Non-invasive diagnosis of coronary artery disease by exercise magnetocardiography

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BACKGROUND

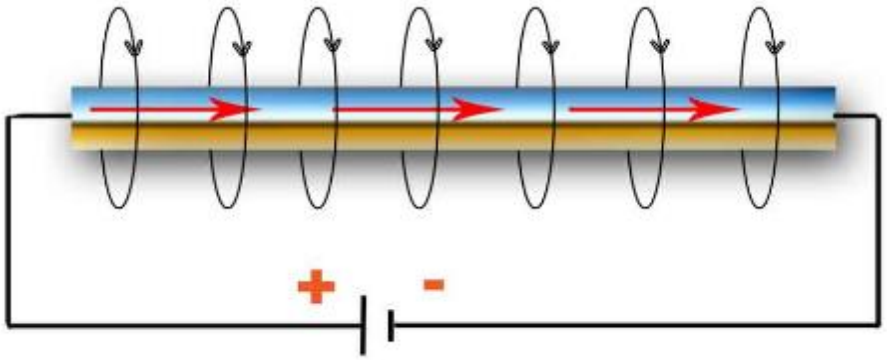
- **Despite efforts to improve early diagnosis and the development of preventive therapies, the prevalence of coronary artery disease (CAD) in the general population remains high and is the leading cause of death for both men and women.**

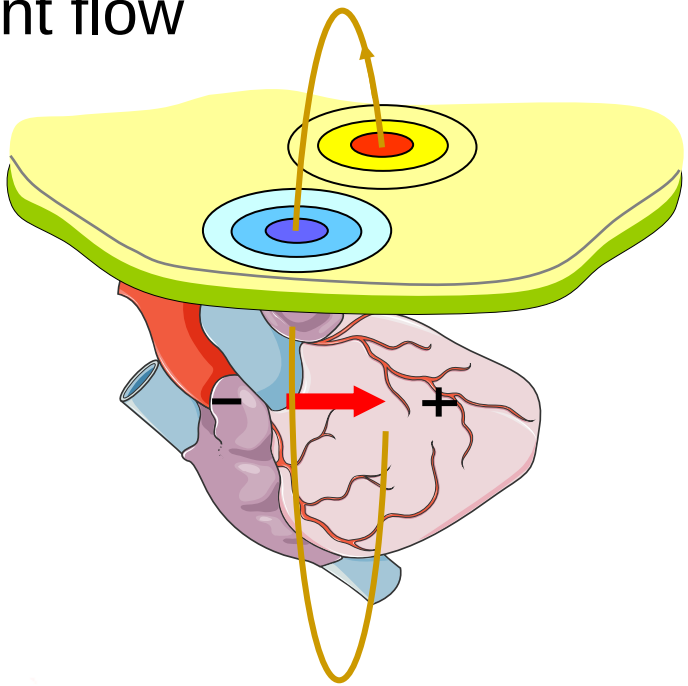
- **Although non-invasive stress testing to detect inducible ischemia has been used to diagnose CAD, less than half of patients are evaluated non-invasively before percutaneous coronary intervention (PCI). This is because of the testing limitation caused by low diagnostic accuracy and radiation hazard in coronary CT or SPECT.**

- **Magnetocardiography (MCG) has been proposed as a non-invasive and functional technique with high accuracy for diagnosis of myocardial ischemia.**

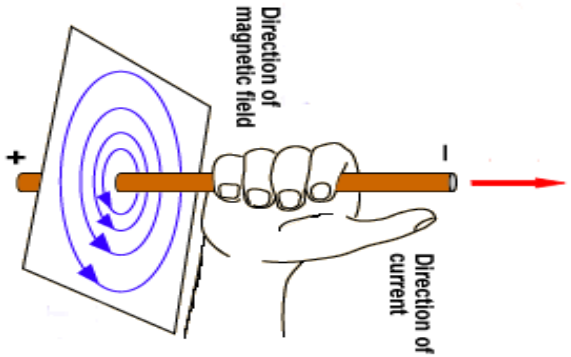
Basic Principle for Magnetocardiography (MCG)

Magnetic field around current flow





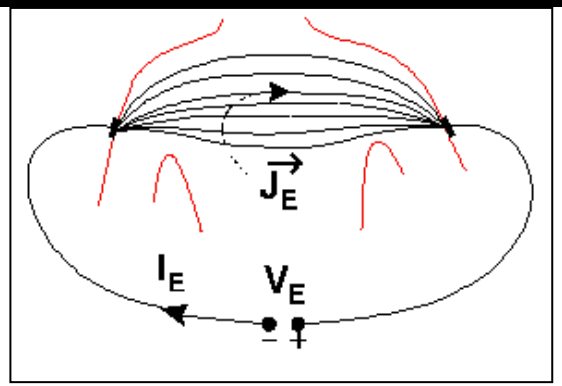
Magnetic field strength is proportional to current strength

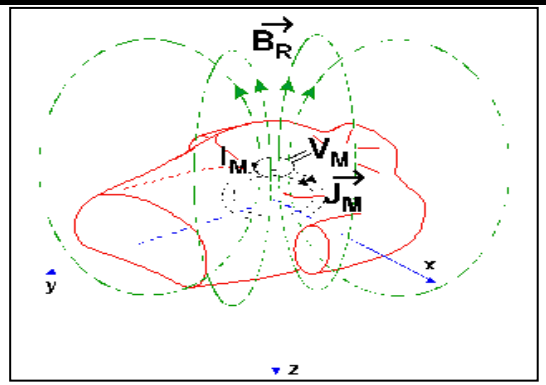


Electrocardiography (ECG) vs Magnetocardiography (MCG)

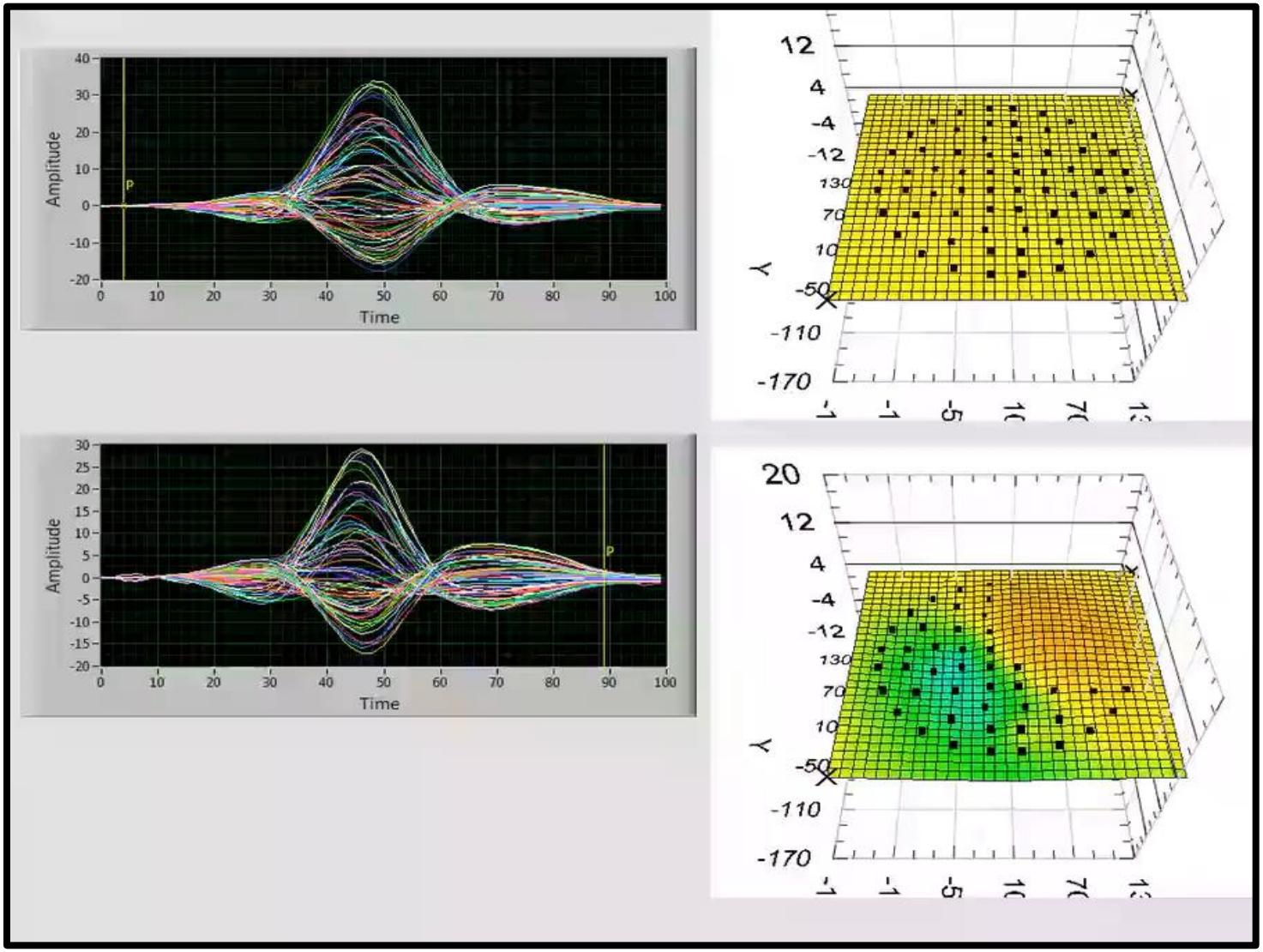
ECG (indirect method)

MCG (direct method)





