The possibility of remote-sensing infrared thermography in the diagnosis of breast diseases (benign changes)

The prevalence of breast pathology is increasing worldwide. Remote-sensing infrared thermography was used for the early detection of breast diseases as a non-invasive method of diagnosis, but the extensive use of this method constrained by imperfect first devices. New thermographs with high resolution and high thermal sensitivity changed the view on thermal diagnostics. Thermographic diagnostics is uprisign to a new level, especially for the early detection of breast pathology. As known, the changes in the breast can be worn both benign and malignant nature. This paper dedicated to thermographic breast pathology diagnosis of a benign nature and shows a high degree of efficiency in detecting this disease early.

Key words: breast, thermography, benign changes, early diagnosis.

Preamble

The emergence of the third and fourth generation thermographs opened new opportunities in the development of non-invasive, highly informative and completely harmless method of diagnostic radiology. Application of matrix photodetectors allowed element-by-element reading of information followed by electronic image processing, as well as increasing visualization resolution and sensitivity (Rosenfeld L.G. et al., 2007). New types of thermographs are being currently developed (Ring E., Ammer K., 2000; Park J.V. et al., 2003; Diakides N.A., Bronzino J.D. (Eds), 2006; Hildebrandt C. et al., 2010).

The infrared thermography (IT) method is used in many areas of medicine, such as sports medicine (Garagiola U., Giani E., 1990), neuroscience (Ishigaki T. et al., 1989), cardiology (open heart surgery) (Kaczmarek M. et al., 1999), is used in vascular pathology (Ammer K., 2006), reflex sympathetic dystrophy syndrome (Gulevich S.J. et al., 1997), as well as for prophylactic examinations of the population during epidemics (Ng E.Y., Acharya R.U., 2009). A lot of researches are dedicated to the early detection of breast cancer (Head J.F. et al., 1993; Head J.F., Elliot R.L., 1995; Diakides N.A., Bronzino J.D. (Eds), 2006). E.Y. Ng (2009) believes that the sensitivity and accuracy of breasts thermography reaches an average of 90%. The author says that changed breast thermograms are a reliable biological marker of breast pathology. One of the signs of tumors is strengthening of vascular pattern of the mammary glands (Head J.F. et al., 1993; Uspensky D.A. et al., 2007).

The prevalence of mammary gland pathology in women is increasing worldwide. Only breast cancer, acc. to the World Health Organization (WHO), is diagnosed each year with one million women, and more than 590 million women die from this disease (Tarasovs'ka E.V., 2007). Mastopathy became widespread among the diseases of mammary glands – which is dishormonal hyperplasic process in the mammary gland (acc. to WHO definition – a fibro-cystic disease of a pathological increase of the breast tissue).

One of the breast features is the great variability of its physiological state depending on the age and condition of the reproductive system, the menstrual cycle period, which creates certain difficulties in distinguishing physiological tissue changes from pathological ones, as well as when determining the type of pathology. Mastopathy has “many faces”, and therefore we can actually talk about a group of diseases with complex clinical and histological picture and united by the generic term “mastopathy.”

To date, there exists a large number of classifications of dishormonal hyperplasia, each of which more or less fully reflects progressive and regressive changes. If at classification of lump formations there are no serious disagreements among specialists, regarding diffuse forms we have certain difficulties, which do not allow putting a rather wide range of changes into strict classification framework.

Over the last years, clinical X-ray classification becomes increasingly common. This classification sub-divides the diffuse form of mastopathy by the following four sub-types (Paleyev N.R. (ed.), 2002):

- diffuse mastopathy with a predominance of cystic component;
- diffuse mastopathy with a predominance of fibrous component;
- mixed form of diffuse mastopathy;
- sclerosing adenosis.

The criterion for determining sub-types is ratio of volumes of connective and fatty tissue.

To the key to successful treatment is early diagnosis of breast diseases.

An objective assessment of the breasts state consist of inspection and palpation, as well as mammography, ultrasound (US), pneumocystography, thermographic studies.

X-ray mammography (XMG) is one of the golden standards of lacteal glands diagnostics. This technique allows to timely detect pathological changes in lacteal glands in 95-97% of cases. The disadvantage of this method is exposure of a women's body to X-rays in general, difficulties in diagnosing of early forms of these diseases in lacteal glands.
Diagnostic efficiency of XMG is also reduced when used in young patients because of high density of glandular tissue.

