-structural'' Substrate-Guided Ablation

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ABSTRACT. *We report the first in vivo use of optical coherence tomography (OCT), a high-resolution (~10 μm) real-time imaging technology, to scan subendocardial tissue and to monitor radiofrequency (RF) lesion formation. Endocardial imaging during an open chest procedure in a female pig was conducted with a forward imaging catheter with a Fourier Domain OCT system at 20 frames per second. Images of the endocardial surface and subendocardial tissue were obtained when the catheter was in direct contact with the endocardial surface. The formation and progressive increase in size of cavities within the myocardium were observed in the OCT images when a steam pop was audible. Our initial findings suggest that imaging with a forward scanning OCT catheter can assess tip electrode–tissue interface contact, image subsurface myocardial structure, and visualize dynamic effects of intramural RF energy delivery.*

KEYWORDS. *radiofrequency catheter ablation, optical coherence tomography, image guidance.*

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Catheter ablation has become a therapeutic option in the management of cardiac arrhythmias. Innovative technologies and ablation strategies have optimized procedure safety and long-term efficacy. However, lack of real-time ablation lesion monitoring remains a major limitation of current ablation approaches. We report the first in vivo use of optical coherence tomography (OCT), a high-resolution (~10 μm) real-time imaging technology, to scan subendocardial tissue and to monitor radiofrequency (RF) lesion formation. OCT generates images by detecting singly backscattered light as a function of depth, providing subsurface imaging to depths of approximately 1 mm with high spatial resolution (~10 μm) and high sensitivity[1].

Endocardial imaging during an open chest procedure in a female pig was conducted with a forward imaging catheter using a Fourieromain OCT system at 20 frames per second.[2,3] The OCT catheter was secured to a commercially available RF ablation catheter, inserted directly into the right atrium (**Figure 1a**) and advanced and navigated within the heart under fluoroscopic guidance (**Figure 1b**). Image penetration through blood

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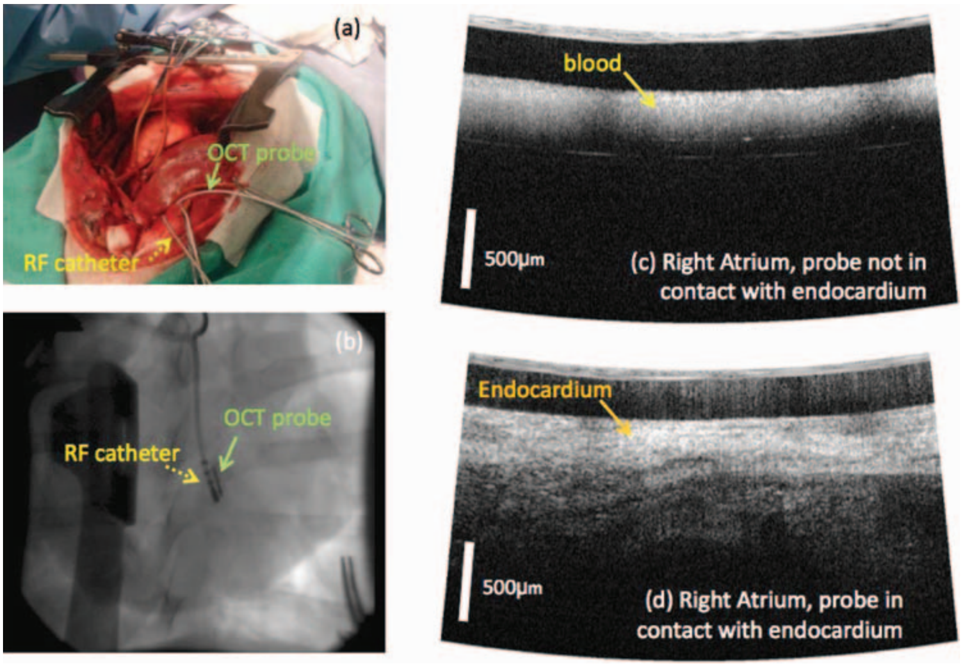

Figure 1: Assessment of probe–tissue contact using optical coherence tomography imaging.

is low due to absorption and scattering (**Figure 1c**). However, high quality images of the endocardial surface and sub endocardial tissue were obtained when the catheter was in direct contact with the endocardial surface, thus displacing the blood (**Figure 1d**). In addition to increased imaging depth, the structured appearance of the myocardium (**Figure 1d**) is clearly different from the homogenous appearance of blood (**Figure 1c**).

