Predicting Breast Attenuation in Patients Undergoing Myocardial Perfusion Scintigraphy: A Digital X-Ray Study

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Attenuation artifacts are the most common sources of error in myocardial single-photon emission computed tomography (SPECT) imaging. Breast artifacts are the most frequent causes of false positive planar images in female subjects. The purpose of this study was to predict breast *adverse* attenuation by measuring breast tissue thickness with digital x-ray. Sixty-five consecutive female patients with angina pectoris, who were referred to myocardial perfusion scintigraphy were enrolled in this study. Eighteen patients with normal perfusion imaging and normal coronary angiography composed the first group, whereas the second group consisted of 28 patients with a positive exercise electrocardiogram with anterior ischemia on myocardial perfusion imaging and greater than 50% left anterior descending artery stenosis on angiography. Nineteen patients in the third group had normal exercise electrocardiograms and normal coronary angiographies, but anterior ischemia on perfusion imaging. Digital x-ray records were obtained for measuring breast tissue thickness and Hounsfield density. The rate of breast *adverse* attenuation was 40% (19/47) in patients with anterior ischemia. The sensitivity and specificity of the prediction of breast *adverse* attenuation (lateral density less than 550 Hounsfield) were 79% and 11%, respectively. When breast attenuation for a breast thickness greater than 6 cm measured in the left anterior oblique view was predicted, the sensitivity and specificity were 79% and 93%, respectively. In conclusion, breast thickness greater than 6 cm measured from the left anterior oblique view with digital x-ray can predict breast *adverse* attenuation in female patients, and thereby may decrease the number of unnecessary invasive diagnostic procedures to be performed.

KEY WORDS: Breast thickness, tissue Hounsfield density, attenuation

Exercise stress test, stress echocardiography, myocardial perfusion scintigraphy, and coronary flow measurement via echocardiography are the main methods for the noninvasive evaluation

of coronary arteries.^{1,2} However, myocardial scintigraphy has some limitations especially in female patients because of breast tissue fold. Attenuation artifacts are the most common sources of error in single-photon emission computed tomography (SPECT) imaging. Breast artifacts are the most frequent causes of false positive planar images in female subjects. Superimposition of breast tissue over the heart may result in linear areas of relatively increased activity, which is believed to be caused by small-angle scatter from the breast tissue fold. This increased activity simulates anterior ischemia³ and engenders false positive scintigraphy results, which may lead to complication by and additional costs as a result of the performance of unnecessary angiography. The Hounsfield unit measurement is well known in medical and nonmedical fields, including the evaluation of coronary artery plaques and examination of fossil bone.^{4,5} Therefore, the purpose of this study was to predict breast *adverse* attenuation by measuring breast tissue thickness and tissue Hounsfield density using digital x-ray.

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Fig. 1. The schematic illustration of breast thickness and Hounsfield density. HD1: external Hounsfield density, HD2: middle Hounsfield density, HD3: internal Hounsfield density. X1 = Breast tissue fold.

METHODS

Study Population

Sixty-five consecutive female patients referred to our radionuclide imaging unit were enrolled in this study. The exclusion criteria were: history of breast cancer or surgery, presence of breast prosthesis, mastitis, history of any cystic lesions of the breast, and determination of left ventricular dysfunction or left ventricular dilatation on echocardiography together with the presence of conduction abnormalities such as left bundle branch block. All patients underwent exercise myocardial perfusion imaging using SPECT imaging with thallium-201. Demographic data of the patients were also enlisted. The study population included two groups: group 1, consisting of 18 patients

with normal perfusion imaging and normal coronary angiography, and group 2, consisting of 28 patients who had a positive exercise electrocardiogram with anterior ischemia on myocardial perfusion imaging and greater than 50% left anterior descending artery stenosis on angiography. Nineteen patients in group 3 were patients having normal exercise electrocardiogram and normal coronary angiography, but anterior ischemia on perfusion imaging. The study was approved by the ethics committee of our hospital and all patients provided written consent.

Digital X-Ray

Digital x-ray records were obtained from lateral, anteroposterior, and left anterior oblique views using a digital x-ray device (Fuji Film, FCR 5000