Ultrasound complements and results obtained with other methods of study. Ultrasound method efficiency in diagnosis of tumor with diameter <1 cm is about 58%. Among disadvantages of the method is low informative value at evaluation of diffuse changes.

Thermography, which principle is based on the difference between skin temperature above damaged and undamaged areas, has been successfully used for recognition of tumors, especially small ones, against the background of adipose tissue, not excluding mandatory XMG. Especially this method is relevant when conducting mass prophylactic examinations, because it allows multiple surveys without harm to women’s health, observing the state of breasts over time at different periods of the menstrual cycle. The emergence of modern thermography machines allowed making thermography mobile, available for conducting routine inspections both at workplaces, and in large clinics.

It is known that tumor tissue as a zone of expressed proliferative activity due to intensive metabolism has higher temperature than the surrounding tissue, which is the basis of methods for detecting infrared (IR) radiation, particularly diagnosis IT in clinical oncology (Head J.F., Elliot R.L., 1993; Head J.F., Elliot R.L., 1995; Ivanitskiy G.R., 2006; Ng E.Y., 2009). Temperature over malignant tumor is usually higher by 1.5-3°C, and temperature over benign tumor is by 1.4-2.5°C lower than over the surrounding tissues.

The method of thermography with its early diagnosis possibilities often detects tumor at an early state. Moreover, presently this is the only possibility to visualize the process of angiogenesis in tumor, so far it still has a very small size.

Thermography allows in most of the observations to make differential diagnosis of malignant and benign processes.

The method of medical IT is a quickly developing technology used for detection and localization of thermal anomalies characterizes by areas of skin surface with reduced or increased temperature.

The principle of examination is to detect infrared radiation, which is correlated with heat emission of a specific body area of a biological object (Wenger E.F., et al., 2006; Ivanitskiy G.R., 2006; Diakides N.A., Bronzino J.D. (Eds), 2006). Usually tissue damage is accompanied by changes in blood flow, which in turn affects skin temperature.

The accuracy of thermographic survey does not depend on a patient’s age, on density of the breast tissue, and makes about 90%. Thermography allows discovering the disease at an early stage by arranging annual survey of women starting from teenager age. Simplicity and accessibility of that method allows monitoring the state of the mammary glands in different age periods and timely diagnosing of pathological changes in the breasts.

Typical application of radiation within electromagnetic spectrum for biomedical purposes is presented in Table 1 (Hildebrandt C. et al., 2010).

Thus, IT has an important place in the whole complex of existing radiation diagnostic techniques.

Object and methods of research
The research was performed using a thermograph, which is described in detail in the previous works (Wenger E.F. et al., 2006; Rosenfeld, L.G. et al., 2006; Rosenfeld L.G., et al. 2007). Patient were undergoing ultrasound and x-ray examination in medical institutions of Ukraine.

Results and discussion
Figure 1 shows thermographic picture of the mammary glands without pathological changes. Temperature in 4 zones of the left and right lacteal glands has been identified, their gradients have been shown.
Table 1. Application of electromagnetic radiation for biomedical purposes

<table>
<thead>
<tr>
<th>Type of radiation, wave length</th>
<th>Type of information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio waves, $10^{-3}$</td>
<td>Anatomy, chemical composition</td>
</tr>
<tr>
<td>Micro waves, $10^{-2}$ (ultrasound)</td>
<td>Anatomy, structural characteristics</td>
</tr>
<tr>
<td>IR radiation, $10^{-5}$</td>
<td>Anatomy and physiology, surface temperature</td>
</tr>
<tr>
<td>Visible light, $10^{-6}$</td>
<td>Anatomical structure of ligaments, inflammation</td>
</tr>
<tr>
<td>Ultraviolet radiation, $10^{-8}$</td>
<td>Chronic inflammation of skin</td>
</tr>
<tr>
<td>X-ray, $10^{-10}$</td>
<td>Anatomy, bones damage</td>
</tr>
<tr>
<td>Gamma-radiation, $10^{-12}$</td>
<td>Physiology, inflammation, metabolism, bones</td>
</tr>
</tbody>
</table>

Mastopathy and its variations.

