Pace-mapping to identify post-infarct VT isthmus sites for non-inducible VT

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DISCLOSURES

FINANCIAL DISCLOSURE:

Research grant: Abbott

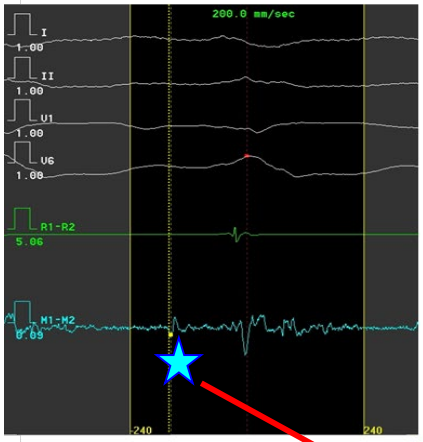
Consulting & Speaker: Abbott, Biosense Webster, Boston Scientific, Meda Pharma, Medtronic, Micro-Port, Stereotaxis

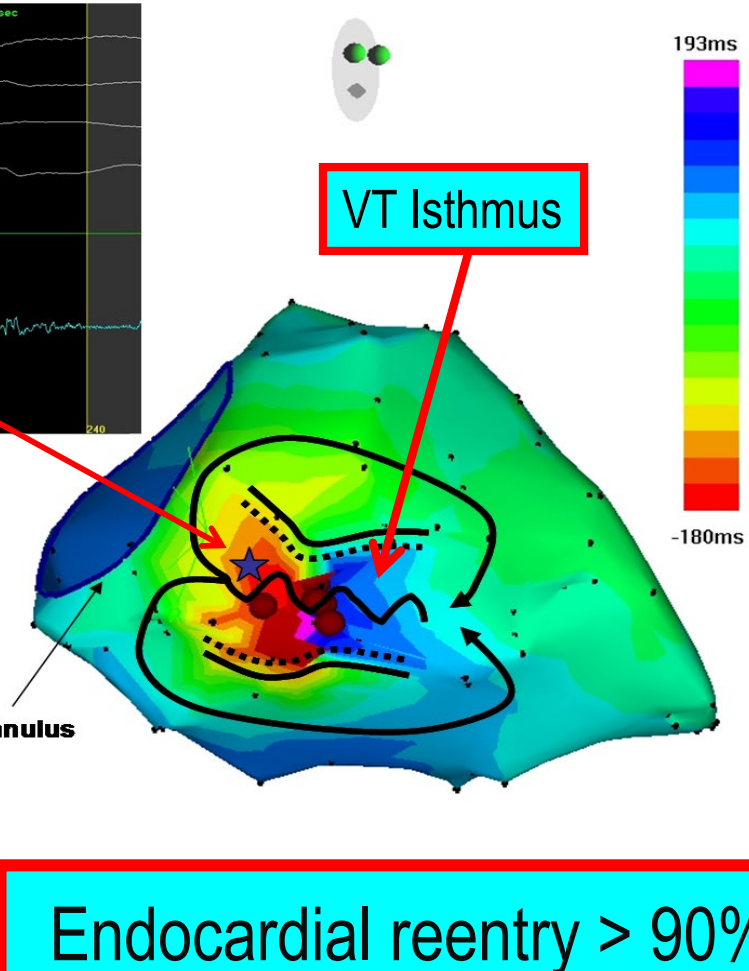
PATENT / SOFTWARE DISCLOSURES:

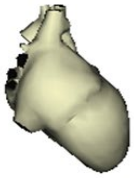
US patent # 20180089825A1

Software SMARTIS®

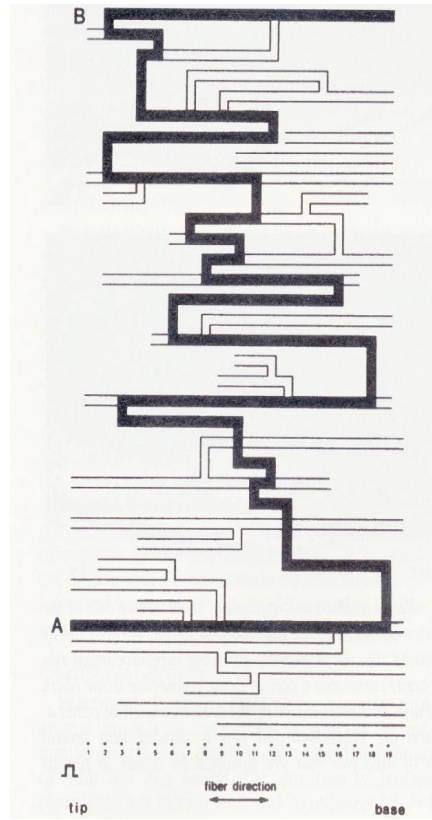
Post-infarct mappable VT







Endocardial reentry > 90%
of post-MI mappable VTs



Surviving myocytes
+
Surrounding fibrosis

➔Slow conduction

Slow conduction perpendicular to the fiber direction in infarcted myocardial tissue is caused by a ''zigzag" course of activation at high speed. Activation proceeds along pathways lengthened by branching and merging bundles of surviving myocytes unsheathed by collagenous septa.

de Bakker JMT. et al. Circulation 1993;88:915-26

VT circuit mapping ➔ limitations

- VT non inducible = 14%
- 12-lead ECG during VT non available = 30%
- VT non tolerated = 70%

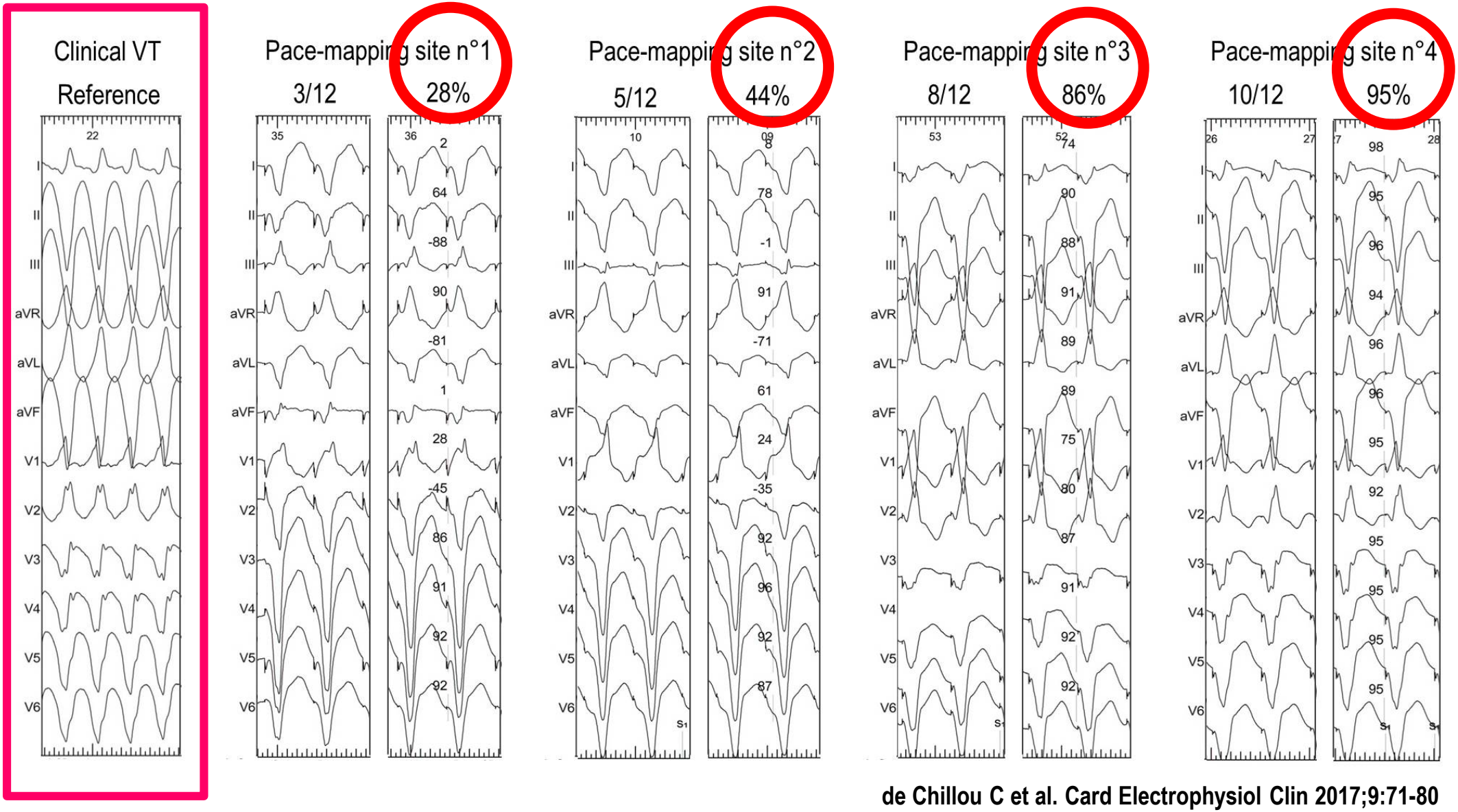
Possibility to map at least one VT morphology in only 25% of patients

(Pr Paolo Della Bella – ESC 2012)

