Dual-frequency electrical impedance mammography for diagnosis of non-malignant breast disease

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Abstract
Electrical impedance tomography (EIT) enables one to determine and visualize non-invasively the spatial distribution of the electrical properties of the tissues inside the body thus providing valuable diagnostic information. The electrical impedance mammography (EIM) system is a specialized EIT system for diagnostic and imaging of the breast. While breast cancer is the main target for any investigation conducted in this area, diagnosis of non-cancerous diseases is very important also because it opens the way to improve quality of life for many women and it may also reduce the incidence of breast cancer through effective treatment of mastopathy. This paper presents main results of a comprehensive examination of 166 women using four methods: multifrequency electrical impedance mammography, ultrasonic investigation, X-ray mammography and puncture biopsy. The objective of the investigation is to estimate the usefulness of multifrequency electrical impedance mammography for diagnosing dyshormonal mammary gland diseases. The results demonstrate advantages of the multifrequency EIM method. In particular, dual-frequency electrical impedance mammography in contrast to the single-frequency variant enables one not only to diagnose mastopathy, but allows also accurate detecting of its cyst-less form based on observation of the absence of difference between average conductivity in both phases of menstrual cycle. Because the cyst-less form of mastopathy is associated with higher risk of the cancer development, this method allows identifying a higher risk group of patients for more frequent investigations.

Keywords: electrical impedance tomography, clinical applications, breast diagnostics

1. Introduction

The number of patients applying to various clinics on account of non-cancerous breast diseases increases last years. All dyshormonal hyperplasic processes in mammary glands are known under the term "mastopathy". Mastopathy is defined as a fibrous and cystic disease with a wide spectrum of proliferative and regressive changes of the mammary gland with an abnormal ratio of epithelial and conjunctive components that are mingled in various combinations. The mastopathy is predominant non-malignant disease of the mammary gland occurring at 20 - 60% of women, more often at the age of 30 - 50. The interest in benign diseases arises first of all because they are risk factors and background state for the development of malignancy. Though mastopathy is not considered to be an obligatory cancer prelude, breast cancer occurs 3 - 5 times more often in patients with diffuse dyshormonal non-cancerous diseases of mammary glands and 30 - 40 times more often with nodular forms of mastopathy aggravated by proliferation of lactic gland epithelium (Letyagin 2001). This evidence has heightened the general interest in non-malignant growth, opening the way to reduce incidence of breast cancer through effective curing of mastopathy. The traditional methods of mastopathy diagnosis (ultrasound, X-ray mammography and biopsy) have certain applicability restrictions. In particular, the x-ray investigation due to ionizing radiation is not recommended for the age under 40, it can not be used for frequent screening in other ages. The ultrasound investigation results are highly dependent on the operator skills and equipment quality. The biopsy is invasive investigation not applicable for regular screening. Electrical impedance tomography (Holder 2005) is considered promising method for diagnosis of breast diseases. Corresponding equipment and diagnostics approaches have been developed by a few research groups (Cherepenin et al 2001, 2002; Kerner et al 2002; Kim et al 2007). This paper presents main results of a comprehensive examination of 166 women with four methods: multifrequency electrical impedance mammography (which is electrical impedance tomography for breast investigation), ultrasonic investigation, X-ray mammography and puncture biopsy. The analysis of the obtained data was based on visual estimation of the electrical impedance images, estimation of indexes and histograms of the conductivity distribution in mammary glands under multifrequency investigation, statistical comparison of measurements in different groups and comparison with ultrasonic and x-ray data. The paper presents criteria for diagnosis of various forms of mastopathy using the multifrequency EIM method.

2. Materials and methods

2.1. Subjects

The report presents main results of a comprehensive examination of 166 women (92 without breast pathology in the 1st group and 74 patients with mastopathy in the 2nd group). In both groups there were formed special subgroups according to the subject's age reflecting the sate of her mammary glands:

1) age below 35 - with normal stable state of mammary glands;
2) age 35–40 - with gradual loss of glandular structures;
3) age 41–45 - with noticeable thickening of ductal cylindrical epithelium, thickening of basal membrane and fibrous change of connective tissue;
4) age 46–50 - with dilatation and occasional cystic widening of lactic ducts surrounded by fibrous tissue;
5) age above 50 years - with slow obliteration of lactic ducts and small vessels accompanied by adipose tissue formation.

92 women were placed in the 1st clinical group based on ultrasonic findings below (Leucbt 1992):

- ultrasonic type of the mammary glands was in conformity with their age (juvenile, reproductive, premenopausal);

- ultrasonic visualizations corresponded to their physiological periods (1st phase of the menstrual cycle, 2nd phase of the menstrual cycle);
- distinct differentiation of the mammary gland tissue;
- the parenchyma thickness did not exceed 14 mm;
- absence of furnace symptomatology, ductectasia, duct wall fibrosis;
- absence of changes in regional zones of lymph outflow.

74 women were placed in 2nd clinical group based on the following ultrasonic information (Leucbt 1992):

- incongruity between ultrasonic type of the mammary glands and their age;
- glandular tissue layer thickening for more than 14 mm in all varieties of diffuse mastopathy;
- fibrous changes in walls of ducts;
- changes in echo-density of glandular tissue indexes that are not typical for the patient's age;
- ductectasia, wall thickening, lumen increase, irregularity of duct circuit, dilations along the main duct;
- presence of multiple cysts.

Mastopathy women of Group 2 were subdivided into 2 subgroups according to the mastopathy type: 1st type mastopathy subgroup without cystic component (41 patients) and 2nd type mastopathy subgroup with one or numerous cysts (33 patients). Women of age 35 and older underwent X-ray examination to confirm the diagnosis. Mastopathy patients (group 2) underwent anticancer and antiatypia puncture thin-needle biopsy. If the mastopathy was suspected only in one breast, the data from the other breast was not included into the 1st clinical group.

