THE IMPORTANCE OF SCAR BORDER ZONE IN POST-MI VENTRICULAR TACHYCARDIA

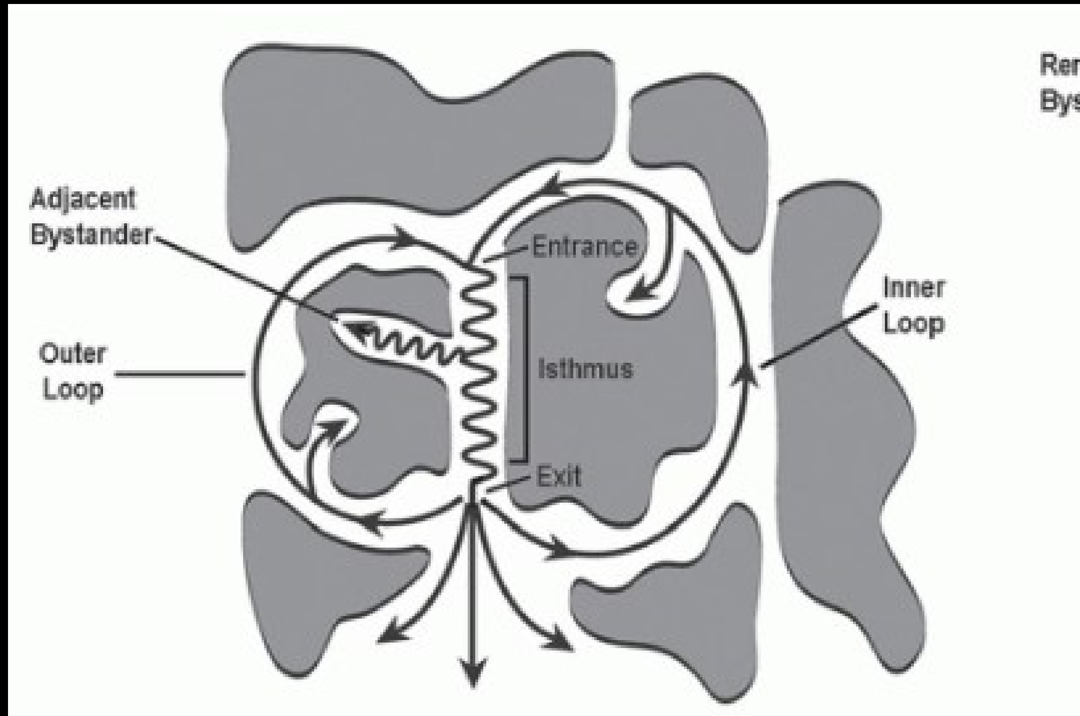
Robert Rademaker

Department of Cardiology, Willem Einthoven Centre of Arrythmia Research and Management

Border zones are always a source of problems

VT from non-reperfused myocardial infarction

- Macro re-entry circuits in areas <1.5mv BV with fixed block due to dense scar
- Stable circuits
- Entrainment, pace-mapping, (fractionated) late potentials



Classical re-entry circuit

Contemporary patients

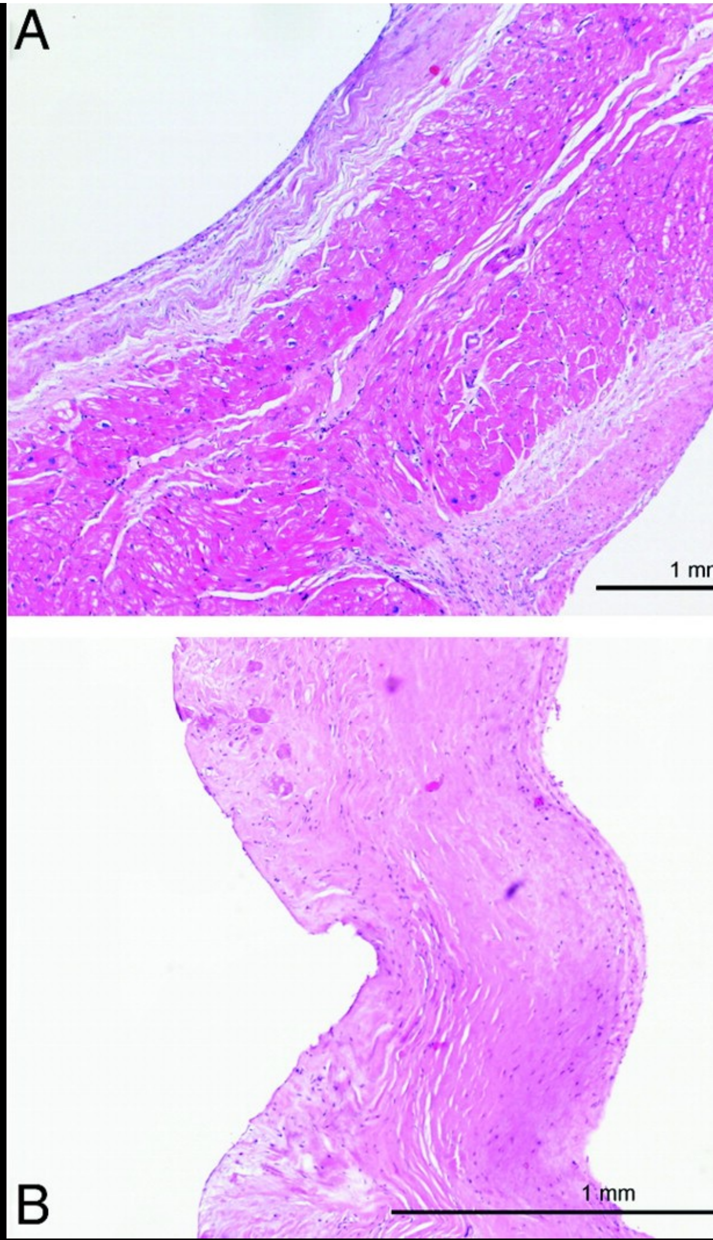
Patchy, non-transmural

- Early PCI and revascularization

- Early reperfusion yields:
  1. More patchy scar patterns
  2. Non-transmural scars
  3. Faster spontaneous VTs

