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

M Korotkova[1,2], **A Karpov**[1,2]
[1]Clinical Hospital 9, Yaroslavl, Russia
[2]"SIM Technika" PKF, Yaroslavl, Russia

E-mail: kb9@mail.ru
sim-tech@net76.ru

Abstract. The electric impedance mammography technique has been implied 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) potencial 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. The research is illustrated with electric impedance mammograms and tables.

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 backprojection method is used to reconstruct the image.

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 emigration and proliferation of stroma cells.

3.1 Alteration Stage

Inflammatory process begins with alteration – which characterizes by damage to cell structure, tissues and organs as a result of the direct ill effect to the cell structure of an organ. 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.

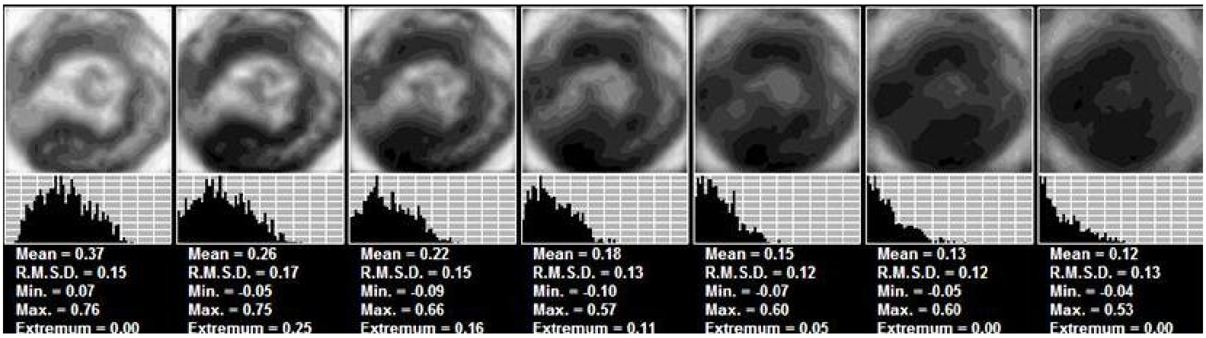

Figure 1. Disturbed circulation and microcirculation stage. Active (arterial) hyperemia stage. A significant hypoimpedance mass with a hyperimpedance contour is situated in the center of the mammogram.

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. Hydropic fluid which contains positive ions suppresses negatively charged hydroxyl and carboxyl groups of hyaluronic acid, which is the major constituent of amorphous substance of connective tissue (1, 2). These processes result in decrease of active component of impedance and in increase of conductivity in the inflammation area. Leukocytic infiltrate emerges on the periphery of this area to delimit the nidus of inflammation. During the stage of vascular changes hyperaemia area and oedema can be observed clinically (figure 2). 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).

Figure 2. Disturbed circulation and microcirculation stage. Active (arterial) hyperemia stage

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 outlet from the bloodstream. Such factors as connective tissue's negative charge neutralization, leukocytes' loss of negative charge and "free" water quantity increase simplify leukocytes' movement in the inflammation area and facilitate formation of leukocytic infiltrate. Leukocytic infiltrate emerges in just 6 hours after the inflammation starts. Leukocytes' movement leads to the formation of leukocytic infiltrate with abundance of cell-substratum which contains different types of leukocytes (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. In the electric impedance mammograms infiltrate can be visualized as a homogeneous well-defined hyperimpedance area with low conductivity index (Figure 3, 4-left). The histogram of electrical conductivity distribution during the stage of inflammation process usually has unimodal asymmetric shape (Figure 3). 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, leukocytoclasis and pus formation take place. Pus contains sediment which consists of cellular