2.2. Methods and equipment

The following diagnostic methods were applied. Ultrasonic examination of mammary glands was applied to all patients on the 5–9th days of their menstrual cycle; the apparatus used was the ultrasonic Combison 530 with electronic linear 7.5 MHz probe. Women of 35 and older were subjected to X-ray mammography on the 5–9th days of their menstrual cycle. Mammodiagnost UC X-ray apparatus and ACFA mammary HDR film in Kodak min-R cassette were used. After ultrasonic and X-ray examinations a puncture biopsy was carried out with a puncture needle using standard procedure.

All patients were subjected to multifrequency electrical impedance mammography. The system used was a 256-electrode 3D electrical impedance tomography device named MEM and developed by research group from the Institute of Radio-engineering and Electronics of the Russian Academy of Sciences. The frequencies used were 10 kHz and 50 kHz; the exam was conducted in the 3–10th and 17–28th days of the menstrual cycle. The results of EIT investigation weakly depend on the patient position (staying or lying), and most of measurements were carried out in lying position. During the investigation the flat array of electrodes is placed parallel to the chest wall and is pressed against the ribs to provide largest possible number of electrodes to be in contact with the body and the least thickness of the breast tissues.

The electrical impedance images obtained are highly correlated with the anatomical structure of a mammary gland, as it will be shown in section 3. The following factors were taken into consideration when the EIT images were assessed: electrical impedance anatomy; correspondence of the electrical impedance image with the age-type; presence of deformity in the image contour; abnormalities of the internal structures architectonics; presence of focus masses (formations) and the contour peculiarity around them; image discrepancies depending on scanning position and side.

2.3. The EIT system

The 3D EIT system used in this work is the modified version of the single-frequency device described in the earlier publications (Cherepenin et al 2001, 2002). The device uses a planar circle-shaped array of the 256 stainless steel electrodes arranged at the device enclosure (figure 1) and dual remote electrode placed at the patient's wrist. The data are acquired from the single frontal plane using the array. Single-pole measurement strategy is implemented: the first poles of the current source and voltmeter are connected to corresponding 256-channel multiplexers, and the second poles are connected to the separate remote electrodes. Thus the collected data set consists of 256*255/2=32640 linearly independent values. The conductivity distribution is reconstructed by the 3D-extended back projection algorithm (Cherepenin et al 2002). It enables static reconstruction, but conductivity is represented in conventional relative units depending on the average body impedance. The reference data for the backprojection image reconstruction is calculated in assumption of the homogeneous conductivity best fitting the measurement results, so the reconstructed conductivity distribution represents deviation from this theoretical homogeneous conductivity. The software implemented on the standard PC enables one to control the device and collect results of measurement through a USB connection, to reconstruct 3D distributions of conductivity represented as 7 cross-sectional images on the screen and to perform simple statistical analysis and comparison of the images. The selected depth levels are 0.4, 1.1, 1.8, 2.5, 3.2, 3.9 and 4.6 cm from the electrodes. The region of interest (ROI) can be selected visually at each level, and corresponding parameters such as min, max and mean values, standard deviation, conductivity histogram are calculated over this ROI. The modified hardware and software of the system enables the operator to change working frequency quickly from the user interface. The frequency range is limited currently by 10 kHz at the bottom because the lower frequencies cause difficulties in providing reliable contact with the patient's body (electrode diameter is 4 mm, tap water is used for moistening the skin), and by 50 kHz at the top due to the noticeable influence of the multiplexers' stray capacitance at higher frequencies.

3. Results

To find the potential of multifrequency electrical impedance mammography in diagnosis of dyshormonal mammary gland diseases EIM studies were conducted following the usual procedure of ultrasonic investigation in all women and x-ray mammography (in women age 35 and older).

The analysis of the multifrequency electrical impedance mammography results began with consideration of electrical conductivity indexes, given in conventional units. The conductivity index means the 2D average value of the conductivity over the ROI. The ROI here is the area covering all visible breast tissues at the selected layer of depth if other is not specified. As it was shown in our previous reports, there is no statistically significant difference in electrical conductivity indexes depending on vertical or horizontal body position or on the left or right body side (Cherepenin et al 2002, Trokhanova et al 2001). The percent discrepancy in the mean conductivity indexes between the left and right mammary gland (in norm), as well as in standing and recumbent position doesn’t exceed 7%. The regularity of the conductivity indexes changes is similar at all scanning level depths. So we used mean values (conductivity indexes) from the second scanning level in depth.

The results obtained are shown in tables 1 and 2, where the following results should be noted: electrical conductivity indexes increase proportionally with the patients’ age irrespective of their groups or menstruation phases. According to the statistics, mastopathy of both types is certain to reduce electrical conductivity from the norm in the corresponding age groups of menstruating women (aged up to 50) at frequency 50 kHz as well as 10 kHz during both menstrual cycle phases (in all cases $p<0.05$). At the postmenopause (51–55 years of age), mastopathy does not influence conductivity or has just a slight excess over the norm (disparity is statistically nonsignificant $p>0.05$). In the group with cystic (2nd type) mastopathy in all menstruation phases and in postmenopause at the frequency of 50 kHz the electroconductivity is higher than in mastopathy of the diffuse, 1st type. In norm and mastopathy of the 2nd type, we see a clear, statistically significant decrease in electroconductivity in both phases of the menstruation cycle and in postmenopause in the corresponding age groups at the frequency of 10 kHz (in all cases $p<0.05$). During the 1st type mastopathy the electroconductivity indexes are the same at all frequences and in all groups.

At any form of mastopathy in menstruating women percent of discrepancy of the mean electroconductivity indexes should not fall below 7%. A lower percent of the electroconductivity change should be considered as norm. In case of women in a menopause diagnosed before as having mastopathy, the percentage shift approached the norm values. This is confirmed by hormone-dependency of the mastopathy etiology.

