Electric Potential Index as Evaluation Criterion for Mammary Gland Structure in Electrical Impedance Mammography

Karpov A, Korotkova M, Tsofin Yu, Linyuk A
Clinical Hospital #9, SIM-Technika
Yaroslavl, Russia

e-mail: kb9@mail.ru; sim-tech@net76.ru

Abstract. Проанализированы данные 1632 электромаммографических исследований, полученных у здоровых женщин разных возрастных групп. The research was carried out utilizing the electrical impedance computer mammograph «MEIK v.5.6»®, позволяющего получать изображения срезов трехмерных распределений электропроводности в тканях молочной железы на глубину до 5 сантиметров. Была проведена визуальная и количественная оценка электроимпедансных изображений с вычислением индекса электропроводности (IC). Полученные количественные данные IC молочных желез обработаны процентильным методом. Возможна оценка плотности молочной железы по IC с точки зрения электроимпедансной маммографии. Оценка плотности молочной железы по IC с точки зрения выполнения электроимпедансной маммографии приведена в соответствии с терминами *ACR*). The article is illustrated with electroimpedance mammograms and tables.

The purpose of this research was to determine the evaluation criteria for the structure of the breast, such as type of density, from the viewpoint of electrical impedance mammography.

1. Materials and Methods

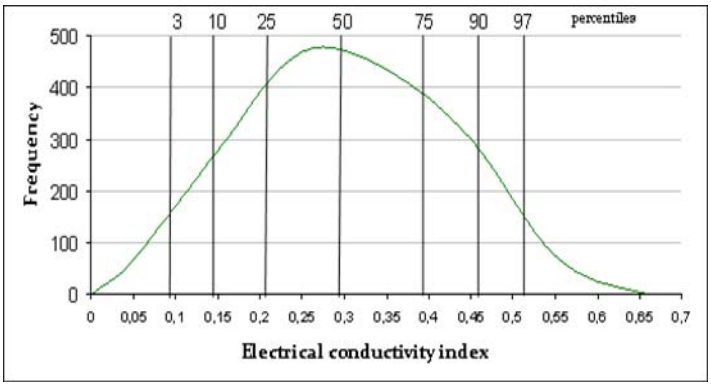
The results of 1,632 electrical impedance mammograph examinations, obtained from healthy women from different age groups, were analyzed. The women were selected for the examination according to the following criteria: absence of complaints on the mammary glands, a normal menstrual cycle, uncomplicated perimenopausal period, absence of chronic somatic and gynaecological diseases, and absence of hormonal contraceptives taking or hormone replacement therapy. The women were distributed by age in years as follows: 20-30 (380 women), 31-40 (428), 41-50 (449) and 51-60 (375). The research was carried out utilizing the electrical impedance computer mammograph «MEIK v.5.6»®, which enables to acquire images of 3-D conductivity distribution layers within mamma's tissues up to 5 cm depth. The weighted reciprocal projection method was employed to reconstruct the 3-D electric conductivity distribution of the examined organ (5, 7). At the same time, the mammary glands were examined with «Ultrasonix SP» ultrasound scanner. Visual and quantitative assessment of electrical impedance images including the calculation of the electric conductivity index (IC)/potential was performed. The quantitative data for the electric potential of the mammary glands obtained during the study were processed using percentile method.

2. Result

Fluctuations of electrical conductivity index in 1,632 studies were as follows: lower limit – 0.01 conventional units, upper limit – 0.68 conventional units. In order to identify the structure of electrical impedance index distribution there were elaborated 8 ranges of criteria at a pitch of 0.09 and the quantity of studies was calculated in each range (Fig 1).

Fig. 1. Distribution of mean electrical conductivity index frequencies and frequency histogram of electrical conductivity index data and percentile ranges

Electrical conductivity index	Number of studies
0 – 0.09	67
0.10 – 0.19	279
0.20 – 0.29	471
0.30 – 0.39	435
0.40 – 0.49	299
0.50 – 0.59	75
0.60 – 0.69	6
Total	1,632



Thus, one can speak about standard (Gauss) distribution of electrical conductivity index: bell-shaped curve, close mean, median and mode values. Usually, to describe the normal distribution the following functions are used: x±SD and x±1.96 SD. More detailed data can be obtained using 3th, 10th, 25th, 40th, 75th, 90th and 97th percentiles (1, 2, 8). In this case, the information on the shape of criterion distribution graph is not required (Fig. 1).

