Effectiveness of atrial fibrillation rotor ablation is dependent on conduction velocity: An *in-silico* 3-dimensional modeling study

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Background

- Previous study :

  Stable rotors are observed in *in-silico* human atrial fibrillation (AF) models, and are well represented by a dominant frequency (DF).

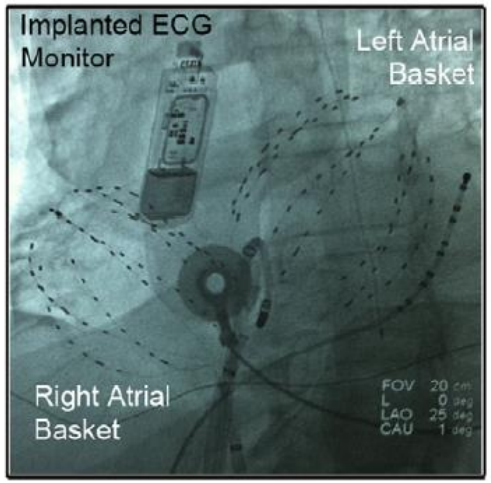
- Current study :

  We hypothesized that the outcome of DF ablation is affected by conduction velocity (CV) conditions and examined this hypothesis using *in-silico* 3D-AF modeling.

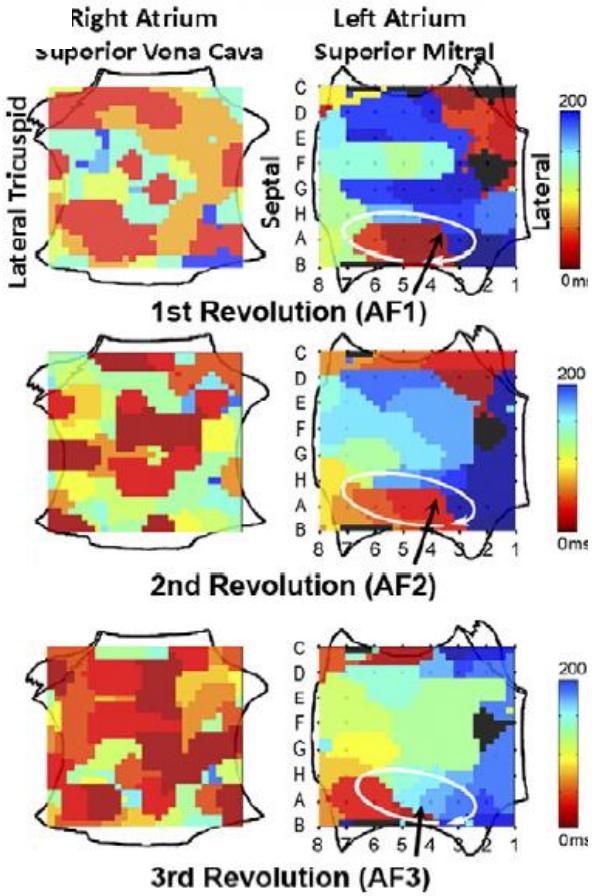
CONFIRM Trial (n=107)

Narayan et al. JACC 2012;60:628-36.