Anatomically the mammary gland presents a complex alveolar-tubular organ, consisting of glandular, adipose and connective tissues with internally developed network of milk ducts. Every scanning level is characterized by presence of certain anatomical landmarks, which can be seen in figure 2. The mammary gland connective tissue carcass is represented by the anterior and posterior folia of pectoral fascia as well as the Cooper's ligaments, situated between glandular and fatty structures of the mammary gland. The anterior folium of pectoral fascia are imaged on the 1st, 2nd and 3rd scanning levels along the periphery zone of the lacteal sinus or the subcutaneous layer of adipose tissue in the form of linear hyperimpedance structures with electrical impedance of 0.3 – 0.5 conventional units. Imaging of the pectoral fascia folia doesn't depend on age or the menstrual cycle. Cooper's ligaments are represented as hyperimpedance areas with electrical conductivity of 0.3 – 0.5 conventional units, radiating from the centre. They are imaged from the 1st to the 5th scanning levels. The imaging of ligaments doesn't depend on the menstrual cycle phases, but their image becomes better defined on the mammograms that belong to the women of a later reproductive and premenstrual periods.

Adipose tissue possesses high electrical impedances and electroconductivity within 0.2 – 0.3 conventional units. Imaging results in adipose tissue depend on patient age. The subcutaneous adipose tissue is imaged in women of any age group as a hyperimpedance formation around the nipple and the zone of lacteal sinus on the 1st, 2nd and 3^{d} scanning levels. The interlobular adipose tissue is mainly present in women of reproductive and premenopausal period from the 2nd to the 5th scanning level as irregular round or oval hyperimpedance inclusions. The retromammary tissue is imaged as hyperimpedance formations of irregular shape and electroconductivity below 0.2, situated in the centre of the tomogram on the 6th and 7th scanning levels. The amount of the retromammary adipose tissue increases with a woman's age and so it is most clearly seen in tomograms of women of late reproductive and premenstrual period.

The mammary glandular parenchyma is imaged as isoimpedance areas of irregular shapes with conductivity of 0.3 – 0.7 conventional units, situated between connective tissue septum (the Cooper's ligaments). The areas are mainly detected for the 1st to the 5th scanning level. Their imaging doesn't depend on the menstrual cycle phase, but is inversely proportional to a woman's age: volume and sizes of parenchyma decreases with the age.

Galactophores of the 1st, 2nd, 3^{d}, and 4th degrees are not imaged individually on mammograms, but their presence in lobules and lobes of the mammary gland influence quantitative and qualitative characteristics of the parenchyma. The main ducts formed from the galactophores of the 1st degree, before joining the nipple, curve and form the zone of the lacteal sinus. The zone is visualized as a hypoimpedance roundish areas with electroconductivity exceeding 0.7 conventional units or as a isoimpedance roundish areas with electroconductivity of 0.5 – 0.7 conventional units, situated in the tomogram's centre in the post nipple areas of all menstruating women on the 1st, 2nd, and less frequently 3^{d} scanning levels. The size and electroconductivity of the lacteal sinus zone has particularities at various physiological periods in a woman's life (first phase of the menstrual cycle, second phase of the menstrual cycle, pregnancy, lactation, postmenopausal)

Different types of mammary glands correspond to different ages, which is very important for estimation of different age-types of electrical impedance images. There are four age types of electrical impedance images of mammary glands.

(i) Juvenile type, figure 3

In the ultrasound images the skin is a hyperechoic line (0.5 – 2.0 mm thick). The main body of the gland is represented by images of glandular structures in form of an integrated fine-grained layer of hyperechogenicity. Connective tissue structures: Cooper's ligaments, fascia, interlobular fibrous tissue are not imaged separately. Pectoral muscles are imaged before the ribs as multidirectional hyperechoic transversally striated solid inclusions.

The electrical impedance mammograms of the juvenile type are characterized by: a poorly defined zone of the lacteal sinus in both phases of the menstrual cycle; predominant imaging of parenchyma; presence of not very evident layer of subcutaneous and retromammary tissue; absence of the interlobular adipose tissue; absence of well-defined Cooper's ligaments.

(ii) Reproductive type, figure 4

In ultrasound image the subcutaneous adipose tissue is imaged as a moderate amount of elongated hypoechoic structures or as a single hyperechoic layer 2 – 3 cm thick. With increase of age and the number of pregnancies parenchyma is being replaced by adipose tissue. This extra fat can be accumulated subcutaneously, between glandular structures midmost or retromammary. Glandular tissue is imaged as integrated hyperechoic fine-grained layer; sometimes hyperechoic roundish formations of adipose tissue are imaged against its background. In the second phase of the menstrual cycle the hyperechoic image of glandular tissue alternates with images of hyperechoic fragments of lacteal ducts. The parenchyma front contour has a wave-like form due to protrusion in the places of Cooper's ligaments fixation. Differentiation of the connective tissue structures, namely, Cooper's ligaments and fascia, increase with age.

The EIT mammograms of the reproductive type are characterized by: a well-defined zone of the lacteal sinus; predominant imaging of fibro-glandular complex at the early reproductive age and reduction of parenchyma on the tomograms of women of the late reproductive age; presence of layer of subcutaneous and retromammary tissue, the amount of which increases with age; appearance of the interlobular adipose tissue; well-defined imaging of the Cooper's ligaments.

(iii) Premenopausal type, figure 5

In ultrasound image the skin is imaged as a hyperechoic line (2.0 – 4.0 mm thick). A well-defined subcutaneous adipose layer is imaged in form of roundish elongated hypoechoic structures. These accumulations of hypoechoic fat, surrounded by hyperechoic border of connective tissue are adipose lobules. During the phase, which precedes the menopause, the mammary gland features decrease of the glandular tissue, particularly in the areas, where it used to be in abundance (behind the nipple and in projection of the upper external quadrant. Partial replacement of the glandular tissue by adipose one is characterized by appearance of numerous areas of hypoechoic fat on the background of hyperechoic glandular tissue. In the second part of the cycle the process is accompanied by multiple images of hypoechoic structures of lacteal ducts. The connective tissue structures are well differentiated in form of multidirectional hyperechoic inclusions.

The EIT images of the premenopausal type are characterized by: decrease of glandular tissue focuses; presence of a well-defined layer of subcutaneous tissue and presence of retromammary tissue; predominance of interlobular adipose formation on the tomograms; well-defined imaging of the Cooper's ligaments; appearance of "mosaic effect" due to the shift of normal correlation of anatomic structures towards predominance of the fibro-adipose components.

