Queen's School of Computing & Department of Medicine
Queen's University
Kingston, Ontario, Canada

Queen's University
I am therefore I compute
175 YEARS

Mapping and Ablating Rotors in the EP Lab; Where are we and where are we going?

Dr Damian P Redfearn

CIHR IRSC
Canadian Institutes of Health Research
Instituts de recherche en santé du Canada

Disclosures

- Grant funding Canadian Institute Health Research
- Grant funding St Jude Medical

“I deny nothing but doubt everything”

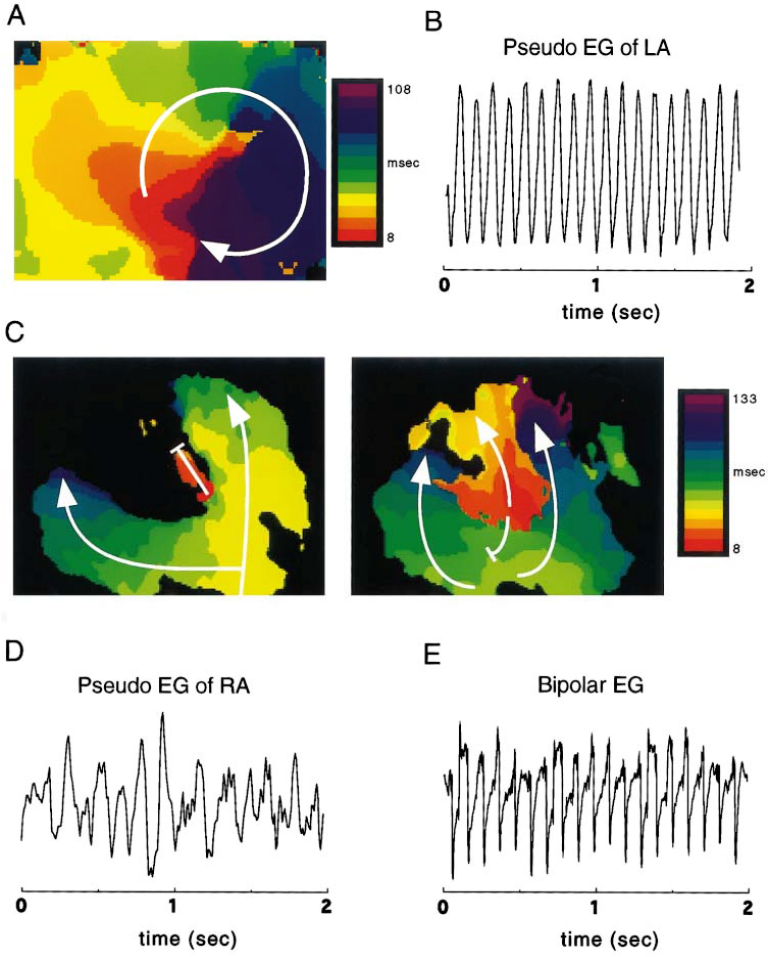
George Gordon, Lord Byron

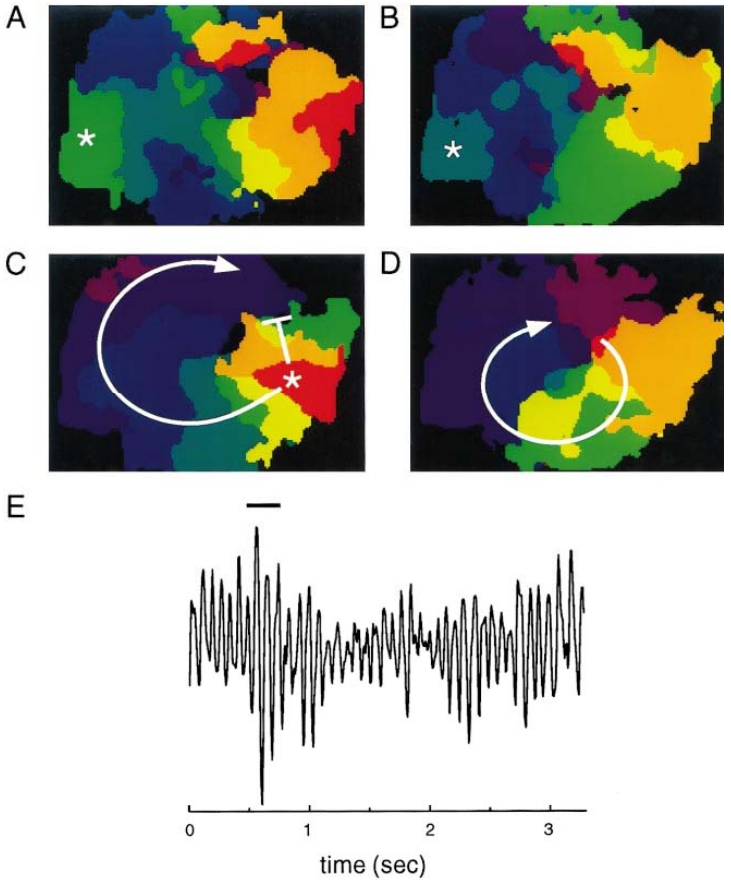
Where are we?

- Rotational wavefronts are evident in vitro; in silico and in vivo.
- Two conflicting hypotheses:
  - Spatiotemporally stable sources that perpetuate and maintain AF and provide a target for ablation (Jalife, Narayan, Shuessler and Lewis)
  - Seemingly random, meandering rotors encountering slow conduction, collision and wavebreak that maintains and perpetuates. (Allesie; Moe)
- Generally regarded as perpetuating sources of AF - rotors
- Do Rotors meander and collide and thus require a containment approach or are they stable and targetable?

Rotor

Dominant Frequency





"Fractionation"

Allan Skanes: Circulation. 1998;98:1236-1248.)