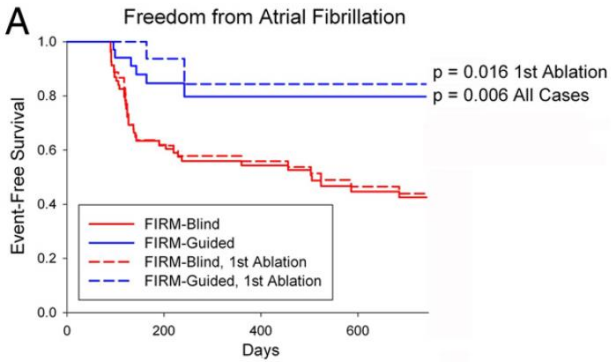
Basket Catheters in Both Atria



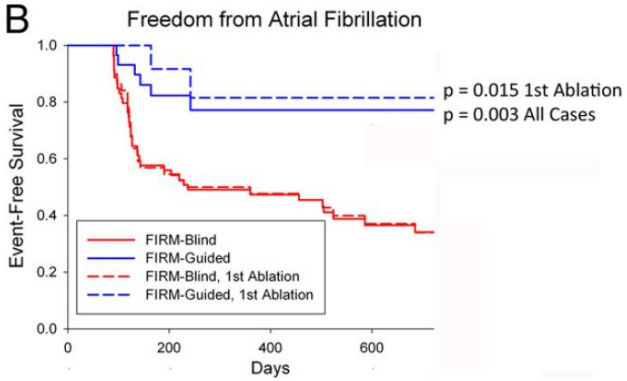
AF Rotor in Low Left Atrium



Overall Patients



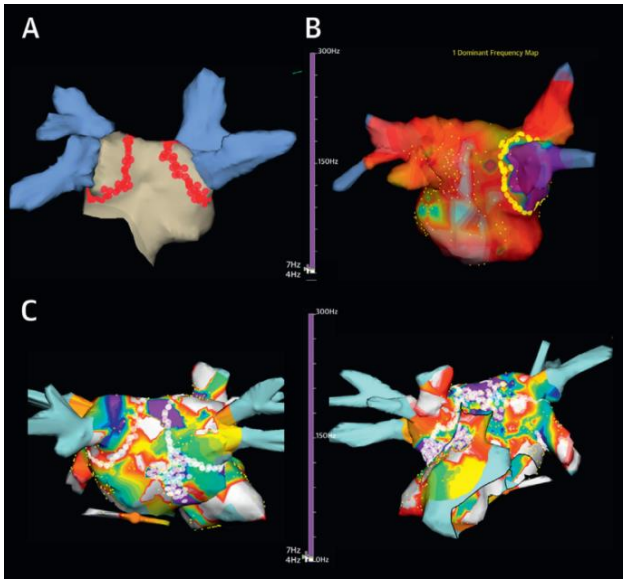
AAD-off Patients

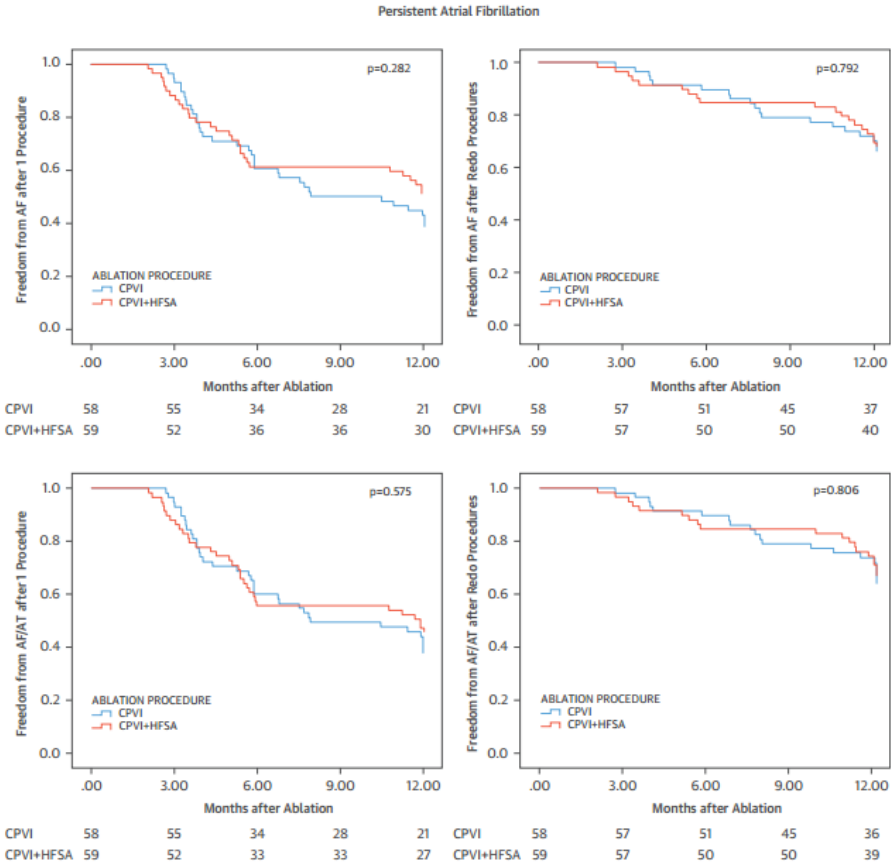


CONFIRM trial (Conventional Ablation for Atrial Fibrillation With or Without Focal Impulse and Rotor Modulation).

RADAR-AF Trial: no DF ablation outcome

F. Atienza, J. Jalife et al., JACC, 2014



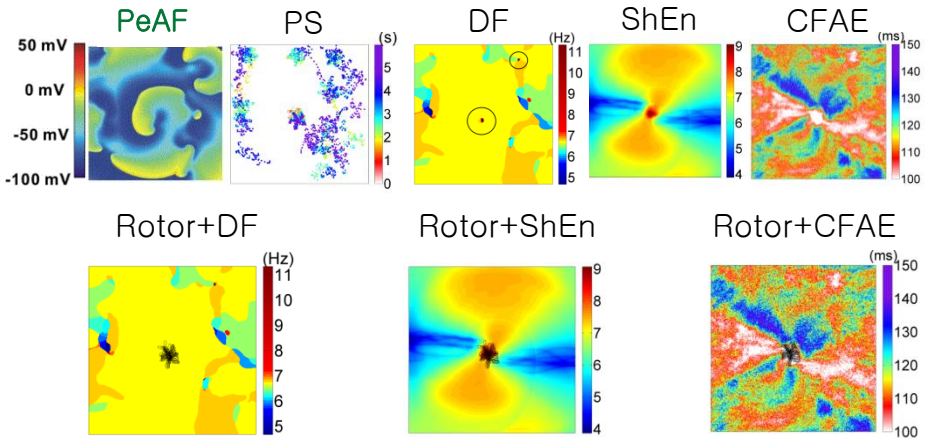


The recent RADAR-AF trial failed to prove the superiority of DF-guided ablation outcomes compared to those of CPVI ablation, and AF termination rates with DF-guided ablation were very low in clinical conditions.