(iv) Postmenopausal type, figure 6

In ultrasound the skin is imaged as 2 hyperechoic lines with a thin hypoechoic adipose layer between them. The skin thickness can vary. Practically the whole mammary gland comprises adipose lobes in form of roundish hypoechoic structures with a hypoechoic border. Sometimes singular inclusions of hyperechoic glandular tissue are imaged. It is explained by the atrophy of glandular tissue and ducts. Mammary glands of elderly virginal women might have a significant amount of glandular tissue. Connective tissues are characterized by thickening of hyperechoic Cooper's ligaments, as well as presents of hyperechoic linear inclusions in the texture of the adipose tissue and into images of the outer contour of lacteal ducts.

The EIT images of the postmenopausal type are characterized by the loss of anatomic landmarks on the electroimpedance images: absence of the lacteal sinus zone; a well-defined “mosaic effect” of an image due to the shift of normal correlation of anatomic structures towards predominance of the fibro-adipose components at all levels of scanning; singular focuses of glandular tissue; absence of a well-defined division of the subcutaneous layer and interlobular adipose tissue; lack of unidirectionality in the connective tissue carcass due to thickening of the Cooper's ligaments, fibrosis of lacteal ducts and appearance of fibrous inclusions in the structure of the adipose tissue.

At visual estimation of electrical impedance images in mastopathy the following particulars are observed (figure 7, 8, 9):

- abnormalities of the image architectonics due to the change of ratio of the mammary gland tissues, resulting in mismatch between the electrical impedance type of image (juvenile, reproductive, premenopausal, postmenopausal) and the woman's age;
- increase of hyperimpedance areas on the images due to fibrous changes of the adipose tissue, fibrosis of the duct walls and the Cooper's ligaments;
- well-defined undistorted contour of the mammary gland
- absence of displacement of the internal structures;
- cases of hypoimpedance inclusions with well-defined contours on the mammograms corresponding to mastopathy of 2nd type, which correspond to the mammary gland cysts or evident pocket-shaped dilatation of ducts and lack of hyperimpedance zones around these foci;
- conductivity of any hypoimpedance foci below the first level in depth, doesn’t exceed 0.95 level in conventional units (in contrast to the typical manifestation of malignancy);
- hypoimpedance areas in images of the women before menopause occur, as a rule, against the background of reduced values of mean electrical conductivity. Hypoimpedance areas in images of the women in the postmenopause period occur, as a rule, against the background of normal values of mean electroconductivity.
- shift to the left of the frequency distribution of electroconductivity compared with the norm;
- decrease of difference between electrical impedance images in case of mastopathy and in norm in the postmenopause period as well as minimal discrepancy of the frequency distribution of electrical conductivity histogram compared with the norm.

The changes of mammary gland structure demonstrated by the EIM are confirmed by the results of ultrasonic examination (see figure 10).

4. Conclusions

Electrical impedance tomography method enables objective diagnosis of mastopathy and other non-cancerous diseases of the mammary gland. This in turn will open the way to improve quality of life for many women and also to reduce the incidence of breast cancer through effective curing of mastopathy.

According to our observations the electrical conductivity of the mammary gland increases with age in norm and in both types of mastopathy. Notwithstanding of identical law of conductivity change in norm and at dysplasia with the age, the method of electrical impedance mammography allows to diagnose mastopathy reliably from the reduction of electrical conductivity in corresponding age groups at different frequencies in menstruating women. Confirmation of visual changes in tomograms at mastopathy by quantitative characteristics of electrical conductivity reduces the human factor in making the diagnosis. The absence of electrical conductivity difference between norm and mastopathy with women in postmenopause confirms that dysplasia appears due to dysfunction in the ovary - mammary gland system and not as an independent disease.

Multifrequency electrical impedance mammography in contrast to single-frequency variant enables one not only to diagnose mastopathy, but allows also accurate detecting of its cyst-less form based on observation of the absence of difference between average conductivity in both phases of menstrual cycle. Because the cyst-less form of mastopathy is associated with higher risk of the cancer development, this method allows identifying a higher risk group of patients for more frequent investigations.

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Table captions

Table 1. The mean electrical conductivity indexes of mammary glands in norm and mastopathy in the 1st phase of the menstruation cycle and in the postmenopause for women of different age groups (10 kHz, 50 kHz)

Table 2. The mean electrical conductivity indexces of mammary glands in norm and mastopathy in the 2nd phase of the menstruation cycle and in the postmenopause for women of different age groups (10 kHz, 50 kHz)

Figure captions

Figure 1. Multifrequeny EIT mammographic system.

Figure 2. Electrical impedance anatomy of mammary gland.

Figure 3. Juvenile type (ultrasonic examination, electrical impedance mammography).

Figure 4. Reproductive type (ultrasonic examination, electrical impedance mammography).

Figure 5. Premenopausal type (ultrasonic examination, electrical impedance mammography).

Figure 6. Postmenopausal type (ultrasonic examination, electrical impedance mammography).

Figure 7. Electrical impedance images of mammary glands in norm and during mastopathy (50 kHz).

Figure 8. Mastopathy of the 2nd type in reproductive age.

Figure 9. Mastopathy of the 2nd type in the postmenopausal period.

Figure 10. Electrical impedance and ultrasonic images of mammary glands in norm and with mastopathy of different types (the 2nd scanning level, 50 kHz).