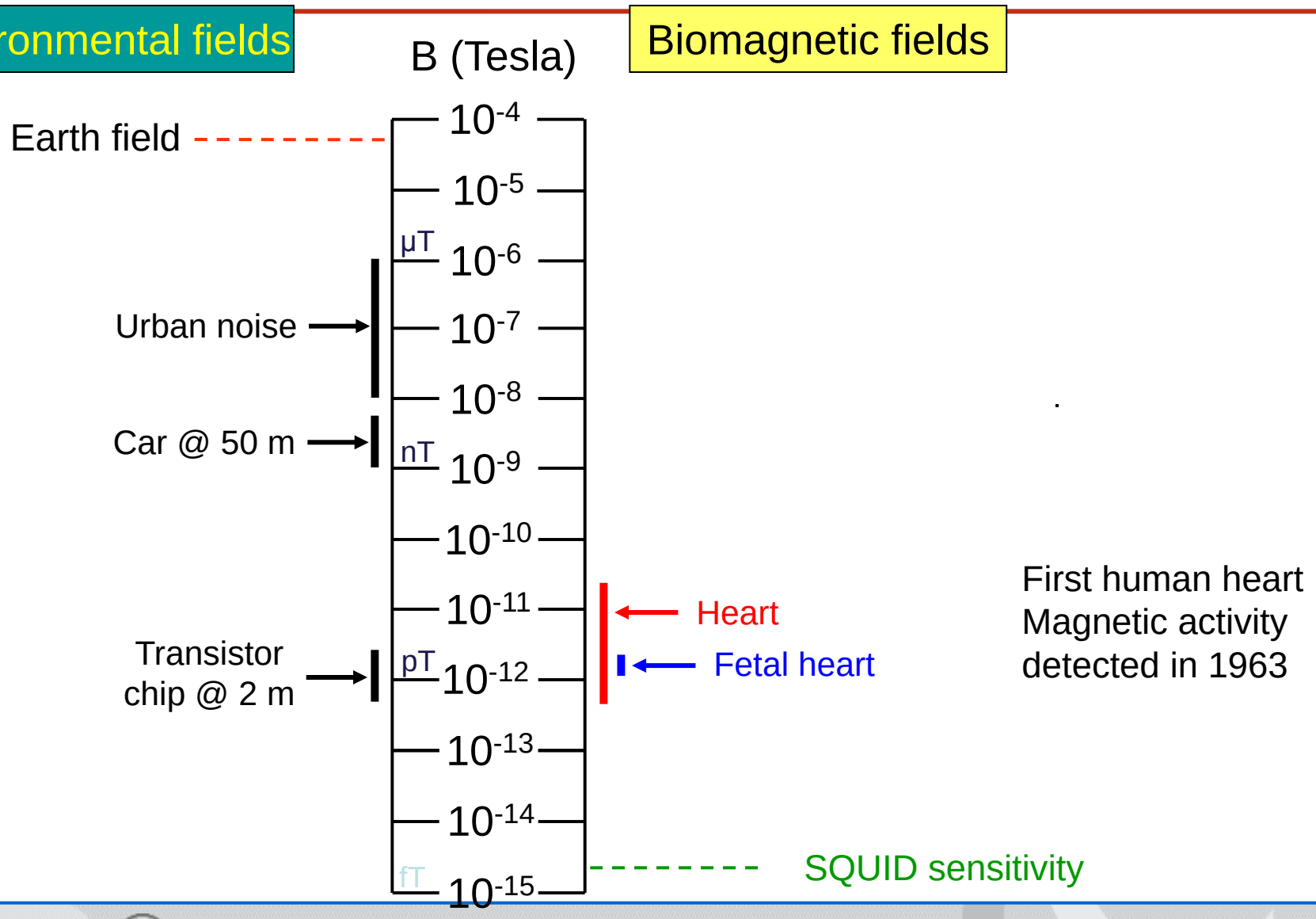
Magnetocardiographic Data



Scalar Diagram

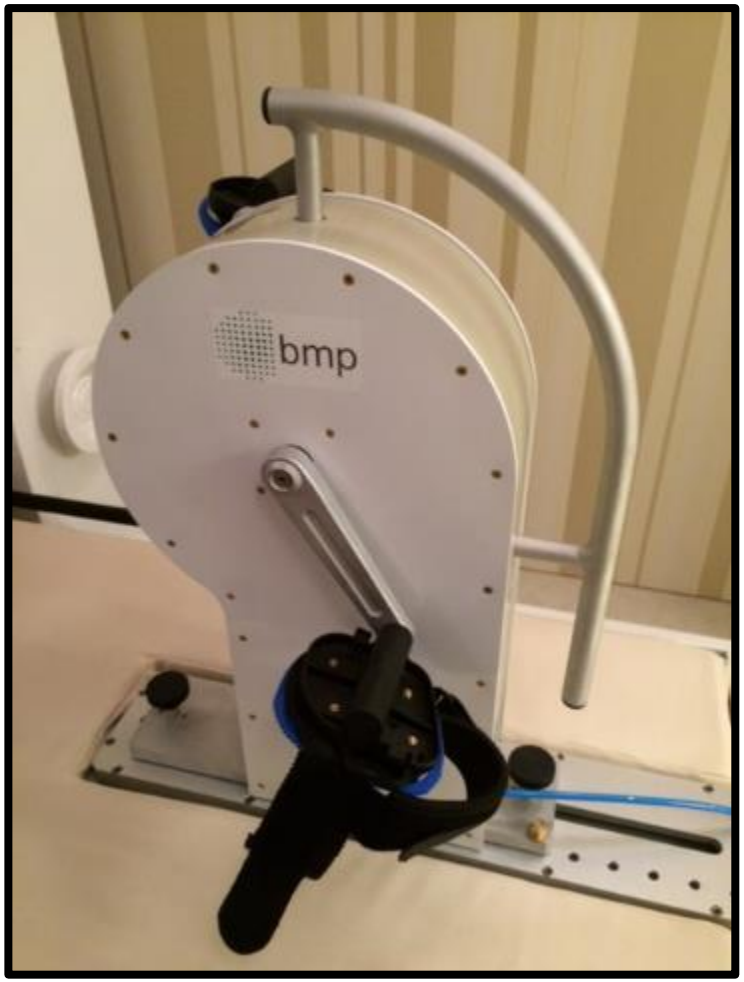
Magnetic Field Plot

Signal strength of MCG fields



Magnetocardiography

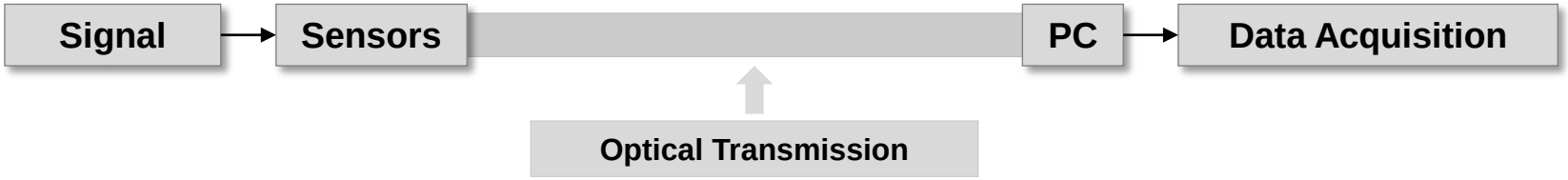
MCG System – Non-magnetic Ergometer



Cutting edge: optical transmission technology(OTT)

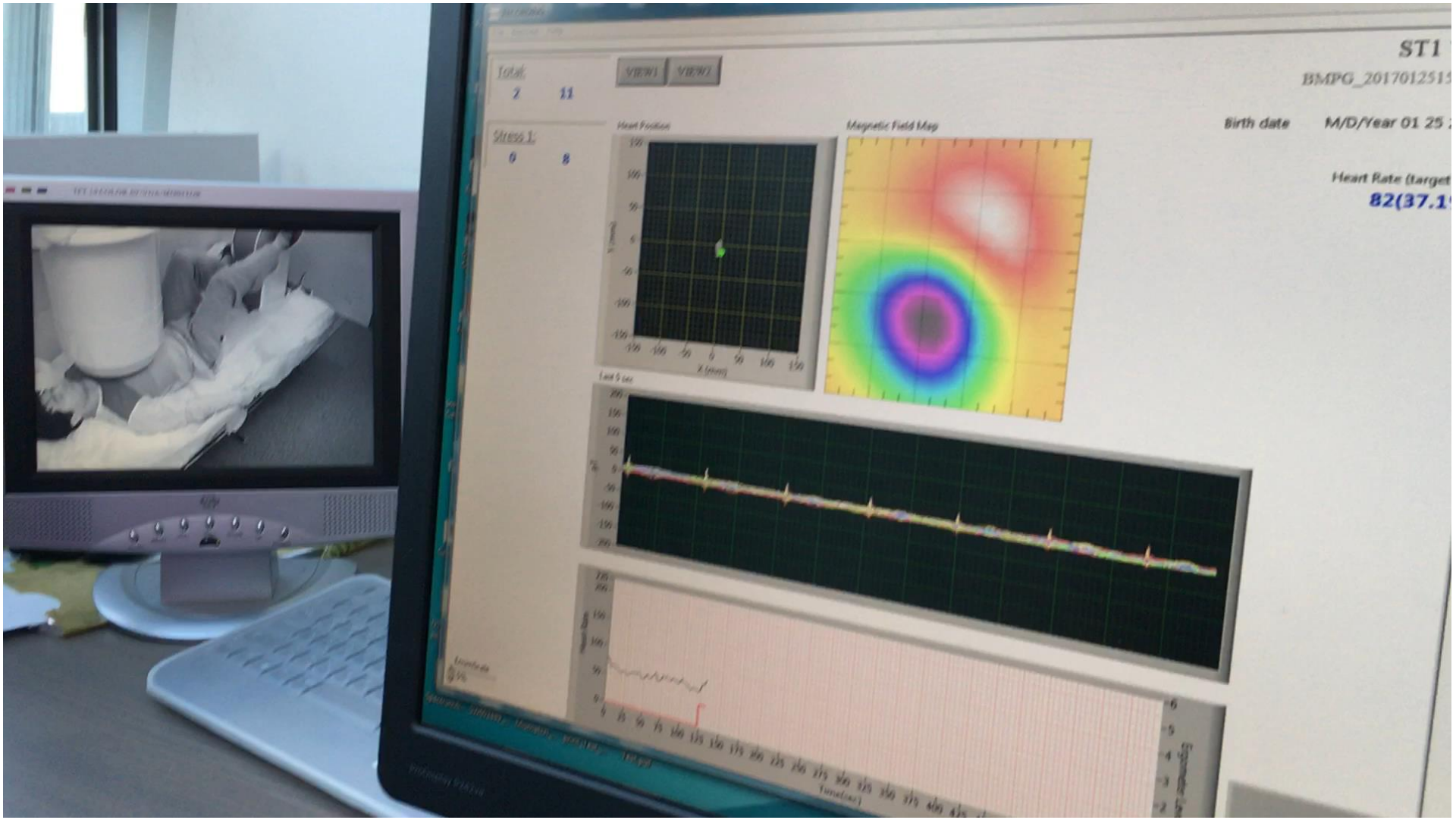
Digital Signal Processing (ASP-Free)
Noise Robustness
Signal Quality
Increase of Dynamic Range