Pace-mapping is able to unmask post-infarct VT isthmuses during sinus rhythm

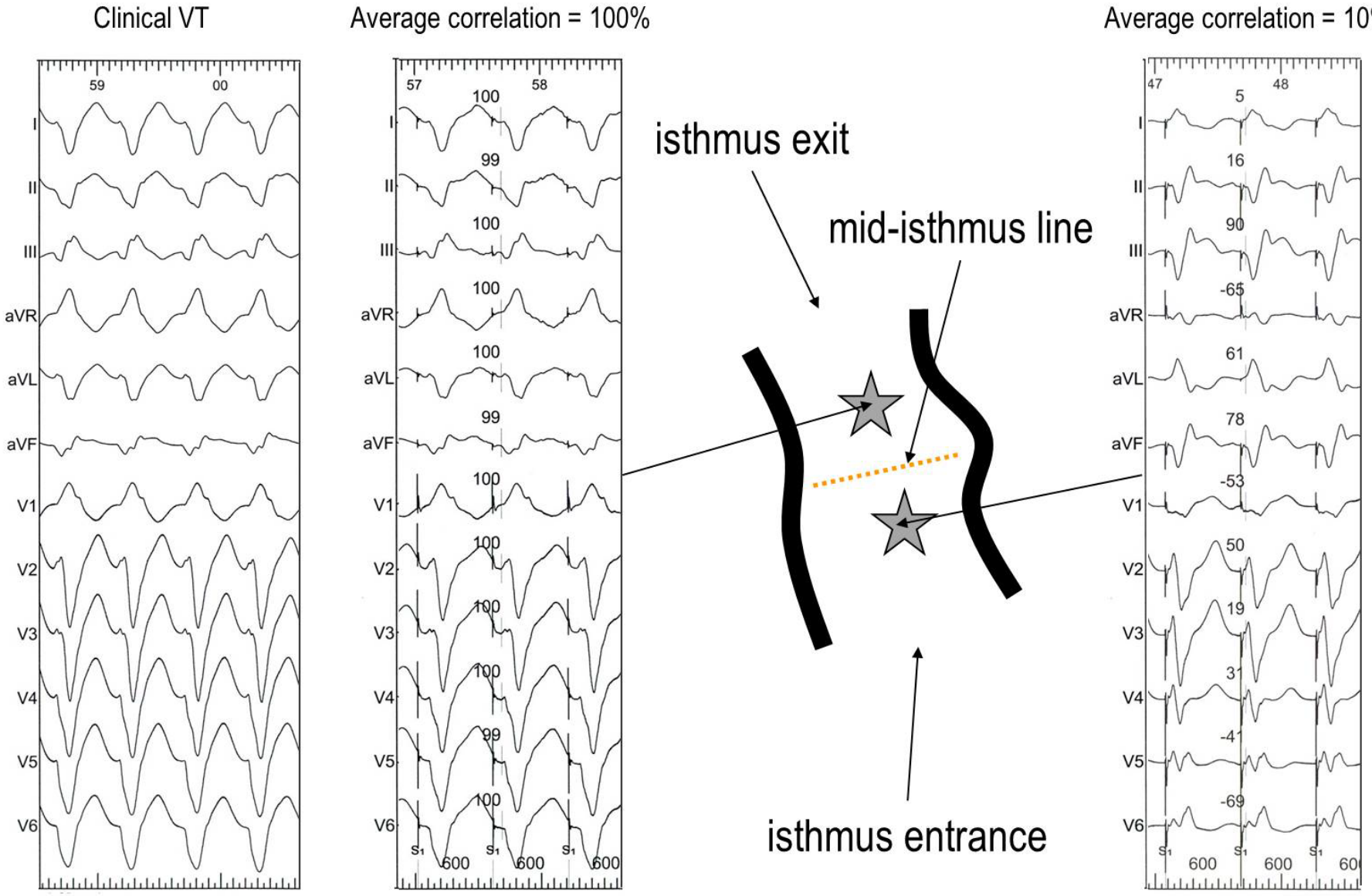
(de Chillou C et al. Heart Rhythm 2014;11:175-181)

The pace mapping technique: comparison between VT morphology and ECG generated at each pacing site



de Chillou C et al. Card Electrophysiol Clin 2017;9:71-80

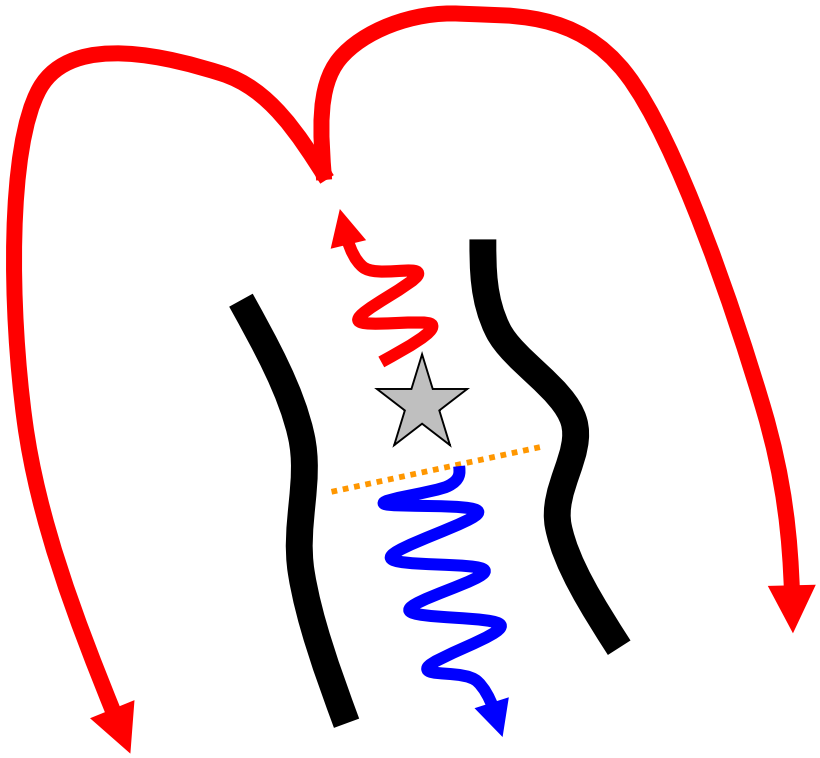
Pace-mapping within a post-infarct VT isthmus



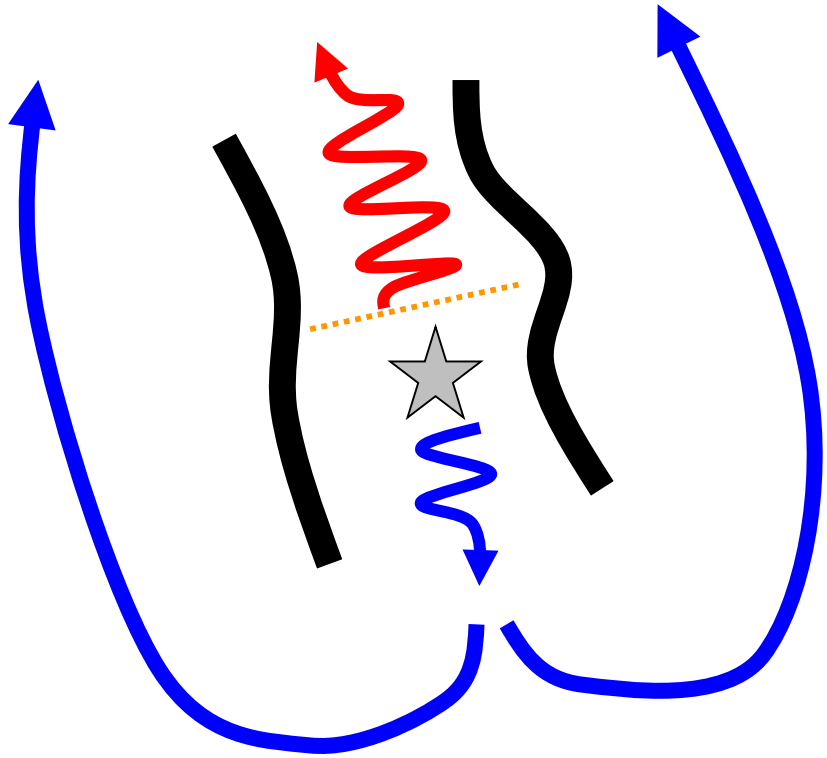
de Chillou C et al. Card Electrophysiol Clin 2017;9:71-80

Pace-mapping within a post-infarct VT isthmus

Propagation maps are different ➔ 12-lead ECGs are different



Pacing during SR immediately **after** the mid-isthmus limit



Pacing during SR immediately **before** the mid-isthmus limit

Applying the "pace-mapping technique" first requires to record an ECG during VT

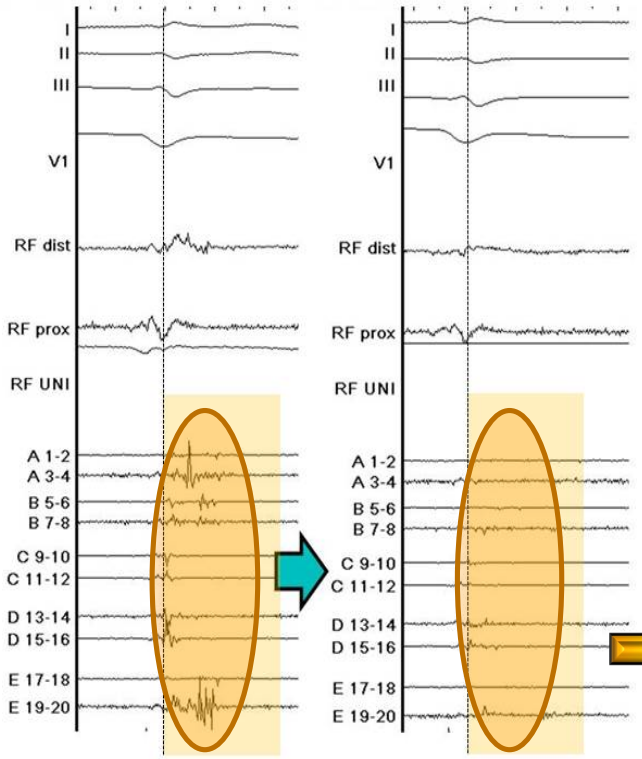
What to do when there is no VT inducible ?

Slow conduction area
(post-infarct VT substrate)

"Substrate-based" identification

Can pace mapping be used as a powerful tool when there is no VT reference ?