Table 1. The mean electrical conductivity indexes of mammary glands in norm and mastopathy in the 1st phase of the menstruation cycle and in the postmenopause for women of different age groups (10 kHz, 50 kHz)

	19 - 34 years		**35 – 39 years**		**40 – 44 years**		**45 – 50 years**		**51 - 55 years Postmenopause**	
	50 kHz	**10 kHz**	**50 kHz**	**10 kHz**	**50 kHz**	**10 kHz**	**50 kHz**	**10 kHz**	**50 kHz**	**10 kHz**
Norm	0.43± 0.09	0.37± 0.09	0.47± 0.09	0.44± 0.09	0.47± 0.08	0.41± 0.09	0.52± 0.03	0.48± 0.05	0.56± 0.06	0.51± 0.07
Mastopathy 1st type	0.30± 0.07	0.29± 0.07	0.31± 0.05	0.30± 0.05	0.38± 0.05	0.38± 0.08	0.38± 0.09	0.38± 0.09	0.55± 0.03	0.54± 0.05
Mastopathy 2nd type	0.33 ± 0.03	0.29± 0.03	0.38± 0.07	0.34± 0.07	0.44± 0.09	0.38± 0.06	0.44± 0.03	0.36± 0.07	0.59± 0.02	0.47± 0.03

Table 2. The mean electrical conductivity indexes of mammary glands in norm and mastopathy in the 2nd phase of the menstruation cycle and in the postmenopause for women of different age groups (10 kHz, 50 kHz)

	19 - 34 years		**35 – 39 years**		**40 – 44 years**		**45 – 50 years**		**51 - 55 years Postmenopause**	
	50 kHz	**10 kHz**	**50 kHz**	**10 kHz**	**50 kHz**	**10 kHz**	**50 kHz**	**10 kHz**	**50 kHz**	**10 kHz**
Norm	0.43± 0.09	0.39± 0.08	0.48± 0.03	0.43± 0.04	0.48± 0.03	0.43± 0.03	0.53± 0.05	0.48± 0.05	0.56± 0.06	0.51± 0.07
Mastopathy 1st type	0.28± 0.05	0.27± 0.07	0.30± 0.07	0.29± 0.07	0.35± 0.05	0.36± 0.06	0.38± 0.09	0.37± 0.09	0.55± 0.03	0.54± 0.05
Mastopathy 2nd type	0.33 ± 0.07	0.29± 0.04	0.36± 0.06	0.31± 0.05	0.4± 0.09	0.34± 0.06	0.46± 0.04	0.37± 0.05	0.59± 0.02	0.47± 0.03

Figure 1. Multifrequeny EIT mammographic system MEM.

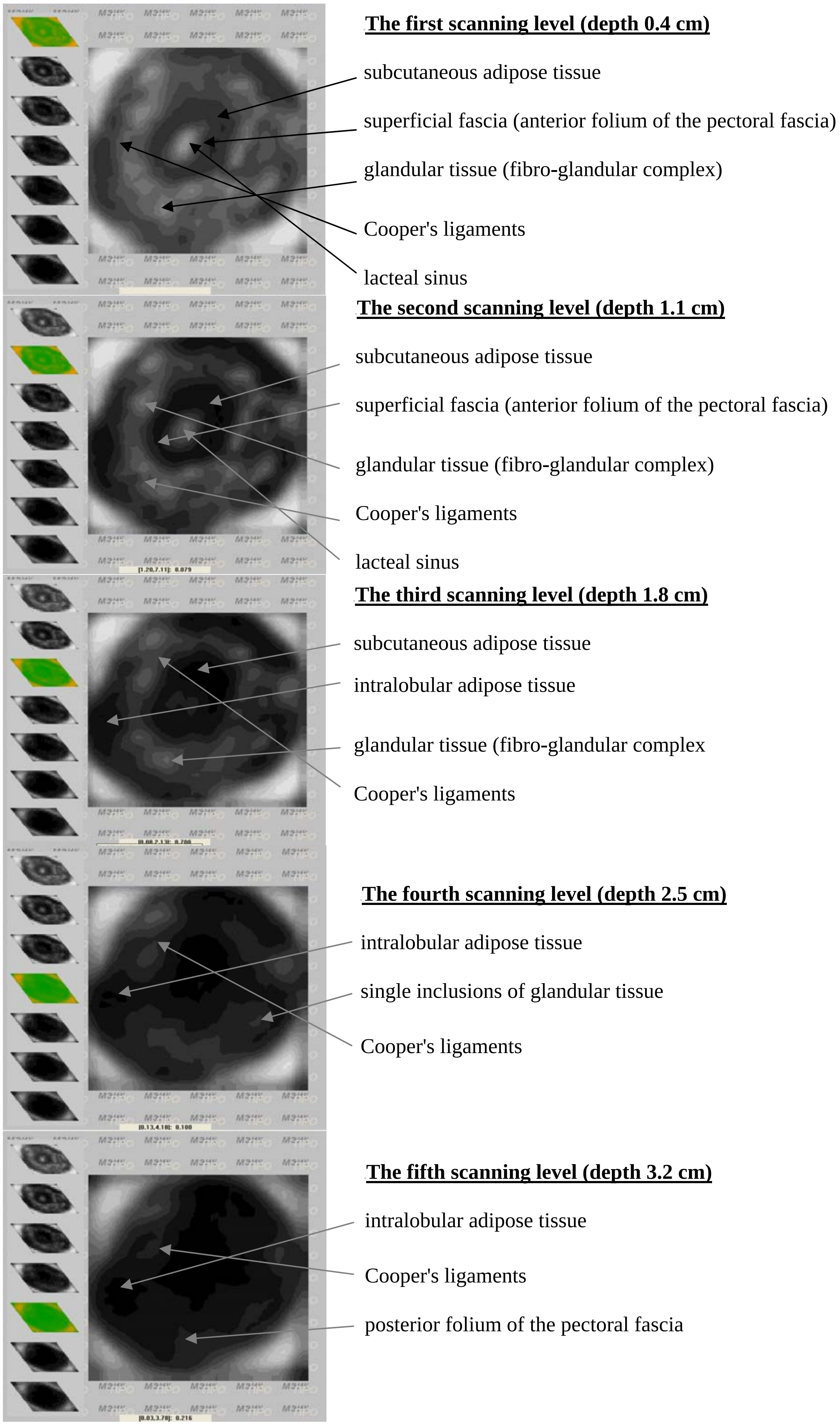
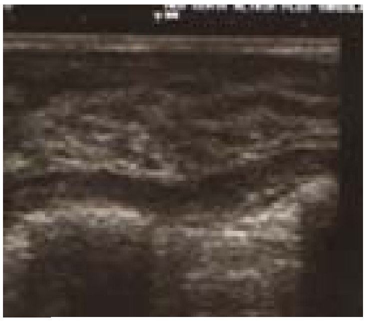
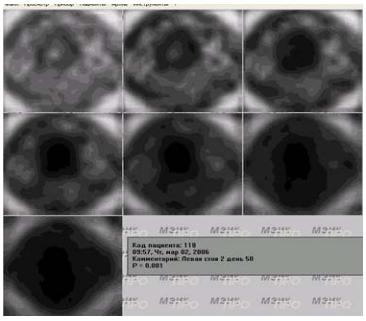


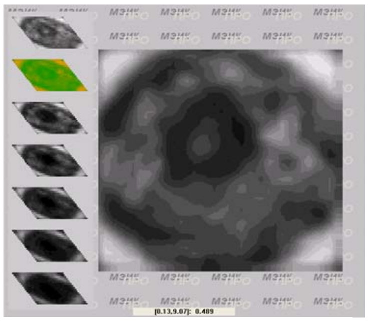
Figure 2. Electrical impedance anatomy of mammary gland.