Continuous, dense

- Larger scar border zones



Wijnmaalen et al 2010
Piers et al 2016

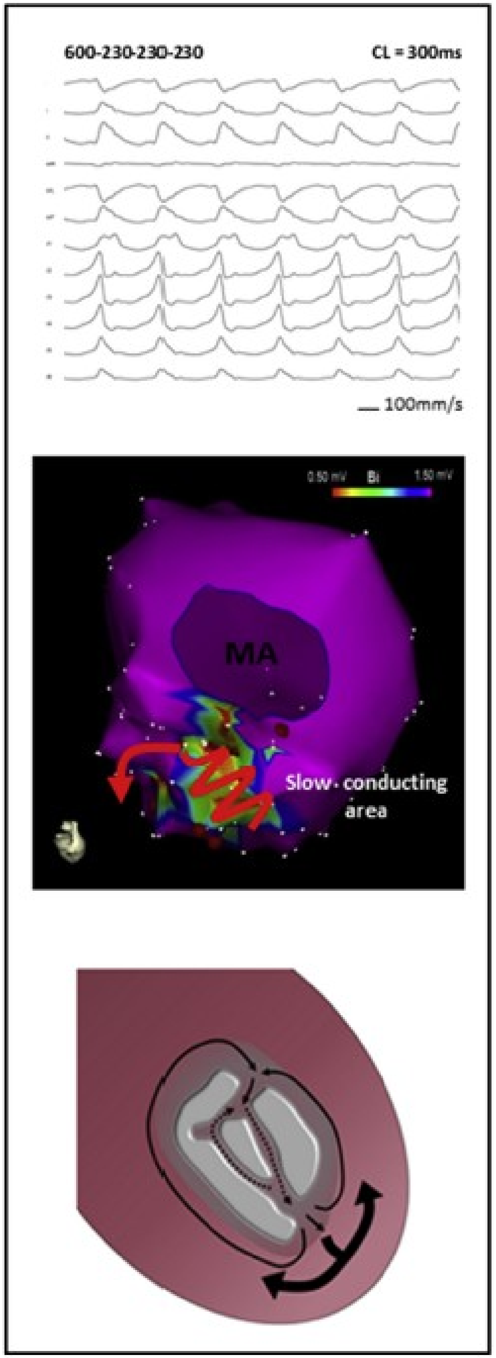
Our experience

1. After substrate ablation: non-inducibility of clinical monomorphic VTs

2. But: faster VTs remaining when close to V-ERP coming from the scar border zones

1: Watanabe et al 2018

Before RFCA



Can we understand the border zone?

Two questions arise:

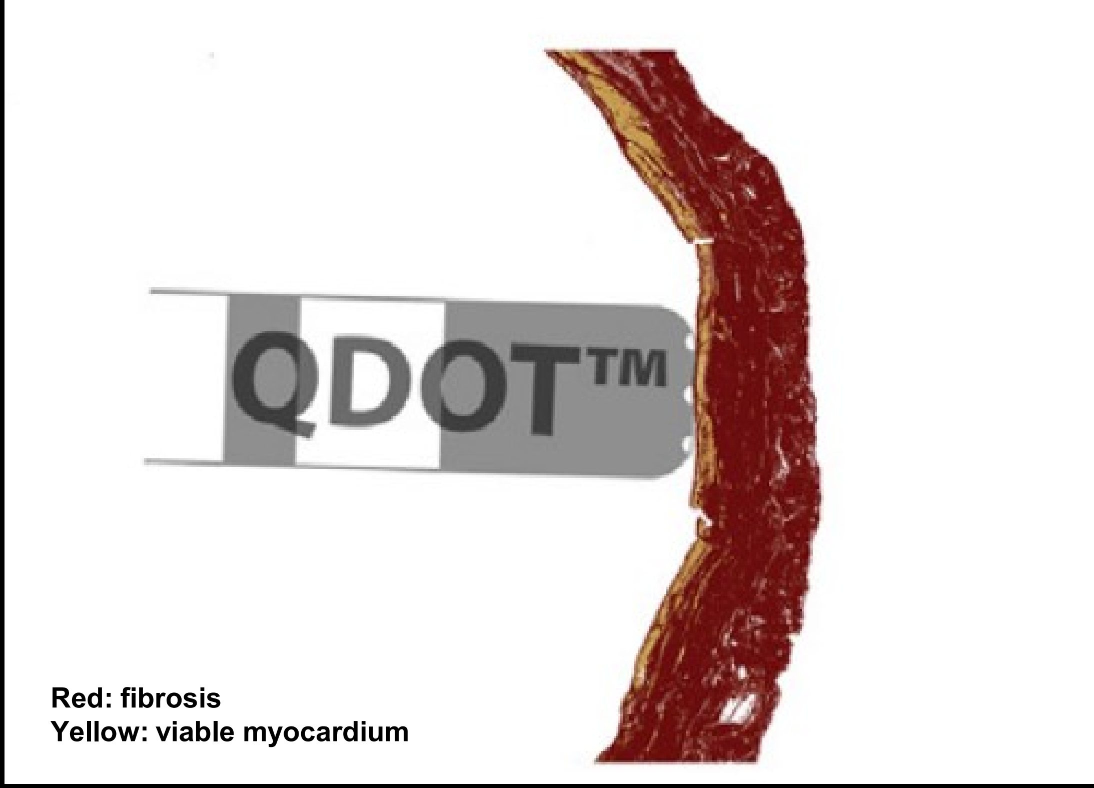
1. What exactly is the border zone as seen on voltage mapping?