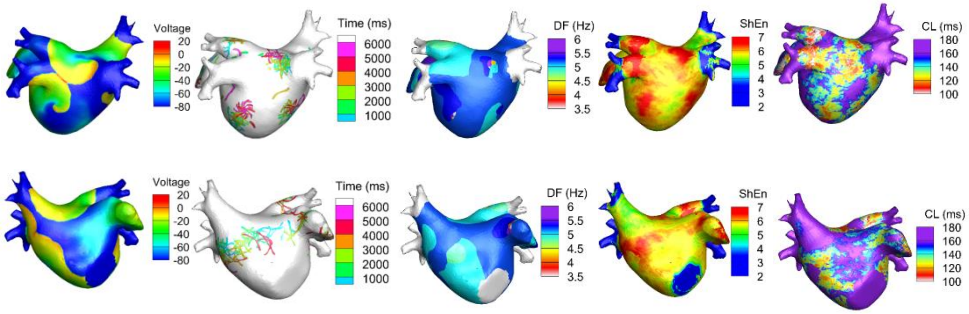
* RADAR-AF, Radiofrequency Ablation of Drivers of Atrial Fibrillation

Wave Dynamics in Simulation

A. Wave dynamics in 2D

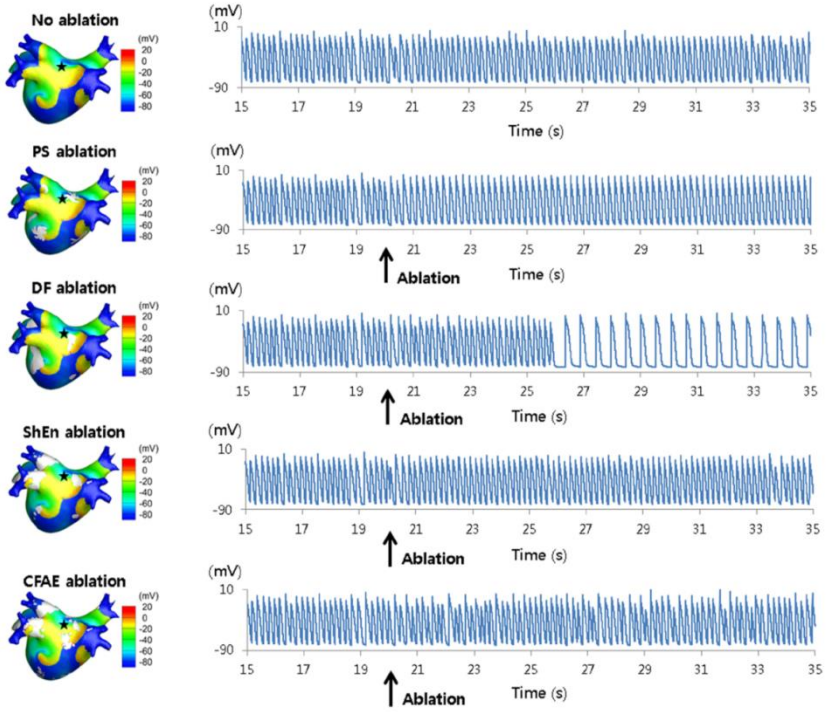


B. Wave dynamics in 3D



C. Various virtual ablation in 3D

M. Hwang et al., PLoS One, 2016

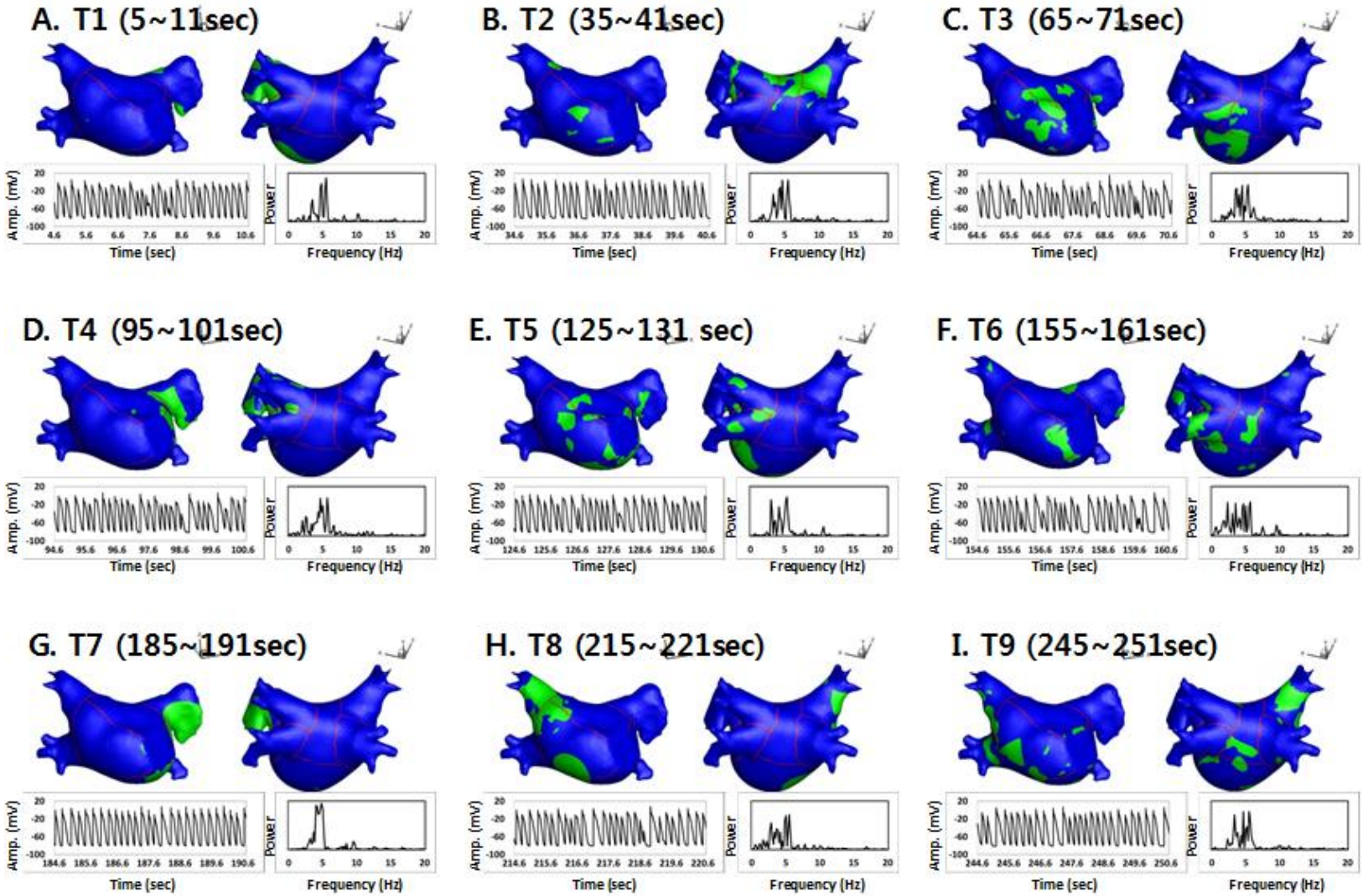


The Highest 5% DF Ablation:

70% defragmentation of AF

Spatiotemporal Change of DF Area