Source

Rotors

Clinical Trial Evidence

Tool	Study	Design	FU mths	Outcome – freedom from AA
Basket	Berntsen et al Heart Rhythm 2016;0:0–7	PAF Cohort	15 ± 4	22%
Basket	Mohanty et al JACC 2016 in press	Persis RCT	12±7	14%
CFE + PVI	Atul Verma N Engl J Med 2015;372:1812-22	Persis RCT	18	49%
DF + PVI	Felipe Atienza J Am Coll Cardiol 2014;64:2455–67)	Persis RCT	12	67%
Body surface	Haïssaguerre M. Circulation. 2014;130:530–8	Persis Cohort	12	64%
EGM voltage	Jadidi. *Circ Arrhythm Electrophysiol*. 2016;9:	Persis cohort	13	69%

Limitations

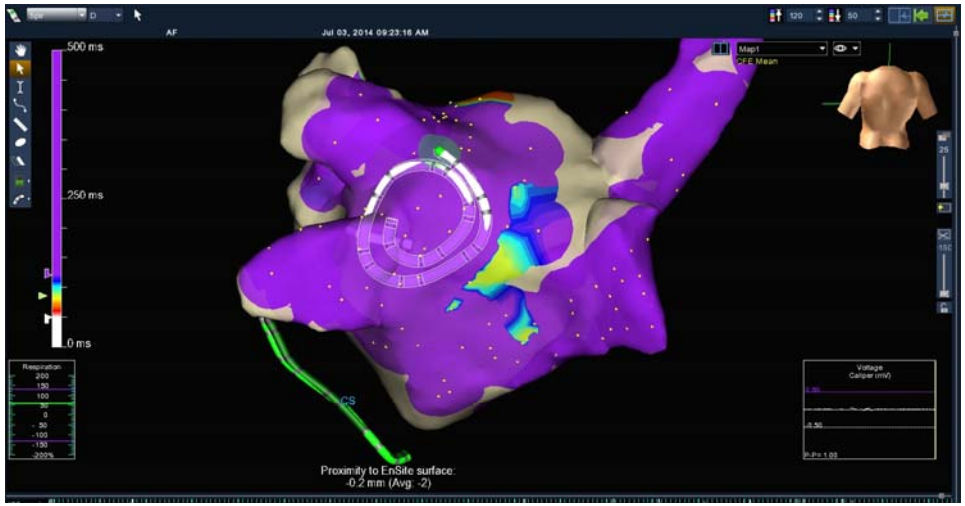
- Assumption that PAF and pAF are a continuum of disease rather than fibrillation as a manifestation of differing pathology.
- Durability and confidence in RF lesion sets and strategies.
- Spatiotemporal accuracy of mapping systems
- Individual variations in architecture and fibrosis will alter rotor dynamics.
- Timing of any mapping in studies involving RF lesions.
- Ablation has pleotropic effects; direct injury, autonomic perturbation, biochemical

Where are we going?

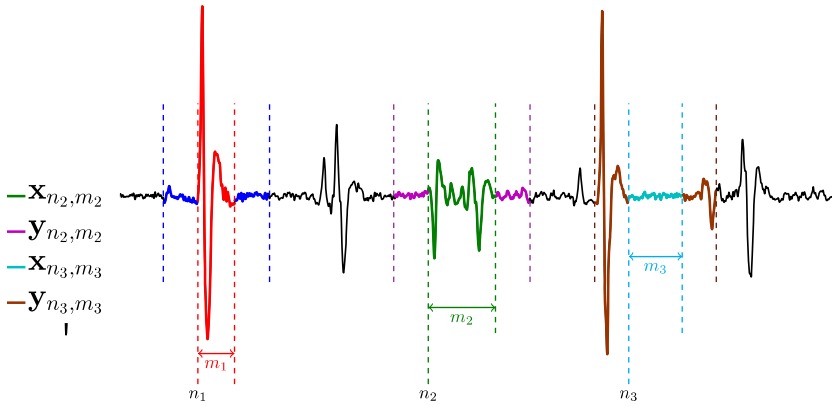
- Stable or meandering
  - Signal processing methods vary in assessment of the signal (intracardiac or surface)
  - Many assumptions made
- How to ablate
  - Consistent barriers for meandering rotors (lines)
  - Targeted ablation
    - Discrete, lines, clusters, interrupted

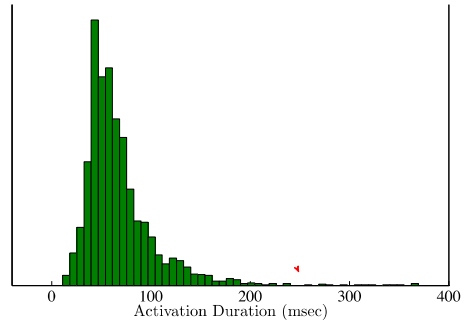
Defining the Challenges

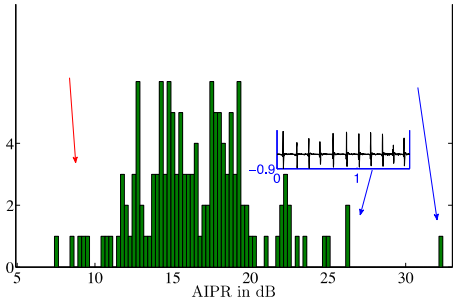
- Complete endocardial coverage
- Determination of local activation times.
- Reproducible spectral analysis.
- Discriminate ‘wave break’ from perpetuating sources.
- Analysis of electrogram characteristics to identify likely sources.