2. What is the relationship between the border zone and fast VTs?

What exactly is the scar border zone?

The area between dense scar and normal, viable myocardium

- Lower limit:
  - The <0.5mV BV cutoff can accurately delineate transmural, dense scar



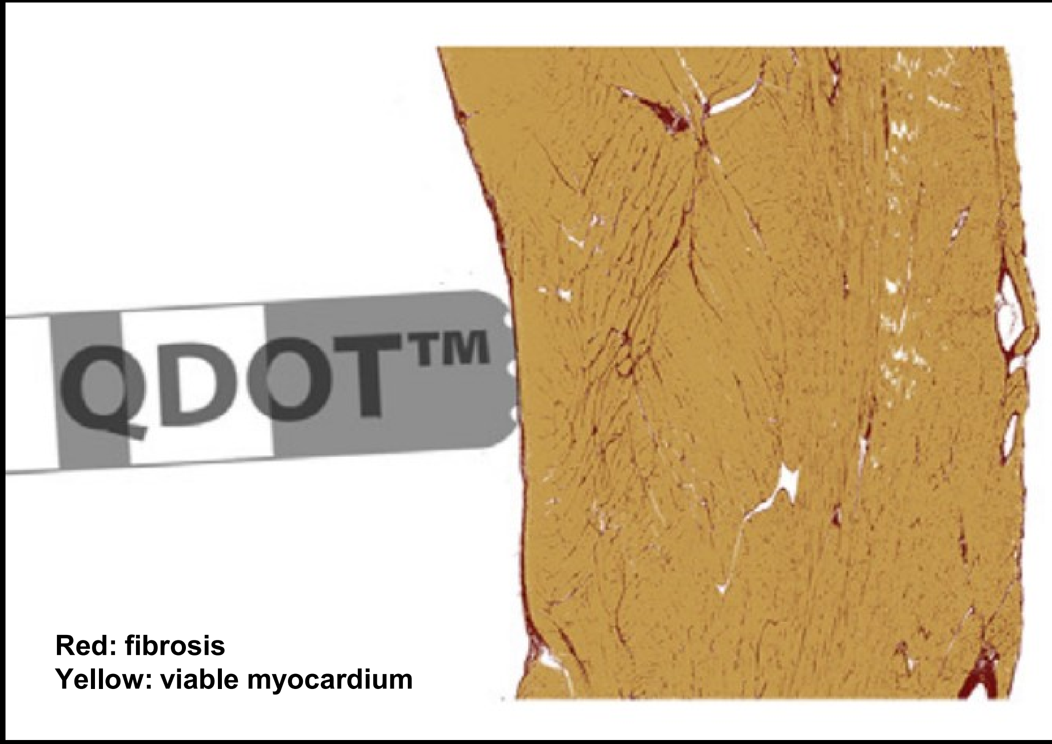
Reddy et al 2004
Glashan et al 2019

What exactly is the scar border zone?

The area between dense scar and normal, viable myocardium

- Upper limit:
  - The >1.5mV BV was derived from patients without structural heart disease and crude comparisons of LVA with dense scar on gross pathology

