MR guided breast biopsy in women at increased risk
for developing breast cancer

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Keywords Breast cancer · MR · Biopsy

Purpose
A family history of breast cancer has long been associated with environmental factors, but is now attributed chiefly to genetic factors. Strategies for reducing the risk of breast cancer among the women from such families include bilateral mastectomy, bilateral ovariectomy, and chemoprevention such as the use of Tamoxifen. These radical procedures are increasingly being replaced by the use of diagnostic imaging techniques to increase the chances of early detection of breast cancer and to maximize curative treatment. The present study has evaluated the effectiveness of MR mammography (MRM) and breast biopsy guided by this method in cases where US and MMG failed to detect suspected lesions.

Methods
Genetic testing was performed on 402 women aged 17–78 (mean age 48.9 years), in collaboration with the International Hereditary Cancer Center (IHCC) of the Pomerania Medical University.1 The tests were performed in all women who had developed breast or ovarian cancer or had a family history that included at least one relative with documented breast cancer before the age of 50 or one relative regardless of age with ovarian cancer. In addition, the women were subjected to: clinical breast examination, breast US and for those over 35 years of age, MMG (provided if not already been performed within the last 12 months). Of the 402 women subjected to the examinations, a group of 379 (94.28%), aged 17–77 (mean age 47.54 years), who either had had no focal lesions detected (BIRADS 1) or had only benign lesions (BIRADS 2), was identified. All the women underwent MRM. Furthermore, they were divided into four subgroups based on the genetic testing results as follows: Group I of 84 (22.16%) women, aged 26–66 (mean age 49.12 years) who carried one of the following pathogenic mutations: BRCA1, BRCA2 and CHECK2; Group II of 39 (10.29%) women, aged 17–72 (mean age 41.18 years), with confirmed Hereditary Breast Cancer—site specific (HBC-ss) or Hereditary Breast-Ovarian Cancer (HBOC) syndromes, Group III: of 32 (8.44%) women, aged 39–77 (mean age 52.32 years), who had had mastectomy or breast-conserving therapy for breast cancer. In these women no genetic mutations were found that would predispose them to developing breast cancer; Group IV of 224 (59.10%) women, aged 19–52 (mean age 47.54), who reported single breast or ovarian cancer cases in a family member of first or greater than first degree of relationship. However, the number of cancers and the age of the patient at the time of the cancer’s onset did not allow for a diagnosis of HBC-ss or HBOC syndromes.

Breast lesions visualized by MRM were classified to one of the MR BIRADS categories developed by the American College of Radiology. Those patients whose breast lesions were not visualized by US and MMG, but detected by MRM, regardless of their BIRADS type, were subjected to either MR-guided core biopsy (subsequently verified by follow open surgical breast biopsy) or directly by MR-guided needle localization open surgical breast biopsy (OSBB).

Results
Of the examined 380 patients, 37 (9.74%) women were identified with breast pathologies detected by MRM that were not visualized by previous US and MMG. In 4/37 (10.81%) of these women, a biopsy could not be performed from technical reason. These patients qualified for routine follow-up visualizing examinations. Group of 26/37 (70.28%) were referred to MR-guided breast core biopsy (standard core biopsy as well as vacuum-assisted core biopsy) and remaining 7/37 (18.91%) to MR-guided needle localization OSBB. Finally, OSBB was performed on 33 women, including 26 who had been after breast core biopsy guided by MRM. The open breast biopsy histopathological findings were correlated with MR BIRADS categories as follows:

- In BIRADS 2 group: 6 (100%) benign breast lesions
- In BIRADS 3 group: 1 (16.67%) invasive ductal cancer and 5 benign lesions (83.33%)
- In BIRADS 4 group: 7 (53.84%) malignant lesions: 2 ductal carcinomas in situ (15.38%), 4 (30.77%) invasive ductal carcinomas, 1 invasive lobular carcinoma (7.69%), and 5 (46.16%) benign lesions
- In BIRADS 5 group: 8 cancers (100%): 6 invasive ductal carcinomas, 1 lobular carcinoma in situ and 1 invasive lobular carcinoma.

Based on the above findings (especially the BIRADS results), the sensitivity of breast MRM in detecting malignant lesions was 93.75% and specificity 64.71%. Comparing the results of needle biopsy to OSBB as a gold standard, there was found only one case of cancer invasiveness underestimation. Histopathology result after standard core biopsy was ductal carcinoma in situ which finally change to invasive ductal cancer after OSBB. Taking into consideration above results, sensitivity of MMR-guided breast biopsy reached 100% and specificity 94%. We analyzed the incidence of cancer in four groups of women divided according to their relative risk for developing breast cancer. There were 12 (75%) breast cancer cases in women with the documented HBC-ss and HBOC in Group II, 3 (18.75%) cases in genetic mutation carriers in Group I, and 1 (6.25%) in a woman with a family history of breast cancer from Group IV. There were no cases of breast cancer in Group III in those patients who had had operations for breast cancers. All 343 women with benign lesions detected by US or MMG and confirmed by MRM were offered annual clinical breast examinations, US, MMG, and MRM. The only exceptions were those women under 30 years of age on whom MMG had not been performed. The follow-up time is currently 3.5 years. In total, 229 (67%) women were followed-up according to the protocol. In none of these, did MRM detect any breast lesions other than those diagnosed by US and MMG.