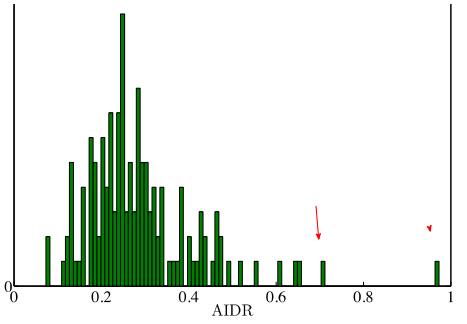


Activation Time Assessment



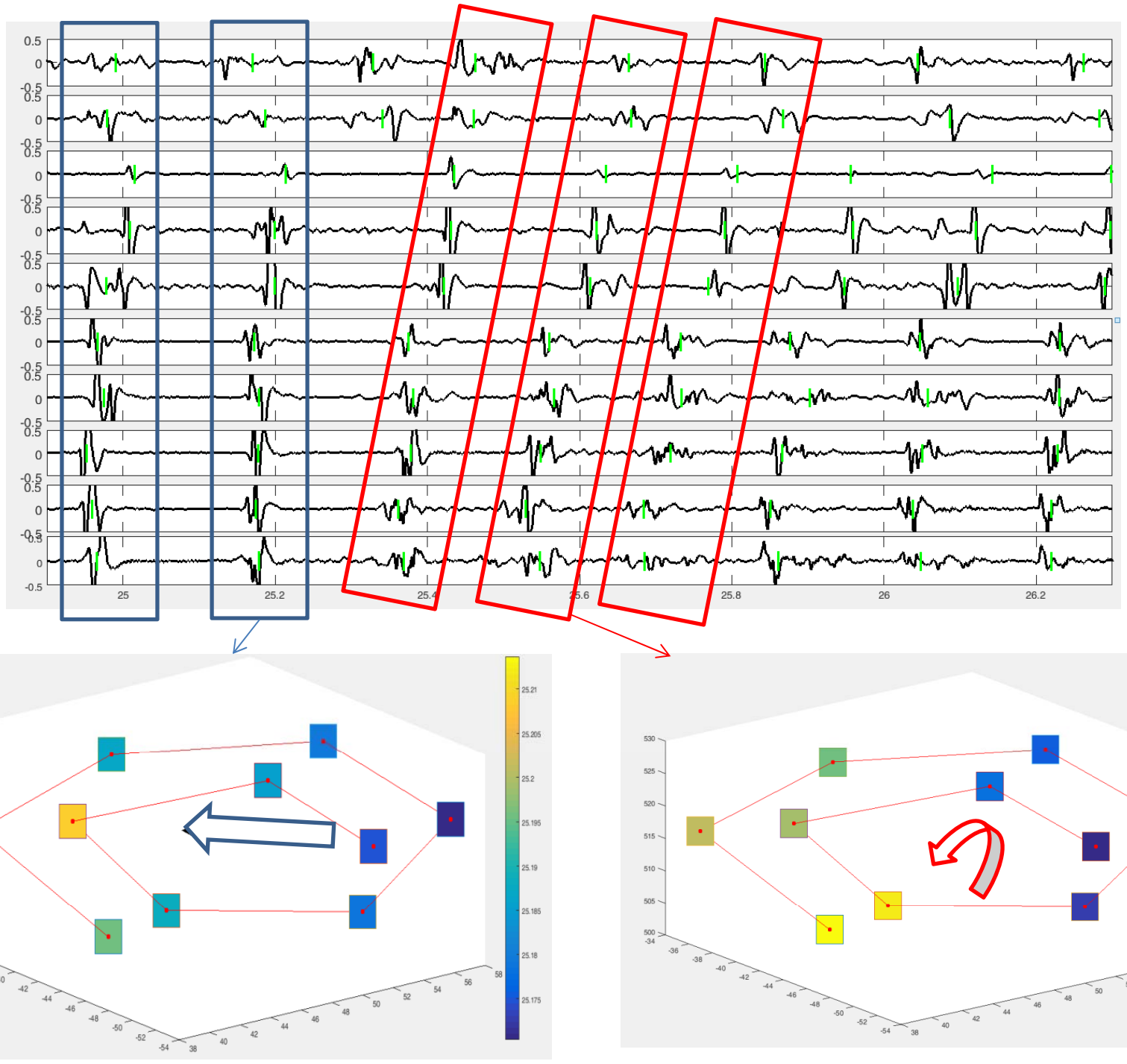




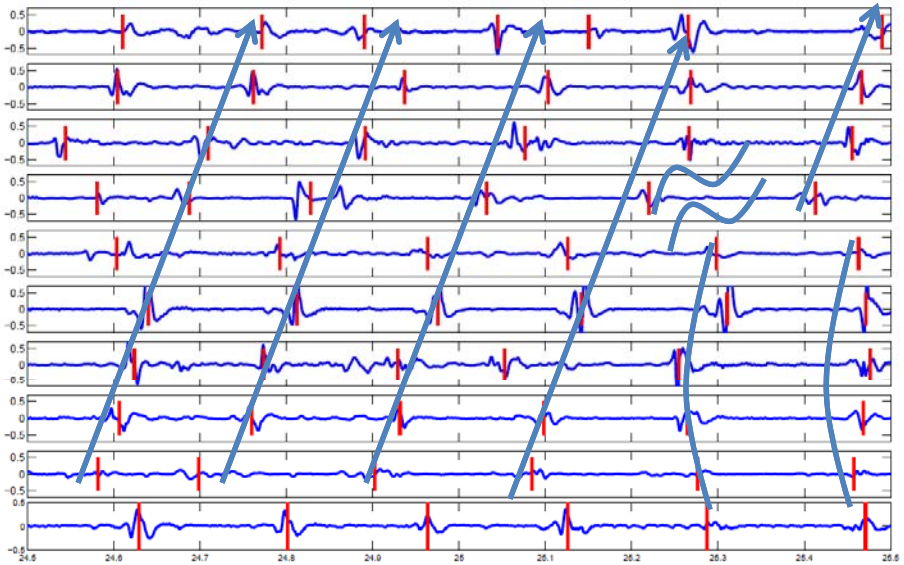


Activation duration and zone classification
Validated against manual annotation

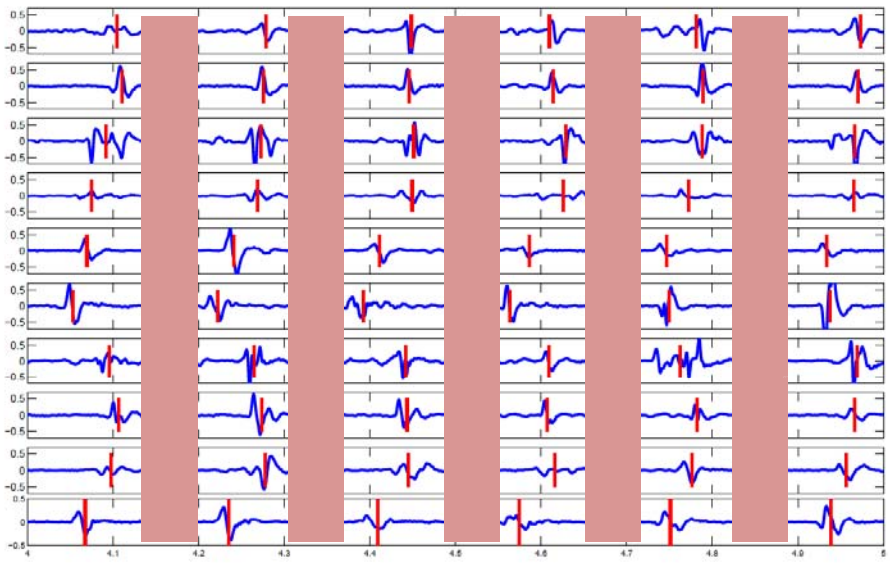
Shariat M et al. IEEE in submission 2016.


0.5
0
-0.5
25
25.2
25.4
25.6
25.8
26
26.2
530
525
520
515
510
505
500
-34
-36
-38
-40
-42
-44
-46
-48
-50
-52
-54
38
40
42
44
46
48
50
52
54
56
58
25.21
25.205
25.2
25.195
25.19
25.185
25.18
25.175
25.66
25.64
25.62
25.6
25.58
25.56
25.54