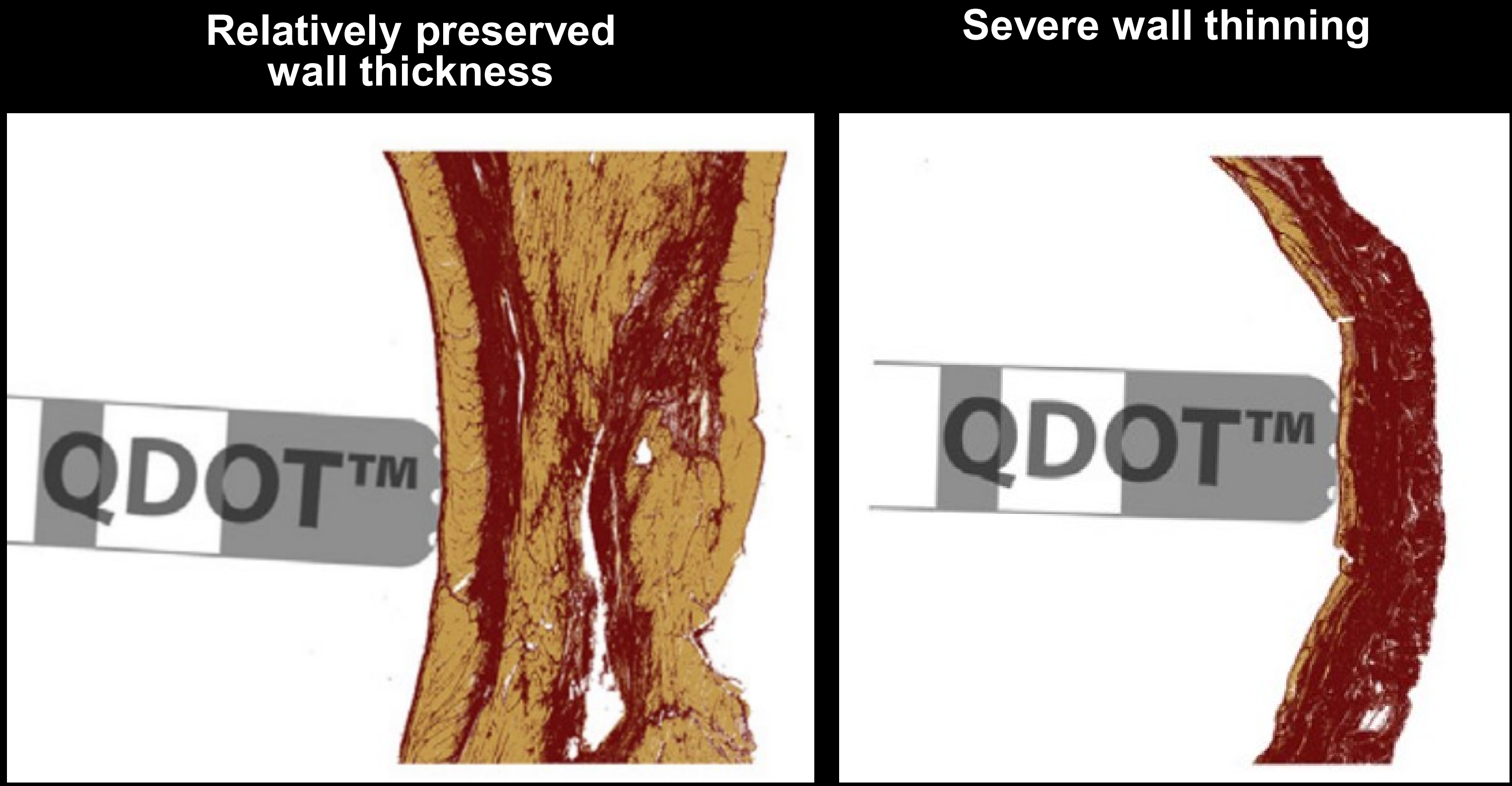
- All cut-offs are used uniformly



Reddy et al 2004
Glashan et al 2019

What exactly is the scar border zone?

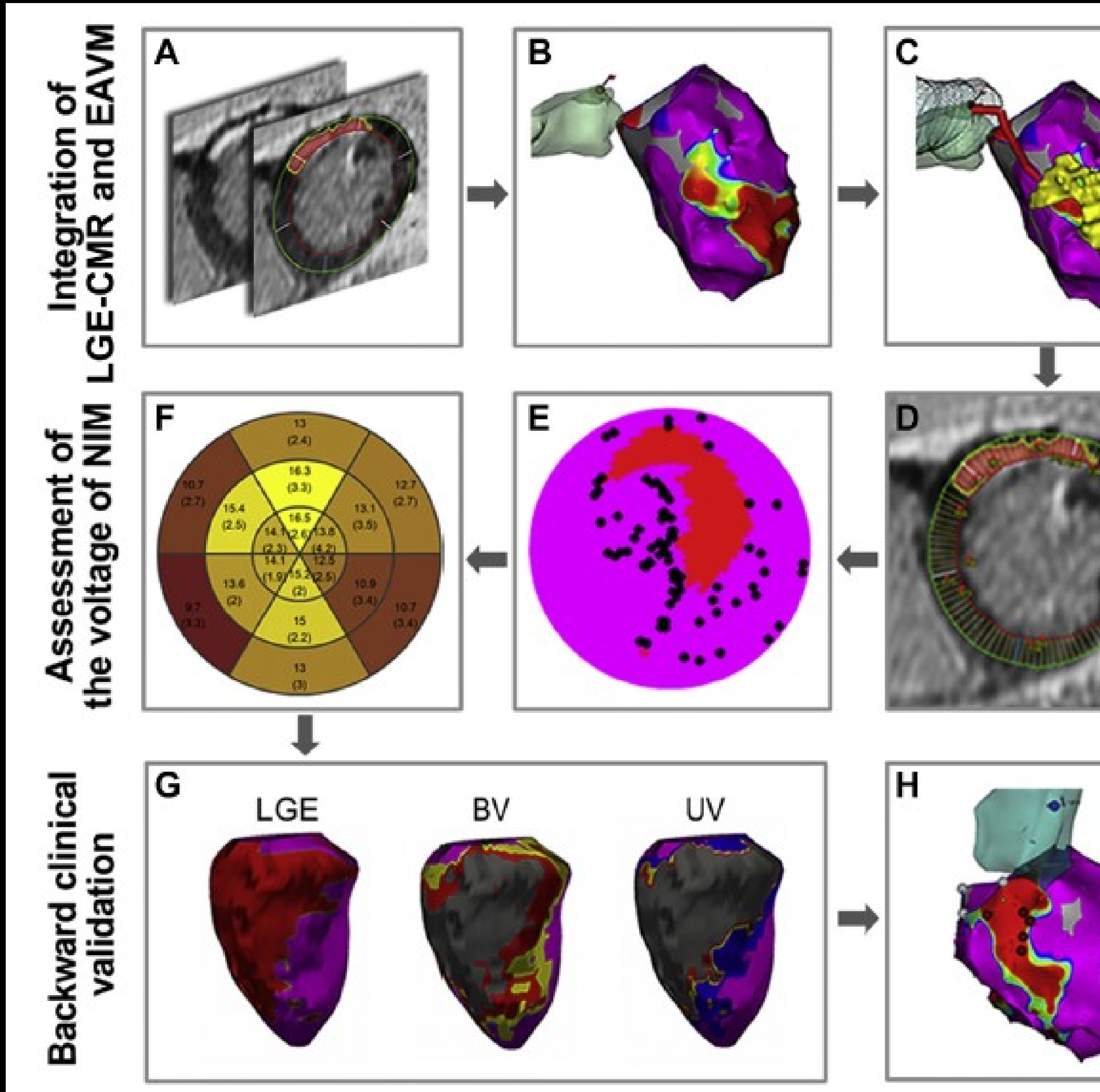
- Bipolar voltage is dependent on wall thickness
- Same cut-offs?