- **bmp OTT (Digital Signal Processing)**
  The filters are removed, and the detected-signal is transmitted by optical cables

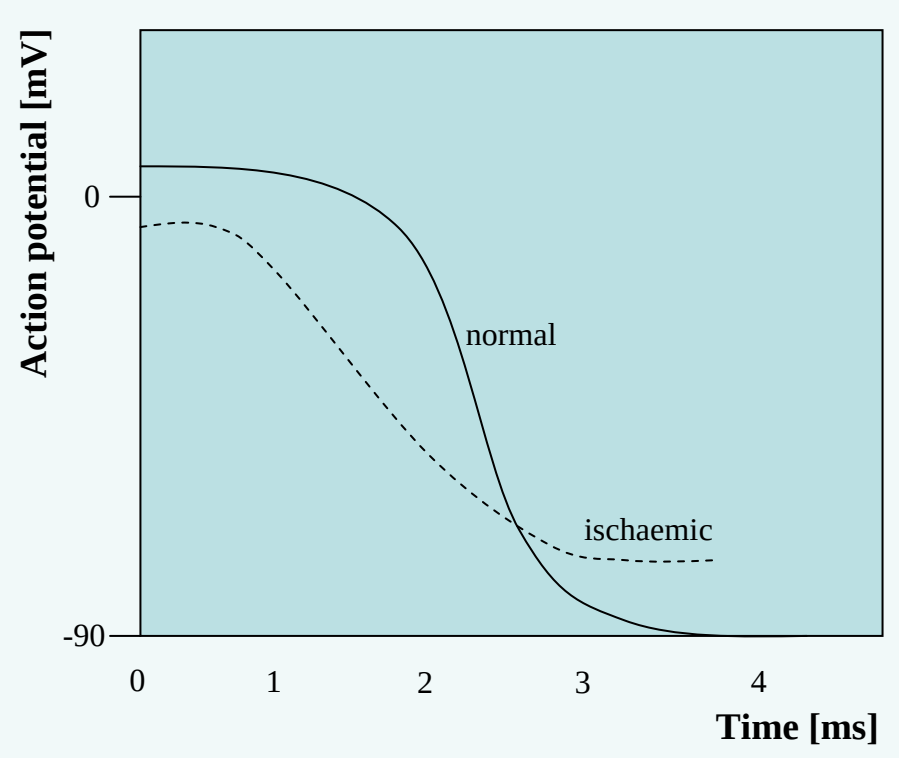


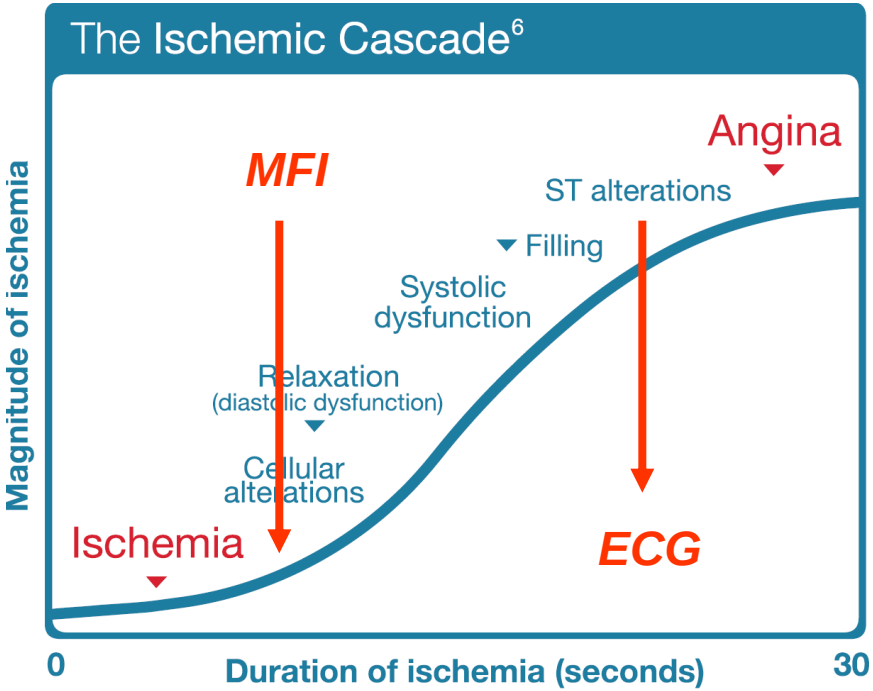
- **Analog Signal Processing (ASP, conventional)**

BMP MCG (May 2017):
Real time MCG imaging



Magnetic Field Imaging (MFI) more sensitive than ECG in Ischemic Cascade





Holland RP, Brooks H. Precordial and epicardial surface potentials during Myocardial ischemia in the pig. A theoretical and experimental analysis of the TQ and ST segments. Circ Res 1975; 37: 471-480.

Kern MJ. Coronary blood flow and myocardial ischemia. In: Zipes DP, Libby P, Bonow RO, Braunwald E, eds. Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine. 7th ed. Philadelphia, PA: Elsevier Saunders; 2005:1103-1128.

Myocardial pseudo current decreases in:

- ischemic heart disease

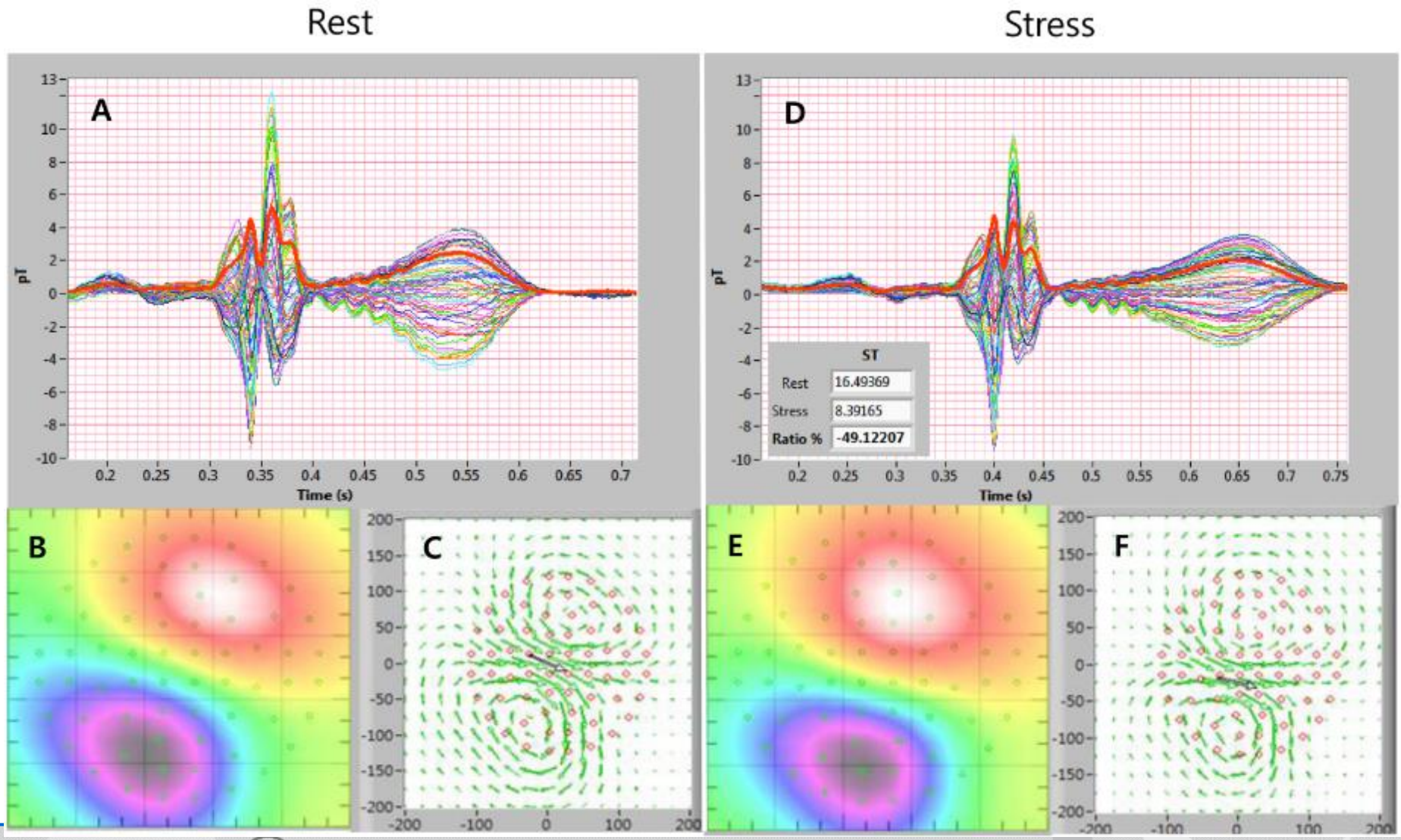
- myogenic heart failure

Magnetic dipole instability and magnetic monopolarity in:

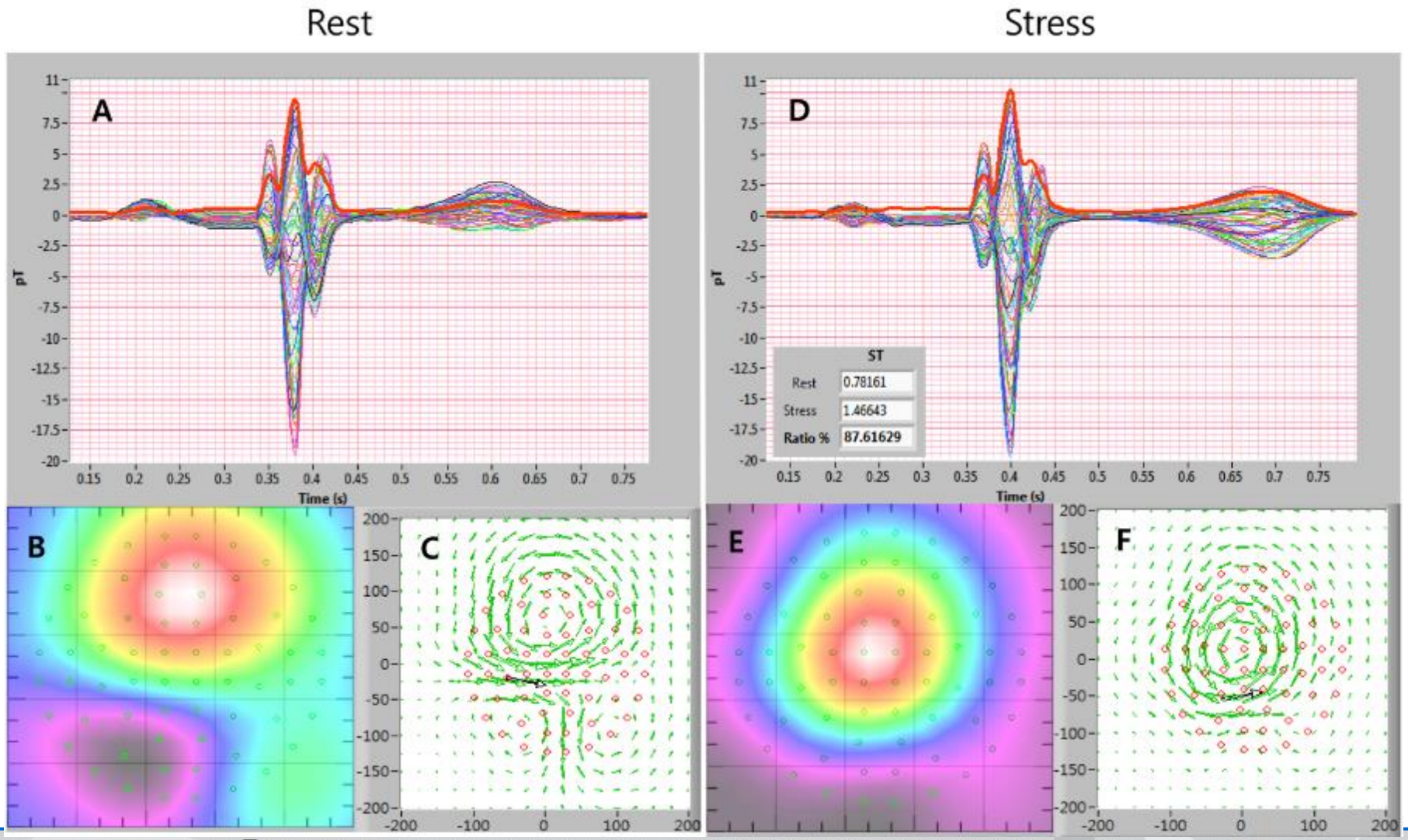
- regional ischemia (ACS, CAD)

- microvascular dysfunction

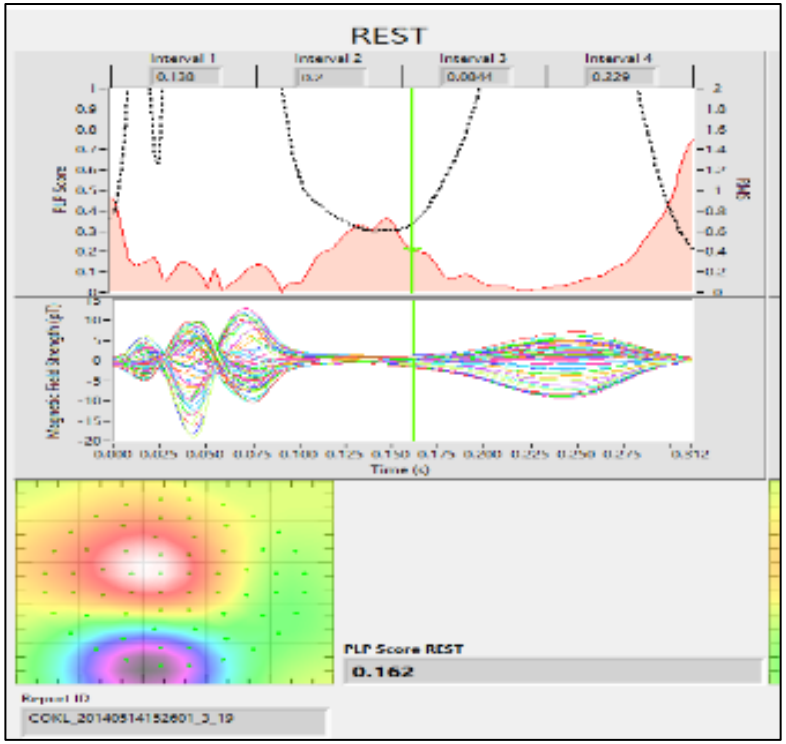
Representative case with no evidence of CAD