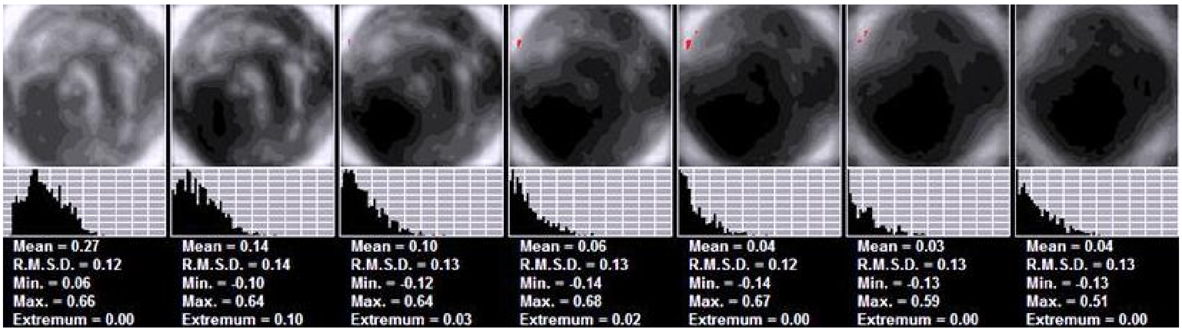

Figure 3. Disturbed circulation and microcirculation stage. Infiltration. A homogeneous hyperechoic mass can be visualized over an area from 7 to 9 on the clock dial.

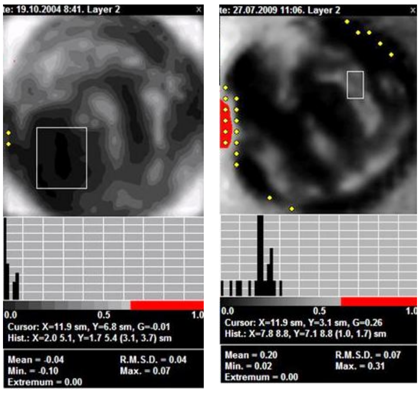

Figure 4. Hyperimpedance (left) and hypoimpedance (right) area of infiltrate.

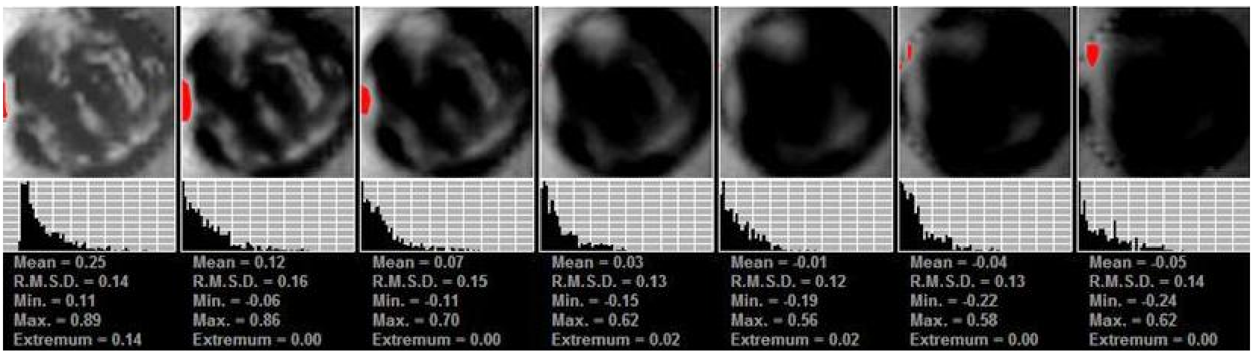

Figure 5. Disturbed circulation and microcirculation stage. Abscess formation. A heterogeneous impedancee structure with a hypoimpedance part in its center can be visualized over a vast area from 12 to 4 on the clock dial.

elements, liquid part and liquor puris. In its composition liquor puris is quite similar to blood plasma (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. As in its composition liquor puris is quite similar to blood serum leukocytic infiltrate loses its hyperimpedance homogeneity.

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 4-right, 5). 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.