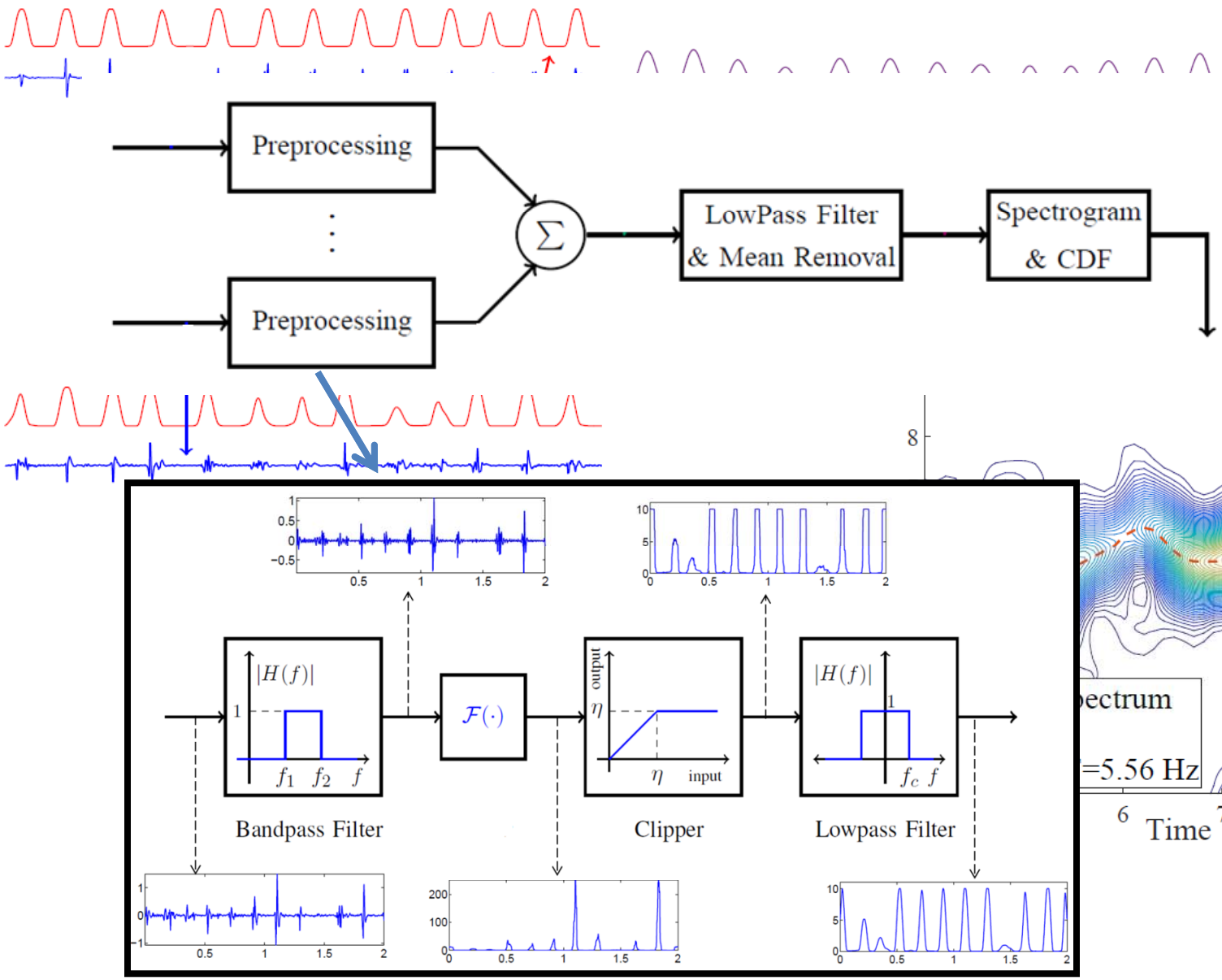
Wavefront collision



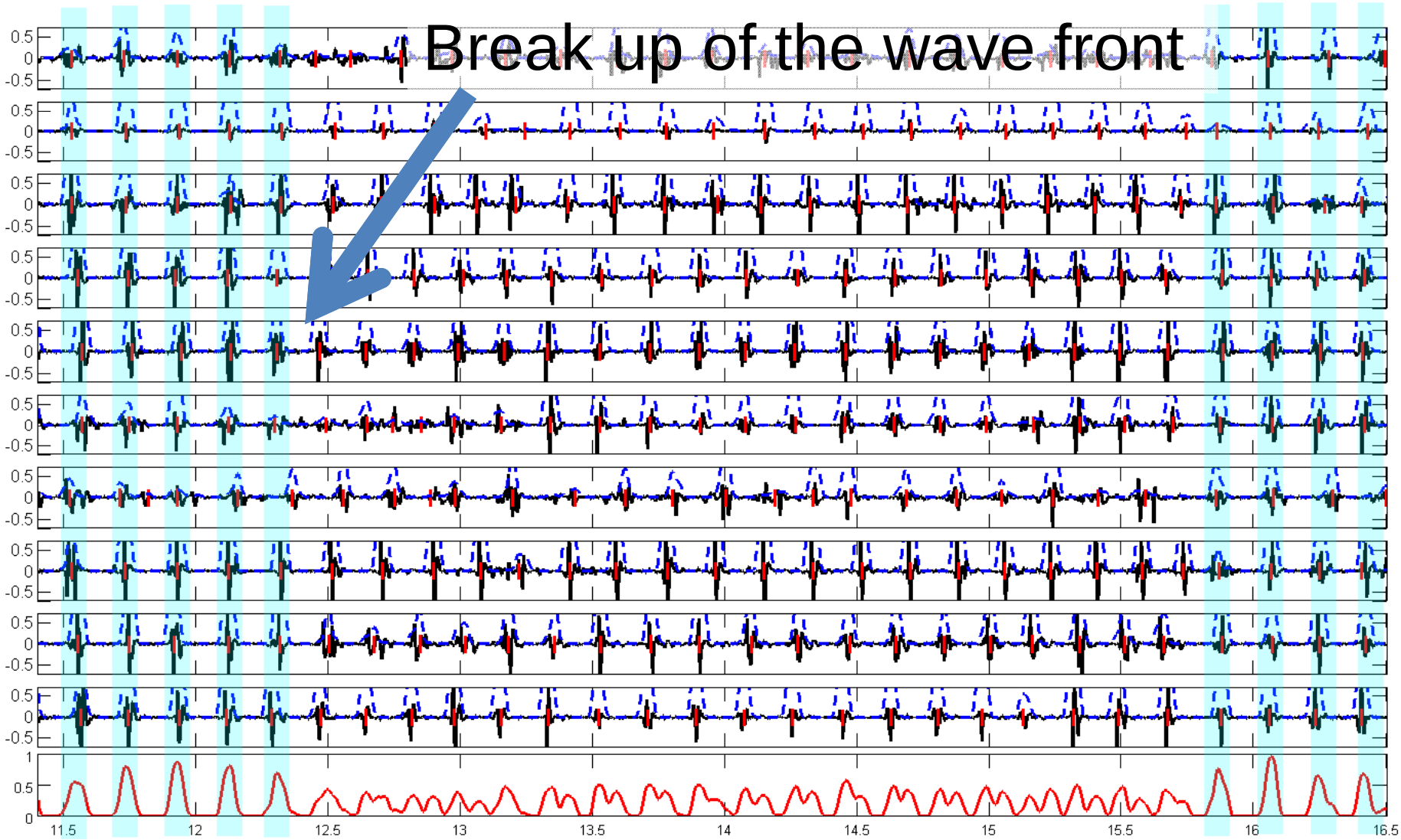
Rotational activity and wavefront collision