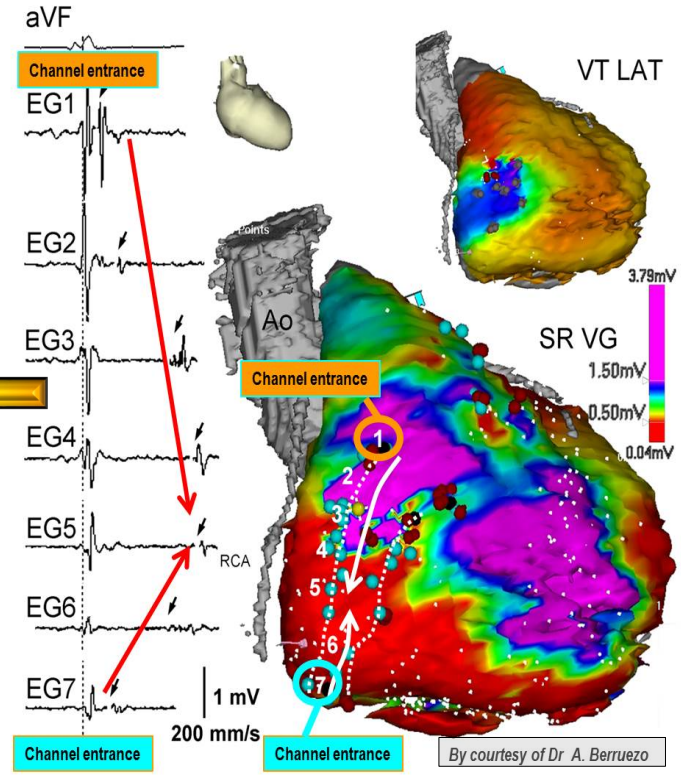
"Channel-based" identification



Jaïs P et al. Circulation 2012;125:2184-96

Elimination of LAVAs (or late potentials)

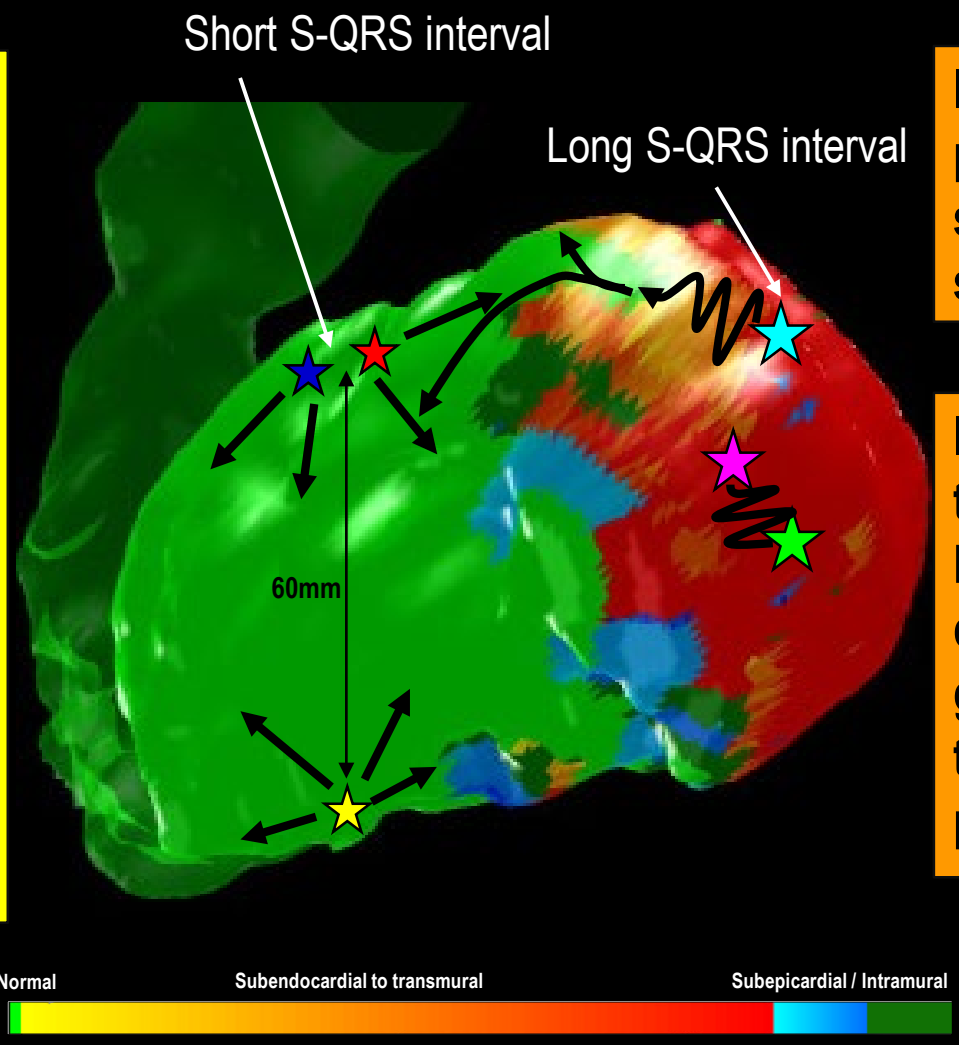
Elimination of scar-related channels

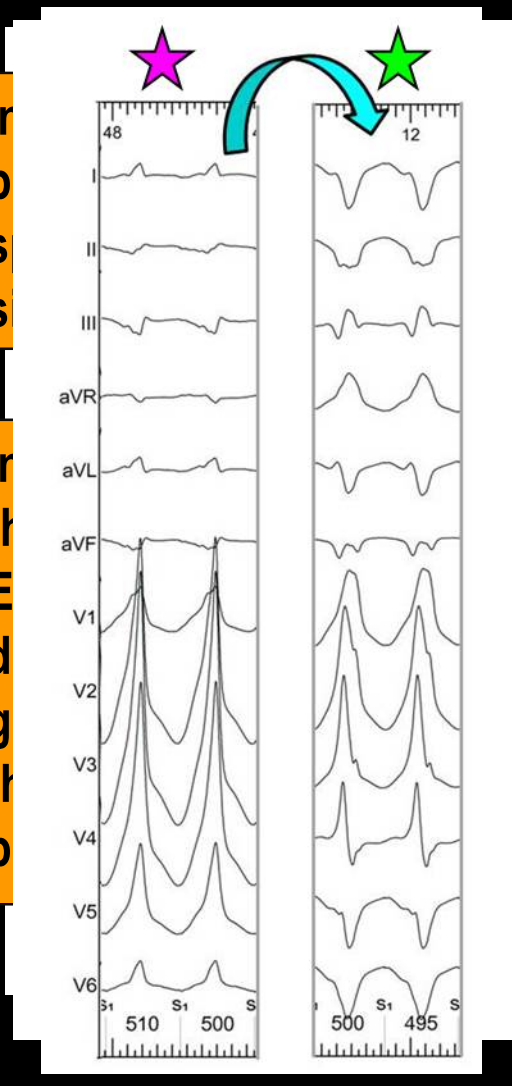


Principles of ventricular pace mapping

The ECG pattern generated by pace-mapping at a given site does not depend on the ECG pattern during VT

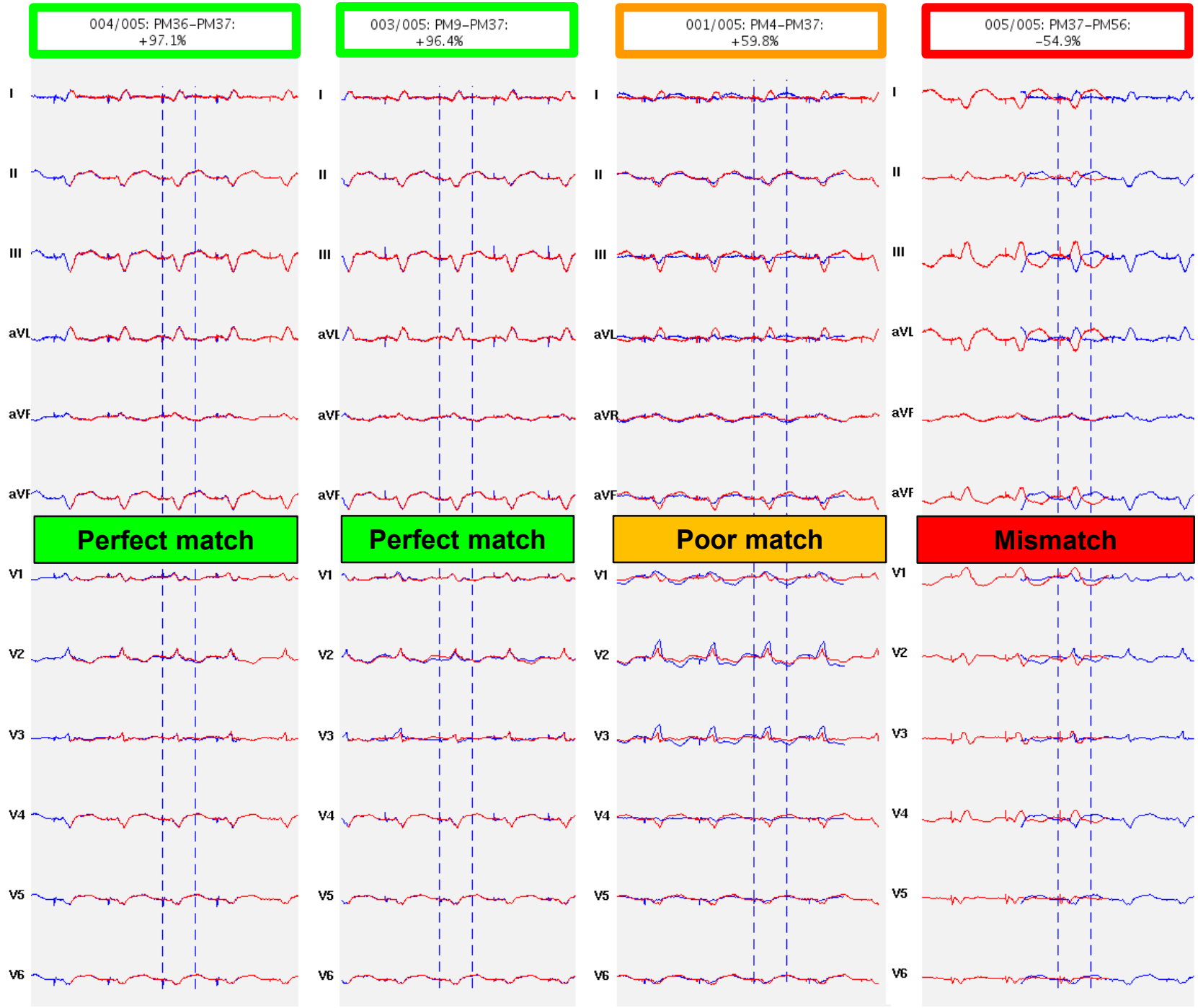
An abrupt change in ECG morphology between two closely spaced pacing sites indicates that there is a slow conduction between these two pacing sites (as it has been shown when pacing in a VT isthmus)