USD (19 years)



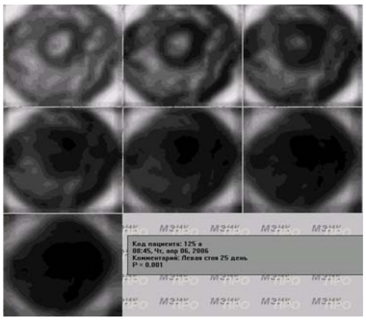
EIM (19 years)



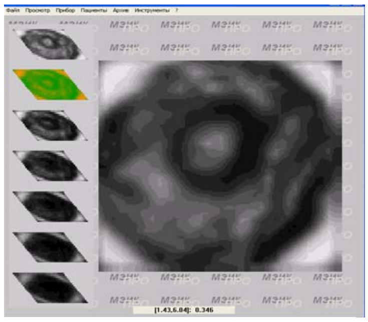
EIM (19 years)

Figure 3. Juvenile type (ultrasonic examination, electrical impedance mammography).

USD (31 years)

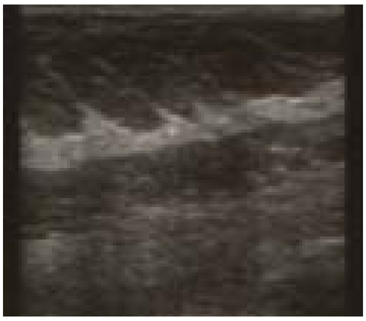


EIM (31 years)

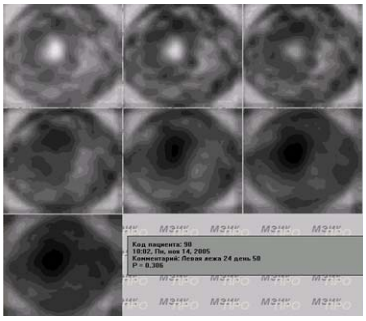


EIM (31 years)

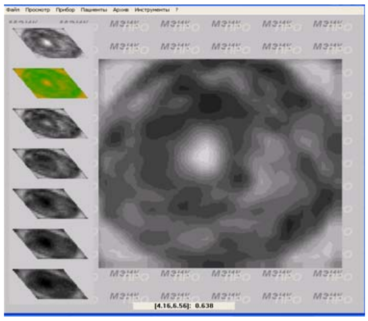
Figure 4. Reproductive type (ultrasonic examination, electrical impedance mammography).



USD (50 years)

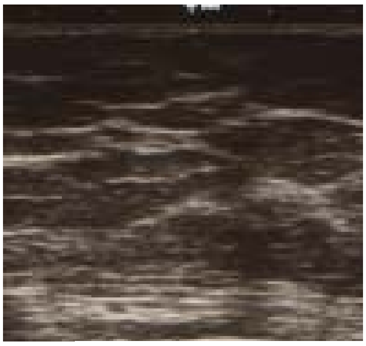


EIM (50 years)

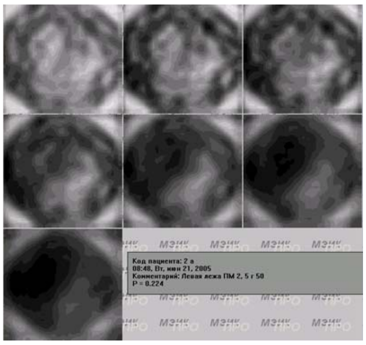


EIM (50 years)

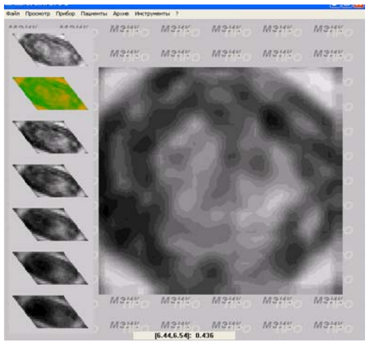
Figure 5. Premenopausal type (ultrasonic examination, electrical impedance mammography).



USD (55 years)



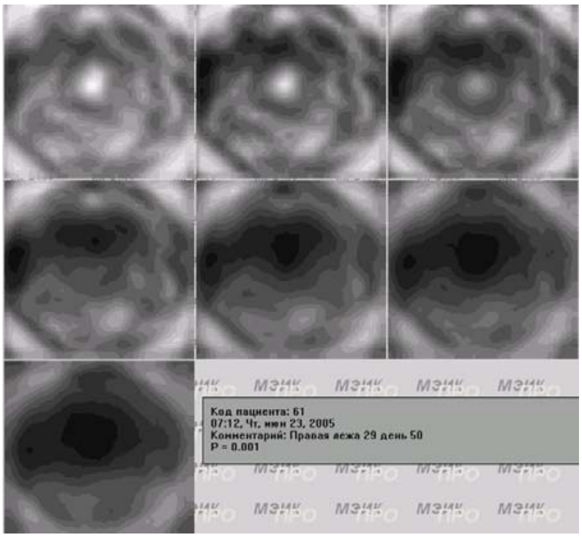
EIM (55 years)



EIM (55 years)

Figure 6. Postmenopausal type (ultrasonic examination, electrical impedance mammography).