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

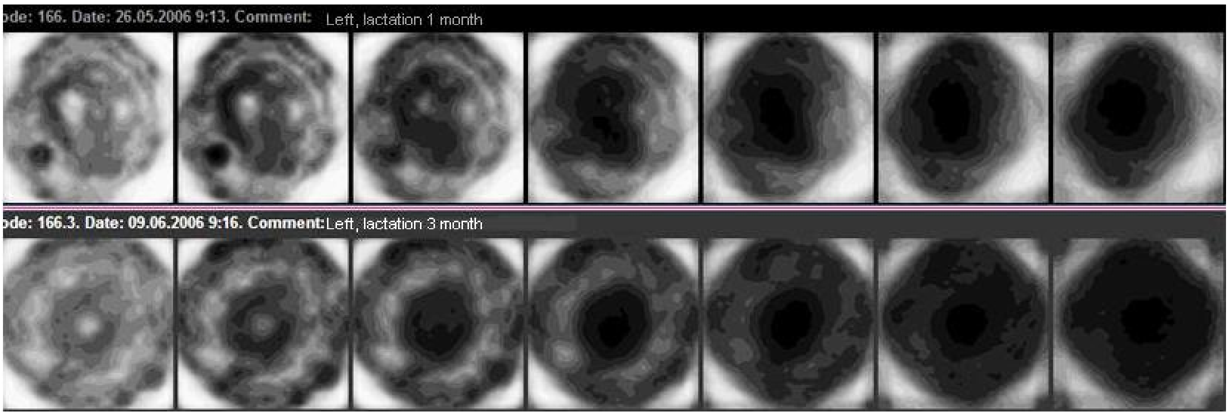

Figure 6. Dynamic mammography. Left mammary gland. Infiltration stage. A hyperechoic well-contoured mass can be visualized at 7 on the clock dial (upper image). Structure recovery after the treatment (lower image).

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 (Figure 6).

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. In the case of significant tissue defect there are two possible

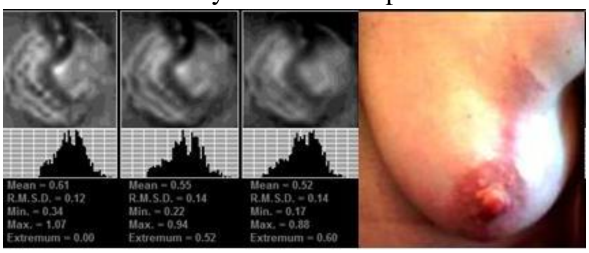

Figure 7. Electric impedance images of the mammary gland (3 scan planes).In the central upper area one observes a hyperimpedance linear zone which correponds with the real scar in shape and size.

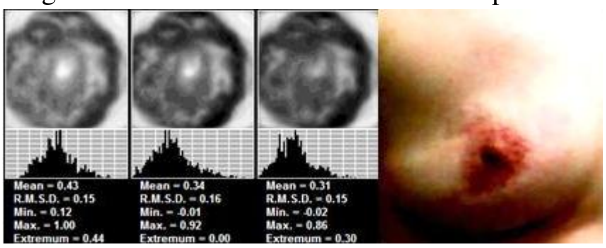

Figure 8. Electric impedance images of the mammary gland (3 scan planes). In the central upper area one observes a hyperimpedance linear zone which corresponds with the real scar in shape and size.

variants of healing, which differ by the electrical properties of cicatrices being formed. When defect healing by primary intention, the cicatrix is formed which fully consists of collagen fibers (1, 2). These collagen fibers have no polar functional group and so they function as a dielectric. In the electric impedance mammograms a cicatrix can be visualized as a hyperimpedance often irregular-shaped strip, it possesses low conductivity index (Figure 7).

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, the main component of which is hyaluronic acid (1, 2). That is why the recovery zone is represented by the areas of high impedance (which is the characteristic of collagen) and by the areas of low impedance (which is the characteristic of amorphous substance of the connective tissue). 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 8). 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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