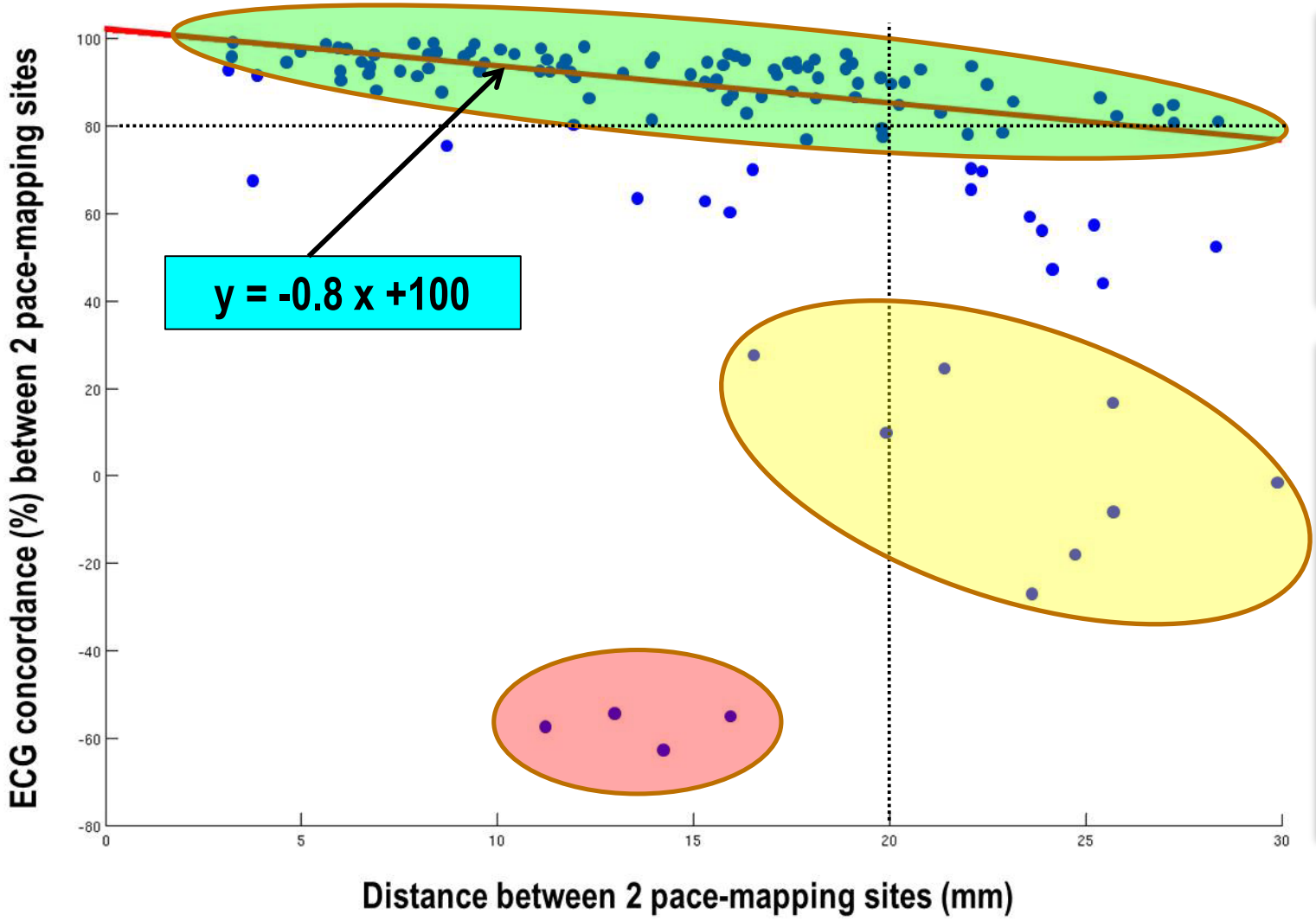
Head to head comparison of ECGs obtained at close (<20mm) pace-mapping sites

PM37 vs. PM36
PM37 vs. PM9
PM37 vs. PM4
PM37 vs. PM56



ECG concordance in relation to the distance between two pace-mapping sites

121 head to head comparisons

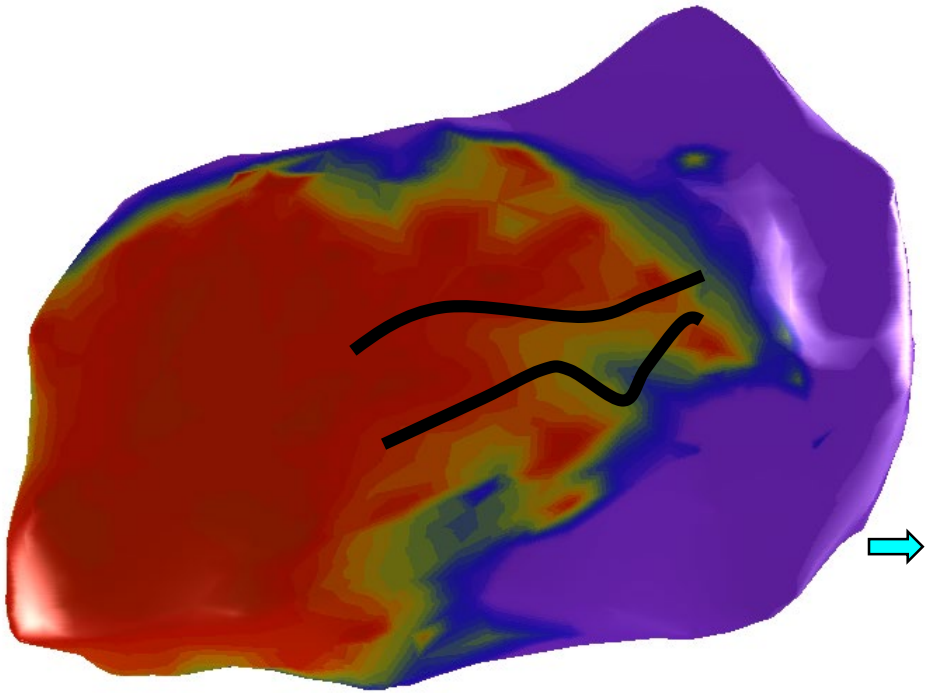


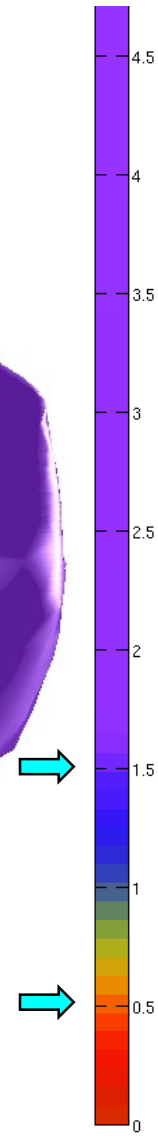
The percentage of correlation between 2 ECG decreases by 0.8% per mm

PMx - PMy = 5mm
➔ expected ECG concordance = 96%

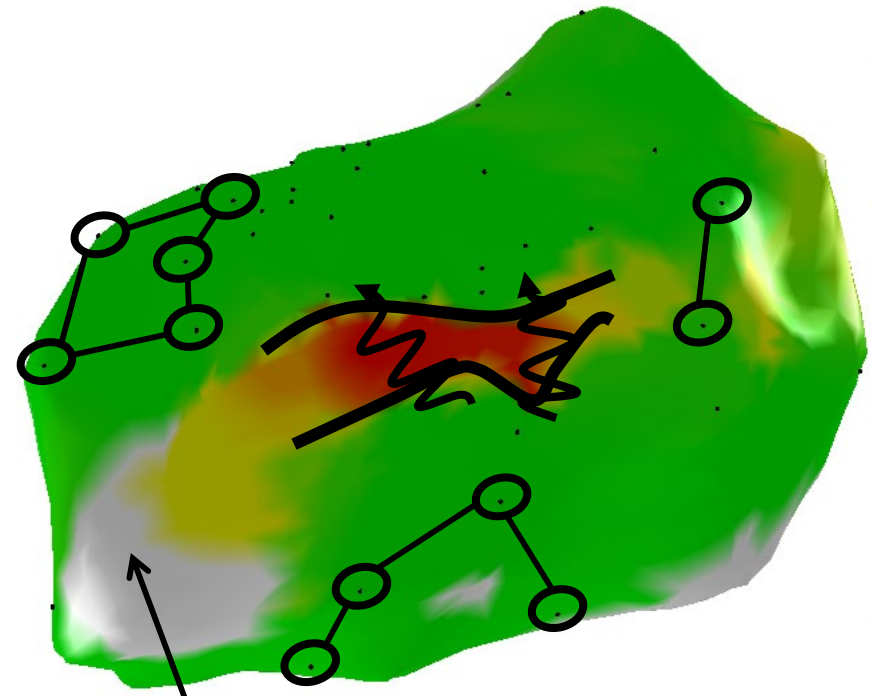
PMy - PMz = 15mm
➔ expected ECG concordance = 88%