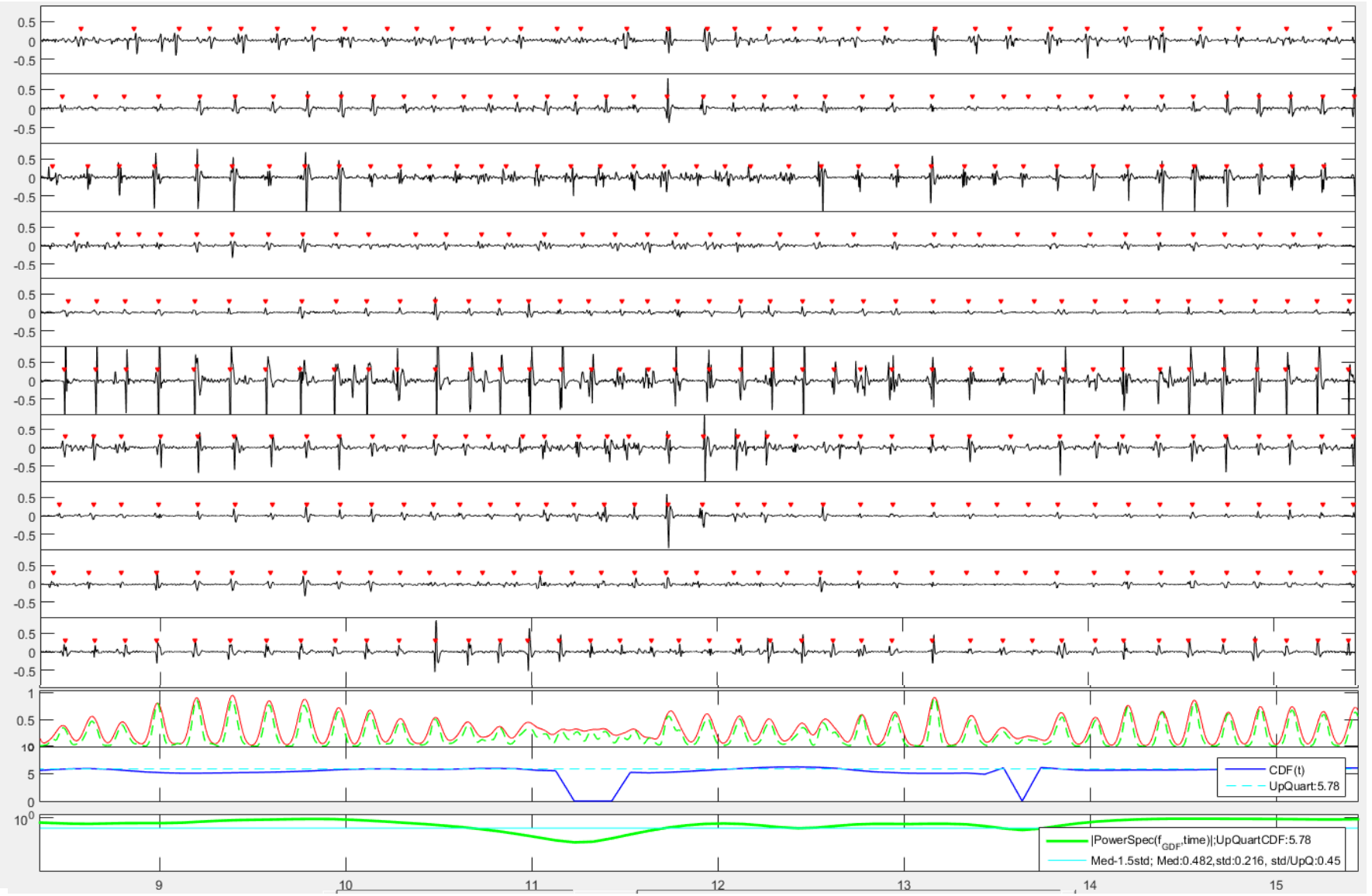
Resumption of planar wavefront


Preprocessing
Preprocessing
Σ
LowPass Filter
& Mean Removal
Spectrogram
& CDF
|H(f)|
1
f1 f2 f
Bandpass Filter
F(·)
output
η
η input
Clipper
|H(f)|
1
fc f
Lowpass Filter
ectrum
=5.56 Hz
Time

