

Stress testing in coronary artery disease by Magnetic Field Imaging: a 3D current distribution model

Matthias Goernig¹, Massimo De Melis², Dania Di Pietro Paolo³, Walfred Tedeschi³,
Mario Liehr^{1,2}, Hans Reiner Figulla¹, Sergio Erne²

¹Clinic of Internal Medicine I, University of Jena, ²Clinic of Neurology, University of Jena,
³BMDSys GmbH, Jena, Jena, Germany

ABSTRACT

Objective: Magnetic field imaging (MFI) combines depolarization and repolarization registration of the cardiac electromagnetic field with a 3D current distribution model. An interesting application for MFI is the possibility to detect myocardial ischemia under stress.

Methods: Using a new reconstruction technique, it is possible to generate a pseudo-current distribution on the epicardial surface: the comparison of the time evolution of such current distributions at rest and under stress shows difference in coronary artery disease (CAD). The model works with a realistic epicardial surface generate on the basis of computerised tomography or magnetic resonance tomography data or with a standardized ellipsoidal model. To take into account the vectorial character of the epicardial current distribution, the current flow in the epicardial surface element is represented in the graphic display by a cone. Thus indicating the direction of current flow the height of the cone represents the current intensity.

Results: As an example of the method, data of pharmacological stress MFI on a CAD patient will be presented. The newly developed algorithm operates in different segments of the electromagnetic heart beat. The indicated myocardial area strongly correlated to invasive coronary angiography results. In such a situation the advantage provided by the "friendly" ellipsoidal surface on the numerical solution of the inverse problem seems to overcome the advantage of a realistic heart model.

Conclusion: We conclude MFI is a promising procedure for a non-invasive stress testing as well as screening method as for localization of myocardial ischemia. (*Anadolu Kardiyol Derg 2007; 7 Suppl 1; 191-2*)

Key words: magnetic field imaging, coronary artery disease, exercise testing

Introduction

Referring to the 2002 American College of Cardiology Foundation (ACC) and the American Heart Association (AHA) guidelines, exercise testing for coronary artery disease (CAD) (1) has a mean sensitivity of 68% and a mean specificity of 69% including patients with left ventricular hypertrophy, 72% and 77% excluding these patients. Besides the pretest probability (PTP), the value of electrocardiographic exercise test depends on the ability to do bicycle exercise testing and to reach submaximal exercise heart rate. After myocardial infarction, patients unable to exercise had an elevated mortality rate (1). For this reason, alternative screening methods for CAD in patients with intermediate PTP of CAD on the basis of gender, age and symptoms are needed. These methods should be fast, easy to interpret, cheap and also doable with pharmacological exercise testing. Therefore, we propose a novel method: Magnetic Field Imaging (MFI), incorporating all the above mentioned characteristics. This method combines the registration of the cardiac electromagnetic field with a 3D current distribution model, making it possible to see even slightly alteration of depolarization and repolarization. Since MFI is based on a recording of the magnetic

field (2), it does have additional information content, which is missed in the electric signal. In fact, MFI contrarily to the electric counterpart, is slightly influenced by inhomogeneities of the body tissue and conductivity and is able to detect vortex currents (3-5). In this work, one of the possible applications of MFI is presented-to detect myocardial ischemia under pharmacological stress.

Methods

As an example of the method we present data of a 67-year old man with known CAD, history of non-ST-elevation myocardial infarction and percutaneous coronary intervention (PCI) of the left anterior descending artery presented in 2005 with newly developed typical angina pectoris. Bicycle exercise testing could not be performed because of gonarthrosis. The 3 minutes of MFI were recorded at rest and under infusion of 144µg/kg/min adenosine respectively in the Biomagnetic Centre of the University of Jena with 56 measuring points. Using a new reconstruction technique, it is possible to generate a pseudo-current density distribution on the epicardial surface: the comparison of the time evolution of such current distributions at

Address for Correspondence: Dr. med. Matthias Goernig, Clinic of Internal Medicine I, University of Jena,
Universitätsklinikum Jena Körperschaft des öffentlichen Rechts und Teilkörperschaft der Friedrich-Schiller-Universität Jena
Bachstraße 18, 07743 Jena, Germany

Phone: ++49 (0)3641 9324529 E-mail: matthias.goernig@med.uni-jena.de

rest and under stress shows difference in patients affected by CAD. The model works with a realistic epicardial surface generate on the basis of computer tomography or magnetic resonance tomography data or with a standardized ellipsoidal model. To take into account the vectorial character of the epicardial current distribution, the current flow in the epicardial surface element is represented in the graphic display by a cone. Thus indicating the direction of current flow the height of the cone represents the current intensity. To improve readability of the display and to provide overview of regional behavior, the cones are also colour coded: green indicate strong activity, red indicate poor activity. The difference between rest and stress are visually interpreted by two different experienced observers.