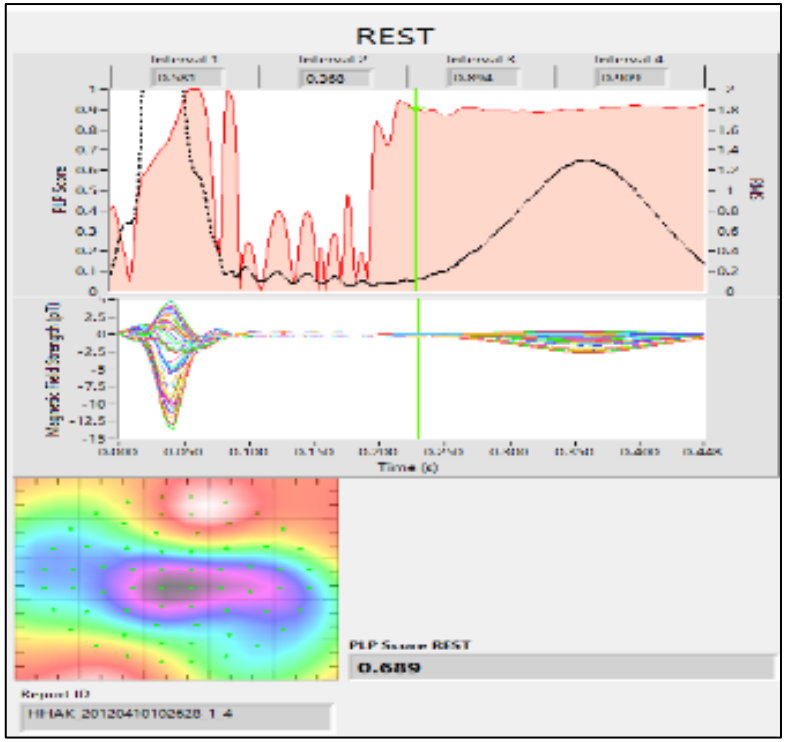


Representative case with CAD



PLP-score at rest

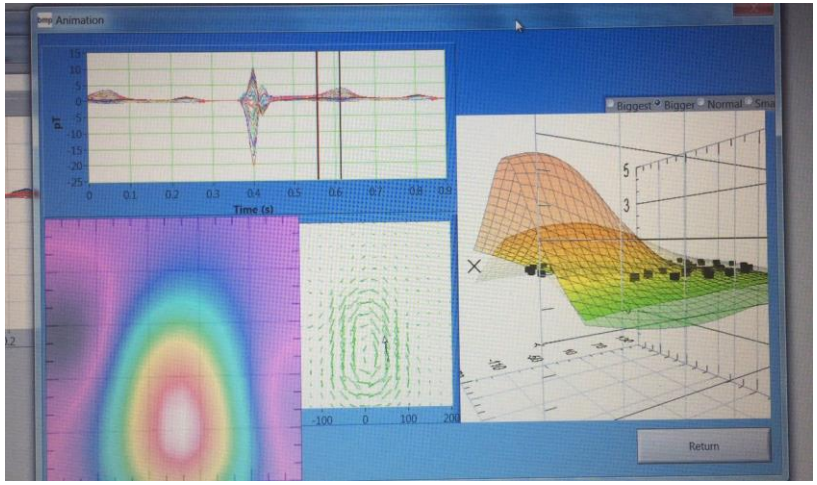


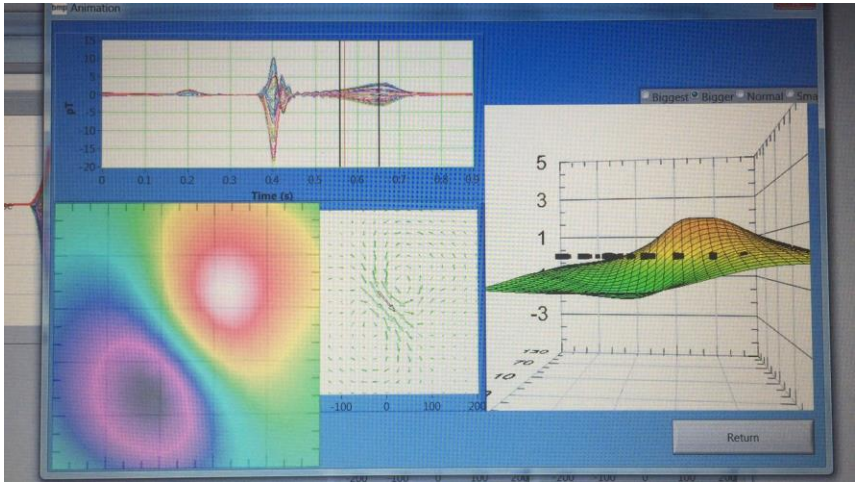


Normal

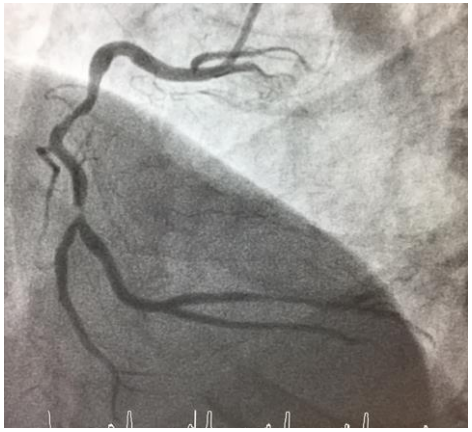
Acute Coronary Syndrome

The Unique magnetic-field pattern is also useful to monitor treatment outcome





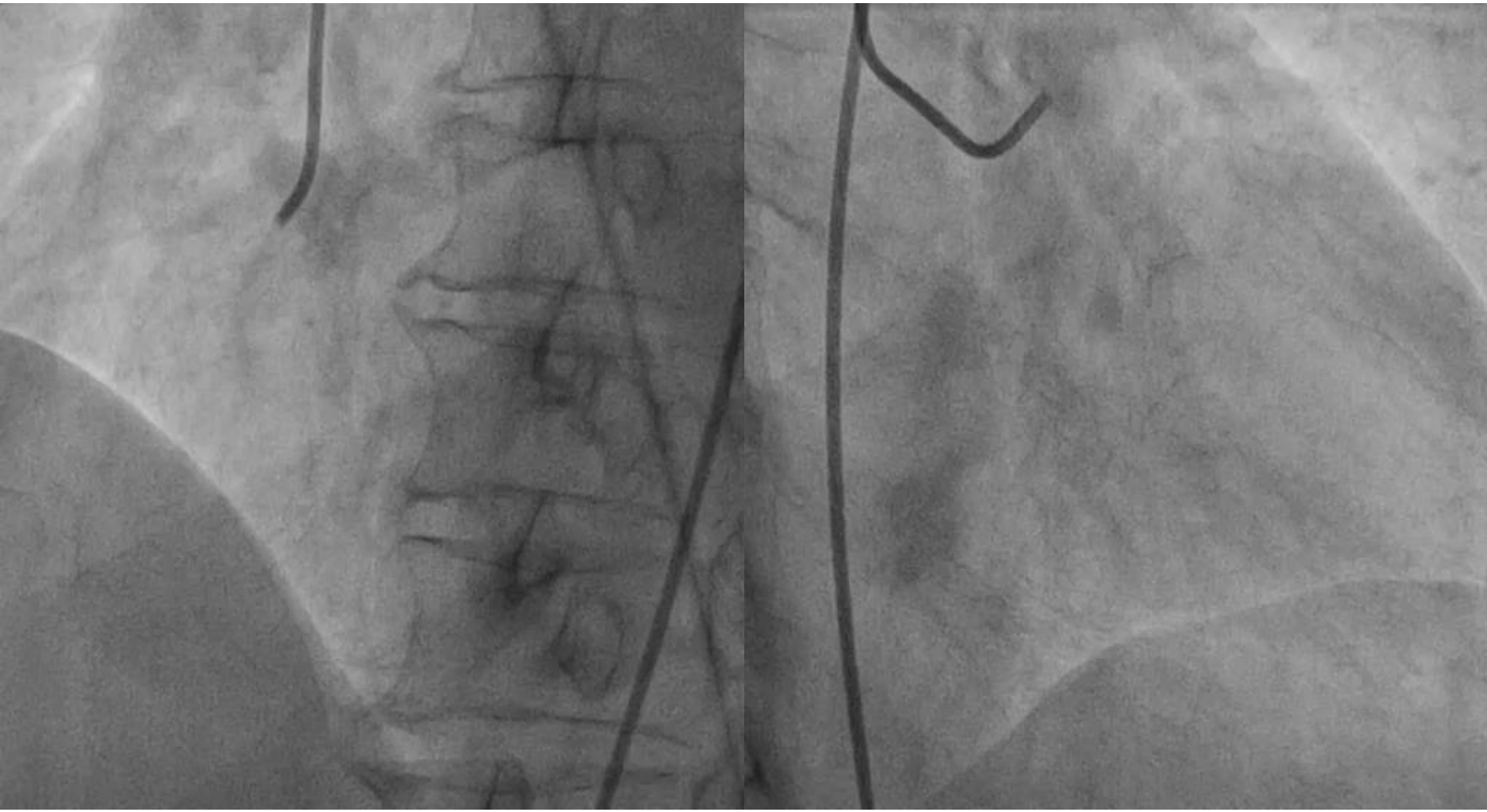
Before Stenting



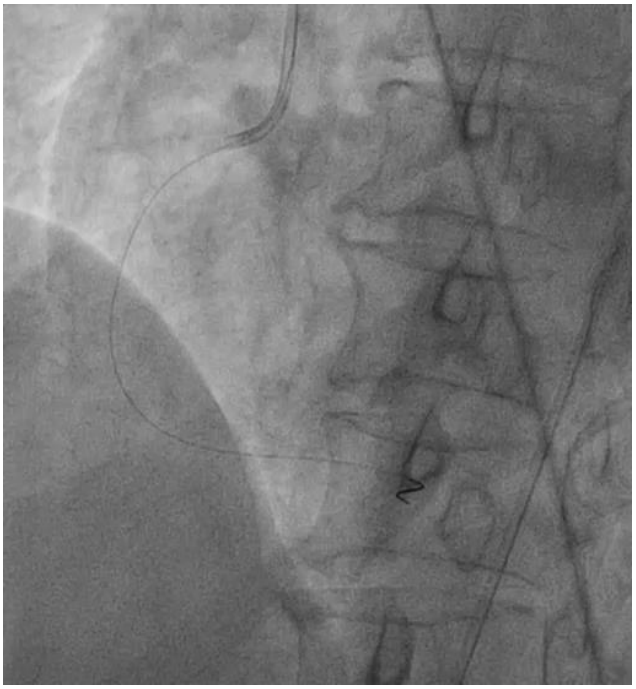
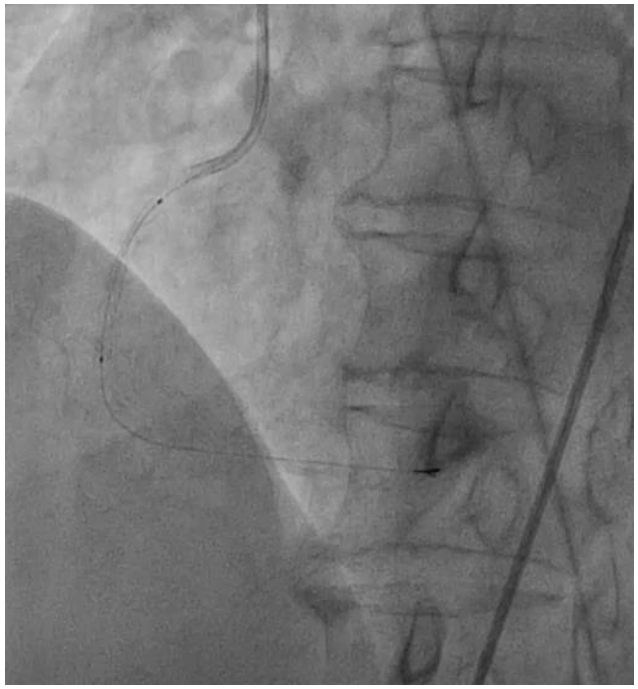
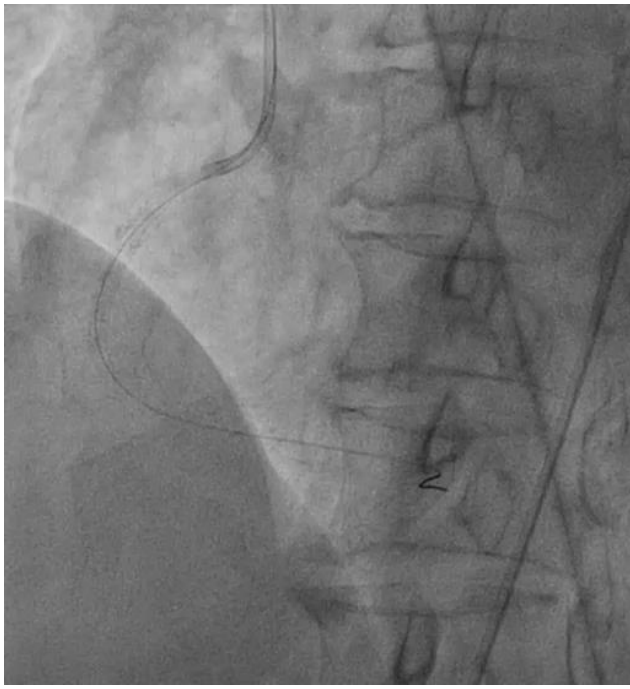
After Stenting

In patient with acute coronary syndrome, both 2D and 3D magnetic maps showed mono-pole dominance pattern at rest. The Co-dominance pattern restored after coronary stenting.