The following pattern was identified after the age-related characteristics of women belonging to the percentile ranges were analyzed. Women aged from 20 to 30, whose data fell to the ranges less than 3rd percentile (IC<0.09) and from 3rd to 10th percentile (IC=0.1-1.4) constituted more than 50%. Women aged from 50 to 60, whose data fell to the ranges higher than 97th percentile (IC>0.53) and from 90th to 97th percentile (IC=0.47-0.52) constituted more than 50%. Age of the women whose data ranged between 25th and 75th percentiles (IC=0.21-0.39) distributed in a uniform manner, the percentage of each age-group constituted from 20 to 30% without any prevalence.

The low electrical conductivity index of the mammary glands typical for women aged from 20 to 30 are conditioned by the peculiarities of breast's anatomy. This group of women is characterized by the prevalent amount of ductal epithelium with alveolar glandular epithelium anlage over connective tissue in the mammary gland structure (9). Therefore, the status of mammary glands possessing electrical conductivity index lower than 0.14 cu, should be regarded as ductal type of the mammary gland structure. "Loss" of ductal epithelium in women aged from 50 to 60 is the reason for high electrical conductivity index of the mammary glands. Therefore, when connective tissue prevails in the structure of a mammary gland, high electrical conductivity should be expected (3). The predominance of women in this age group is observed in two percentile ranges - more than 97th percentile and from 90th to 97th percentile. Therefore, the status of mammary glands possessing electrical conductivity index higher than 0.47 cu, should be regarded as amorphous type of the mammary gland structure. The combination of ductal components and connective tissue with adipocytes is the reason for electrical conductivity index values from 0.21-0.39 in women of all age groups. Therefore, the status of mammary glands possessing electrical conductivity index within the range from 0.21 to 0.39 cu, should be regarded as a mixed type of the mammary gland structure. Different combinations of the structures that determine the conductivity and permittivity of tissues, define the large range of the values of mean electrical conductivity index. Within the ranges from 10th

to 25th percentile and from 75 to 90th percentile the data of two age groups of women prevail. Therefore, the status of mammary glands possessing electrical conductivity index within these ranges, should be regarded as a mixed type of the mammary gland structure with prevalence of ductal or amorphous component respectively.

Below the summary table of density estimates for the breast in terms of electrical impedance mammography is provided (Table 1).

Table 1. Types of mammary gland structure from the perspective of electrical impedance mammography

	Formulation	**Electrical conductivity**	**Percentiles**
Type Ia	Amorphous type of mammary gland structure.	**above 0.47**	**>90‰**
Type Ib	Mixed type of mammary gland structure with amorphous component predominance.	**0.40 – 0.46**	**75-90‰**
Type II	Mixed type of mammary gland structure.	**0.21 – 0.39**	**25-75‰**
Type III	Mixed type of mammary gland structure with duct component predominance. High density of ductal component.	**0.14 – 0.20**	**10-25‰**
Type IV	Ductal type of mammary gland structure. Extremely high density of duct component	**below 0.14**	**<10‰**

3. Conclusion

Thus the estimation of the density of mammary glands from the perspective of electrical impedance mammography using electrical conductivity index is possible. The defined ranges of electric conductivity correspond to different types of mammary gland "density". Low values of electric potential correspond to "dense" breasts, the so-called ductal type. High values of electric potential are characteristic of the amorphous type of breasts, consisting mainly of fat and connective tissue. A distinctive feature of this method for evaluating structure of the breast is the expression of its anatomical and histological structure in numerical terms. Estimation of the density of mammary glands from the perspective of electrical impedance mammography using electrical conductivity index in *ACR* terms is provided below (Table 2).