Table 1. Comparison of Patients' Data in all Study Groups

Variables	Group 1	Group 2	Group 3	<i>p</i>
Age/years	57±10	59±10	57±8	0.712
Body mass index (kg/m ²)	27.27±3.40	29.53±3.60	29.38±2.63	0.137
Hypertension (<i>n</i> , %)	9 (50)	11 (61)	7 (63)	0.683
Smoker (<i>n</i> , %)	4 (22)	5 (18)	3 (16)	0.875
Diabetes (<i>n</i> , %)	1 (6)	12 (43)	4 (21)	0.016
Hyperlipidemia (<i>n</i> , %)	8 (44)	14 (50)	6 (32)	0.453
Family history of coronary artery disease (<i>n</i> , %)	8 (44)	10 (36)	6 (32)	0.675
Metabolic equivalent (ml/O ₂ /kg ⁻¹)	6.4±1.1	6.7±1.4	6.3±1.0	0.636
Anteroposterior breast tissue thickness/cm	4.55±1.42	5.38±2.04	5.87±2.46	0.147
Anteroposterior internal density (Hounsfield Units)	462.2±133.2	494.9±125.6	483.4±125.3	0.696
Anteroposterior external density (Hounsfield Units)	766.3±163.8	853.2±109.5	816.0±131.8	0.104
Anteroposterior middle density (Hounsfield Units)	547.3±107.2	614.6±119.3	593.4±105.4	0.146
Lateral breast tissue thickness/cm	2.4±1.4	2.4±0.8	3.4±1.4	0.01
Lateral internal density (Hounsfield Units)	632.7±74.8	642.1±75.8	581.2±85.1	0.032
Lateral external density (Hounsfield Units)	811.2±102.2	785.4±90.1	787.9±75.3	0.608
Lateral middle density (Hounsfield Units)	683.4±81.1	673.7±75.3	640.6±91.4	0.224
Left anterior oblique breast tissue thickness/cm	4.7±2.8	7.1±3.1	8.5±2.9	0.01
Left anterior oblique internal density (Hounsfield units)	591.9±148.5	554.6±146.0	512.5±116.3	0.227
Left anterior oblique external density (Hounsfield units)	880.9±109.4	840.8±132.0	878.1±101.5	0.434
Left anterior oblique middle density (Hounsfield units)	682.1±102.7	654.4±115.4	616.9±103.5	0.193

R, CR-IR 342, Tokyo, Japan). The breast thickness was measured from all views, in centimeters, from the subcutaneous adipose tissue to the pectoral muscle with digital x-ray records. Tissue Hounsfield density was measured for all views as middle density (the middle point of the breast thickness), external (the lateral 1/4 of the breast) and internal density (the medial 1/4 of the breast) (Fig. 1).

Exercise Myocardial Perfusion Imaging

Patients with a normal basal electrocardiogram and without any contraindication underwent exercise testing according to the Bruce protocol.⁶ One millimeter or more horizontal or down-sloping ST-segment depression for at least 80 ms was defined positive. Metabolic equivalent threshold values were also recorded. Exercise myocardial perfusion imaging using SPECT imaging with thallium-201 was performed according to established standards.⁷ Cardiac short and horizontal, vertical axis tomography views were obtained using a 180-degrees rotating gamma camera (Elsint-Cardiol, Apex-Spx system, Multispect 2HD/HD3) with parallel-hole high-resolution collimators. During image acquisition, projection data were obtained with an image acquisition time of 30 sec. Reconstruction was performed using filtered back projection with a Butterworth filter in 128×128 matrices.

Anterior ischemia was defined as a reversible perfusion defect observed in the related area.

Selective Coronary Arteriography

All patients underwent a standard cardiac catheterization via a standard femoral approach, and selective coronary arteriography was done as previously described.⁸ The coronary angiograms were assessed quantitatively⁹ using computer-assisted measurements undertaken by an experienced observer blinded to the clinical status of the patient. The presence of greater than 50% narrowing in the diameter of the left anterior descending artery was considered as significant stenosis.

Statistical Analysis

All data were expressed as mean ± SD. The differences between groups were analyzed using one-way analysis of variance (ANOVA) and assessments were made for sensitivity and specificity. A multiple stepwise (forward and backward) linear regression analysis was performed for multivariate analysis. The multivariate model consisted of attenuation (anterior ischemia in group 3) as dependent variable and of independent variables, which had significant correlation with attenuation in the simple linear regression analysis.

Fig. 2. Distribution of left anterior oblique and lateral breast tissue thickness among the study groups. LT: Lateral, LAO: Left anterior oblique, cm: centimeter.

A p value less than 0.05 was considered statistically significant. The SPSS 10.00 (Statistical Package for Social Sciences) for Windows was used for the entire statistical workup.

RESULTS

Variables such as age, hypertension, smoking status, and hyperlipidemia did not differ among the three groups. However, diabetes was significantly increased in group 2. The rest of the data are shown

in Table 1. Breast adverse attenuation rate was 40% (19/47) in patients with anterior ischemia. In patients with attenuation, breast thickness measured in left anterior oblique and lateral views (Fig. 2) were found to be increased, whereas lateral density was found to be decreased (Table 1).