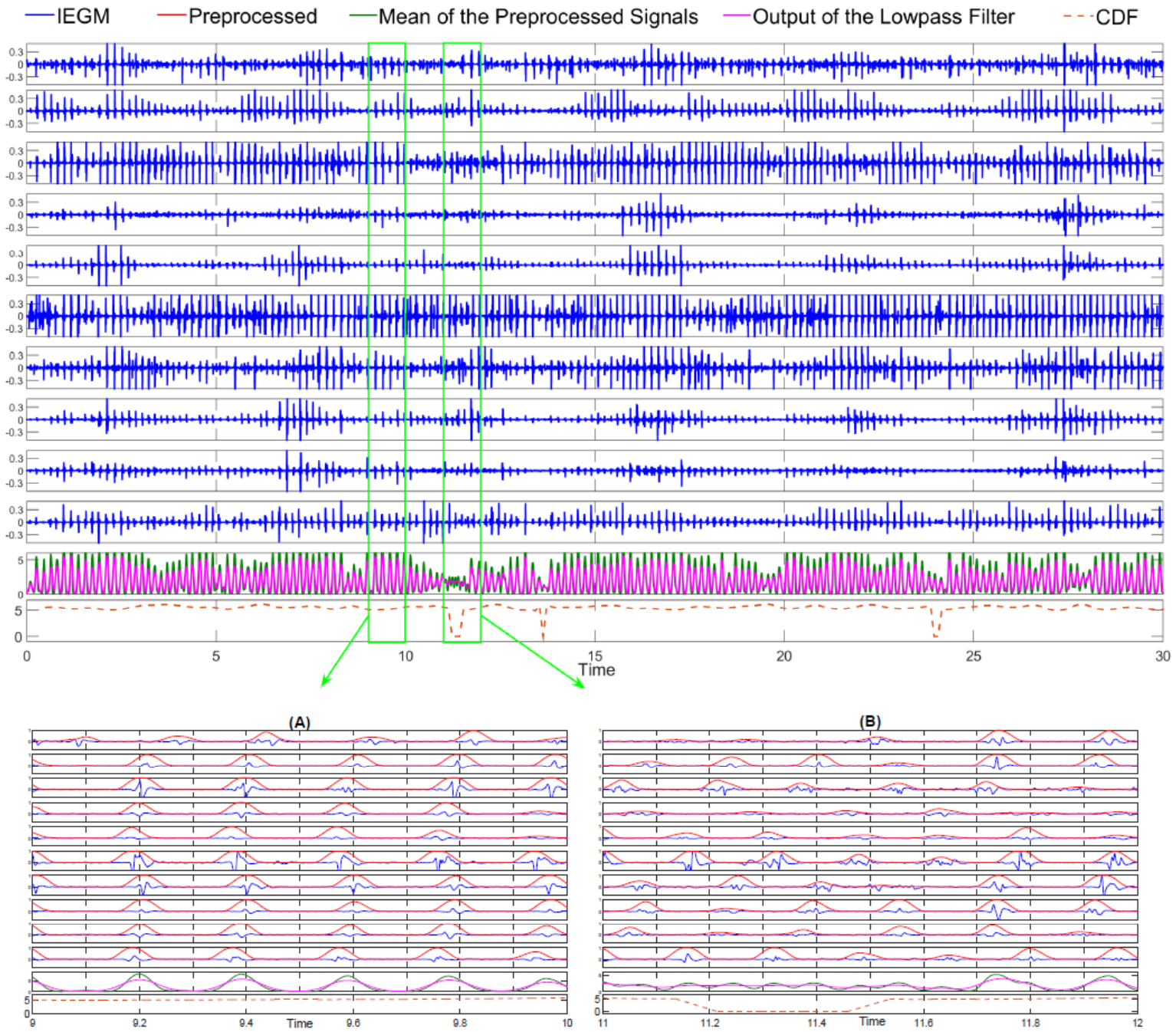
Break up of the wave front



Red channel is mean of pre-processed (dashed blue line) activations from the multipolar catheter.