Glashan et

MRI-validated cut-offs

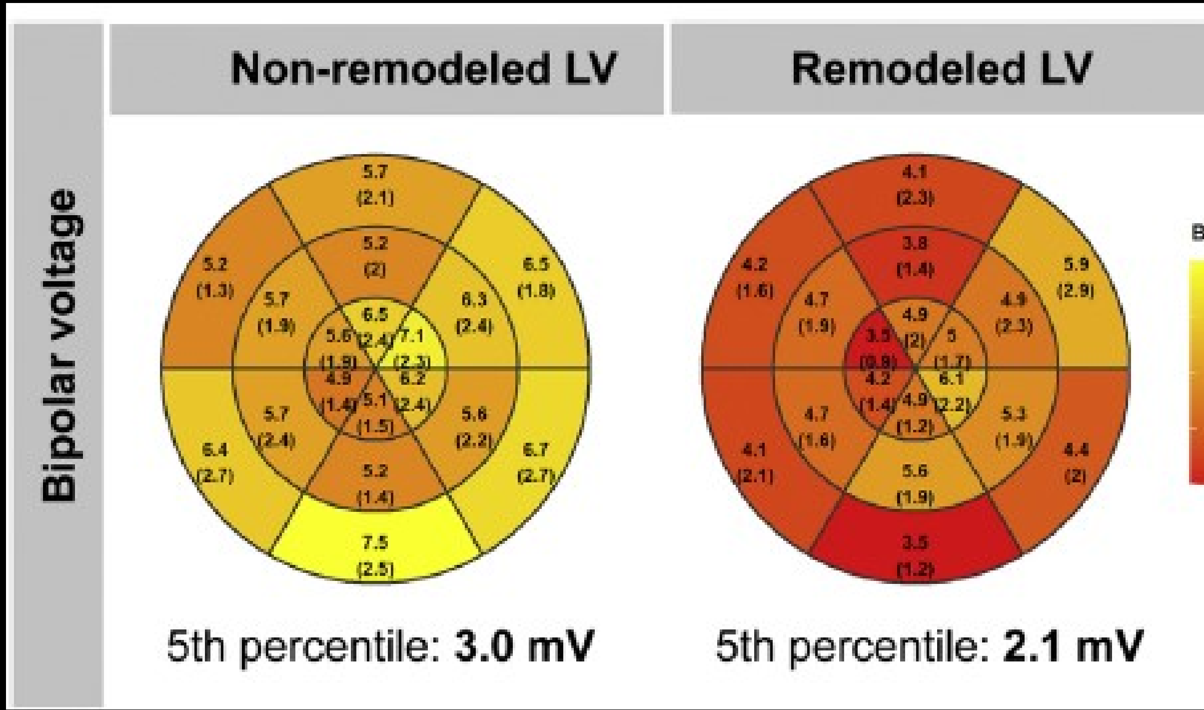
1. Segmentation of high resolution LGE-MRI to determine fibrosis
2. Integration with bipolar voltage maps
3. Derivation of optimal cut-offs in patients with remodeled and non-remodeled LV's



Sramko et al 2019 (IKEM)

MRI-validated cut-offs

- Patients with LVEF>47%
  - >3.0mV BV
- Patients with LVEF<47%
  - >2.1mV BV
- Of note, 97/99% functional substrate targets were in area <2.1/3.0mV compared to 59% in <1.5mV BV



Sramko et al 2019
(IKEM)

Two questions arise:

1. What exactly is the border zone as seen on voltage mapping?
    1. For patients with LV-remodeling: >0.5 and <2.1mV BV
    2. For patients without LV remodeling >0.5 and <3.0mV BV

2. What is the relationship between the border zone and fast VTs?

Two questions arise:

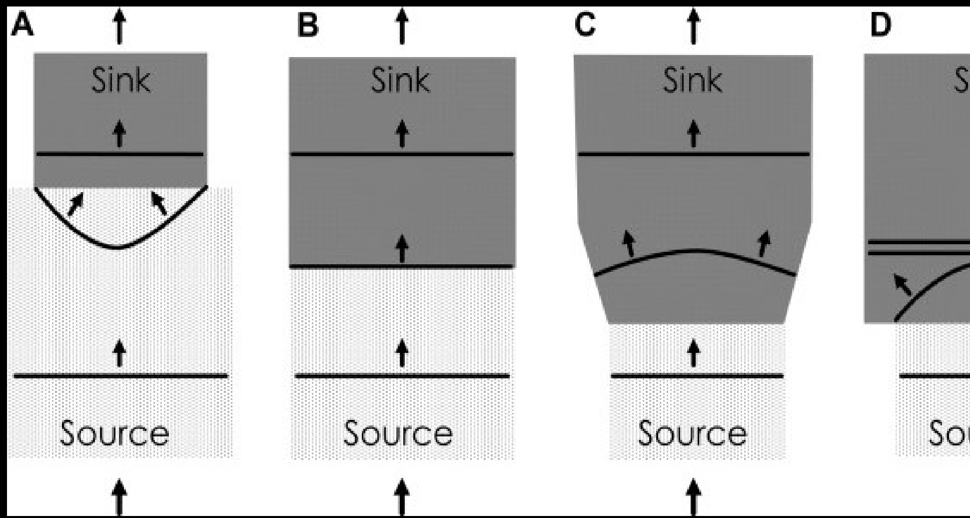
1. What exactly is the border zone as seen on voltage mapping?
    1. For patients with LV-remodeling: >0.5 and <2.1mV BV
    2. For patients without LV remodeling >0.5 and <3.0mV BV
2. What is the relationship between the border zone and fast VTs?

