Electric Impedance Imaging of the Mammary Gland in the Case of Mastitis

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Abstract. The electric impedance mammography technique has been applied for several years. The aim of the research in hand is to reveal the peculiarities of the electric impedance imaging in various stages of the inflammatory process in the mammary gland. We have conducted an examination of twenty six patients: five of them in the stage of arterial hyperemia, eight in the stage of infiltration, three of them in the stage of abscess and ten in the stage of cicatrization. The examination was carried out on the “MEIK” (version 5.6) potential electric impedance computer mammograph. The weighted reciprocal projection method was used to reconstruct the 3-D electric conductivity distribution of the examined organ. Any inflammatory process is phasic and always attended by the complex vascular alterations with exudation of liquid components of plasma, blood cells outwandering and stromal cells proliferation. Pathophysiological and histopathological peculiarities of each stage of the inflammatory process are well reflected in the electric impedance images. This fact enabled the authors of the research to define the electric impedance imaging as the histofunctional scanning.

1. Introduction
Electric impedance potential mammography method has been applied in the obstetric division of Clinical Hospital 9 (Yaroslavl) for several years already. The most commonly encountered mammary gland pathology in the perinatal period is inflammation – mastitis. Inflammation (Lat. inflammatio – ignite, set on fire) - pathological process characterized by the development of local alterative, vascular and proliferative reactions of an organism to ill effects. In the inflammatory process the following stages are distinguished: alteration, disturbed circulation and microcirculation, proliferation [1, 2, 3].

The research in hand aims to reveal the peculiar features of the mammary gland electric impedance image in different stages of the inflammatory process.

2. Methods and Materials
We have conducted an examination of 26 patients, 5 of them - in the stage of active (arterial) hyperemia, 8 - in the stage of infiltration, 3 – in the stage of abscess formation, 10 - in the stage of cicatrization (scarring). The examination was carried out on the electric impedance computer mammograph “MEIK” v.5.6, in which modificado backprojection method is used to reconstruct the image (50 kHz, 0.5 mA). The computational result of surface intensity for the data acquired on a homogenious object was used as the referential measurement. Throughout the instrumentality of these measurements the electical conductivity index was calculated (expressed in conditional units). When the reconstruction is finished, seven consecutive scan planes are created, which correspond to sections.
of the mammary gland in axial (base) view with the depth increasing from 0.4 to 4.6, i.e. from the areolar area to the retromammary space.

3. Result

Inflammatory processes in the mammary gland develop in loose connective tissue and are accompanied by the complex of vascular changes with exudation of liquid constituents of the blood, blood cells migration and proliferation of stroma cells.

3.1 Alteration Stage

This short-term stage quickly develops into the second one - the stage of disturbed circulation and microcirculation. That is why usually alteration stage cannot be registered.

3.2 Disturbed Circulation and Microcirculation Stage

3.2.1 Active (Arterial) Hyperemia Stage. During this stage linear and volume blood velocity increases at the expense of a short-term vascular spasm. Arteriotony in the capillaries and veins increases too.

High blood pressure leads to the structural alteration of endothelial capillary walls. It activates the process of water molecules, ions, plasma proteins (i.e. exudation). Extracellular oedema arises in the nidus of inflammation [1, 2]. These processes result in decrease of active component of impedance and in increase of conductivity in the inflammation area. During the stage of vascular changes hyperaemia area and oedema can be observed clinically. On the electric impedance mammograms hypoimpedance areas can be visualized, they possess high conductivity index and their location corresponds with the oedema area contoured by the hyperimpedance on the periphery (figure 1). The histogram of electrical conductivity distribution which is characteristic of this stage of inflammation process has unimodal symmetric form and refers to the class of distributions which are subjects to the normal distribution law. The difference between the mean electrical conductivity index and the mode is insignificant (figure 1).

3.2.2 Passive (Venous) Hyperemia Stage. As the inflammation oedema grows, it impedes blood outflow through venous system and arterial hyperemia comes to venous hyperemia. Blood pressure increases in the venous part of capillars of the inflamed tissue. Blood flow slows down all the way to its arrest. These processes contribute to leukocyte exit from the bloodstream and to leukocytic infiltrate formation. Leukocytic infiltrate emerges in just 6 hours after the inflammation starts [2]. Thereby the area of cell membranes grows significantly and this fact results in increase of reactive component of impedance and in decrease of conductivity in the inflammation area. During the migration of leukocytes to the inflammation area the formation of infiltrate can be observed clinically.