Voltage Map

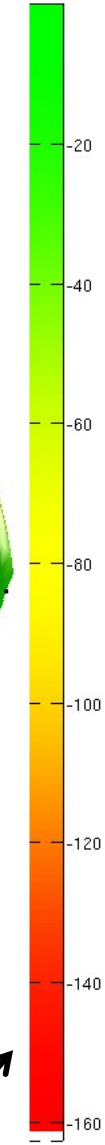




ECG-mismatch Map

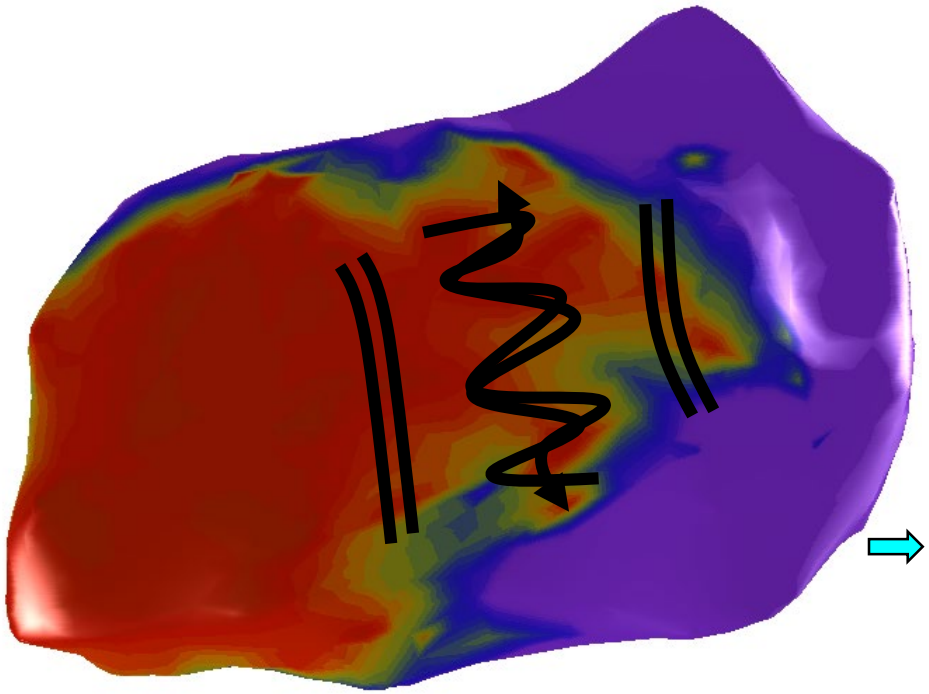


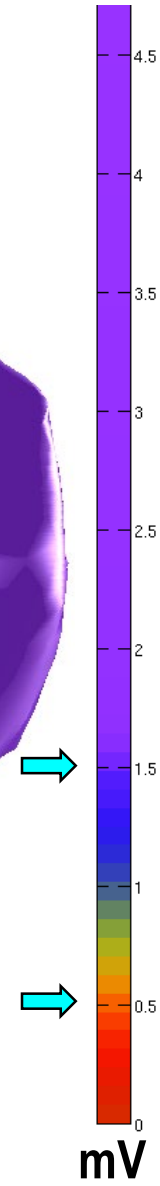
Distance too important between 2 pacing sites