Case: F/59yrs, 2-VD (RCX, RCA) abdominal pain at exercise

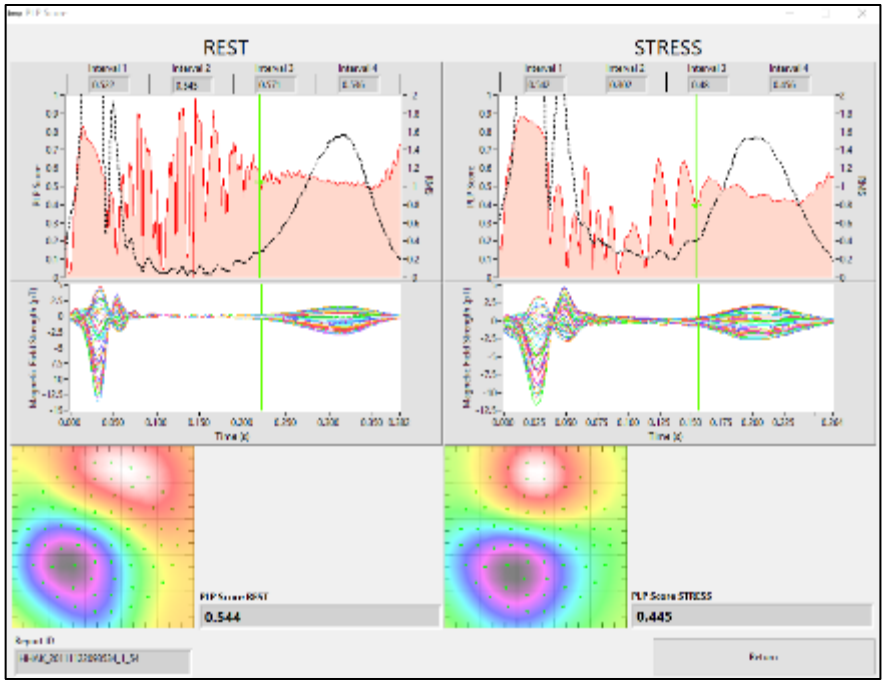


Case: F/59yrs, 2-VD (RCX, RCA) abdominal pain at exercise

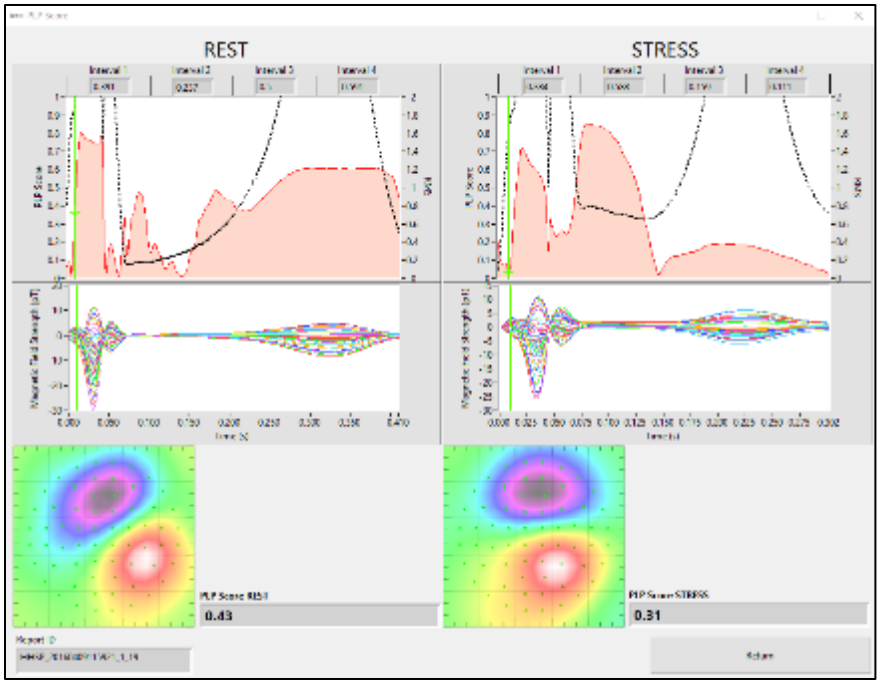




Case: F/59yrs, 2-VD (LCx, RCA)

abdominal pain at exercise



Pre-PCI



Post-PCI

Ischemia-scores

- **ST-T-Score: xxx (abnormal): angle dynamic pos**
- **distance dynamic pos**
  ratio dynamic pos).

  (possible scores: 0-3)

- **VMCG-ST-Score:** **xxx (Tbeg-Tmax)**
  xxx (RT1/2 - Tmax). Normal <0.05.

  (possible scores: 0-2)

- **PLP-curve:** **decrease (normal)**
- **horizontal(normal)**
- **increase(abnormal).**

  (possible scores: 0-1)

- **T-dispersion:** **xxx. (normal <8.0)**

  (possible scores: 0-1)

- **Stfluc-score (solely at exercise: normal <40%** **(possible scores: 0-1)**

- **Possible total scores at rest: 0-7 Possible total scores at exercise: 0-8**

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DOI 10.3233/CH-141912
IOS Press

Validation of magnetocardiography versus fractional flow reserve for detection of coronary artery disease

Jai-Wun Park[a,c,1,*], Eun-Seok Shin[b], Soe Hee Ann[b], Martin Gödde[a], Lea Song-I Park[a], Johannes Brachmann[a], Silvia Vidal-Lopez[c], Jan Wierzbinski[c], Yat-Yin Lam[d] and Friedrich Jung[e]

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[d]*Prince of Wales Hospital, Chinese University of Hong Kong, Hong Kong*
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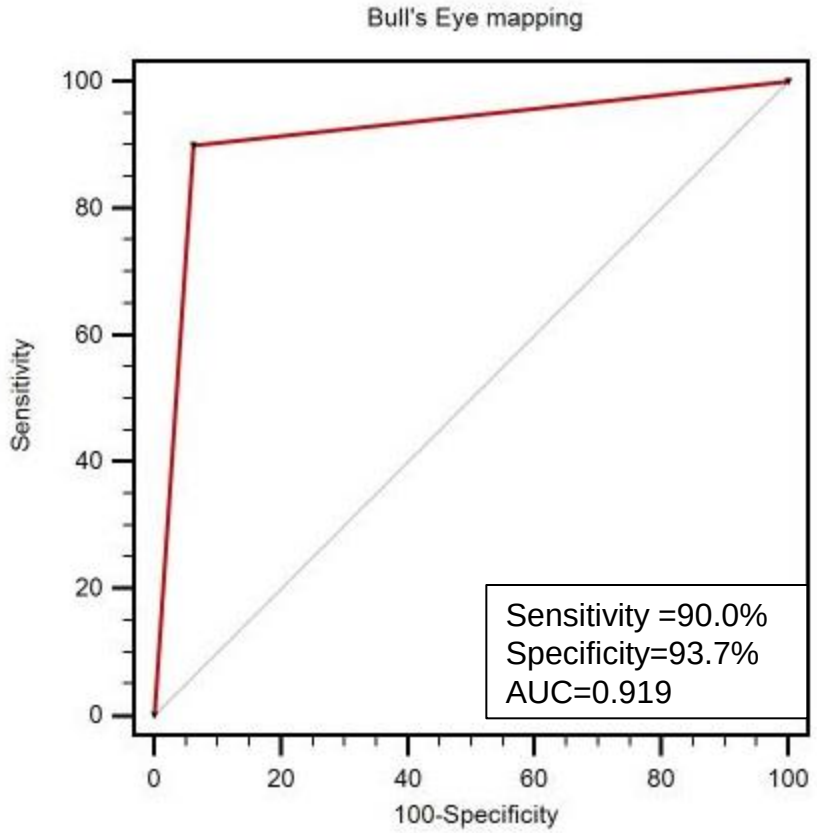
Sensitivity & Specificity of MCG vs. FFR on Coronary Territory Basis (n=52)

Bull's-eye mapping	FFR positive	FFR negative
MCG positive	18	2
MCG negative	2	30
	Value	95% CI
Accuracy	91.9%	68.3-98.8
Sensitivity	90.0%	79.2-99.2
Specificity	93.7%	79.5-98.0