Li C, Lim B, Pak HN et al. PLoS One. 2016



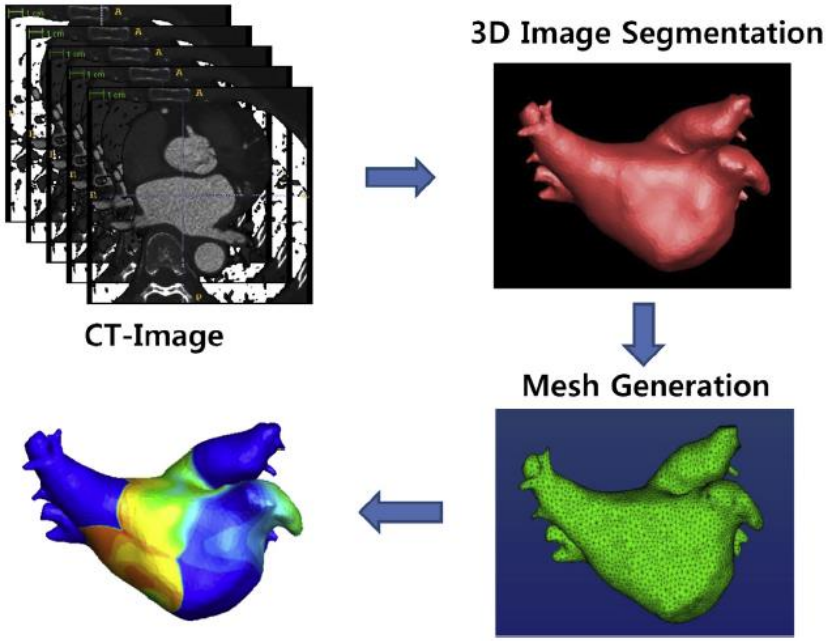
Hypotheses

- Does rotor ablation terminate or defragmentate AF?
- Is target rotor spatiotemporally stable and consistent?
- Which condition does determine rotor dynamics?

Method

3D Left atrial (LA) Modeling

- Patient's CT images are merged.
  (10 persistent AF, 61.8±13.5 years)
- 3D mesh generation by
  the customized software (CUVIA).