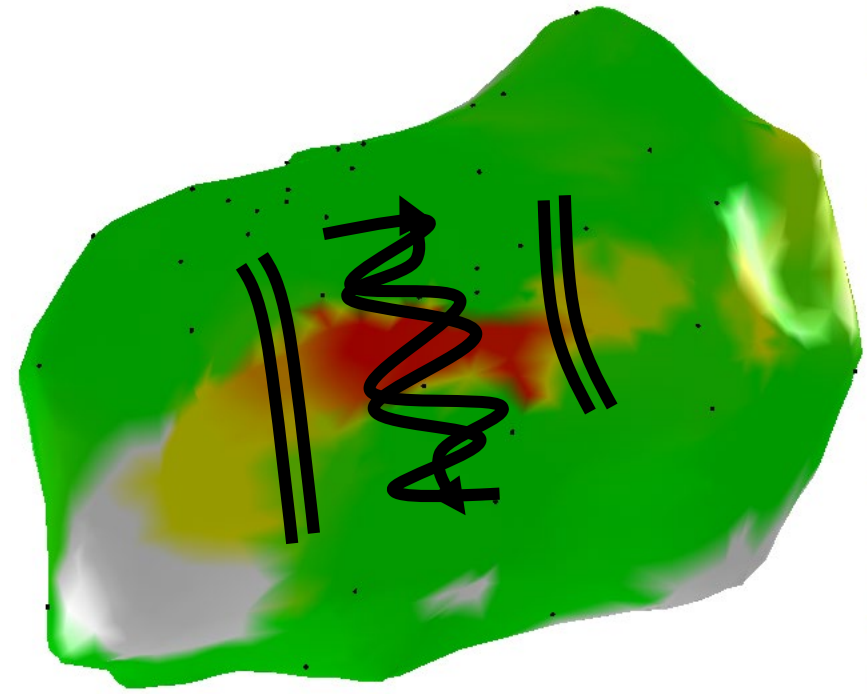
Mismatch scale

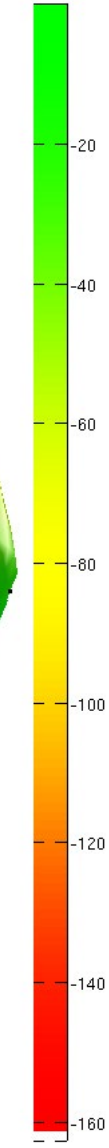
Voltage Map





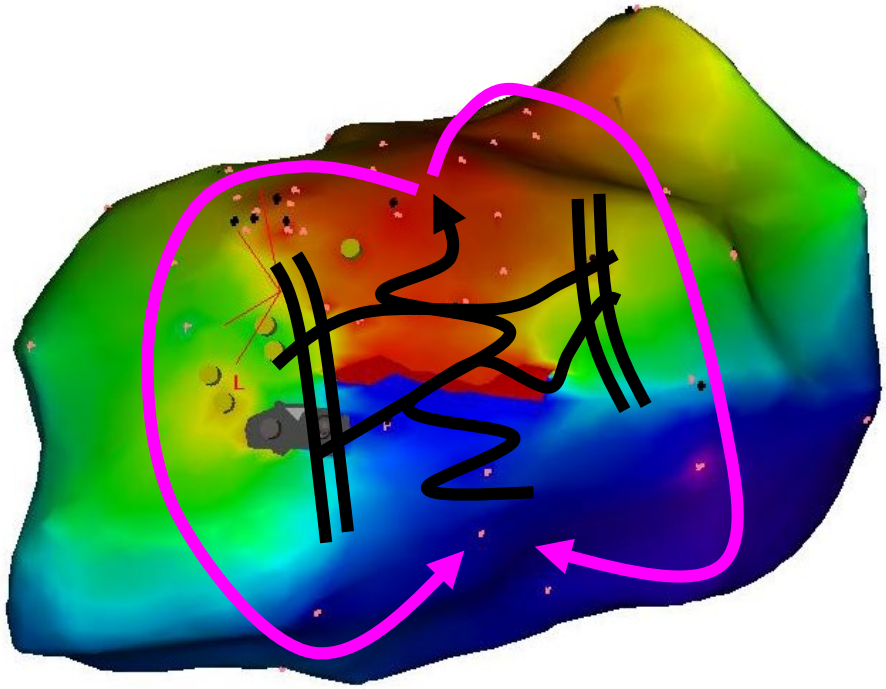
ECG-mismatch Map





Slow conduction map

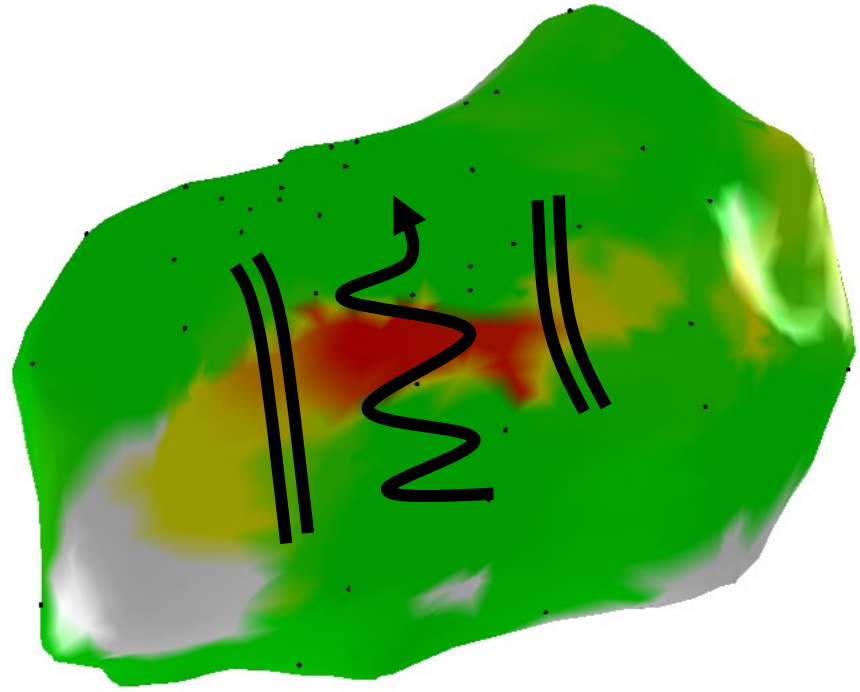
Pace-mapping Map



91%

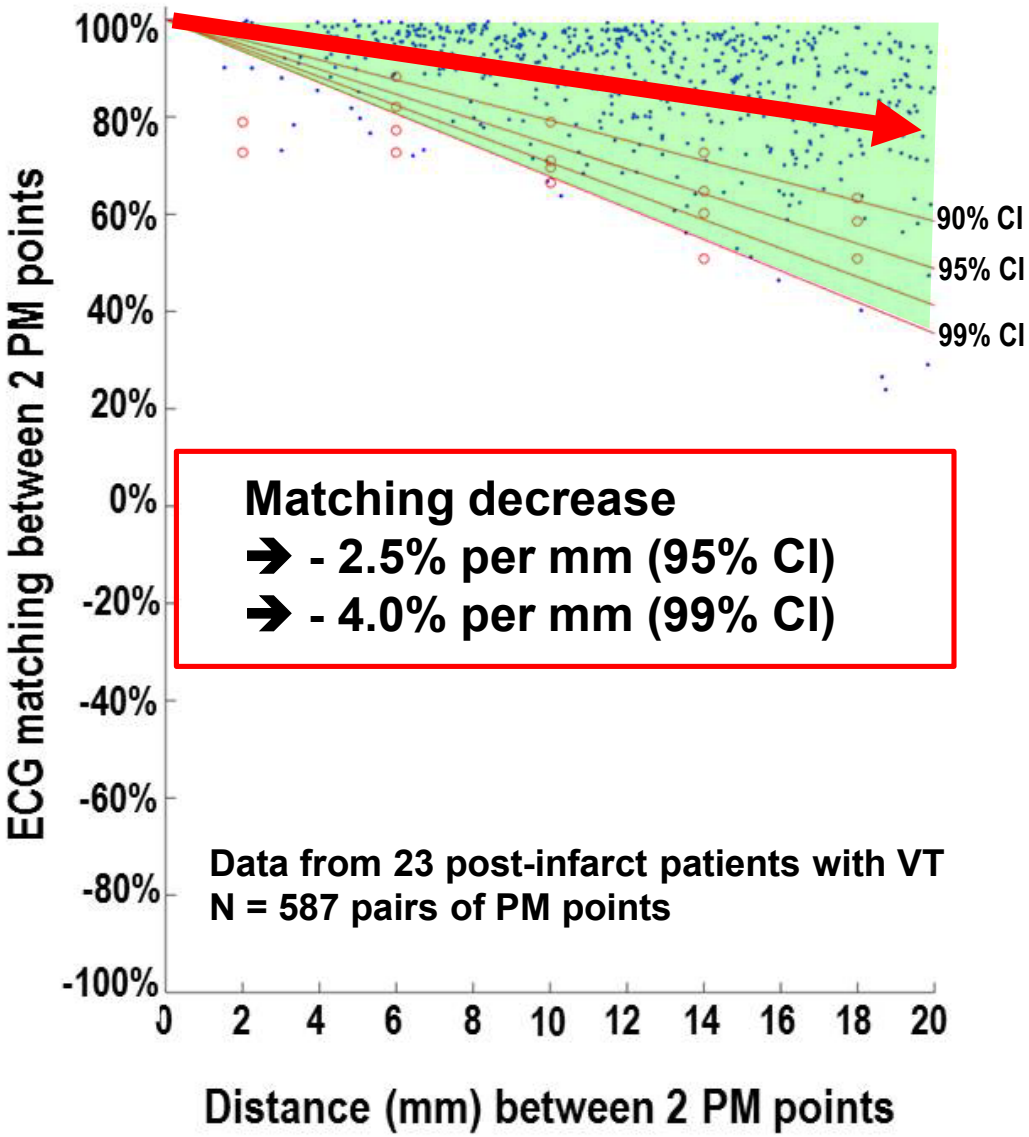
-36%

ECG-mismatch Map

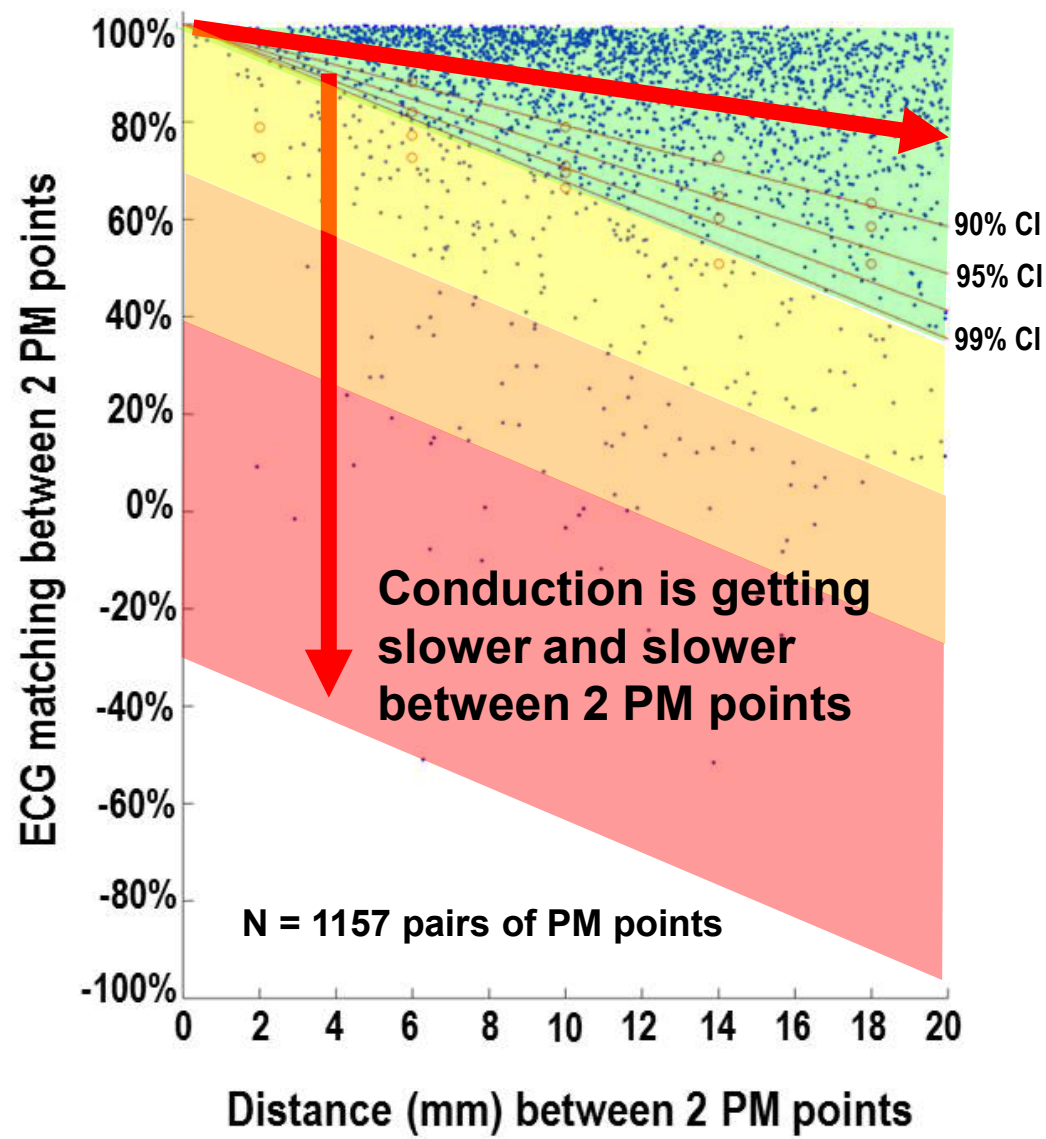


Slow conduction map

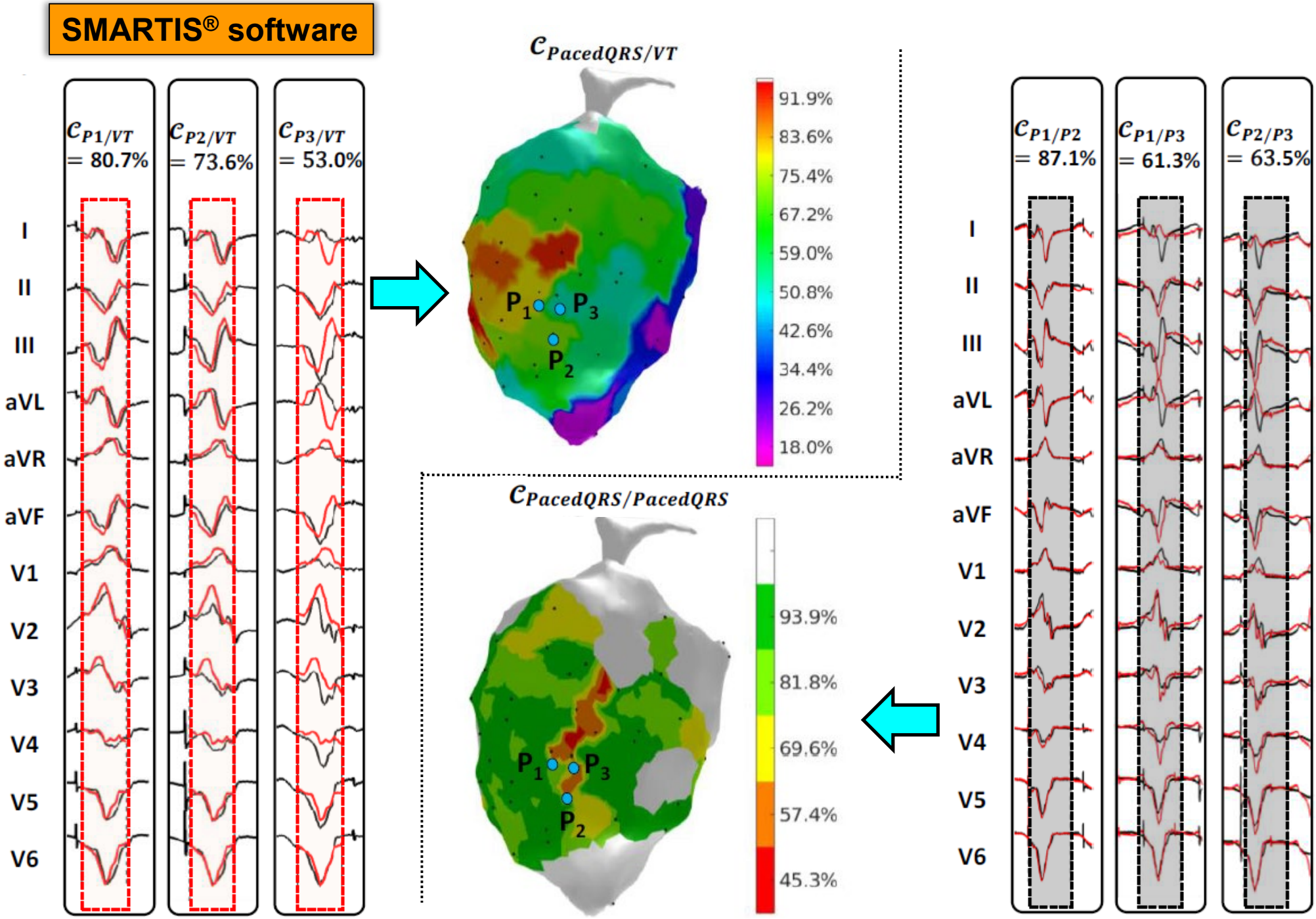
PM points in healthy area



PM points in scar area



Odille F, de Chillou C et al. IEEE Trans Biomed Eng 2019 Mar 7. doi:10.1109/TBME.2019.2903631