ROC Curves

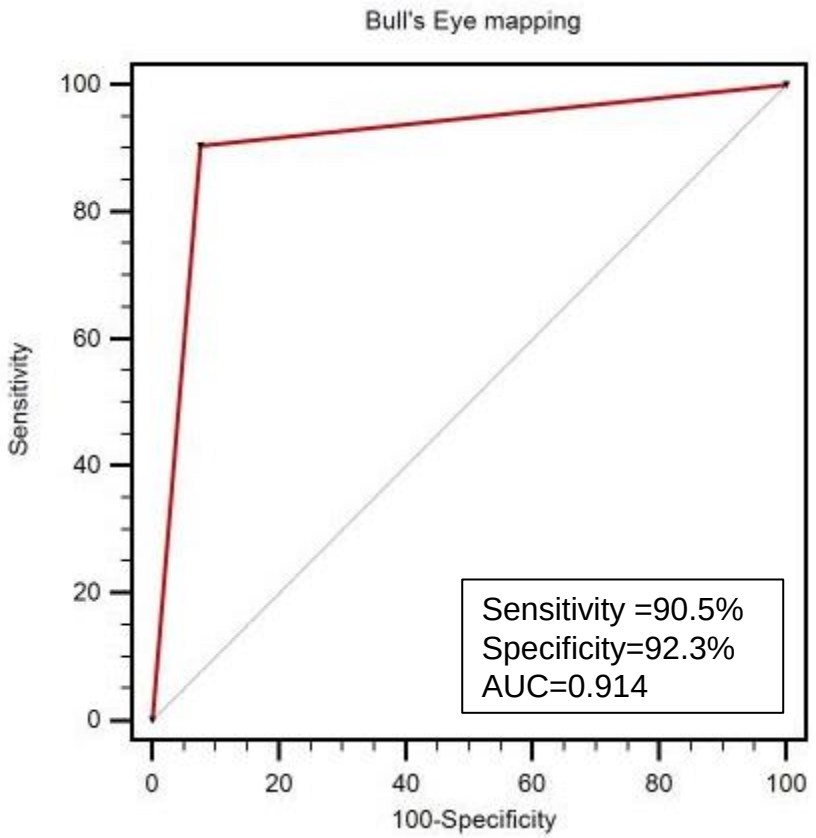


Park J-W, Shin ES, et al. Clin Hemorheol Microcirc 2015;59:267-281.

Sensitivity & Specificity of MCG vs. FFR on Patient Basis (n=47)

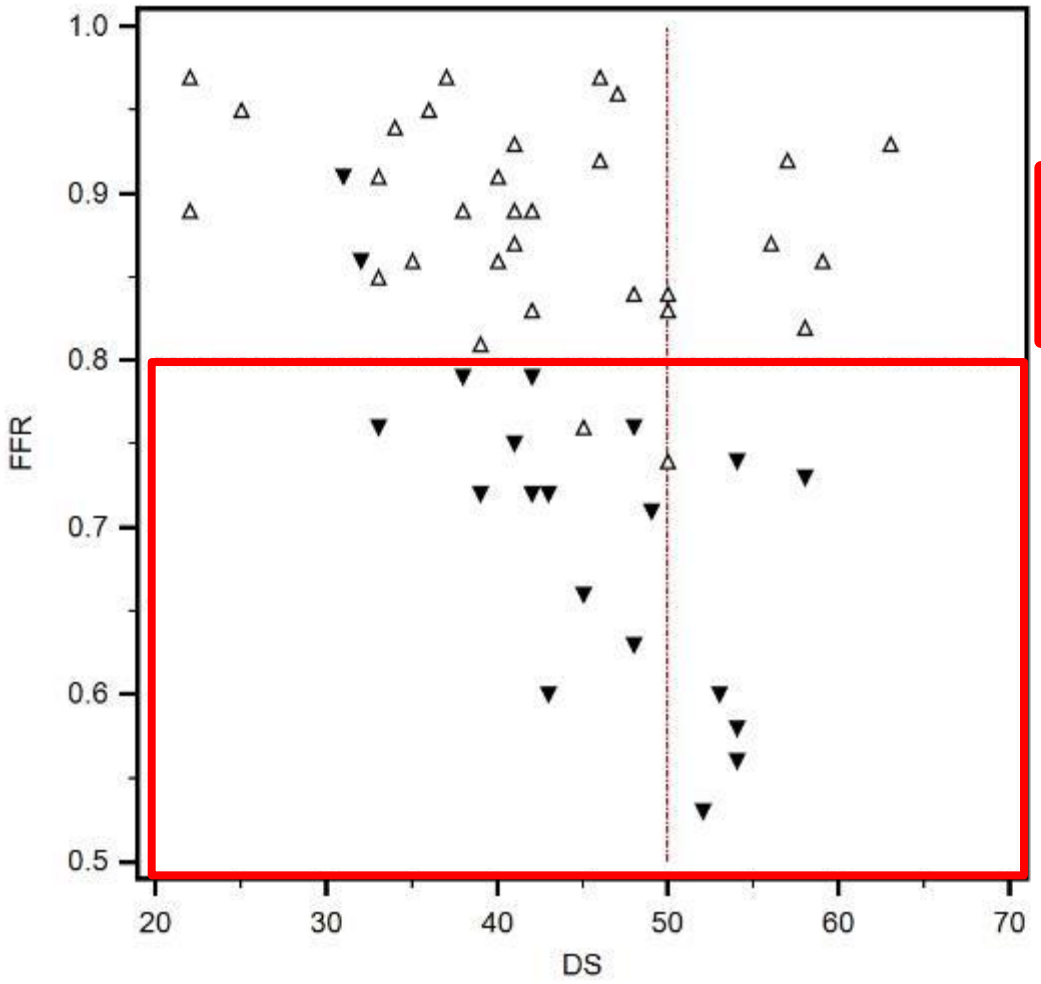
Bull's-eye mapping	FFR positive	FFR negative
MCG positive	19	2
MCG negative	2	24
	Value	95% CI
Accuracy	91.4%	69.6-98.8
Sensitivity	90.5%	74.9-99.1
Specificity	92.3%	77.4-97.8

ROC Curves



Park J-W, Shin ES, et al. Clin Hemorheol Microcirc 2015;59:267-281.

Angiography vs. MCG
Which is better?



Diameter Stenosis
: Sensitivity 80.0%
Specificity 58.1%

Bull's-Eye MCG
△ Non-ischemia
▼ Ischemia

Bull's Eye MCG
: Sensitivity 90.0%
Specificity 93.7%

Park J-W, Shin ES, et al. Clin Hemorheol Microcirc 2015;59:267-281.

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Incremental diagnostic value of combined quantitative and qualitative parameters of magnetocardiography to detect coronary artery disease

Eun-Seok Shin [a,1], Yat-Yin Lam [b,1], Ae-Young Her [c,1], Johannes Brachmann [d,1], Friedrich Jung [e,1], Jai-Wun Park [d,*,1]

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[c] Division of Cardiology, Department of Internal Medicine, Kangwon National University School of Medicine, Chuncheon, South Korea
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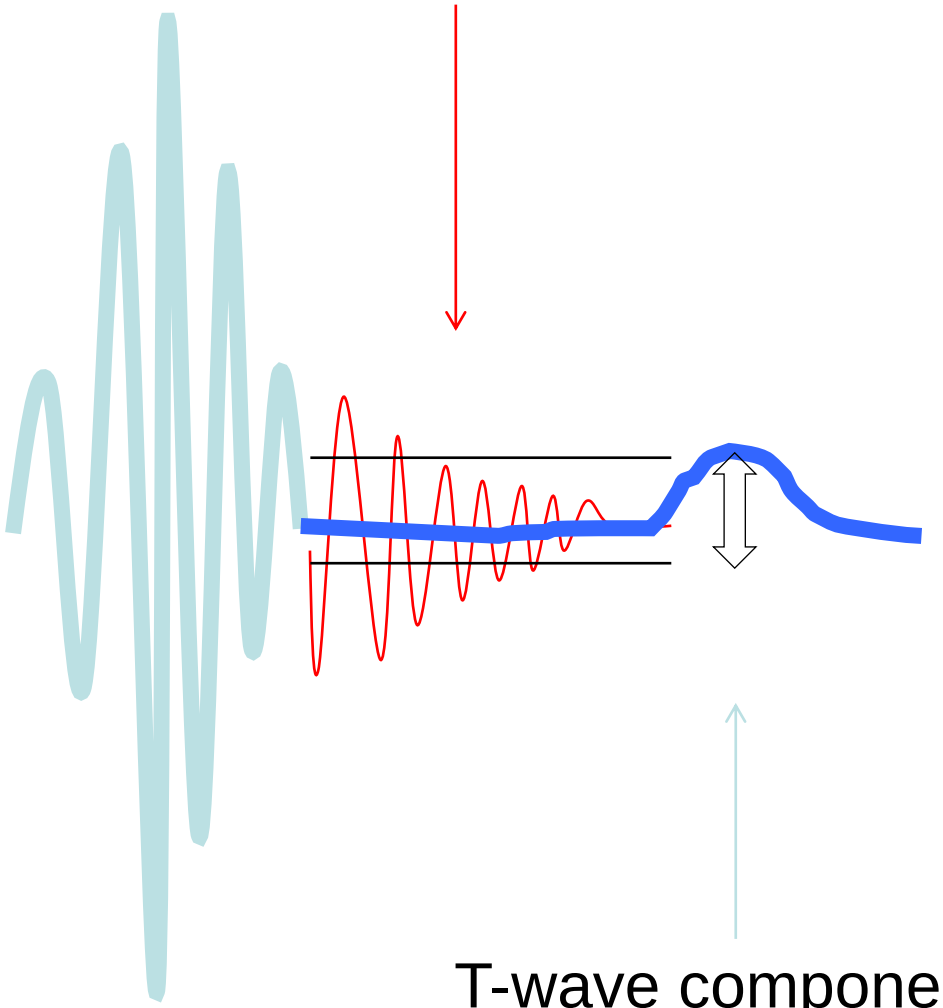
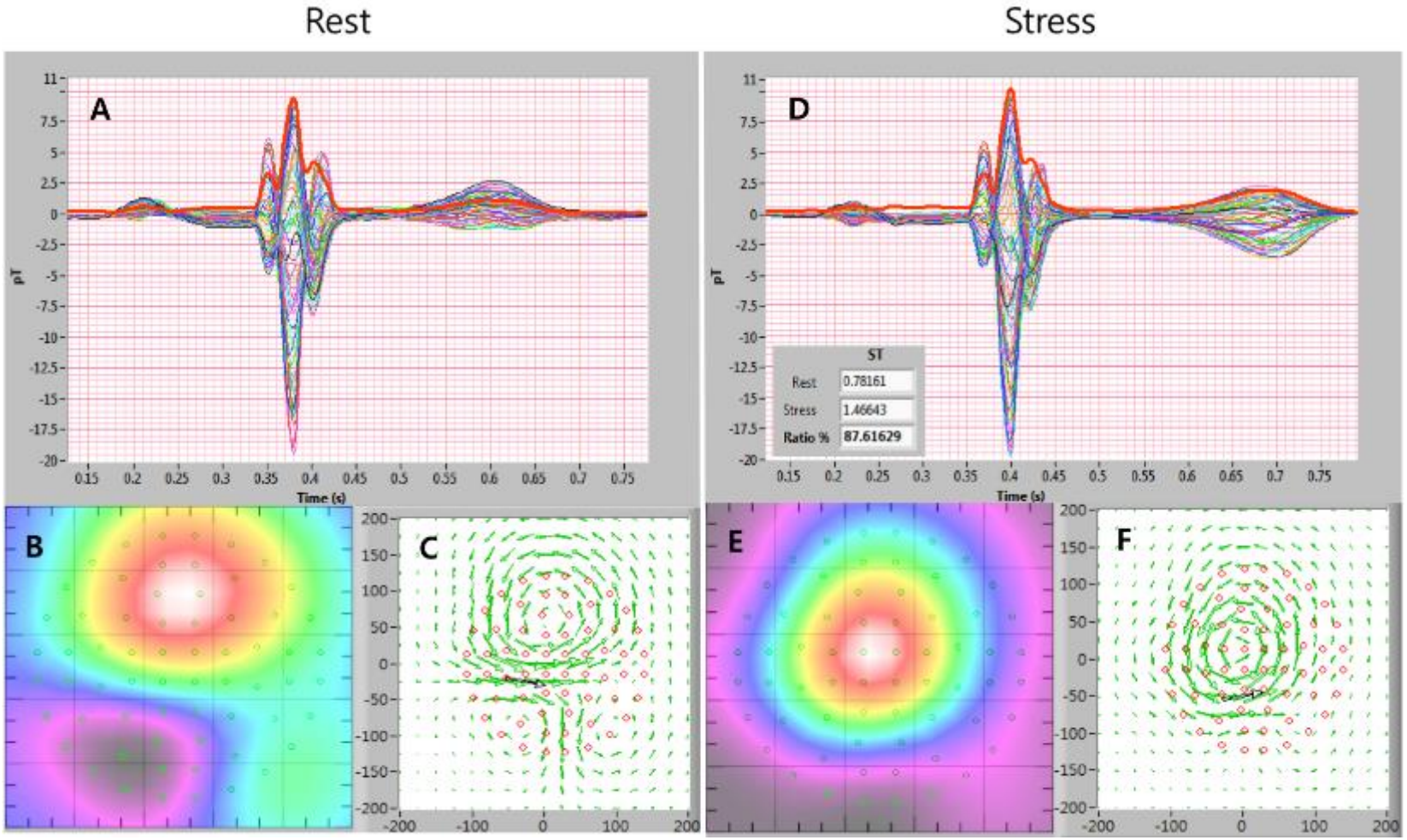
“fluctuation“