**Mastopathy with prevalence of fibro-cystic component**

On the above thermograms of patients with different manifestations of fibro-cystic mastopathy, in all cases we can see hypothermia with various temperature gradients.

Patient G., 68 years old, fibro-cystic mastopathy of the left breast (Figure 2). The temperature gradient in the focal zone of hypothermia in the left breast (1) and adjacent regions (2) and (3) varies from $-1.22^\circ$C ($T_2 - T_1$) to $3.2^\circ$C ($T_3 - T_1$).

Patient G., 23 years old. IT (Fig. 3): a benign formation (fibro-cystic fibroadenomatosis) in the left breast (acc. to ultrasound and XMG data). Focus of hypothermia in the left breast features thermal asymmetry gradients ($-1.2^\circ$C); temperature gradient between skin over new formations and the surrounding tissues makes from $-1.5^\circ$C to $-2.1^\circ$C.

Patient Sh., 54 years old. Fibrocystic mastopathy of the left breast. Fibrocystic area is characterized by a large variability that affects thermographic representation of this type of pathology (Fig.4).

Patient S., 35 years old. Fibro-cystic fibroadenomatosis. In IT (Fig. 5) we can clearly see the network of blood vessels of the left and right lacteal glands. There is a growing vascular pattern.

Research results of Uspensky D.A. et al (2007) have shown that such a state of blood flow in the area of localization of lacteal glands’ microcalcifications may be a precursor to malignant process. Vascular pattern increasing identification is an important factor for the comprehensive survey of the lacteal glands’ state.
Diffuse fibroadenomatosis

Patient B., 45 years old. Diffuse fibroadenomatosis (Fig.6). Through IT we determine temperature of the left mammary gland nipple as 32.31°C, of the right one - 30.24°C. The temperatures in the midline of the left breast: 30.62; 30.62; 30.86; 30.72°C; the right breast: 31.14, 31.13, 30.24, 31.41; 31.86°C. IT data are confirmed by clinical results. XMG has been done, through which we found that breast tissue is heterogeneously calcificated through the moderate diffuse fibroadenomatosis. In the right part, at the border of lower quadrants there is low-intensity oval shade with a clear outline (2.3 x1.4 cm). Diagnosis: category 2 acc. to BI-RADS (Breast Imaging-Reporting and Data System (benign tumor)).

Patient M., 54 years old. Through IT (Fig. 7) we determine a hypothermic formation in the left breast. Temperature gradient of skin in the formation zone and around is -1,1°C. Ultrasound has visualized a focus formation in the left breast. Diagnosis: diffuse fibroadenomatosis with predominance of fibrosis, a microcyst at the left. Temperature of skin around the cyst is by 1°C lower than the temperature of tissues around; temperature in the area of the right breast nipple is 31.67°C, and of the left one is 30.63°C.

In the microcyst area the temperature gradient is from -1.1 to -1.2°C.

Biopsy has been applied: in the aspirate from the focus formation of the left breast we identified fragments of adipose tissue and scattered small complexes of proliferating ductal epithelium, characteristic of ductal hyperplasia/adenosis of the breast.

Patient S., 55 years old. Diffuse fibroadenomatosis of the left breast with adenosis (Fig.8). IT showed thermal heterogeneity of lacteal gland tissues, the presence of hypothermal formations in the right and left breasts with a temperature gradients -0,75°C (T2-T1) and -1,14°C (T4-T3).

Diffuse mastopathy with a predominance of cyst component

Patient L., 51 years old. The thermogram shows multiple hypothermal inclusions in both lacteal glands (Fig.9) The temperature gradient between tumors and adjacent tissues is -0.96°C (left breast) and -0.93°C (right breast) (lipoma). Ultrasound examination has been done, which revealed the presence of heterogenic formations and ultrasound signs of fibro-fatty involution with a cyst component in both lacteal glands.

Patient L., 42 years old. IT showed hypothermic formation in the right breast (Figure10). Temperature gradient between the focus and adjacent tissues is (1,14-1,28)°C, which is a sign of cyst-like inclusions in the breast. XMG has been done, the results of which showed no signs of malignancy. Diagnostic category has been defined (B1-RADS). Ultrasound examination showed signs of mass lesion of the breast with signs of invasive growth against the background of atypical adenosis, ductal ecatsy at the right part, cysts at the left part. The data obtained fully correspond to thermographical investigation data.