SMARTIS® software
$c_{P1/VT}$ = 80.7%
$c_{P2/VT}$ = 73.6%
$c_{P3/VT}$ = 53.0%
I
II
III
aVL
aVR
aVF
V1
V2
V3
V4
V5
V6
$c_{PacedQRS/VT}$
91.9%
83.6%
75.4%
67.2%
59.0%
50.8%
42.6%
34.4%
26.2%
18.0%
P1
P2
P3
$c_{PacedQRS/PacedQRS}$
93.9%
81.8%
69.6%
57.4%
45.3%
$c_{P1/P2}$ = 87.1%
$c_{P1/P3}$ = 61.3%
$c_{P2/P3}$ = 63.5%

The "mathematical corner"
Correlation and spatial gradient between 2 ECGs

- Correlation between the ECG obtained at a given pace-mapping site (x) and an ECG during VT:

$$\mathcal{C}_{PacedQRS/VT}(\boldsymbol{x}) = \frac{1}{12}\sum_{lead=1}^{12} c\left(S^{lead}_{PacedQRS}(\boldsymbol{x}), S^{lead}_{VT}\right)$$

- ➔ Spatial gradient:

$$\mathcal{G}_{PacedQRS/VT}(\boldsymbol{x}) = \left|\nabla \mathcal{C}_{PacedQRS/VT}(\boldsymbol{x})\right| \simeq \frac{\left|\mathcal{C}_{PacedQRS/VT}(\boldsymbol{x}+\boldsymbol{\delta x}) - \mathcal{C}_{PacedQRS/VT}(\boldsymbol{x})\right|}{\|\boldsymbol{\delta x}\|}$$

- Correlation between two ECG obtained at 2 different pacing sites:

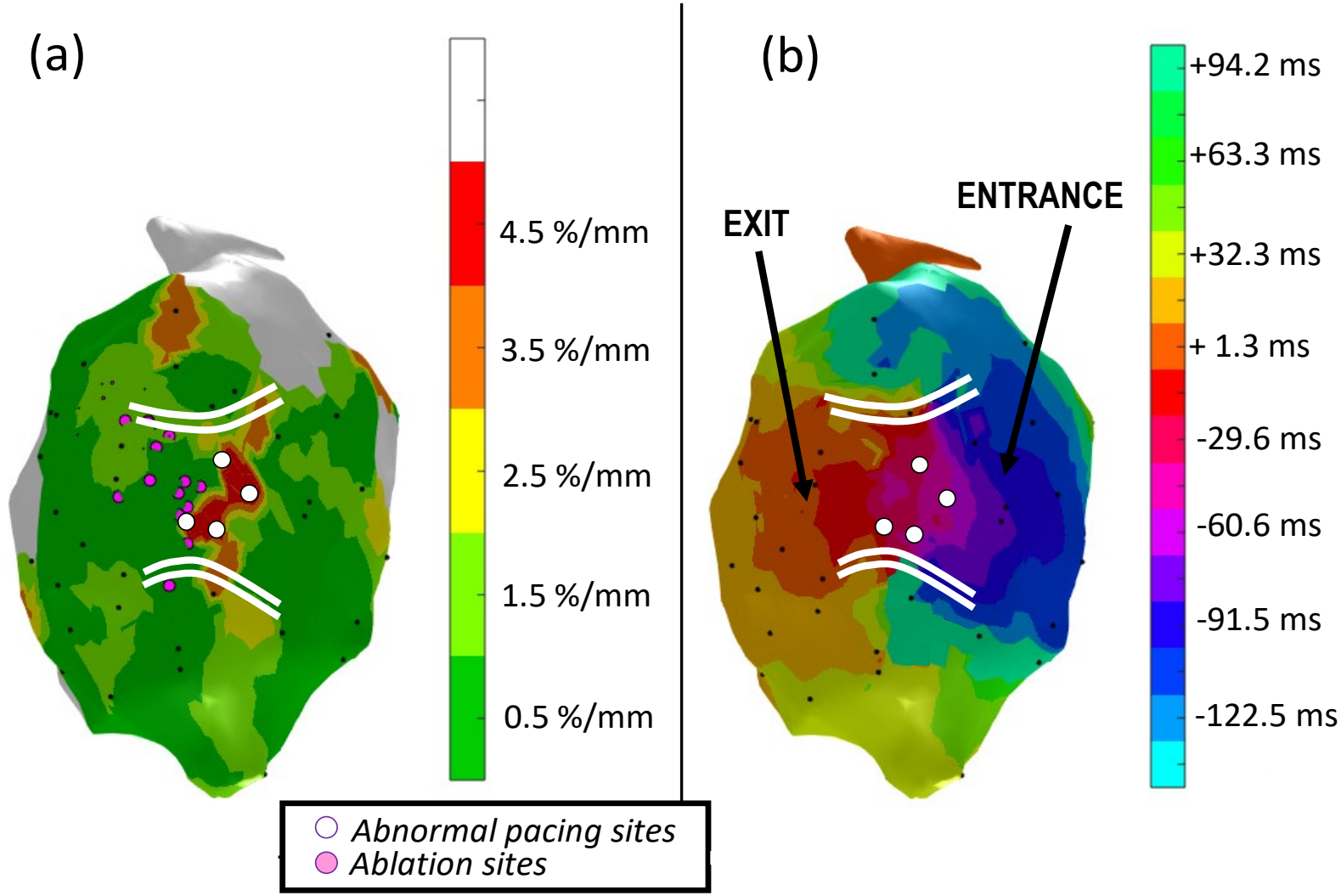
$$\mathcal{C}_{PacedQRS(\boldsymbol{x})}(\boldsymbol{x}+\boldsymbol{\delta x}) = \frac{1}{12}\sum_{lead=1}^{12} c\left(S^{lead}_{PacedQRS}(\boldsymbol{x}), S^{lead}_{PacedQRS}(\boldsymbol{x}+\boldsymbol{\delta x})\right)$$

- ➔ Spatial gradient:

$$\mathcal{G}_{PacedQRS/PacedQRS}(\boldsymbol{x}, \boldsymbol{x}+\boldsymbol{\delta x}) = \left|\nabla \mathcal{C}_{PacedQRS(\boldsymbol{x})}(\boldsymbol{x}+\boldsymbol{\delta x})\right| \simeq \frac{\left|\mathcal{C}_{PacedQRS(\boldsymbol{x})}(\boldsymbol{x}+\boldsymbol{\delta x}) - \mathcal{C}_{PacedQRS(\boldsymbol{x})}(\boldsymbol{x})\right|}{\|\boldsymbol{\delta x}\|} = \frac{\left|\mathcal{C}_{PacedQRS(\boldsymbol{x})}(\boldsymbol{x}+\boldsymbol{\delta x}) - 100\%\right|}{\|\boldsymbol{\delta x}\|}$$

Unit: % per mm

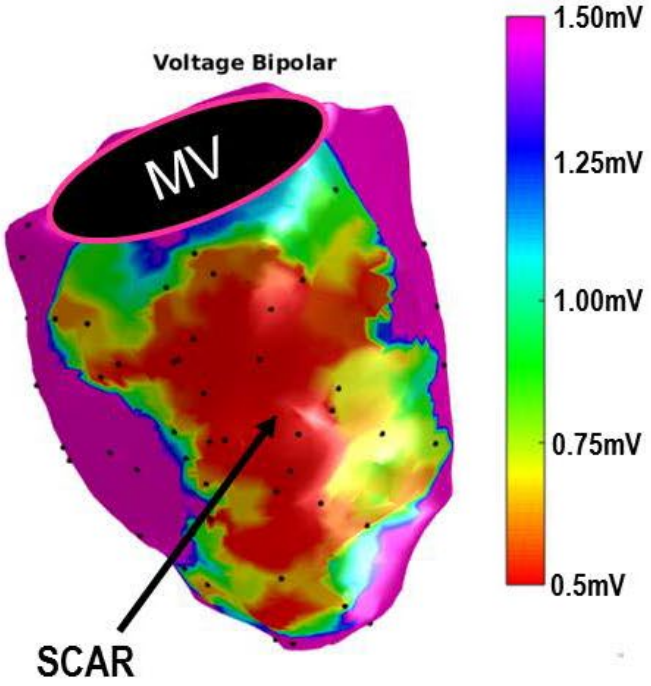
VT isthmus definition using pace-mapping with no need for a VT-reference ECG

