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Possibilities of electrical impedance tomography in gynecology

Trokhanova O V[1], Chijova Y A[1], Okhapkin M B[1], Korjenevsky A V[2] and Tuykin T S[2]

[1]Yaroslavl State Medical Academy, Yaroslavl, Russia; [2]Kotel'nikov Institute of Radioengineering and Electronics of the RAS, Moscow, Russia

trokhanova@yandex.ru

Abstract. The paper describes results of comprehensive EIT diagnostics of mammary glands and cervix. The data were obtained from examinations of 170 patients by EIT system MEM (multi-frequency electrical impedance mammograph) and EIT system GIT (gynecological impedance tomograph). Mutual dependence is discussed.

1. Introduction

Electrical impedance tomography (EIT) is a method of imaging the spatial distribution of the electrical impedance provided by measurements taken from the object surface with further solving an inverse problem.

A mammary gland is an integral part of the female reproductive system, and its diseases, which are generally benign, are consequences of general processes in the organism and reproductive organs of a woman. It is important to note that to consider pathologies of genitals and mammary glands separately is a basic mistake. When planning treatment of patients with gynecological pathology it is necessary to consider the condition of genitals, as well as to conduct a complex survey of mammary glands. Multi-frequency electrical impedance mammography system "MEM" (MEM) [1, 2] with 256 electrodes has successfully been used for several years only for mammary gland diagnosis.

Recently impedance measuring has been applied for detection of cervical intraepithelial neoplasia [3]. Nowadays there is also a possibility to visualize tissues of a cervix uterus by Gynecological Impedance Tomorgraph "GIT" (GIT) [4]. Combination of both EIT investigations (MEM and GIT) enables to improve quality of women's health diagnostics. Possible scenarios of such a combination and preliminary clinical results of a complex assessment and diagnostics of the reproductive system will be presented in the paper.

2. Materials and methods

The paper presents an integrated study of the breast and the neck of the womb of 170 women between the age of 21 and 50 who had never been tested and had no complaints concerning their reproductive organs.

Multi-frequency electrical impedance tomography at a frequency of 50 kHz and 10 kHz was used for mammary glands and gynecological diagnostics. Both MEM and GIT are 3D electrical impedance tomography systems, which have a planar array of 256 and 48 measuring electrodes correspondingly. While MEM device has a regular and orthogonal electrode array with diameter 12-cm [1, 2], GIT device has a non-regular, non-orthogonal electrode array with diameter 30-mm [4]. GIT non-regular

electrode placement enables to increase covering and spatial density of electrodes on a small area of 33 mm diameter. To reduce spurious couplings and wiring complexity, the measuring electronics (analogue front-end, microcontroller and communication unit) of the MEM and GIT are embedded inside the corresponding probes. This is quite challenging in case of the GIT system as the available space is only 30 mm in diameter and 20 mm in height inside the vaginal probe. 3D back-projection algorithms are used for the image reconstruction.

There were also other methods used for the cervix and breast examinations: history taking, physical examination, palpation, breast ultrasound, X-ray mammography, a visual inspection of cervix by mirrors, extended colposcopy, target biopsy of cervix, Papanikolau`s smear method. The obtained results of the study were statistically processed.

3. Results

Considering the mammary gland examination by electrical impedance mammography, five groups were formed [5]: norm, mastopathy, cyst, fibroadenomas and cancer.

In the first group (norm) 53 women (31.2%) out of 170 showed no changes in the mammary glands: a clear electrical impedance anatomy, correspondence of the electrical impedance image according to the age type of mammary gland structure, absence of deformations of the image contours, distinct architectonics of internal structures, absence of focal masses, absence of any difference in images depending on the patient position and the side of scanning, symmetry of the graph of frequency distribution of the conductivity. 82 women (48.2%) showed signs of mastopathy of different types: well-defined undistorted contour of the mammary gland, absence of the internal structure displacement, abnormalities of the image architectonics due to the change of ratio of the mammary gland tissues, resulting into mismatch of the electrical impedance (juvenile, reproductive, premenopausal, postmenopausal) type of image and the age, increase of hyper-impedance areas on the images due to fibrous changes of the adipose tissue, fibrosis of the duct walls and the Cupper ligaments, increase of the mean electrical conductivity zones due to hyperplasia of glandular tissue at adenosis. 21 women (12.4%) were identified to have an isolated cyst of a mammary gland: hypoimpedance formations with rather blurred contours, featuring electrical conductivity of 0.65 – 0.94 conventional units. 12 women (7%) had fibroadenomas of the mammary gland: isoimpedance formations with rather blurred contours, featuring electrical conductivity of 0.50 – 0.64 conventional units. 2 women (1.2%) were diagnosed to have cancer of the mammary glands: hypoimpedance areas with high electrical conductivity above 0.95 conventional units. Additionally there are observed: deformation of contours, impaired architectonics, and displacement of internal structures and difference in conductivity depending on the side of scanning.