<table>
<thead>
<tr>
<th>IT</th>
<th>Ultrasound</th>
<th>XMG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothermic changes in the field of lacteal glands of local concentration. Temperatures gradient - (0.5-1.5)°C</td>
<td>Cystoid formation</td>
<td>Cystoid formation</td>
</tr>
<tr>
<td>Hypothermic changes of lacteal glands structure. Temperatures gradient - (0.3-1.0)°C</td>
<td>Fibroadipose involution</td>
<td>Category 2</td>
</tr>
<tr>
<td>Hyperthermic changes of lacteal glands structure. Temperatures gradient + (0.5-1.5)°C</td>
<td>Signs of diffuse fibroadenomatosis with expressed adenosis</td>
<td>Category 3</td>
</tr>
<tr>
<td>Increased vascular pattern in the field of lacteal glands</td>
<td>Does not show</td>
<td>Does not show</td>
</tr>
</tbody>
</table>

Patient R., 53 years old. IT (Fig. 11) showed multiple formations in the right (partially in the left) breasts. XMG showed calcinations of the left breast due to small fibroadenomatosis elements of involution type, signs of a fat-containing oval formation with slurred edges, straight outlines, with microcalcinites in structure has been found. Temperature gradient between tumor and surrounding tissues makes – (0.89-1.64) °C.

Patient P., 52. Thermogram of the patient with cyst-like formations in breasts (shown by arrows)
Thermogram of the patients with cyst-like formations in breasts (shown by arrows)

Patient Sh., 21 years old. Thermogram (Fig. 12) shows multiple hyperthermal formations on the skin surface and in the lacteal glands. Ultrasound and XMG have not discovered any change in the area of lacteal glands. It was not possible to find the reason of these formations.

Breast cyst
Patient P., 52 years old. IT showed cyst-like formations in lacteal glands (Fig.13). The arrows indicate location of cyst-like formations: the right breast - at 11, 3 and 7 o’clock; in the left breast - at 5 and 6 o’clock.

Ultrasound and XMG results confirmed the presence of cyst-like formations dominated by fibrotic changes, adenosis of dispersed nature in the form of mostly fatty tissue in lacteal glands; the presence of diffuse fibroadenomatosis. The temperature gradient in the cyst area comparing to adjacent areas does not exceed ± (0.65 - 0.75)°C, temperature variations by areas of cyst formations in the left and right lacteal glands makes 0,04-0,21° C.

Thermogram of a patient with benign changes in the nipple of the right breast and hypothermal changes typical for cyst-type formations in the range of 5-7 hours are shown in Fig. 14a. XMG and biopsy have been done. As a result the following was discovered: areas of changes found do not contain tumor proliferates and grouped microcalcitates. Fibrogland calcinations have been found in the breast. Fig. 14, 14а represents thermograms of patients with thermal asymmetry of lacteal glands typical for cyst formations with a negative temperature gradient (shown by arrows).

Generalized survey results are shown in Table 2.

Revealed pathologies of unknown origin
Patient P., 22 years old. IT revealed hyperthermia of the left breast (Fig.15). The temperature gradient between areas shown by arrows 1 and 2 (DT1-2) is +1,3°C.

Ultrasound showed no changes in the mammary gland.

Patient K., 23 years old. Thermogram (Fig. 16) shows that temperature of the left breast is higher than temperature of the right one. There are hyperthermia focuses in the area of the left breast, they are indicated by arrows, temperature gradient is +0,69°C. Additional studies (ultrasound, XMG) showed no changes in the mammary glands.

Conclusions
High effectiveness of remote IT in diagnosis of lacteal glands diseases has been demonstrated.
Non-invasive nature and easiness of IT allows its multi use without damaging patients’ health, revealing changes in lacteal glands at early stages with further diagnostics based on the results of clinical studies.

Comprehensive diagnostics of lacteal glands using thermography increases information content and reliability of diagnostic search.

Literature

www.umj.com.ua | UKR. MED. CHASOPYS, 3 (95) – V/VI 2013


Address for correspondence:
Kovalchuk Igor Semenovich
01034, Kyiv, 22, Reitars'ka St.
Kyiv City Clinical Endocrinology Centre

Received on 08.01.2013