The univariate relation of adverse attenuation with other parameters is presented in Table 2. In univariate analysis, attenuation correlated with lateral breast tissue thickness ($r=0.37$), lateral internal Hounsfield density ($r=-0.32$) and left anterior oblique breast tissue thickness ($r=0.33$).

Table 2. The Univariate Association of Adverse Attenuation with Other Parameters

Variables	P	R
Age/years	0.54	-0.07
Body mass index (kg/m^2)	0.49	0.10
Anteroposterior breast tissue thickness/cm	0.15	0.18
Anteroposterior internal density (Hounsfield units)	0.97	0.005
Anteroposterior external density (Hounsfield units)	0.93	-0.11
Anteroposterior middle density (Hounsfield units)	0.87	0.02
Lateral breast tissue thickness/cm	0.002	0.37
Lateral internal density (Hounsfield units)	0.009	-0.32
Lateral external density (Hounsfield units)	0.76	-0.03
Lateral middle density (Hounsfield units)	0.09	-0.21
Left anterior oblique breast tissue thickness/cm	0.008	0.33
Left anterior oblique internal density (Hounsfield units)	0.14	-0.19
Left anterior oblique external density (Hounsfield units)	0.52	0.08
Left anterior oblique middle density (Hounsfield units)	0.11	-0.20

In multivariate analysis, lateral internal Hounsfield density ($p=0.021$, odds ratio=1.010, 95% CI=1.002–1.019) and left anterior oblique breast tissue thickness ($p=0.004$, odds ratio=2.268, 95% CI=1.301–3.956) were found to be the predictors of adverse attenuation.

The sensitivity and specificity of predicting breast adverse attenuation (lateral density less than 550 Hounsfield) were 79% and 11%; respectively. In breast adverse attenuation for a breast thickness of greater than 6 cm measured in the left anterior oblique view, the sensitivity and specificity were predicted as 79% and 93%, respectively. Lateral breast thickness greater than 3.5 cm had a sensitivity of 36% for detecting breast adverse attenuation, with an excellent specificity of 94%.

DISCUSSION

Currently, there are no available data indicating the rate of breast adverse attenuation. The ratio of attenuation was found to be 40% (19/47) in our patients with anterior ischemia. This high rate also shows the clinical importance of our findings. Although there are some correction methods^{10–12} used for eliminating breast attenuation in female patients, attenuation continues to be a problem in perfusion imaging.

Breast adverse attenuation has been found to be associated with increasing age¹³ and body mass index.¹⁴ However, in univariate analysis, we found neither age nor body mass index to be related with attenuation. As to Cohen et al¹³, although not proven, the underlying cause of this attenuation is the changes that occur in the breast with aging such as increasing breast volume and breast tissue density. Although not agreeing that age is associated with attenuation, we found that Hounsfield density and breast tissue thickness were predictors for attenuation in multivariate analysis.

Gated SPECT has been used to decrease attenuation artefacts.^{10,11} Recently, another attenuation correction method has been suggested.¹² The former utilizes electrocardiography to improve the specificity of myocardial imaging, whereas the latter uses tomography images for this purpose. To our knowledge, the present study is the first suggesting that adverse attenuation could be predicted by measuring breast thickness and tissue Hounsfield density. A breast thickness

greater than 6 cm measured from the left anterior oblique view predicted attenuation with 79% sensitivity and 93% specificity. From this point of view, we recommend that SPECT results obtained in anterior ischemia in patients with a breast tissue thickness of greater than 6 cm should be assessed cautiously. In these patients, using gated SPECT or preferentially performing stress echocardiography could be a more reasonable approach to the assessment of ischemia. The Hounsfield density had a sensitivity of 79% and a very low specificity.

The increase in positive test results obtained in group 2 may be caused by the increased prevalence of risk factors for diabetes and coronary artery disease. Therefore, it is also clinically important to be skeptical about attenuation in high-risk patients.

This new method requires the use of digital x-ray, but it may have some value in decreasing unnecessary invasive interventions.

Study Limitations

Without coronary artery stenosis, microvascular dysfunction may reduce coronary flow reserve and may result in ischemia such as in patients with cardiac syndrome X.^{15,16} It is possible that some patients diagnosed with attenuation in fact had microvascular dysfunction, which is determined by measuring coronary flow reserve. Not measuring coronary flow reserve was one limitation of our study. However, cardiac syndrome X was excluded in the adverse attenuation group by indicating a normal exercise stress test without ST depression.

In addition, no data have been encountered regarding the correlation in measuring Hounsfield density between CT and digital x-ray. However, we believe that the simplicity and the probability of detecting adverse attenuation before SPECT could make digital x-ray a helpful tool.

CONCLUSIONS

Measuring breast thickness using digital x-ray is an easy method and may be helpful in preventing unnecessary invasive procedures by allowing the selection of appropriate diagnostic methods in investigating ischemia.

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