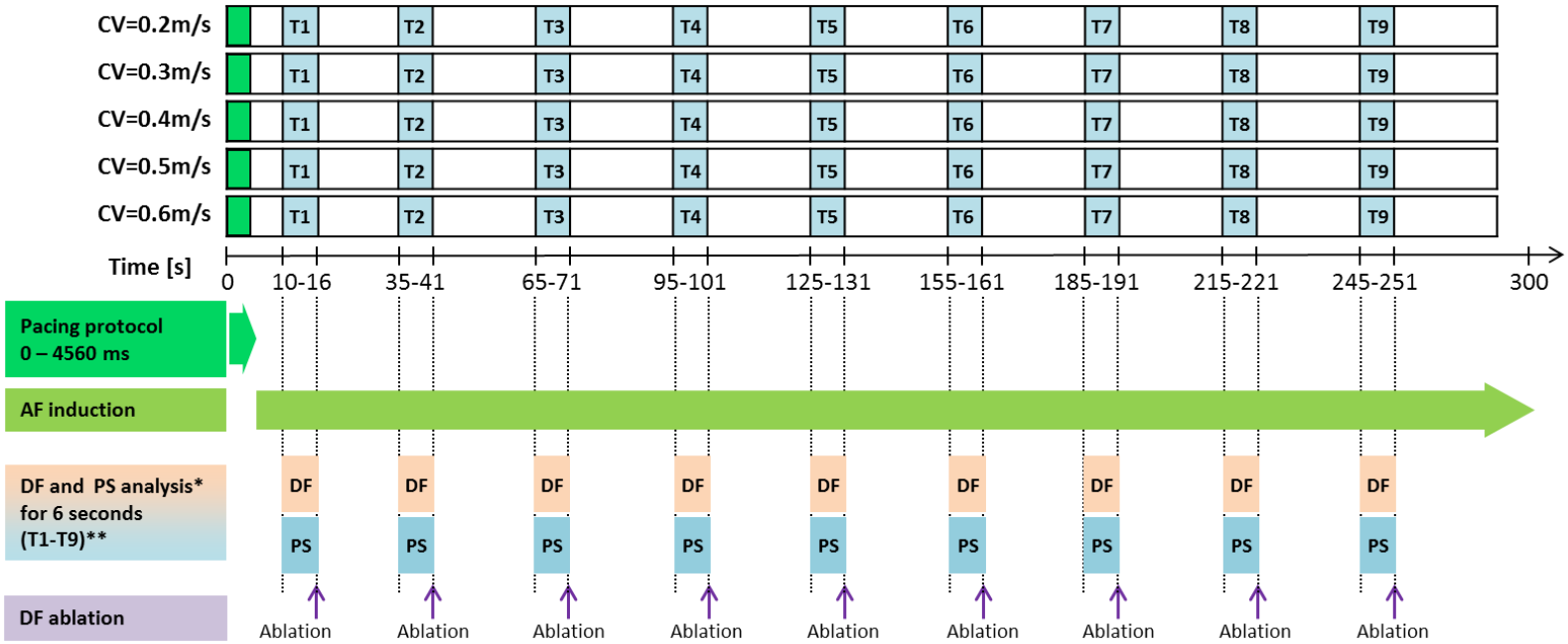


- Based ionic currents: **Courtemanche model**.
- Our modified ion currents [1,2] :

  0.8 x I_{to}
  0.5 x I_{kur}
  0.4 x I_{CaL}
  1.5 x I_{K1}

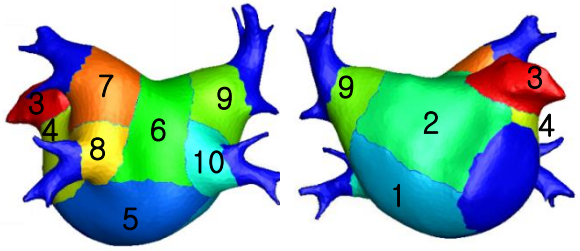
1) Van Wagoner DR et al. Circulation Res. 1997;80(6):772-81.
2) Girmatsion Z et al. Heart Rhythm Society. 2009;6(12):1802-9.

Method: Analysis algorithm



- Ramp pacing (200, 190, 180ms / 8회)
- AF induction 시간: max 300초

- DF analysis (6s) : spatiotemporal stability of DF (**mean variance**)
- PS analysis (6s) : **1ms당 출현하는 PS 개수, Longest PS life span**
- DF ablation after DF analysis.