Conclusion
1. All women who are carriers of BRCA1 and BRCA2 mutations and have documented HBC-ss and HBOC syndromes should undergo MRM annually as an adjunct to US and MMG.

1 Collaboration group consisted of: Prof. Jan Lubinski, Dr Tomasz Byrski, L. Romanska.
image, variation in EM sensor readings increased to a maximum of 0.4 mm in the x axis, 1.01 mm in the y axis, and 0.89 mm in the z axis. At this point, a change in baseline EM sensor readings was observed by a factor of 0.1 mm in the Y axis readings. The gantry began to rotate soon after in preparation for the full scan. The variation in EM sensor readings increased to a maximum of 0.8 mm in the x axis, 1.78 mm in the y axis and 1.12 mm in the z axis. The scanner bed was then moved to the appropriate position prior to the full scan. The variation observed while the scanner bed moved was at a maximum of 1.3 mm in the x axis, 2.68 mm in the y axis, and 2.01 mm in the z axis. There is a brief decrease in variation after the bed moves and before the full CT scan; however, the gantry continues to rotate during this period. Variation in EM sensor values decreases to a maximum of 0.7 mm in the x axis, 1.79 mm in the y axis and 1.12 mm in the z axis. During the CT scan, the variation increases again to a maximum of 1.5 mm in the x axis, 2.91 mm in the y axis, and 1.786 mm in the z axis. Variance and standard deviation were not calculated given the approximate nature of time recordings relative to event initiation during the CT scan cycle and the subsequently short duration of the cycle events. Figure 1 depicts the Y and Z axis EM sensor readings along the course of the CT scan cycle. These figures were chosen because of their large variation in comparison to the x coordinate plane.

Conclusions
We have demonstrated that a CT scanner induces increased variability in EM sensor readings and that the effect is more severe when the CT gantry is rotating. There is also evidence of a baseline shift after the scout image was taken. At this point, the gantry is fixed yet the CT scanner bed is in motion. This implies that bed motion may cause a measurable shift in values that can be compensated for during clinical intervention. The implication for CT guided procedures includes the desire to always take measurements under the same CT operation conditions, in a well tested, stable protocol. We further recommend stopping the gantry motion when a precision measurement is required.

Videodensitometric myocardial perfusion assessment on coronary angiograms
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Keywords Densitometry · Myocardial perfusion · Angioplasty · Acute myocardial infarction

Purpose
Successful recanalization in acute myocardial infarction (AMI) is described by an increase in blood flow in the epicardial artery. It is usually characterized by Thrombolysis in Myocardial Infarction (TIMI) flow grade. However, microcirculatory reperfusion in the myocardium does not depend only on the epicardial flow. Several techniques, such as myocardial contrast echocardiography, magnetic resonance imaging, and radionuclide studies show that many patients have inadequate flow at myocardial tissue level despite a reopened epicardial coronary artery. Therefore, assessment of myocardial perfusion has a great importance in risk stratification after AMI and successful intervention. Assessment of perfusion on coronary angiograms is currently performed by visual grading in the clinical practice. Interobserver and intraobserver variabilities associated with subjective angiographic assessments are limitations of these visual grades. An automatic, computerized, densitometric measurement method is presented to assess myocardial perfusion, on coronary angiograms.

Methods
The present prospective study comprised 62 patients who underwent AMI followed by successful angioplasty of the occluded coronary artery. Phase matched digitally subtracted angiographic images were

Fig. 1 This Figure shows the noise in the position signal for a stable electromagnetic sensor on the CT scanner table measured using the ATC Flatplate transmitter. It shows the effects of taking a scout image, table movement while the gantry is running, and of actual X-ray scanning. The background noise level was observed to increase significantly when the scanner gantry was moving

Fig. 1 Videodensitometric measurement method. Region of interest (dashed white polygon) after a proximal LAD occlusion. Corresponding time–density curve is shown right to the angiogram

Fig. 2 Visual assessment versus videodensitometry. Receiver operating characteristic curves of TMP (left diagram), and $G_{\text{max}}/T_{\text{max}}$ with vessel masking (right diagram) to predict enzymatic infarction size characterized by sum CK $> 5,000$
used for the measurements with stabilized image acquisition parameters. Epicardial vessels on the angiograms were masked out with an automatic multiscale vessel detection algorithm which analyses eigenvalues of the Hessian matrices of image points. Time-density curves (TDC) were recorded in infarct-related polygonal regions, selected by a cardiologist experienced in the analysis of coronary angiograms. Frequencies higher than 0.6 Hz were removed from the TDC to eliminate artifacts from cyclic heart contractions. G_{max} was defined as maximal amplitude of the TDC, T_{max} is the time to reach G_{max}. Both values were automatically computed from the resulting curve (Fig. 1). Perfusion was characterized with \( G_{max}/T_{max} \). This novel videodensitometric method has been compared with enzymatic infarct size as expressed by sum of CK release, 90-min ST-segment resolution and ejection fraction 3 days after successful revascularization.