Norm. 29 years old. 50 kHz.



Mastopathy. 29 years old. 50 kHz.

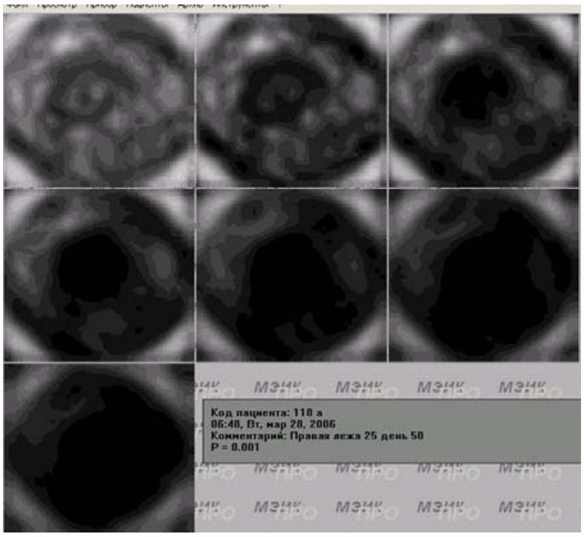
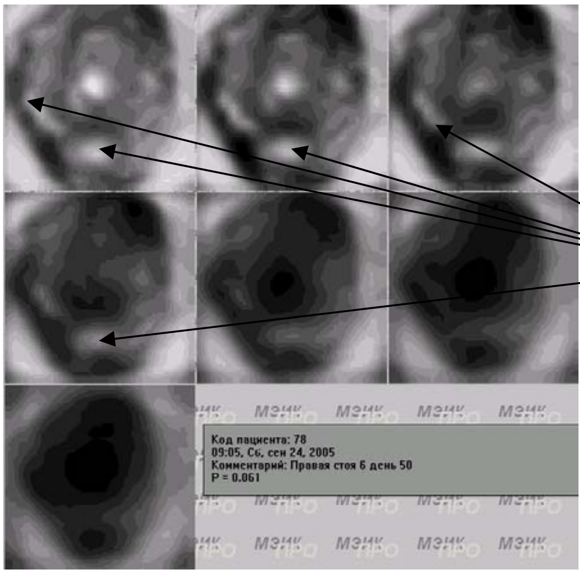
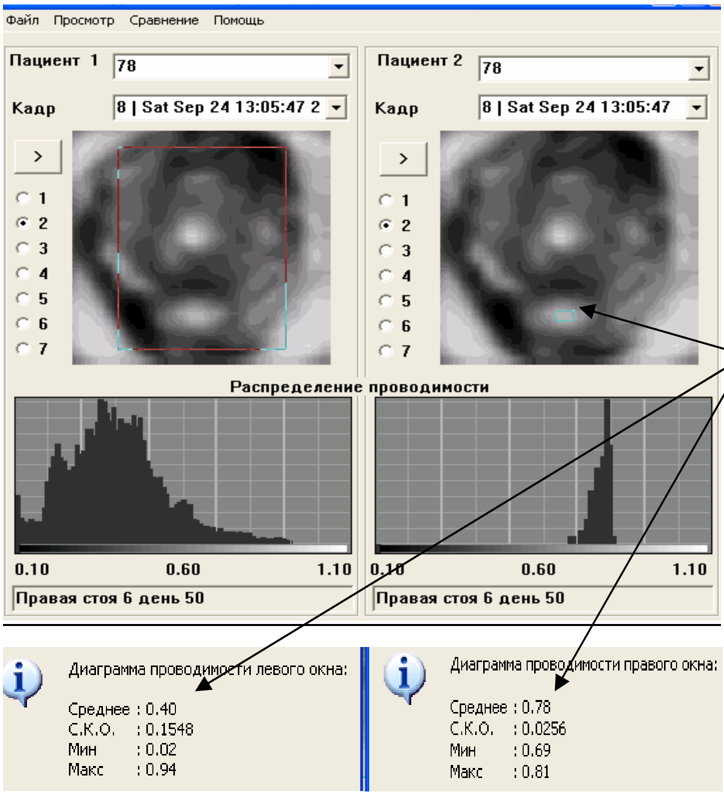


Figure 7. Electrical impedance images of mammary glands in norm and during mastopathy (50 kHz).

Mastopathy. Age 39. 50 kHz.



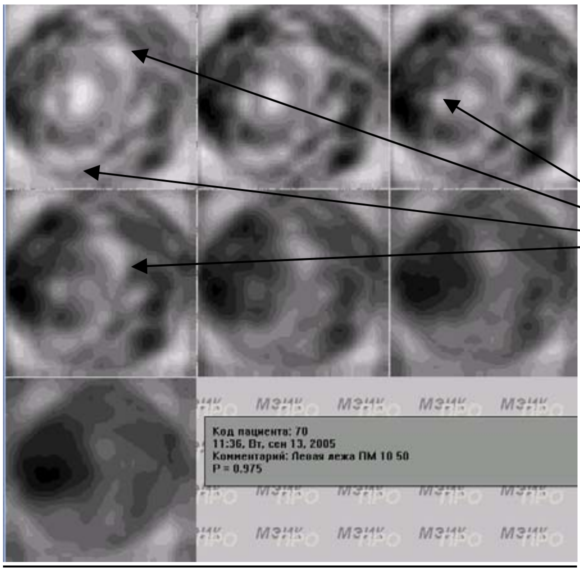
Multiple cysts of the right breast (mixed form of mastopathy). Visualized on the 1, 2, 3, and 4 scanning level