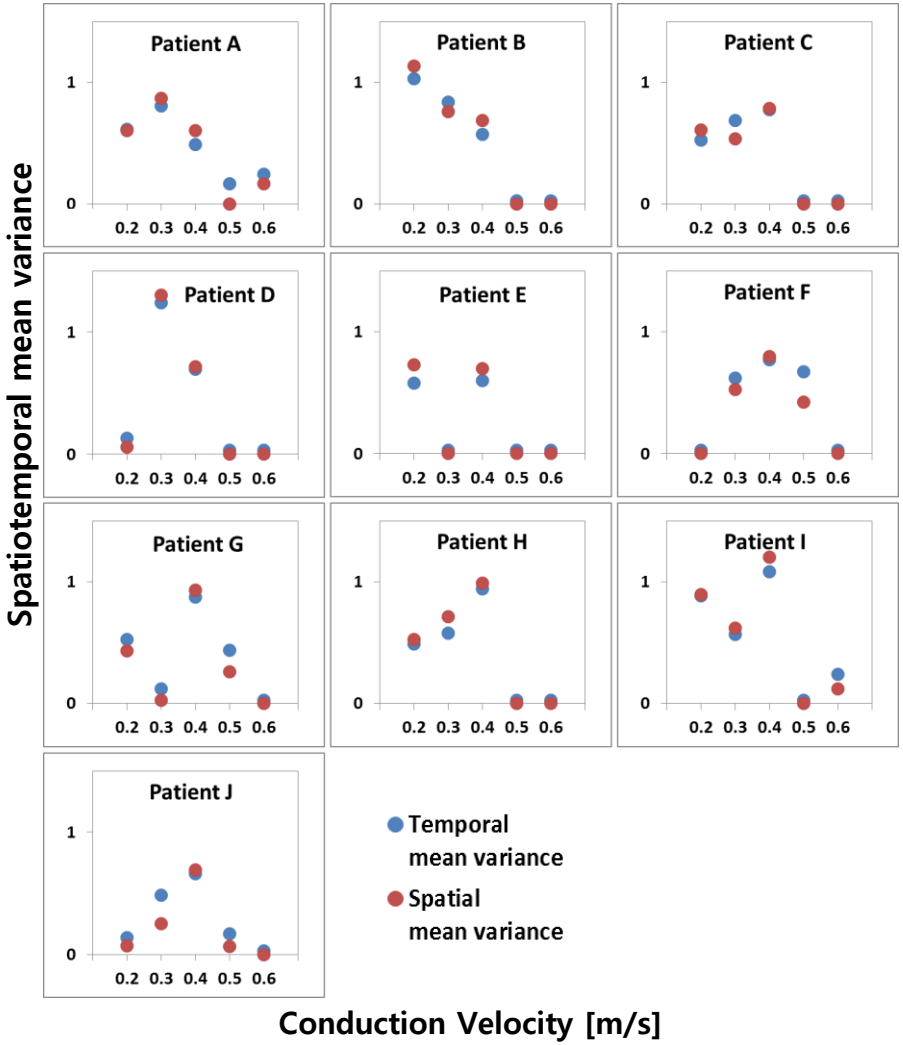


Ten segments of LA

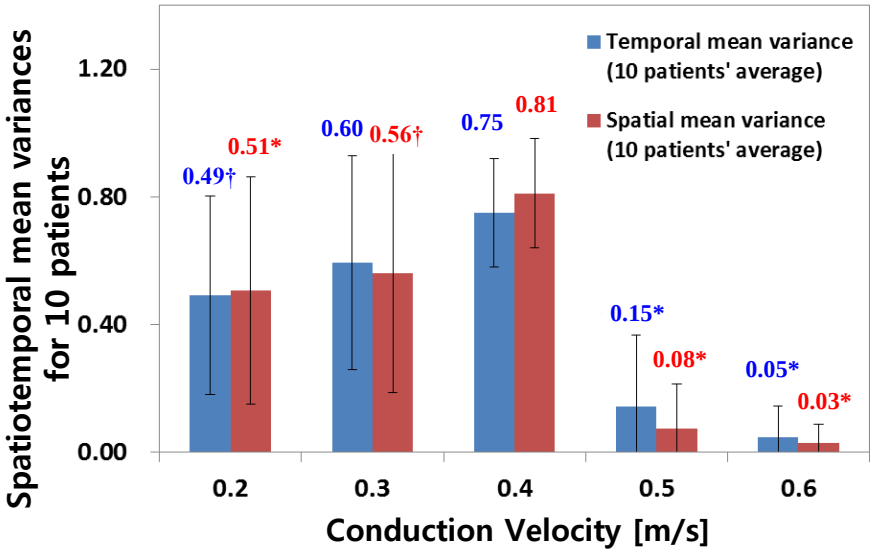
PS: Phase Singularity

Result: Spatiotemporal stability of DF

A. Spatiotemporal mean variance of regional proportion of the 10% highest DF area



B. Spatiotemporal mean variance of regional proportion of the 10% highest DF area for 10 patients

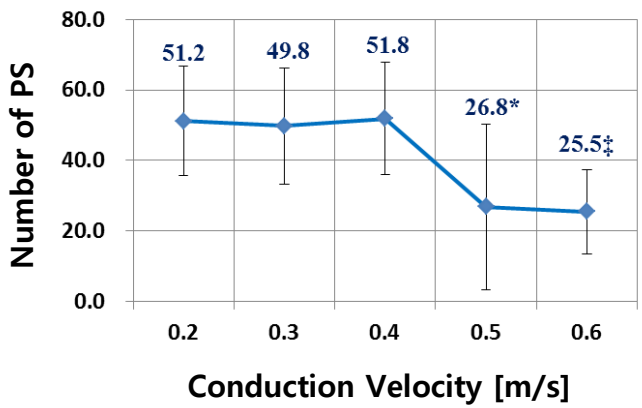


- Spatiotemporal mean variance : highest DF의 시간, 공간에 따른 분산정도
- High mean variance의 의미 :
  → spatiotemporally high heterogeneity