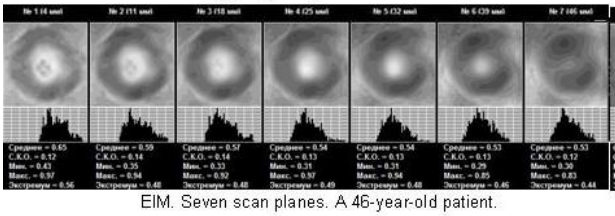
Table 2. Mammary gland structure from the perspective of electrical impedance mammography execution and breast density types according to the classification of the American College of Radiology (ACR)

	EIM classification	*ACR classification*
Type Ia	Amorphous type of mammary gland structure. IC above 0.47.	Predominantly fat. Under 25% of tissue is represented by parenchyma
Type Ib	Mixed type of mammary gland structure with amorphous component predominance. IC = 0.40 – 0.46.	
Type II	Mixed type of mammary gland structure. IC = 0.21 – 0.39.	Gland tissue consists of individual fibro-glandular elements. 25-50% of tissue is represented by parenchyma
Type III	Mixed type of mammary gland structure with duct component predominance. High density of ductal component. IC = 0.14 – 0.20.	Heterogeneously dense. 50-75% of tissue is represented by parenchyma

Type IV	Ductal type of mammary gland structure. Extremely high density of duct component IC below 0.14.	Extremely dense. 75-100% of parenchyma tissue.

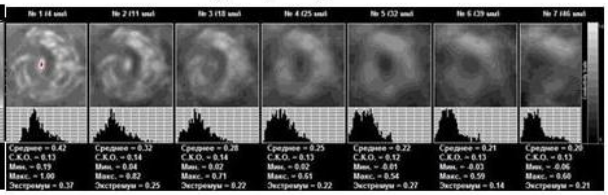
The types of mammary gland structure from the perspective of electrical impedance mammography.
Ниже, в качестве примера, приведены электроимпедансные томограммы молочных желез различной плотности.

Type I (*ACR I*).



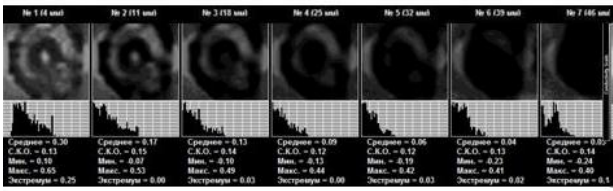
EIM. Seven scan planes. A 46-year-old patient.

Type II (*ACR II*).



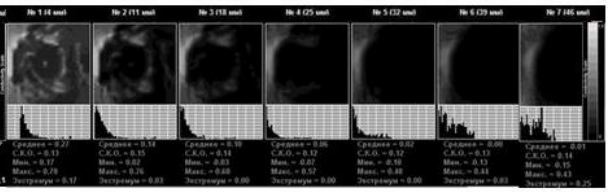
EIM. Seven scan planes. A 35-year-old patient.

Type III (*ACR III*).



EIM. Seven scan planes. A 27-year-old patient.

Type IV (*ACR IV*).



EIM. Seven scan planes. A 20-year-old patient.

References

1. American College of Radiology. Breast imaging reporting and data system (BIRADS), Reston, V.A. **2003**.
2. Biomedical Engineering, v24/is4-6, **1996**
3. Dunaeva O., Gerasimov D., Karpov A., Machin M., Tchayev A., Tsofin Yu., Tsyplyonkov V. Using Backprojection Algorithm for 3D Image Reconstruction in EIT. World Congress on Medical Physics and Biomedical Engineering, Munich, Germany, **2009**
4. Electrical Impedance Tomography. IOP, **2005**
5. Glants S. Medical and Biological Statistics. Moscow, **1999**
6. Gubler E. Quantitative methods for analysis and identification of pathology. Leningrad, **1978**
7. Karpov A., Korotkova M., Mumtazuddin Ahmed M., Myachin M., Tsofin Yu. Seminar on electrical impedance potential mammography. Yaroslavl, **2011**
8. Karpov A., Korjenevsky A., Mazurov D., Mazaletskaya A. 3D Electrical Impedance Scanning of Breast Cancer. World Congress on Medical Physics and Biomedical Engineering, Chicago, **2000**, p.62
9. Lwanga S.K., Tye C-Y. Statistics in medical research. WHO, **1986**
10. Mumtazuddin Ahmed M. Histology functional and Clinical. HEC Islamabad, **2009**