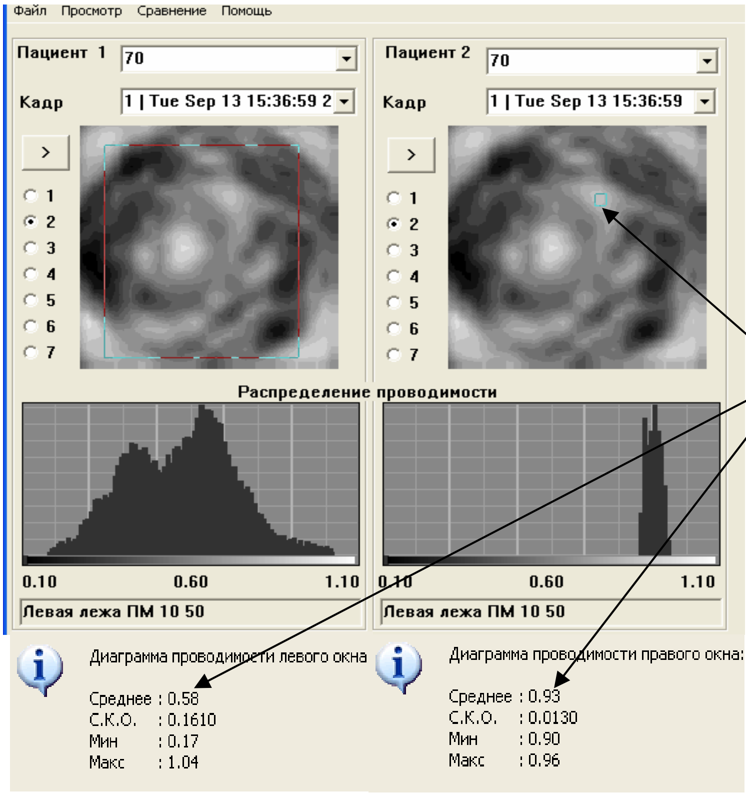
Mean electroconductivity in the hypoimpedance area is 0.78, the background mean electroconductivity is 0.4

Figure 8. Mastopathy of the 2nd type in reproductive age.

Mastopathy in anamnesis.
Age 70. 50 kHz.

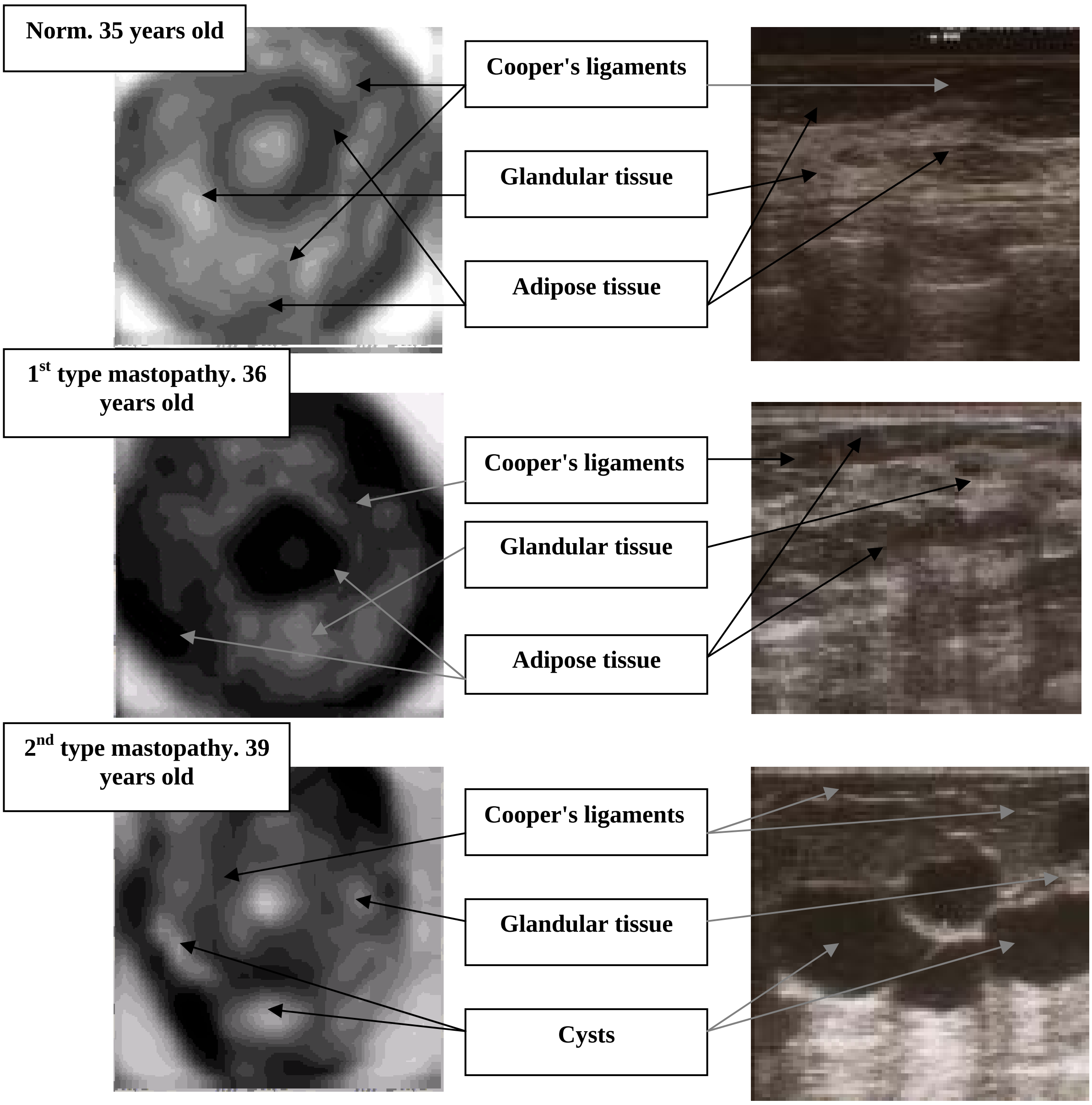


Multiple cysts of the left breast (mixed form of mastopathy in anamnesis). Visualized on the 1, 2, 3, and 4 scanning levels



Mean electroconductivity in the hypoimpedance area is 0.93. The background mean electroconductivity is 0.58, corresponds to age norm.

Figure 9. Mastopathy of the 2nd type in the postmenopausal period.



Note: 1st type mastopathy is acystic form, 2nd type mastopathy is cystic form

Figure 10. Electrical impedance and ultrasonic images of mammary glands in norm and with mastopathy of different types (the 2nd scanning level, 50 kHz).