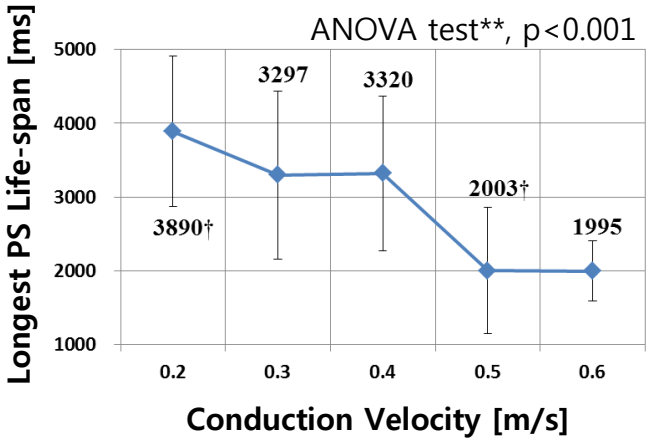
*, p<0.001 vs. CV0.4m/s; †, p<0.01 vs. CV0.4m/s; ‡, p<0.05 vs. CV0.4m/s

Result: Phase singularity and DF ablation

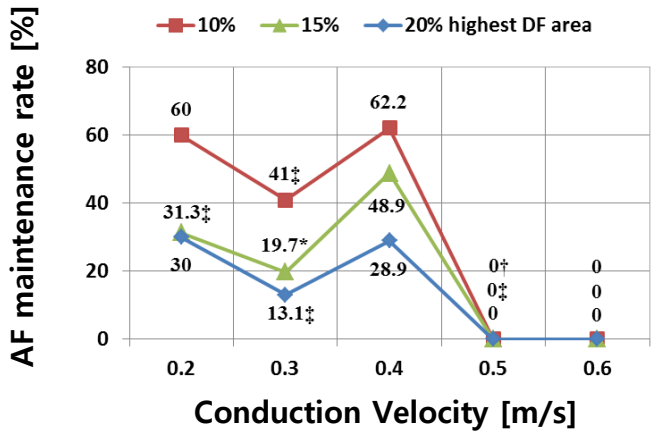
A. Number of PS per 1 ms



B. Longest PS life-span



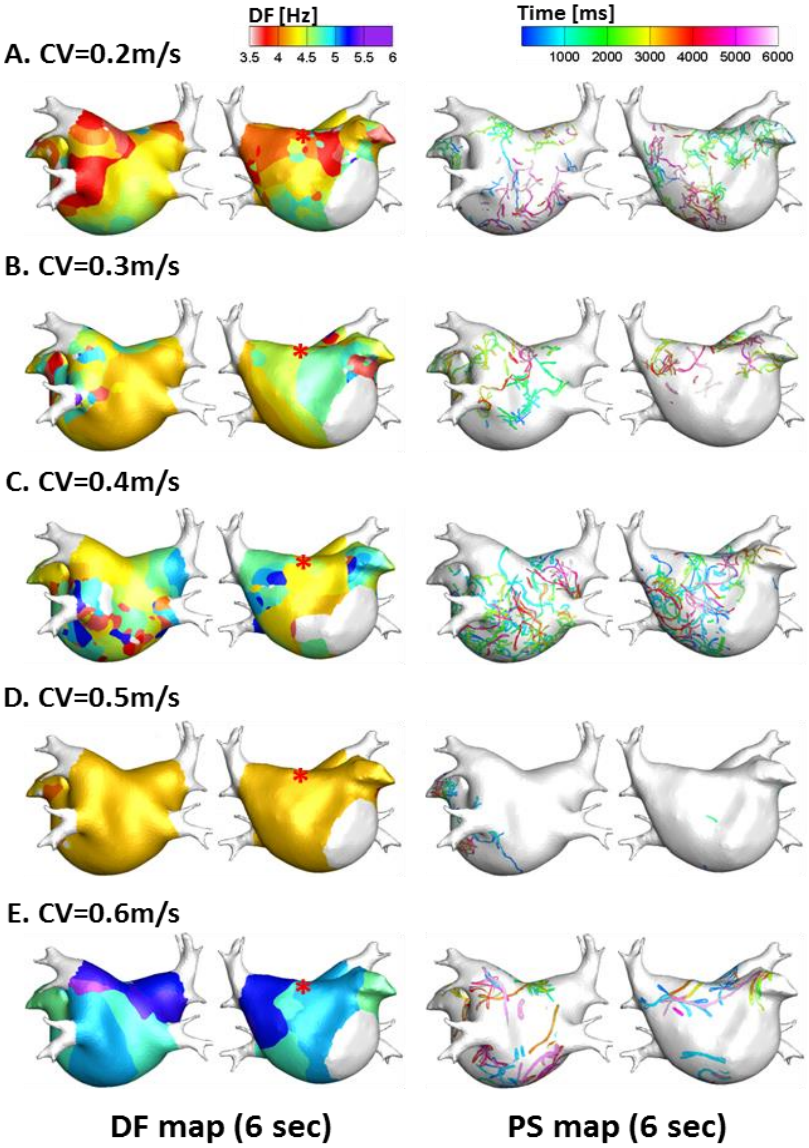
C. AF maintenance rates after DF ablation