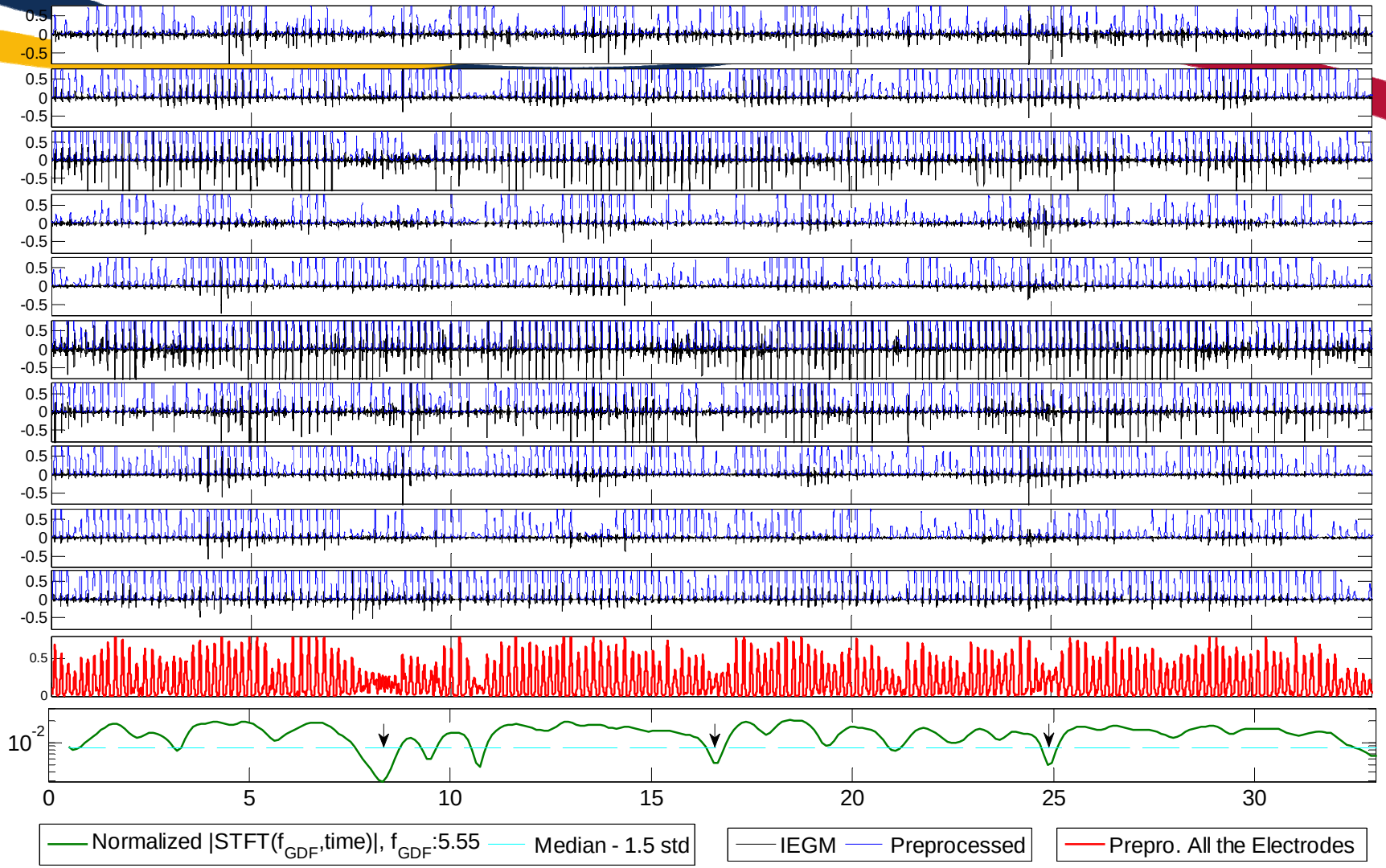


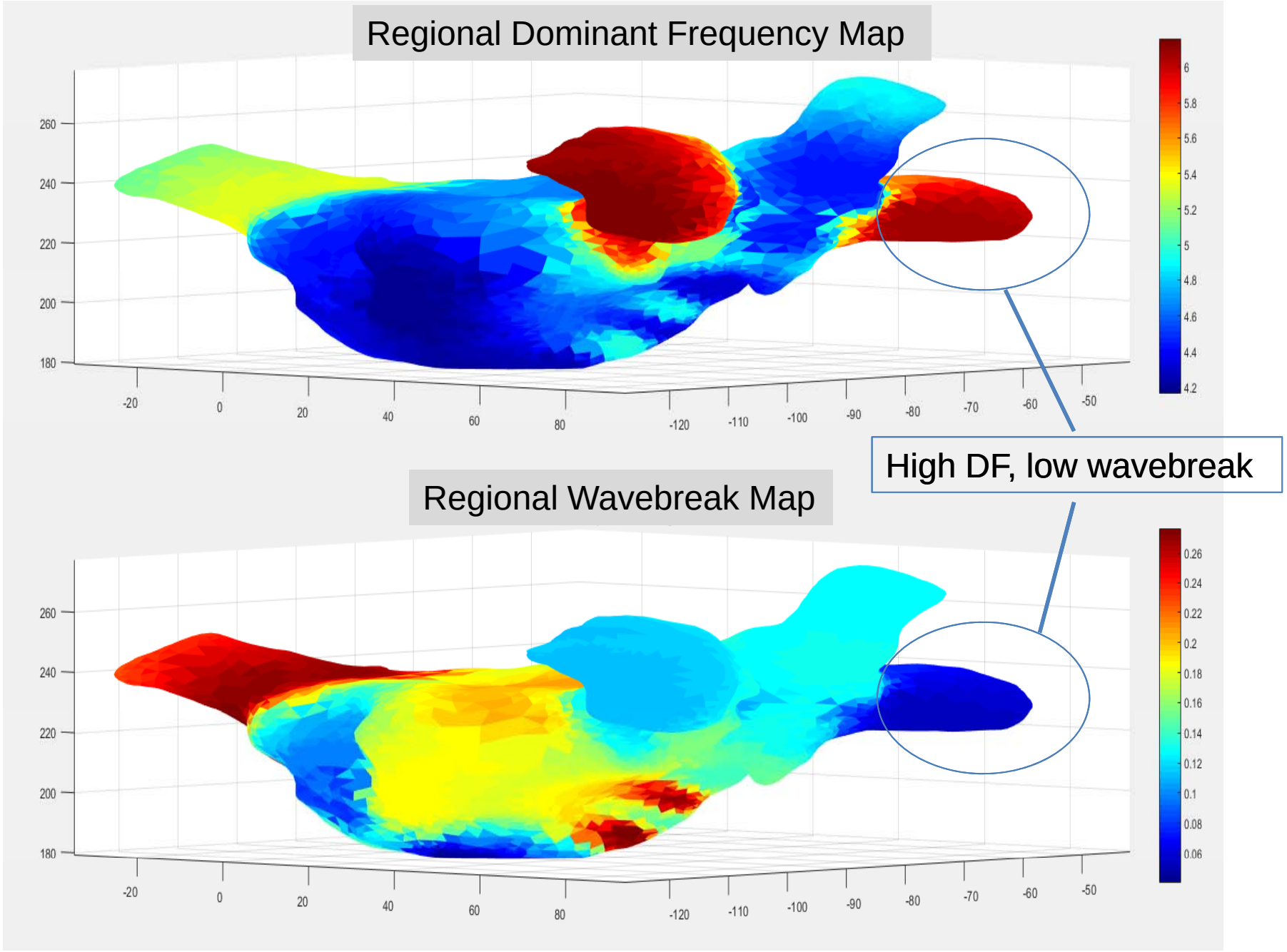
Addition of low pass filter allows appreciation of the wavefront disorganization


IEGM
Preprocessed
Mean of the Preprocessed Signals
Output of the Lowpass Filter
CDF
Time
(A)
(B)
Time
Time

Right atrial site with very high catheter and EGM DF, but multiple wave breaks

Periodic wave break

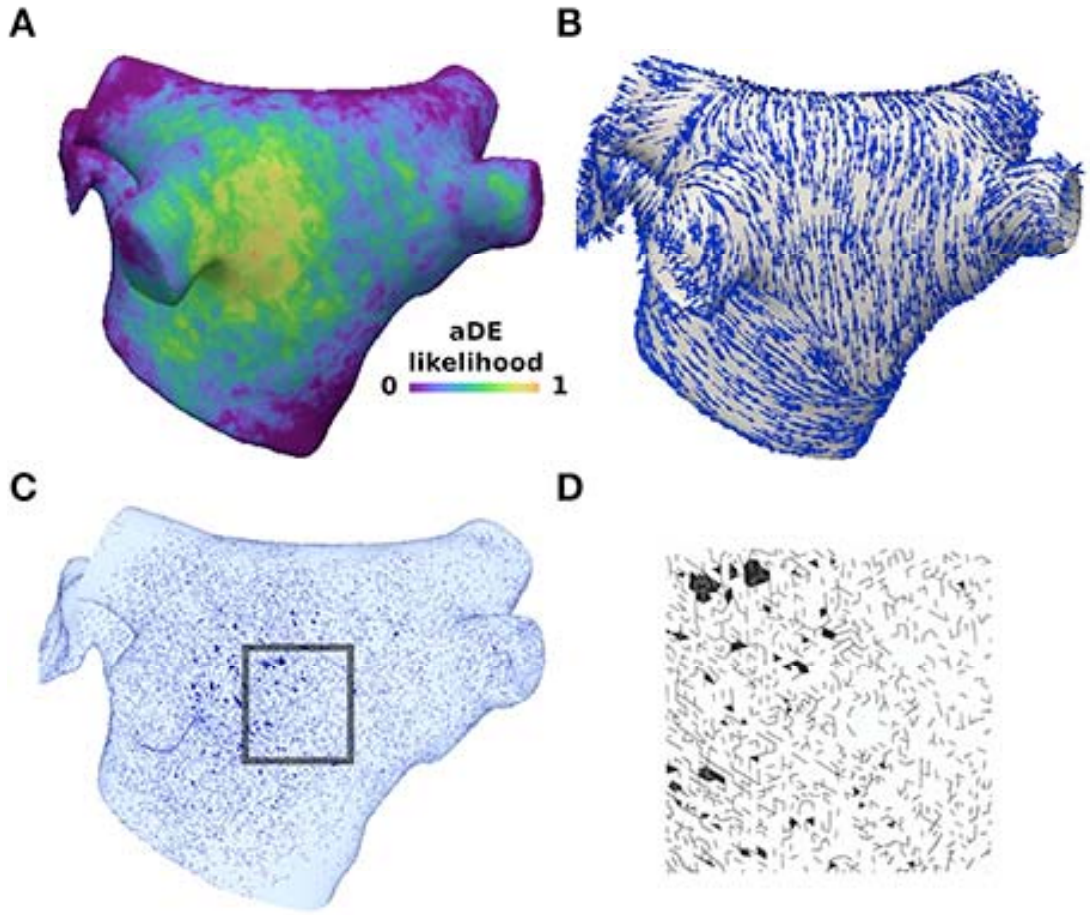



Regional Dominant Frequency Map
260
240
220
200
180
-20
0
20
40
60
80
-120
-110
-100
-90
-80
-70
-60
-50
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
High DF, low wavebreak
Regional Wavebreak Map
260
240
220
200
180
-20
0
20
40
60
80
-120
-110
-100
-90
-80
-70
-60
-50
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06

Next Steps

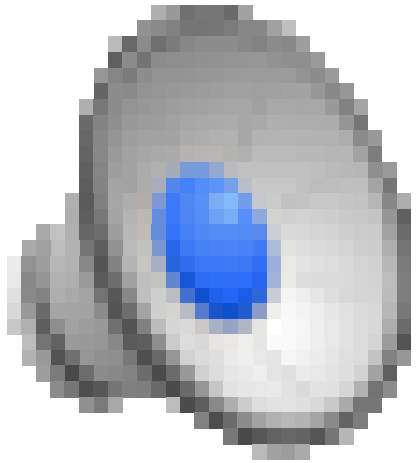
- AF modelling….in silico studies

Novel Radiofrequency Ablation Strategies for Terminating Atrial Fibrillation in the Left Atrium: A Simulation Study