**Results**

All patients underwent successful recanalization of the occluded epicardial artery within 8 h from the onset of symptoms. Bland & Altman analysis reveals a reliable interobserver agreement in our computerized method. Significant linear correlations were found between \( G_{max}/T_{max} \) and enzymatic infarct size \((R=-0.445, P < 0.001)\), ST-segment resolution \((R = 0.364, P = 0.004)\) and ejection fraction \((R = 0.278, P = 0.029)\). Optimal cut-off values have been determined for TIMI Myocardial Perfusion Grade (TMP), \( G_{max}/T_{max} \) to predict sum of CK < 5,000 U/l (Fig. 2). The computerized method increased sensitivity \((73–85\%)\) and specificity \((76–79\%)\) as well. \( G_{max}/T_{max} \) without vessel masking did not improve results of ROC analysis significantly, compared to TMP.

**Conclusion**

Myocardial selective videodensitometric perfusion measurement, characterized by \( G_{max}/T_{max} \) of the time-density curve in the infarct related myocardial area is a reliable parameter to assess recovery of myocardial function during the time of acute coronary intervention. Vessel masking improves the results compared to simple densitometric analysis. Therefore, this novel method could be used to immediately assess myocardial viability after recanalisation, or as an objective end-point in clinical trials of new interventional devices and drugs, in place of the visual classification grades.

**Automated coronary artery segmentation using morphological operators**

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**Keywords** Coronary angiogram · Morphological · Segmentation

**Purpose**

Coronary angiogram is one of the most valid methods for diagnosing the presence of coronary artery disease. Therefore, the development of digital image analysis techniques for the objective and precise analysis of coronary angiograms becomes an important research. The problem of coronary image analysis is to find accurate information for the dimensions of the arteries to construct a structural description of the coronary tree to make the reliable extraction of higher level diagnostic information possible. However, vessels may be broken into several disconnected components and discontinuities may occur at bifurcation or stenosis points. To achieve the purpose of providing accurate information, it is imperative to develop excellent segmentation and automated techniques for angiogram image analysis. The purpose of this study is to propose an algorithm to extract the skeletons and borders of coronary arteries in digitalized angiograms automatically.

**Methods**

In this paper, we proposed an automatic tubular enhancement algorithm based on eigenvalue analysis of the Hessian matrix to extract the skeletons and borders of coronary arteries in digitalized angiograms. Morphological majority filter is also applied in the segmented image to smooth the contours and to remove some small isolated regions. Initially, the approximate contour of coronary angiogram is roughly estimated by region growing and edge dilation. The purpose of this step is to depict the main contour of the coronary simply without considering its complexity of background. The rudimentary coronary is then segmented into closed fractions by edge skeleton growing iteratively. No matter how other closed fractions will affect and under-segmentation caused by the complicated background, this step ensures that most of the fractions inside the coronary will be closed. The temporary fraction map is further enhanced by the eigenvalue analysis of the Hessian matrix to highlight tubular structures from tissues and background noises in angiogram images. Then, the retained fractions are filtered by the Otsu dynamic threshold method iteratively. In this stage, the true fractions of the coronary will grow along the coronary to form the main object of the coronary. Finally, the segmentation result will be achieved by performing the intersection between the main object and the dilated edges.

**Results**

To demonstrate the correctness of the proposed method in detecting the artery skeletons and segmentation result, the proposed method was examined using a set of clinical coronary angiogram images. Both of the right and left coronary angiograms were included in the data sets. Simulation results showed that we were able to extract the principle coronary artery contours and centerlines by the proposed method successfully. Moreover, the segmentation results preserve the original coronary artery width while with less background noises. It is clear that the borders are successfully and automatically extracted. Especially, the proposed method performed well in low-contrast noisy angiograms with many artery crossings.

**Conclusions**

In recent clinical researches, it has been revealed that coronary artery analysis becomes important indicators of coronary heart disease. In this study, an automatic tubular enhancement algorithm based on eigenvalue analysis of the Hessian matrix was proposed to extract the skeletons and borders of coronary arteries in digitalized angiograms. Experiment result showed that the proposed method can successfully extract the principle coronary artery contours and centerlines. The segmented results can be further used to analyze the diagnostic information of coronary artery. Through the analysis of coronary artery, we hope that the cardiopathy could be diagnosed earlier to get the prevention or treatment better. Further research is aimed in the direction of quantitative analysis of coronary arteries for the development of computer-aided diagnosis (CAD) system.

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**A comparison study of two reconstruction methods for gated cone-beam CT**

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**Keywords** Image-guided therapy · Surgical guidance · Cone-beam CT

**Purpose**

C-arm based Cone-Beam CT (CBCT) imaging enables the in situ acquisition of three dimensional images. In the context of image-guided interventions this technology has the potential to reduce the complexity of a procedure’s workflow, with imaging and intervention carried out in the same location. For interventions carried out in the thoracic-abdominal regions, image acquisition while the patient is