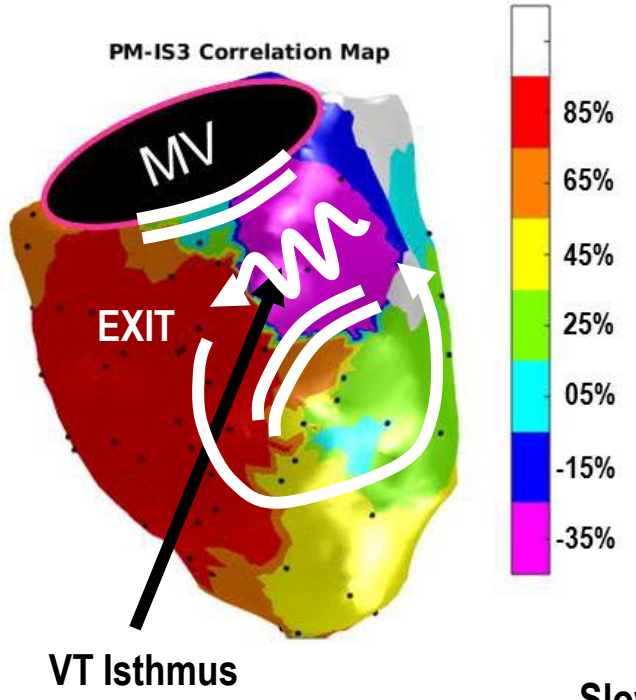


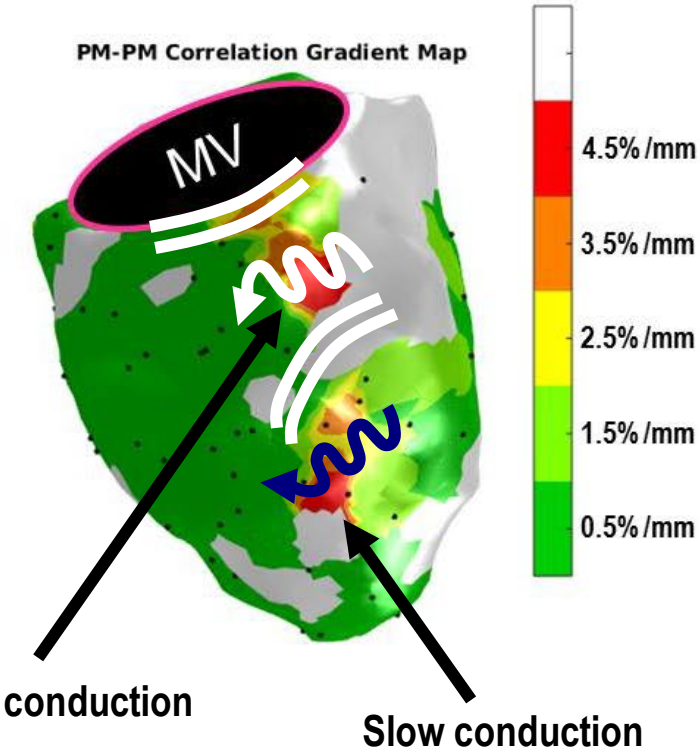
Odille F, de Chillou C et al. IEEE Trans Biomed Eng 2019 Mar 7. doi:10.1109/TBME.2019.2903631

Multiple slow conduction zones (isthmuses ?) #1

SMARTIS® software

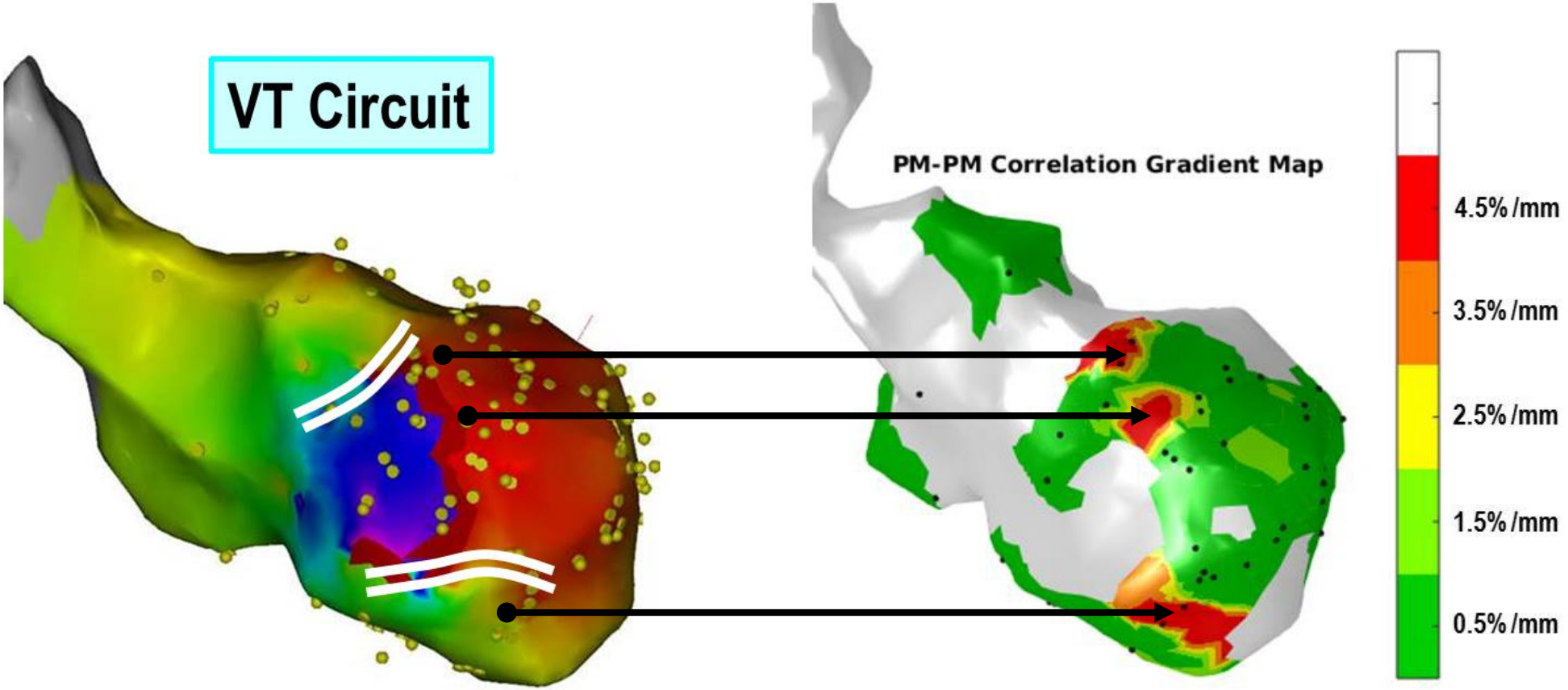


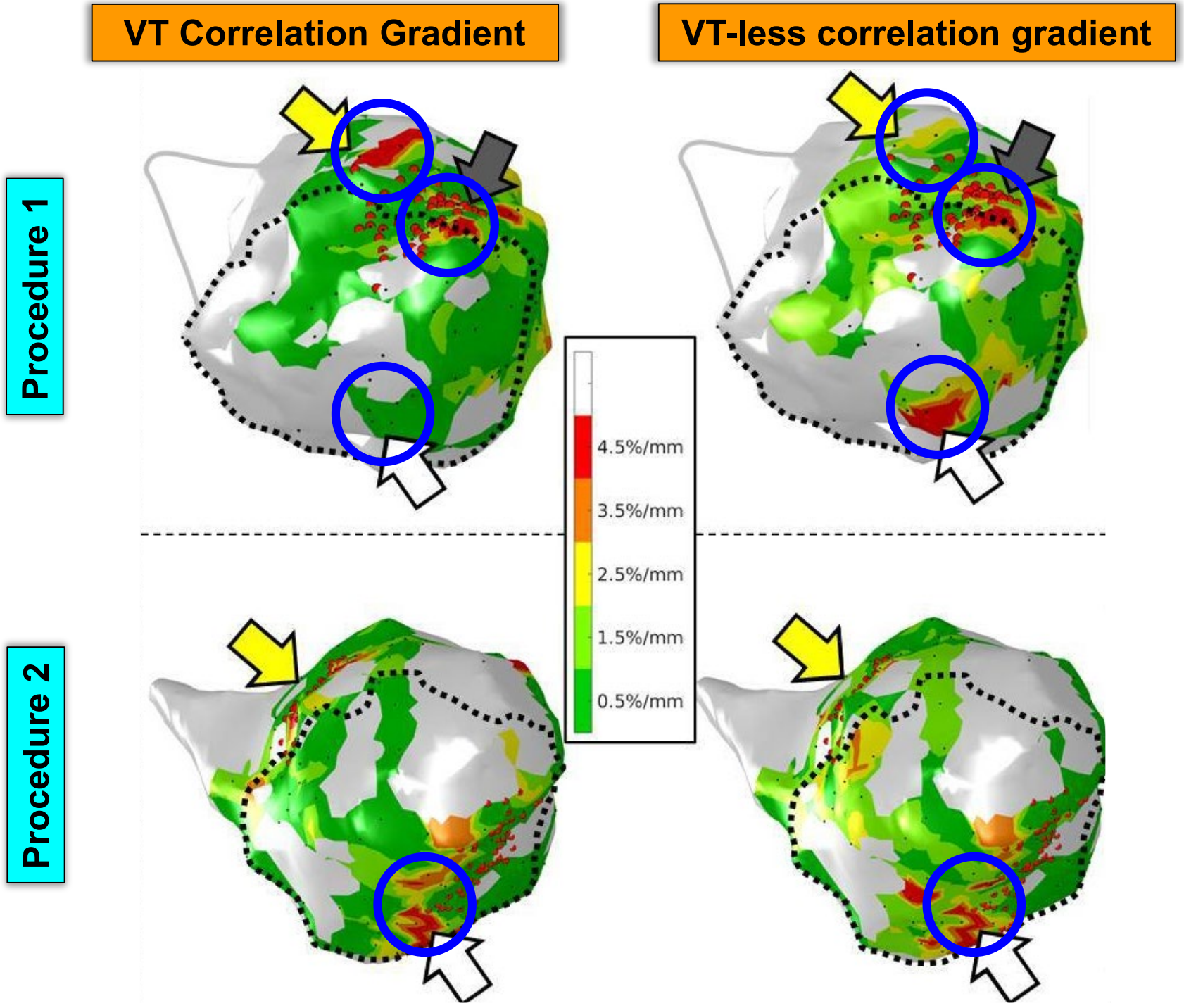




Multiple slow conduction zones (isthmuses ?) #2

SMARTIS® software




VT Correlation Gradient
VT-less correlation gradient
Procedure 1
Procedure 2
4.5%/mm
3.5%/mm
2.5%/mm
1.5%/mm
0.5%/mm

Conclusions

Conclusions

- A ‘pace-mapping’ map is a surrogate of an activation map
- Head-to-head comparison of all ECGs obtained at close (<20mm) pace-mapping sites → gradient correlation map → myocardial areas with preserved vs. slow conduction
- Retrospective data → slow conduction zones identified by SMARTIS® are matching with documented VT isthmuses
- Pace-mapping is able to unmask post-infarct VT isthmuses regardless the availability of a 12-lead ECG during VT
- Clinical evaluation → VT ablation guided by SMARTIS®