Results

Figure 1 shows the resting MFI (left) and the stress MFI (right) at the time point of T-maximum before PCI. There is a strong difference in the pseudo-current distribution comparing rest and stress results in the posterior medial to apical ellipsoid. Angiography shows 80% de novo stenosis of the proximal right coronary artery (RCA). The difference disappears in the control stress MFI 4 weeks after PCI and with patient asymptomatic.

Discussion

The MFI is a promising method in cardiology. Besides risk stratification for arrhythmic events, diagnostic of ischemic myocardial tissue is an interesting application for this technique (6, 7). In different centres in Europe studies for exercise testing in CAD using MFI are initiated. A pseudo-current distribution on an ellipsoid model, which can detect myocardial ischemia under stress, has been introduced. Using adenosine stress the limitation of ability to do bicycle exercise has been overcome. The

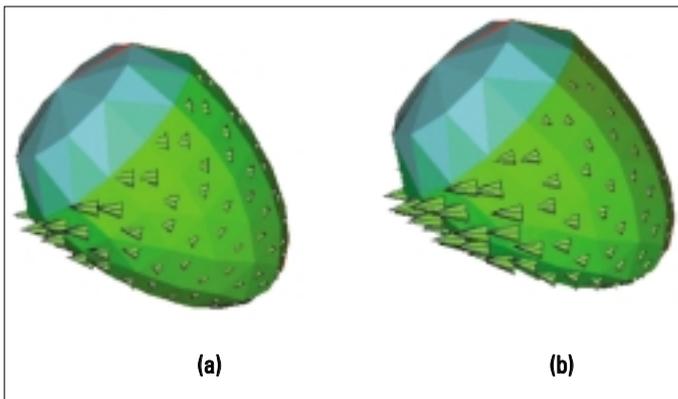


Figure 1. Stress MFI at the time point T-maximum of a 67-year old man with an angiographic proven proximal 80% RCA stenosis before PCI, a) rest, b) under adenosine (144µg/kg/min)

MFI- magnetic field imaging, PCI- percutaneous coronary intervention, RCA- right coronary artery

algorithm operates in different segments of the heart beat. The most suitable difference in current intensity could be seen at T-maximum. Comparison of time evolution between rest and stress registrations showed elevated current densities in ischemic areas of the heart surface. In the presented case, a significant difference between rest and stress in current density could be demonstrated in medial to apical posterior ellipsoid model before PCI, which disappeared after intervention. The indicated myocardial area strongly correlated to invasive coronary angiography results: 80% de novo stenosis of the proximal RCA was treated by balloon dilatation and stent implantation. In such a situation the advantage provided by the “friendly” ellipsoidal surface on the numerical solution of the inverse problem seems to overcome the advantage of a realistic heart model.

Conclusion: The pseudo-current distribution model is a promising procedure for a non-invasive stress testing on the basis of MFI. The method could be used as screening method and for localization of myocardial ischemia as well. The value of the technique has to be proven by a clinical trial.

References

- Gibbons RJ, Balady GJ, Bricker JT, Chaitman BR, Fletcher GF, Froelicher VF, et al. American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Committee to Update the 1997 Exercise Testing Guidelines.: ACC/AHA 2002 guideline update for exercise testing: summary article. A report of the American College of Cardiology/American Heart Association Task Force on Practice. J Am Coll Cardiol 2002; 40: 1531-40.
- Erné SN, Pasquarelli A, Kammrath H, Della Penna S, Torquati K, Pizella V, et al. Argos 55-the new MCG system in Ulm. In: Yoshimoto T, Kotani M, Kuriki S, Karibe H, Nakasato N, editors. BIOMAG - 98. Proceedings of the 11th International Conference on Biomagnetism; 1998 Aug; Sendai, Japan; Tohoku University Press: 1999. p. 27-30.
- Wikswa JP Jr. Cellular action currents. In: Williamson SJ, Romani GL, Kaufman L, Modena I, editors. Biomagnetism: An Interdisciplinary Approach. New York; Plenum Publishing: 1983. p. 173-207.
- Brockmeier K, Schmitz L, Bobadilla Chavez JD, Burghoff M, Koch H, Zimmermann R, et al. Magnetocardiography and 32-lead potential mapping: repolarization in normal subjects during pharmacologically induced stress. J Cardiovasc Electrophysiol 1997; 8: 615-26.
- Liehr M, Haueisen J, Goernig M, Seidel P, Nenonen J, Katila T. Vortex shaped current sources in a physical torso phantom. Ann Biomed Engineering 2005; 33: 240-7.
- Tolstrup K, Madsen BE, Ruiz JA, Greenwood SD, Camacho J, Siegel RJ, et al. Non-invasive resting magnetocardiographic imaging for the rapid detection of ischemia in subjects presenting with chest pain. Cardiology 2006; 106: 270-6.
- Park JW, Hill PM, Chung N, Hugenholtz PG, Jung F. Magnetocardiography predicts coronary artery disease in patients with acute chest pain. Ann Noninvasive Electrocardiol 2005; 10: 312-23.