Functional conduction block

- Heterogeneous properties of infarcted region:
  - Source-sink mismatch
  - Ion channel changes
  - Gap junctional changes

- Different local refractory periods

Source-sink mismatch

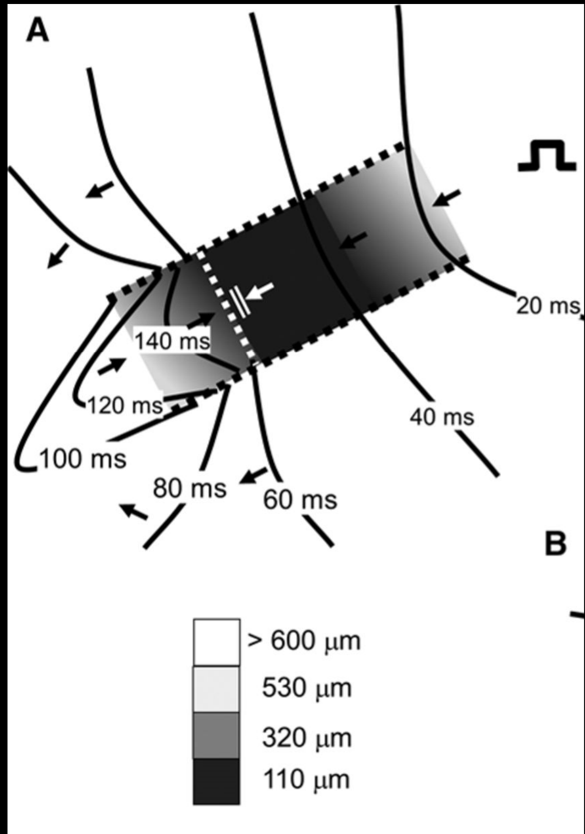


Ciaccio et al 2016

Functional conduction block

- Border zone contains strands of preserved myocardium
- Outer loop determines the VTCL (Tung)
- Very fast VTs close to the refractory period

Initiation of circuit

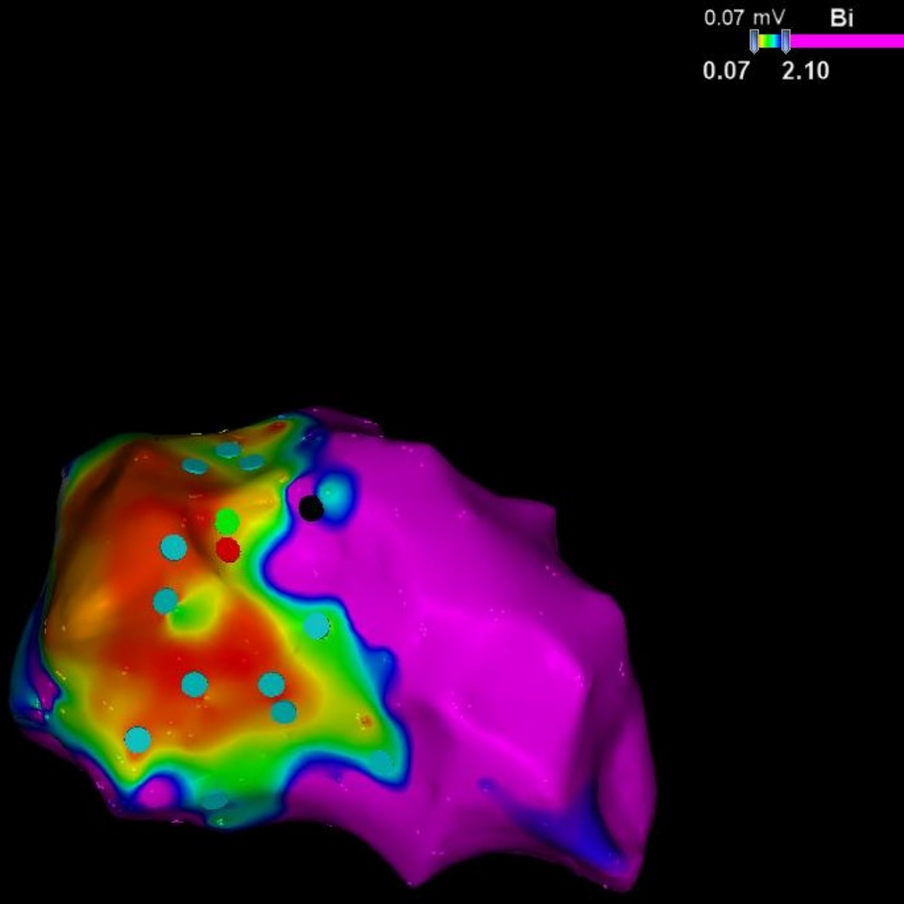


Ciaccio et al 2016

Methods

- Consecutive post-MI VT ablation patients were included
- Residual ischemia was excluded
- VTCL < VRP + 30ms = fast VT
- Border zones were measured after exclusion of valve areas

- Presence of fast VTs, VTCL and VT recurrence was correlated with border zone sizes



Patient characteristics

- 138 patients (68±8 years, LVEF 35%±10%)
- 86% classified as LV-remodeled based on echo
- 62% underwent early reperfusion therapy
- Presenting VTCL 386±86ms
- Mean V-ERP 260±29ms
- Retrospectively: 20% patients presented with ≥1 fast VT

Procedural data

- 96% of patients was inducible for ≥1 VT during the procedure (median 2 [1 – 3])
- After last RF 57% was inducible ≥1 VT, 60/79 for only fast VTs
- At the time: fast VTs near V-ERP were not targeted

Watanabe 2018

Border zone sizes results:

1. Border zone sizes and fast *presenting VTs*

2. Border zone sizes and fast *remaining VTs after ablation*

3. Border zone sizes and VT recurrence

Border zone sizes: *presenting fast VTs*

Low voltage area	Presenting with ≥1 fast VT n=27	Presenting with only non-fast VT n= 111	P-v