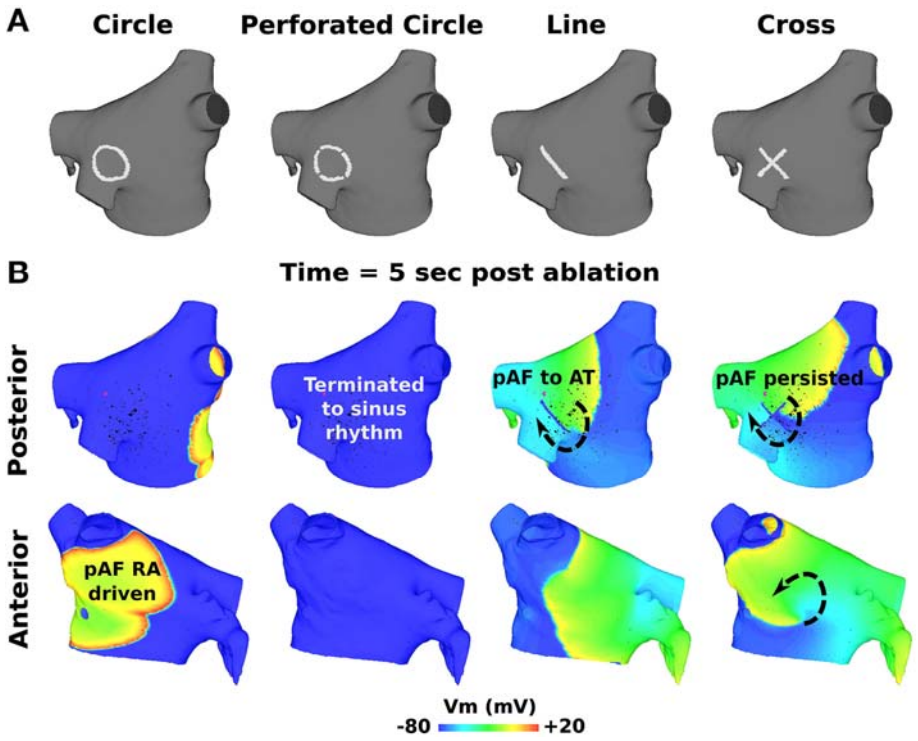
Bayer JD. Front. Physiol. 7:108.

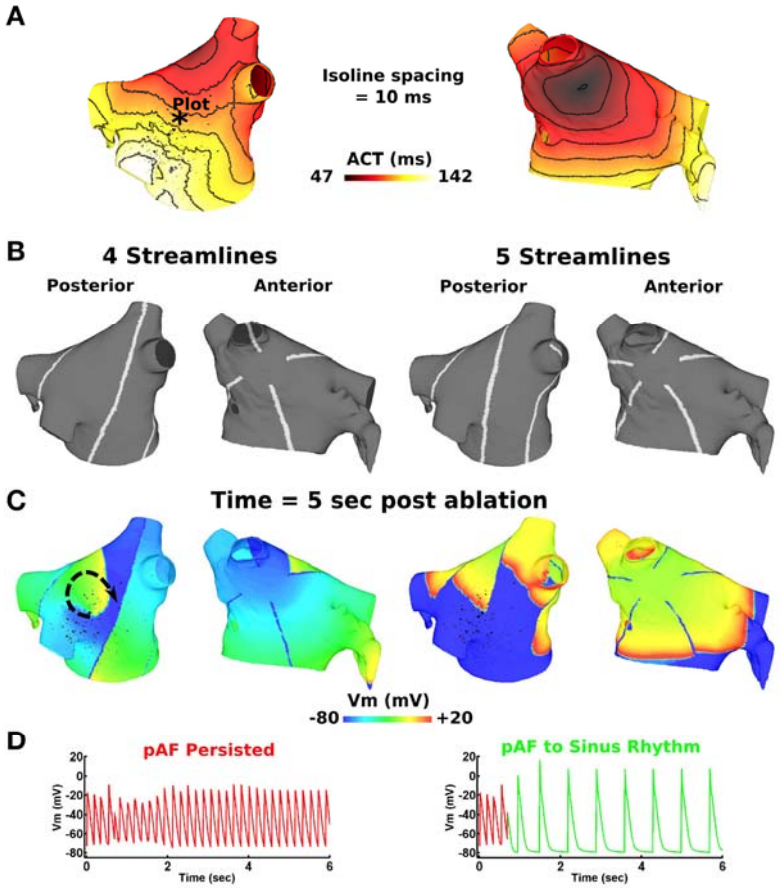
Novel Radiofrequency Ablation Strategies for Terminating Atrial Fibrillation in the Left Atrium: A Simulation Study



Next Steps

- AF modelling….in silico studies





Redfearn 2016

Next Steps

Tool	Study	Design	FU mths	Outcome – freedom from AA
Basket	Berntsen et al Heart Rhythm 2016;0:0–7	PAF Cohort	15 ± 4	22%
Basket	Mohanty et al JACC 2016 in press	Persis RCT	12±7	14%
CFE + PVI	Atul Verma N Engl J Med 2015;372:1812-22	Persis RCT	18	49%
DF + PVI	Felipe Atienza J Am Coll Cardiol 2014;64:2455–67)	Persis RCT	12	67%
Body surface	Haïssaguerre M. Circulation. 2014;130:530–8	Persis Cohort	12	64%
EGM voltage	Jadidi. *Circ Arrhythm Electrophysiol*. 2016;9:	Persis cohort	13	69%
Cox	Weimer. Circ Arrhythm Electrophysiol . 2012 1; 5(1): 8–14.	Persis cohort	71	93%

Discussion

- Traditional approaches to persistent AF (PVI, lines, CFE) appear to have failed to achieve success desired.
- Rotational wavefronts occur in many places and do not necessarily imply a ‘rotor’ as driving source.
- Source guided approaches via surface or regional approaches may offer better success through clinical and in silico results.
- Regional sequential approaches should not yet be abandoned, both regional DF and wavebreak assessments may categorize sources from collision and wave break up points.
- Containment techniques show best results in silico and in clinical practice (CM III) and may be required in patients with significant substrate disease (Utah IV).

Queen's School of Computing & Department of Medicine

Queen's University
Kingston, Ontario, Canada

Queen's University

I am therefore I compute

175 YEARS

Thank you

CIHR IRSC
Canadian Institutes of Health Research
Instituts de recherche en santé du Canada