Figure 1. Disturbed circulation and microcirculation stage. Active (arterial) hyperemia stage. A significant hypoimpedance mass (1-4 scan planes) with the hyperimpedance contour is situated in the center of the mammogram (the first row - scanning planes, the second row - electroimpedance tomodgrams, the third row – histogram of electroconductivity distribution, the fourth row – qualitative assessment, on the right – conductivity scale).
In the electric impedance mammograms infiltrate can be visualized as a homogeneous well-defined hyperimpedance area with low conductivity index (Figure 2). The histogram of electrical conductivity distribution during the stage of inflammation process usually has unimodal asymmetric shape (Figure 2). The difference between the mean electrical conductivity index and the mode as well as the shape of the histogram depends on the distribution of the infiltrate. When inflammation makes progress, leukocytoclasia and pus formation take place [2]. These processes result in decrease of reactive component of impedance and in increase of conductivity in the abscess formation area. Clinically, abscess formation manifests itself in softening of the inflamed area. Leukocytic infiltrate loses its hyperimpedance homogeneousness.

Clusters of pus manifest themselves by high conductivity. In the electric impedance mammograms the process of pyogenic dissolution of infiltrate is accompanied by the loss of homogeneity and by the emergence of hypoimpedance areas with high conductivity index corresponding with the location of pus clusters (Figure 3). The difference between the mean electrical conductivity index and the mode is significant. The histogram of electrical conductivity distribution during the abscess formation has a multimodal shape.

**Figure 2.** Disturbed circulation and microcirculation stage. Infiltration. The homogeneous hyperechoic mass can be visualized (1-4 scan planes) over an area from 7 to 9 on the clock dial (the first row - scanning planes, the second row - electroimpedance tomograms, the third row - histogram of electroconductivity distribution, the fourth row – qualitative assessment, on the right – conductivity scale).

**Figure 3.** Disturbed circulation and microcirculation stage. Abscess formation. A heterogeneous impedance structure with a hypoimpedance part in its center can be visualized (1-3 scan planes) over a vast area from 12 to 4 on the clock dial (the first row - scanning planes, the second row - electroimpedance tomograms, the third row – histogram of electroconductivity distribution, the fourth row – qualitative assessment, on the right – conductivity scale).
3.3 Proliferation Stage

Proliferation is the last stage of the inflammation process. During inflammation the tissue always dissolves to a greater or lesser extent. The dissolution which is caused by the inflammation process and finished during the infiltration stage, ends with the complete recovery of damaged tissue structures and thus does not lead to dysfunction [1, 2]. Infiltrate regression is accompanied by its substitution by connective tissues and by the recovery of electrical properties of damaged tissues.

The dissolution of tissues reaches its maximum in the case of suppurative inflammation. A cavity is formed in the place of the former inflammation. In what follows, this tissue defect gradually fills in at the expense of growth of local cells of the connective tissue – fibroblasts, but tissue structures and functions recovery never takes place. When defect healing by primary intention, the cicatrix is formed which fully consists of collagen fibers [1, 2]. In the electric impedance mammograms a cicatrix can be visualized as a hyperimpedance often irregular-shaped strip, it possesses low conductivity index (Figure 4).

Figure 4. Electric impedance images of the mammary gland (3 scan planes). In the central upper area one observes a hyperimpedance linear zone which corresponds with the real scar in shape and size.

When healing by the second intention, the defect is articulated from the rest of the tissue by collagen fibers, and the nidus itself consists of amorphous substance of the connective tissue [1, 2]. In this case the cicatrix is visualized as hyperimpedance strips with low conductivity index and an isompedance area with medium conductivity index which is located between the stripes (Figure 5). The difference between the mean electrical conductivity index and the mode is minimal. The histogram of electrical conductivity distribution during the proliferation stage has a unimodal symmetrical shape.

4. Conclusion

Pathophysiological stages of the inflammation process are accompanied by the alteration of the electrical properties of damaged tissues of the mammary gland. Stage-dependent alterations of the electrical properties of mammary gland tissues define the peculiar features of the mammary gland electric impedance image. That is why electric impedance mammography method can be defined as a method of histofunctional scanning. The imaging of different inflammation process stages by means of electrical impedance tomograms allows using this method to diagnose mastitis, choice of treatment and its monitoring.

5. References

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