STfluc-score counts the no of extrema

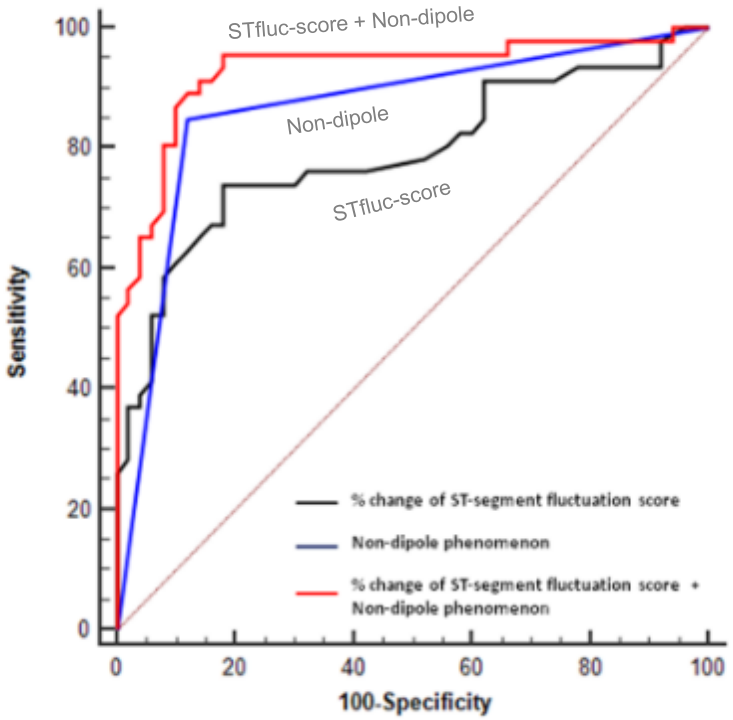


STfluc-score decreases during exercise when T-wave component increases

CAD: Non-dipole pattern



ROC curves for STfluc-score and non-dipole phenomenon



	C-Statistics	95% CI	p Value
% change of ST-segment fluctuation score	0.790	0.695 - 0.867	<0.001
Non-dipole phenomenon	0.864	0.779 - 0.925	<0.001
% change of ST-segment fluctuation score and Non-dipole phenomenon	0.930	0.860 – 0.972	<0.001

Shin E-S et al. IJC 2017;228:948–952.

Magnetocardiography Scoring System to Predict the Presence of Obstructive Coronary Artery Disease

Eun-Seok Shin[1]*, Seung Gu Park[2], Ahmed Saleh[3], Yat-Yin Lam[4], Jong Bhak[2,5], Friedrich Jung[6], Sumio Morita[7], Johannes Brachmann[3]

Clin Hemorheol Microcirc 2018, accepted

OBJECTIVE

- **This study sought to develop a novel scoring system of magnetocardiography for predicting the presence of significant obstructive coronary artery disease (CAD).**

Shin ES et al. Clin Hemorheol Microcirc 2018, accepted

METHOD

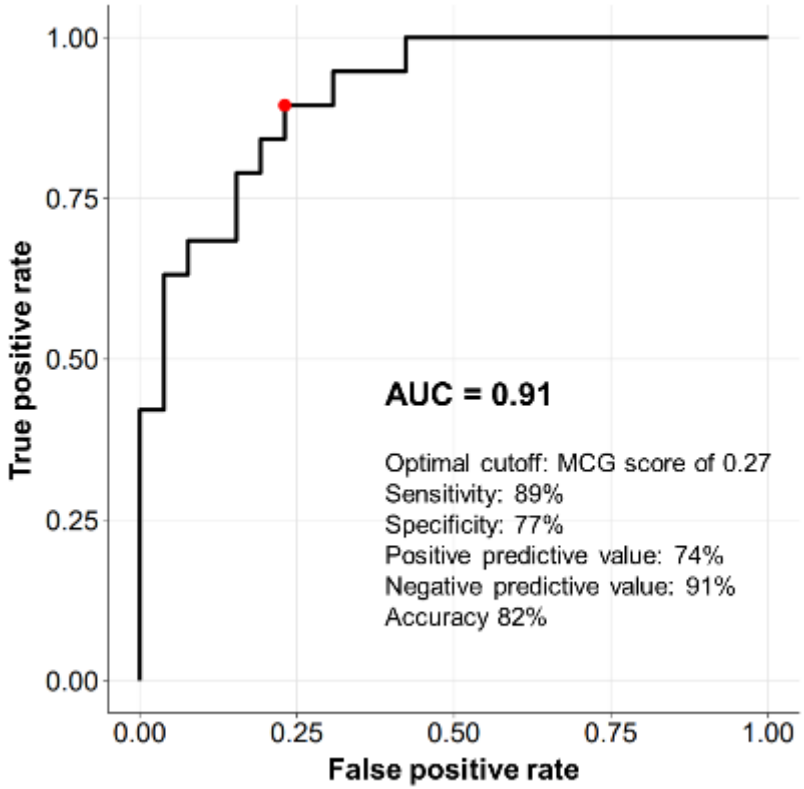
- **In a training set of 108 subjects, predictors of ≥70% stenosis in at least one major coronary vessel were prospectively identified from >12 candidate variables.**

- **The final model was then retrospectively validated in a separate set (n = 45).**

RESULTS

- **The scoring system consisted of MCG variables (T-wave score, T-wave dispersion, T-wave vector-MCG).**
- **In the multivariable logistic regression, among those in the training set, elevated scores were predictive of ≥70% stenosis in all subjects (OR: 40.85; 95% CI: 6.28 to 265.90; p <0.001).**
- **In the validation set, the score had an area under the receiver-operating characteristic curve of 0.91 (p <0.001) for coronary stenosis ≥70%.**
- **At an optimal cutoff, the score had 89% sensitivity, 77% specificity, 74% positive predictive value (PPV), 91% negative predictive value (NPV), and accuracy of 82% for ≥70% stenosis.**
- **Partitioning the score into 3 levels of predicted risk, 91% of subjects could be identified or excluding CAD with a PPV of 81% and an NPV of 84% and, respectively.**

Receiver-operating characteristic curve



The magnetocardiography score had a very robust area under the curve (AUC). The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy at the optimal cutoff are included.

Conclusion

- **MCG is an attractive alternative diagnostic tool in CAD and arrhythmias due to its non-invasive, contactless, highly sensitive, and excellent diagnostic accuracy.**
- **MCG results significantly better correlate with FFR results than coronary angiography results.**

Conclusion

- **MCG is an useful predictor for CAD and may become the gold standard diagnostic tool for defining myocardial ischemia.**