All breast pathologies, founded by electrical impedance mammography method were confirmed by conventional techniques (ultrasound and X-ray mammography).

Preliminary results of the EIT investigation with GIT device were presented in [6]. In the current report extended results are enlisted. According to the new results patients were divided into 4 groups under their pathologies, which were diagnosed by conventional methods (exploration by mirrors, an extended colposcopy and cytology). Thus, the 4 groups were named: “in norm”, “inflammation changes”, “CIN I”, “CIN II&CIN III”.

Group “Inflammation changes” combines nonspecific changes of the neck of the womb: erosion, leucoplakia, polyps, warts, inflammation. Group “CIN I” means cervical intraepithelial neoplasia grade I. It is characterized by a low level of squamous intraepithelial lesion. Group “CIN II and CIN III” combines cervical intraepithelial neoplasia of grade II and III. A cytological examination reveals a high degree of squamous intraepithelial lesion and an extended colposcopy diagnoses suspicion of an invasion.

The results of electrical impedance imaging of cervix (typical for a group) are shown in figure 1. Mutual correlated statistics by diagnostics of the cervix and mammary glands are presented in table 1.

Table. 1. Pathology of the neck of the womb in various diseases of the mammary glands.

Pathology of cervix / Path. mammary glands	In norm	Inflammation changes	CIN I	CIN II, CIN III
The absence of disease (n=53)	32 (60.4%)	14 (26.4%)	3 (5.7%)	4 (7.5%)
The mastopathy of different type (n=82)	37 (45.2%)	28 (34.1%)	11 (13.4%)	6 (7.3%)
Isolated cycts (n=21)	15 (71.4%)	4 (19.1%)	2 (9.5%)	-
Fibroadenoma (n=12)	3 (25%)	3 (25%)	4 (33.3%)	2(16.7%)
Cancer (n=2)	1(50%)	1(50%)	-	-