To evaluate whether OCT can identify dynamic tissue change due to RF energy delivery in vivo, temperature-controlled RF energy was delivered for 60 s with a target temperature of 85°C using a Maestro 3000 generator (Boston Scientifi, St Paul, M) and an 8Fr, 5-mm tip Blazer II catheter (Boston Scientific) after 15 s of imaging with stable contact with the endocardial surface. The formation and progressive increase in size of cavities within the myocardium were observed in the OCT images when a steam pop

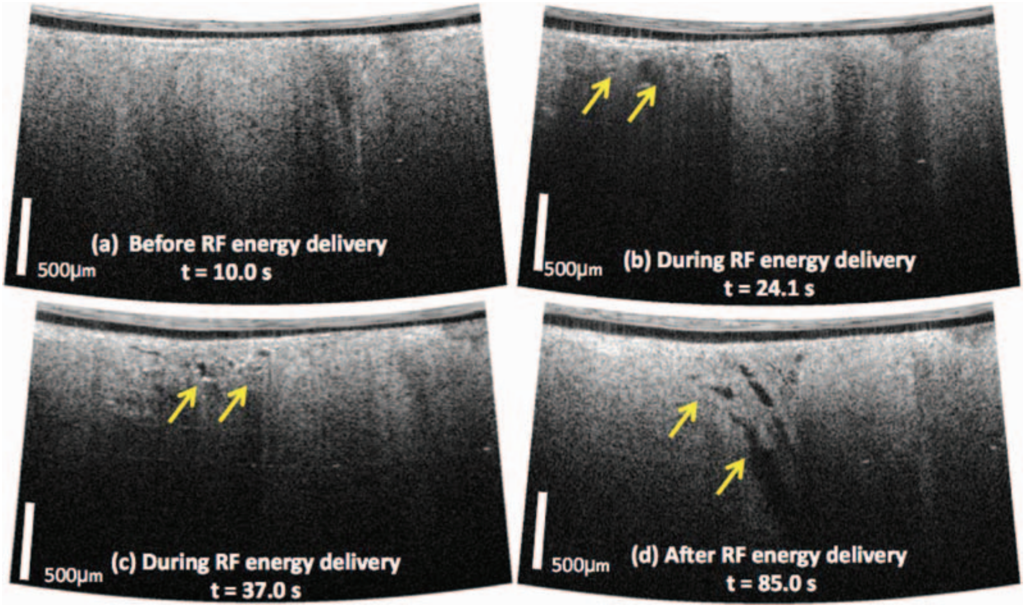

Figure 2: Optical coherence tomography visualization of subsurface cavity formation due to radiofrequency ablation energy delivery. This case resulted in an adverse event (steam pop) due to overtreatment.

was audible (**Figure 2**). The cavities may represent an early subsurface manifestation of the steam pop.

Our initial findings suggest that imaging with a forward scanning OCT catheter can assess tip electrode–tissue interface contact, image subsurface myocardial structure, and visualize dynamic effects of intramural RF energy delivery. Real-time OCT imaging may establish a new ablation paradigm. It may favorably impact on ablation safety and its outcome by predicting tissue overheating and intramyocardial steam pops, providing feedback to titrate RF energy delivery, and most importantly identifying differences in tissue characteristics to guide a potentially more specific ''electro-structural'' substrate ablation strategy, targeting culprit structures responsible for the initiation and maintenance of challenging cardiac arrhythmias such as atrial fibrillation and ventricular tachycardia.

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