Border zone sizes: *presenting fast VTs*

- No differences in size of LVA (all cut-offs)

Low voltage area	Presenting with ≥1 fast VT n=27	Presenting with only non-fast VT n= 111	P-v
BV <0.5mV, %	4 [1 – 13]	7 [2 – 14]	0.1
BV <1.5mV, %	27 [16 – 39]	27 [26 – 47]	0.8
BV <2.1/3.0mV, %	44 [31 – 50]	37 [26 – 47]	0.2

Border zone sizes: *presenting fast VTs*

- No differences in size of LVA (all cut-offs)
- No difference in border zone conventional cut-offs

Low voltage area	Presenting with ≥1 fast VT n=27	Presenting with only non-fast VT n= 111	P-v
BV <0.5mV, %	4 [1 – 13]	7 [2 – 14]	0.1
BV <1.5mV, %	27 [16 – 39]	27 [26 – 47]	0.8
BV <2.1/3.0mV, %	44 [31 – 50]	37 [26 – 47]	0.2
Conventional BV border zone (0.5-1.5mV), %	22 [12 – 26]	17 [11 – 23]	0.1

Border zone sizes: *presenting fast VTs*

- No differences in size of LVA (all cut-offs)
- No difference in border zone conventional cut-offs
- Larger border zone using MRI validated cut-offs

Low voltage area	Presenting with ≥1 fast VT n=27	Presenting with only non-fast VT n= 111	P-v
BV <0.5mV, %	4 [1 – 13]	7 [2 – 14]	0.1
BV <1.5mV, %	27 [16 – 39]	27 [26 – 47]	0.8
BV <2.1/3.0mV, %	44 [31 – 50]	37 [26 – 47]	0.2
Conventional BV border zone (0.5-1.5mV), %	22 [12 – 26]	17 [11 – 23]	0.1
MRI validated border zone (0.5 – 2.1/3.0mV), %	32 [26 – 42]	26 [19 – 36]	0.0

Border zone sizes results:

1. Border zone sizes and fast *presenting VTs*
    1. *Patients with spontaneous fast VTs have larger scar border zones when using MRI validated cut-offs (0.5>2.1/3.0mV BV)*

2. Border zone sizes and fast *remaining VTs after ablation*

3. Border zone sizes and VT recurrence

Remaining fast VTs after ablation

- 43% of all patients remained inducible for fast VTs (mean VTCL 257±32ms)

Low voltage area	Inducible for fast-VT after ablation (n=60)	Inducible for only other VT after ablation (n=19)	P v

Remaining fast VTs after ablation

- 43% of all patients remained inducible for fast VTs (mean VTCL 257±32ms)

- Again, no differences when using conventional cut-offs for both LVA or border zone

Low voltage area	Inducible for <u>fast-VT</u> after ablation (n=60)	Inducible for only other VT after ablation (n=19)	P v
BV <0.5mV, %	8 [2 – 16]	9 [21 – 39]	0
BV <1.5mV, %	31 [22 – 44]	32 [22 – 39]	0
BV <2.1/3.0mV, %	46 [34 – 55]	41 [26 – 48]	0
Conventional BV border zone (0.5-1.5mV), %	22 [15 – 28]	20 [12 – 31]	0

Remaining fast VTs after ablation

- 43% of all patients remained inducible for fast VTs (mean VTCL 257±32ms)
- Again, no differences when using conventional cut-offs for both LVA or border zone
- Larger border zones when inducible for fast VTs using MRI cut-offs

Low voltage area	**Inducible for fast-VT after ablation (n=60)**	**Inducible for only other VT after ablation (n=19)**
BV <0.5mV, %	8 [2 – 16]	9 [21 – 39]
BV <1.5mV, %	31 [22 – 44]	32 [22 – 39]
BV <2.1/3.0mV, %	46 [34 – 55]	41 [26 – 48]
Conventional BV border zone (0.5-1.5mV), %	22 [15 – 28]	20 [12 – 31]
MRI validated border zone (0.5 – 2.1/3.0mV), %	35 [27 – 43]	26 [20 – 37]

Border zone sizes results:

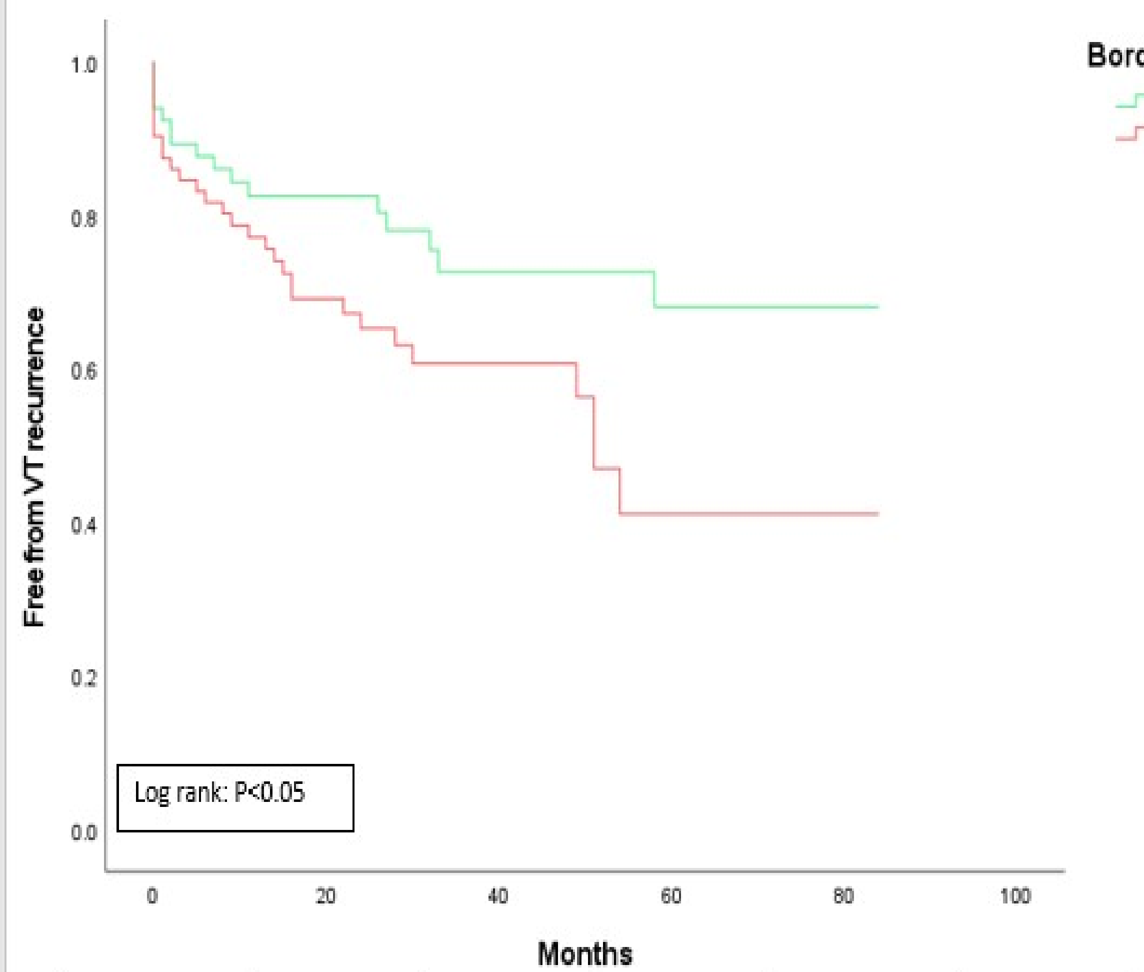
1. Border zone sizes and fast *presenting VTs*
    1. *Patients with spontaneous fast VTs have larger scar border zones when using MRI validated cut-offs (0.5>2.1/3.0mV BV)*

2. Border zone sizes and fast *remaining VTs after ablation*
    1. *Larger scar border zones in patients inducible for fast VTs, but only the MRI validated cut-offs*

3. Border zone sizes and VT recurrence

Border zone sizes and VT recurrence

- Median follow-up 26 months [8 – 47], 33% VT recurrence
- Median VTCL 360ms [273 – 400]
- 8/27 patients who presented with ≥1 fast VT, also recurred with a fast VT VTCL 270ms [243 – 300]



Patients at risk	0 months	20 months	40 months	60 months	80 months
Above 27% BZ	71	40	20	6	5
Below 27% BZ	65	40	22	14	6

Summary of results

1. Twenty percent of post-MI patients referred for VT ablation presented with at least one fast VT

2. Patients who presented with at least one fast VT had larger border zones

3. Patients who remained inducible for fast VTs after ablation of all known substrate had larger border zones

4. Patients with larger border zones had a higher VT recurrence rate

Discussion

- The MRI validated cut-off appear to be superior to determine low voltage areas and scar border zones
- Larger border zones seem to harbor VT substrate not reached by current ablation techniques
- Because functional block only appears during shorter cycle lengths, these arrythmias might be difficult to control via ablation

Strange things happen in the border zone

Table 1. Baseline characteristics

	All (n=138)
Age	68±8.4
Male	118 (86)
Hypertension	49 (36)
Diabetes mellitus	21 (15)
History of AF	37 (27)
QRS-duration, ms	113 [95 – 146]
LVEF, %	35±10
Remodeled LV*	119 (86)
ICD before ablation	107 (78)
Prior PCI	41 (30)
Prior CABG	32 (23)
Acute reperfusion therapy	86 (62)
Infarct location by coronary dependent area	
LAD	47 (34)
RCx	18 (13)
RCA	73 (53)
Medications at admission	
ACE-inhibitor/ARB	112 (81)
Beta-blockers	104 (75)
Amiodarone	54 (39)
Presenting arrythmia**	
*≥1 Fast VT****	27 (20)
Other tolerated VT	70 (51)
Other non-tolerated VT	41 (29)
VT clinical presentation	
Mean presenting VT cycle length, ms	386±86
VTCL patients using amiodarone	428±86
VTCL patient not using amiodarone	359±75

*LVEF <47% or LVES >50 ml/m2

** Retrospectively after V-ERP determination

***VTCL= ≤ V-ERP + 30ms,

Table 2: Procedural data

	All (n=138)
Mapping points	288±200
Surface area after removal of AMA, cm^2	200±52
LV-volume, cm^3	224 [169 – 300]
Procedural time, min	200 [76 – 251]
RV V-ERP**	259±29
Using amiodarone, ms	273±28
Not using amiodarone, ms	251±26
Inducible for any VT during procedure	132 (96)
Number of VTs inducible	2 [1 – 3]
*VTCL induced, ms**	365±81
Inducible for fast VT ***	15 (11)
VTCL fast VT, ms	265±18
Inducible after last RF application	79 (57)
VTCL induced, ms	281±61
Inducible for fast VT after last RF application***	60 (44)
VTCL fast VT, ms	257±32
VTCL other VT, ms	356±72
Low voltage areas	
BV <0.5mV, %	7 [2 – 13]
BV <1.5mV, %	27 [16 – 37]
BV <2.1/3.0mV, %	37 [27 – 48]
Conventional BV border zone (0.5-1.5mV), %	18 [11 – 24]
MRI validated border zone total (0.5 – 2.1/3.0mV), %	27 [20 – 38]

* Mean VTCL induced per patient used