IMAGE

Direct observation of a stable spiral wave reentry in ventricles of a whole human heart using optical mapping for voltage and calcium

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From the studies of Gordon Moe in the 1960s, functional reentry has been investigated as a mechanism for tachycardia and fibrillation; however, it was not until 1990 that optical mapping (OM) experiments using sheep hearts verified the existence of reentrant spiral waves.[1] Eventually, it was shown that electromechanical 3-dimensional vortex filaments drive cardiac fibrillation.[2] To date, only multiple complex and short-lived reentrant waves have been recorded using OM on human ventricles.[3] The presence of single spiral waves in human ventricles has only been demonstrated using low-resolution intracardiac electrocardiograms (ECGs).[4] We report the first high-resolution visualization of a stable spiral wave in human ventricles using OM (voltage and calcium) (Figure 1A) of the posterior epicardial surface ($\sim$7 $\times$ 7 cm^2) of an explanted heart from a 38-year-old female transplant recipient, who presented with cardiogenic shock secondary to viral cardiomyopathy.

Supplemental Video 1 shows 2 episodes of transiently stable scar-free ventricular tachycardia produced by a functional reentrant wave. The first is a spiral wave (cycle length 325 ms) that rotates clockwise across the interventricular septum, followed by another spiral wave rotating counterclockwise (360 ms). Reentries were initiated with rapid pacing during a down pacing protocol used to calculate action potential duration restitution (at pacing periods of 330 and 390 ms, respectively; stimulus site shown in Figure 1B). The clockwise example lasted for >50 rotations, producing monomorphic ECG before degenerating into ventricular fibrillation that self-terminated after 19 seconds. The induction of reentries was reproducible, and we observed other episodes. No drugs affecting electrophysiology were used.

The spiral waves were not anatomic but were functional reentries, following functional and dynamic lines of block that moved continuously across the tissue. Furthermore, no anatomic or anchoring regions of block were observed before spiral wave initiation or after termination, such that pacing waves propagated smoothly across the tissue without regional slowing. The isochronous and conduction velocity maps are consistent with a spiral wave propagating over the anisotropic cardiac tissue (Figure 1B). These results suggest that stable functional reentry can be responsible for a subset of monomorphic ventricular tachycardia in human hearts.

KEYWORDS Explanted human heart; Functional reentry; Langendorff-perfused whole human heart; Optical mapping human heart; Reentry; Spiral wave; Ventricular fibrillation; Ventricular tachycardia (Heart Rhythm 2022;19:1912-1913)

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Appendix
Supplementary data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrthm.2022.06.015.

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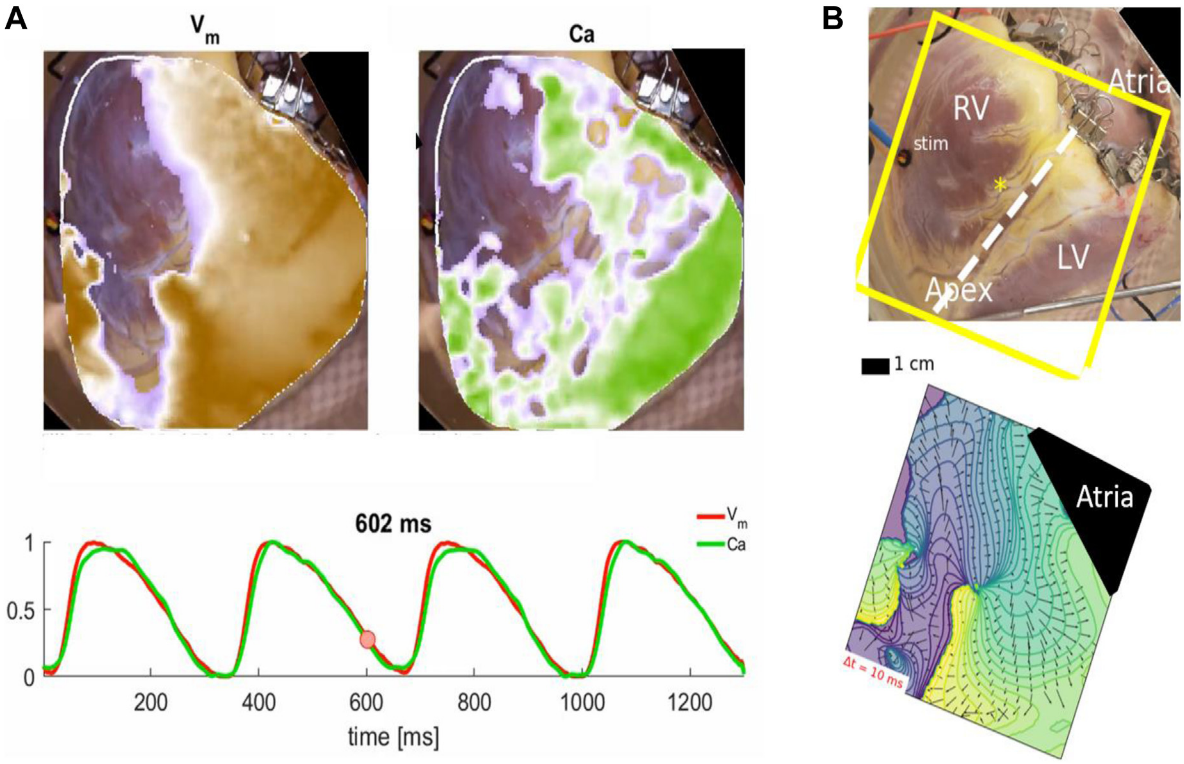

Figure 1 **A:** Movie frame showing an instant in time of the clockwise functional reentrant waves for voltage and calcium. Below are the voltage and calcium signals in time from one pixel in the center of the tissue. **B:** Image of the heart identifying the RV and LV; lower image shows contour lines during one rotation of the voltage signal. LV = left ventricle; RV = right ventricle.