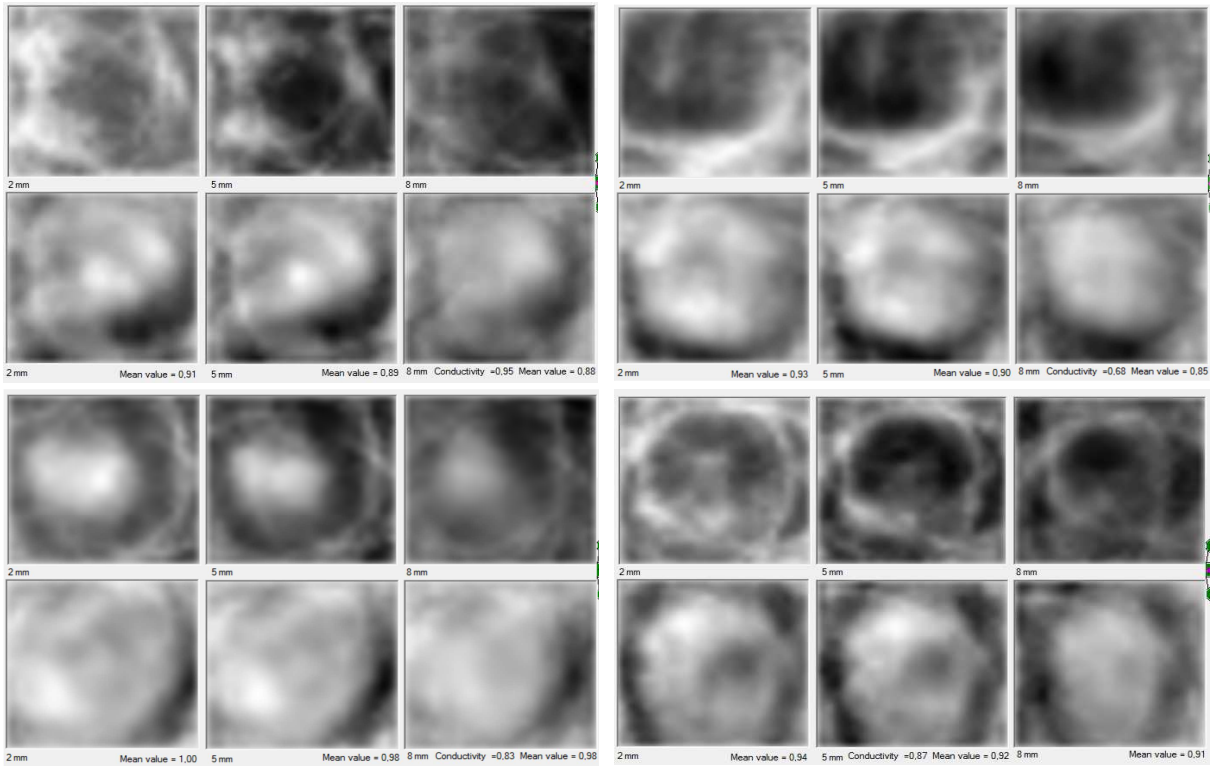

Figure. 1. Electrical impedance tomograms of the neck of the womb. 4 shots (patients). Each shot has two frequency images (upper line of 10 kHz, lower line of 50 kHz) and three slices (2mm, 5mm, 8mm depth in row from left to right). Left up: norm, 41 years old; right up: with different inflammation changes, 25 years old; left down: with CIN I, 31years old; right down: with CIN II and CIN III, 25 years old.

The characteristics of the average cervix electrical conductivity for the groups (in normal state and 3 pathology types) for two frequencies are given in table 2.

Table 2. Average value electrical conductivity at a frequency of 50 kHz and 10 kHz for 4 patient groups. The average values by group ± standard deviation are presented.

Depth & freq. / Pathology	1 level (2 mm)		2 level (5 mm)		3 level (8 mm)	
	50 kHz	10 kHz	50 kHz	10 kHz	50 kHz	10 kHz
The absence of disease (n=88)	0.89±0.06	0.40±0.1	0.85±0.07	0.36±0.09	0.83±0.09	0.30±0.05
Inflammation changes (n=50)	0.91±0.04	0.47±0.1	0.88±0.05	0.37±0.1	0.86±0.05	0.35±0.1
CIN I (n=20)	0.89±0.04	0.41±0.02	0.85±0.04	0.3±0.02	0.83±0.04	0.28±0.02
CIN II, CIN III (n=12)	1.01±0.1	0.38±0.05	1.0±0.1	0.26±0.05	1.0±0.1	0.23±0.04

Analysis of the results showed that the average electrical conductivity decreases statistically significantly ($\rho<0.05$) when scan depth increases on both frequencies scanning in all groups, except for the group "CIN II and CIN III", in which there was no statistically significant ($\rho>0.05$) dependence of the average electrical conductivity on scan depth at a frequency of 50 kHz only. Group "CIN II and CIN III" average electrical conductivity obtained at a frequency of 50 kHz (for any scan depth) is statistically significantly higher ($\rho<0.05$) than average electrical conductivity of all the other groups. The average electrical conductivity at a frequency of 50 kHz is statistically significantly ($\rho<0.05$) higher than at 10 kHz for all the groups.

4. Conclusions

The results showed possibility to distinguish pathology by EIT investigation for mammary glands previously [1, 2, 5] but now this has been demonstrated for cervix uteri. Thus, the method of electrical impedance tomography can be used as a method of screening for both mammary glands and cervix.

The method of electrical impedance tomography for cervix diagnostics is especially effective to identify higher degree of squamous intraepithelial lesion and suspicion of invasion. This will allow choosing the right treatment.

A comprehensive examination of the reproductive system by the method of electrical impedance tomography will improve the quality of diagnostics and the formation of risk groups for both types: mammary gland cancer and cervix uteri cancer.

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