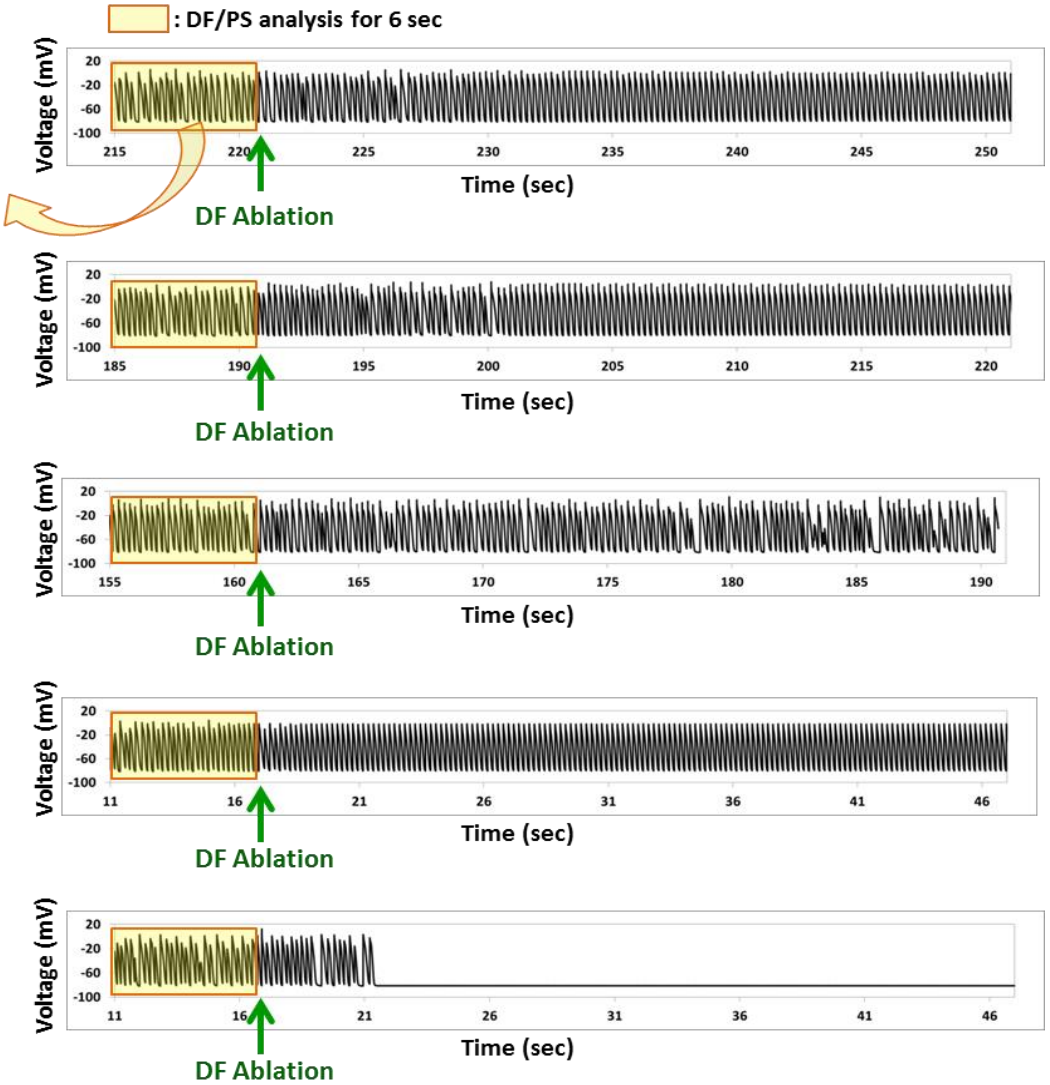
- **Higher CV :**
  long wavelength → few wavebreak allowed
  AF is terminated easily.
- **Lower CV :**
  AF is induced easily, well maintained, and hard to terminate due to continuous wavebreak.

*, p<0.001 vs. CV0.4m/s; †, p<0.01 vs. CV0.4m/s; ‡, p<0.05 vs. CV0.4m/s
**, ANOVA test is applied with all CV conditions.

DF and PS maps, and ablation outcome depending on CV



Red * : Action potential recording site



Summary

- Virtual ablation targeting the highest 10% DF defragmented AF in 47%.
- However, the location of high DF site is highly variable spatiotemporally.
- Spatiotemporal stability of rotor is dependent on the condition of CV.

Conclusion

- DF ablation is more likely to terminate or defragment AF under the conditions of short AF maintenance duration at AF induction circumstance, but not under conditions with long-lasting and sustained AF, depending on the CV.

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