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Using of electrical impedance tomography for diagnostics of the cervix uteri diseases

O V Trokhanova¹, Y A Chijova¹, M B Okhapkin¹, A V Korjenevsky² and T S Tuykin²

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

E-mail: trokhanova@yandex.ru

Abstract. The report presents results of investigation of the neck of the womb (cervix) of 64 women aged from 19 to 70, that formed 4 clinical groups (1st group: 15 women without any pathology of the cervix, 2nd group: 27 women with erosion, 3rd group: 11 women with dysplasia, 4th group: 11 women with cancer of the cervix). The aim of this research is to assess the capabilities of electrical impedance tomography in the diagnostics of the cervix diseases. The methods of the research were: visual examination with the speculum, colposcopy, and biopsy of the cervix. Also the new method of visualization of the cervix was used - electrical impedance tomography with the help of gynecological impedance tomograph (GIT). The following results were obtained. The electrical conductivity of the cervix in norm and in different pathology has different indices, which allow differential diagnostics of benign and malignant diseases. Summary: the method of electrical impedance tomography allows not only visually estimate portio vaginalis, but receive indices of electrical conductivity of the cervix on the depth up to 0.8 cm and thereby reveal pathological changes in epithelium without invasive and operative intervention.

1. Introduction

More than 493 000 new cases of cervical carcinoma (8 for 100 000 of population) are being annually registered in the world. Carcinoma of uterine cervix mortality makes up about 280 000 women a year (3.5 for 100 000). Every 2.5 minutes in the world a woman dies from carcinoma of uterine cervix [1, 2]. In Russia more than 125 000 cases of this disease are annually detected (8.7 for 100 000) and about 7000 women a year die from cervical carcinoma [2]. Carcinoma of uterine cervix is the second in frequency women’s cancer following cancer of mammary gland It is characterized by bimodal distribution of the patients with the morbidity peak at the age of 35 – 39 and 60 – 64.

Because of any clinical finding absence of precursor cervical cancer the question of the early detection of this pathology is urgent. The method of electrical impedance tomography can be used for imaging and diagnostics of the cervix. For its evaluation the gynecology electrical impedance tomography system has been developed [3]. It allows not only to estimate vaginal part of the neck of womb visually but get electroconductivity characteristics of the cervix at the 8 mm depth and thereby detect epithelium pathological changes without invasive and surgical intervention.

The aim of this research is to assess the capabilities of electrical impedance tomography in the diagnostics of the diseases of the neck of womb.
2. Materials and methods of examination
The report presents main results of a comprehensive examination of the cervix of 64 women from 19 to 70 years.

The following diagnostic methods were applied: visual examination on the uterine speculum, colposcopy, biopsy of the cervix. All examination results were statistically processed by alternative variation method with obtaining a mean value and standard deviation. To check the data reliability we resorted to Student’s criterion.

Also the new method of visualization of the cervix was used - electrical impedance tomography with the help of compact gynecological impedance tomograph (GIT). The apparatus used was a 32-electrode 3D electrical impedance tomography system developed by the Institute of Radioengineering and Electronics of the Russian Academy of Sciences. The frequency used was 50 kHz. The work area of the tomography with 32 electrodes is applied to the portio vaginalis. Auxiliary electrode is placed to the woman’s wrist. During the scanning process the device, utilizing the 32 contact electrodes of the matrix successively injects into the cervix weak alternative electric current and registers corresponding distributions of electric potentials on its surfaces. The obtained data are used then for reconstruction of the electrical impedance images with the help of the mathematical algorithms utilizing a personal computer to which the device is connected via the USB port. After the reconstruction procedure is over, three images of the cervix, matching the three scanning planes, appear on the screen. The first scanning plane corresponds to the 2 mm depth from surface, the other two planes follow every 3 mm to the depth 8 mm.

In order to define particularities of the cervix electrical conductivity in norm and in case of pathology were subjected to clinical methods of examination, colposcopy and biopsy. As a result the following clinical groups were formed:
- The 1st clinical group composed of 15 women without any pathology of the cervix.
- The 2nd clinical group composed of 27 women with the ectopia of the cylindrical epithelium of the cervix.
- The 3rd clinical group composed of 11 women with dysplasia of the cervix.
- The 4th clinical group composed of 11 women with cancer of the cervix.

3. Examination results
3.1. Electrical impedance characteristics in norm
From the anatomical point of view, the cervix is a smoothly muscular organ covered with the laminated pavement nonkeratinous epithelium. Cervical canal which is situated inside is covered with the cylindrical epithelium. The zone of two kinds of epitheliums crossing corresponds to the external fauces and as a rule, is the place where the pathology of the cervix locates. On the electrical impedance images a zone of the external fauces looks like the hypoimpedance area the size of which is different at different phases of the menstrual cycle. The size of the area is bigger during the first phase when estrogens predominate and it diminishes at the second phase when progesterone influences. The zone of the external fauces of the women of the postmenopausal period is not visualized because of the reduction of the estrogen and progesterone background at this age. The portio vaginalis looks like isoimpedance mass which corresponds to the muscular layer with hypoimpedance inclusions.

The characteristics of the average electroconductivity of the cervix during the different physiological periods of life at the different scanning depth are shown in the table 1. As the table figures show there is no statistically significant difference between the rates of the electrical conductivity of the cervix of the women of different physiological periods in normal state (p>0.05). The rates of the electrical conductivity statistically don’t have any difference at the various scanning levels (p>0.05).


**Table 1.** The characteristics of the average electroconductivity of the cervix during the different physiological periods of life at the different scanning depth, M±SD.

<table>
<thead>
<tr>
<th>Period</th>
<th>1 level (2 mm)</th>
<th>2 level (5 mm)</th>
<th>3 level (8 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Juvenile period</td>
<td>0.96±0.10</td>
<td>0.96±0.09</td>
<td>1.003±0.005</td>
</tr>
<tr>
<td>Reproductive period</td>
<td>0.96±0.09</td>
<td>0.95±0.10</td>
<td>0.94±0.10</td>
</tr>
<tr>
<td>Postmenopause</td>
<td>1.003±0.005</td>
<td>1.007±0.005</td>
<td>1.007±0.005</td>
</tr>
</tbody>
</table>

3.2. **Electrical impedance characteristics in case of pathology of the cervix**

The most frequent pathology of the cervix is the ectopia of the cylindrical epithelium and the dysplasia of the cervix which is considered as the precancerous state. So, naturally, the carcinoma of uterine cervix is of the great interest as the state threatening the life of a woman. Having this pathology, we can see visually, in the electrical impedance images, the extension of the hypoimpedance zone of the external fauces or the appearance of the hypoimpedance foci which correspond to the locating of dysplasia or cancer. The characteristics of the average electroconductivity of the cervix with ectopia, dysplasia or cancer in comparison with the normal state are shown in table 2.

**Table 2.** The characteristics of the average electroconductivity of the cervix during the different physiological periods of life in normal state and during the pathology at the different scanning depth, M±SD.

<table>
<thead>
<tr>
<th>Pathology</th>
<th>1 level (2 mm)</th>
<th>2 level (5 mm)</th>
<th>3 level (8 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Juvenile period</td>
<td>0.96±0.10</td>
<td>0.96±0.10</td>
<td>0.96±0.20</td>
</tr>
<tr>
<td>Reproductive period</td>
<td>0.96±0.09</td>
<td>0.95±0.10</td>
<td>0.94±0.10</td>
</tr>
<tr>
<td>Postmenopause</td>
<td>1.003±0.005</td>
<td>1.007±0.005</td>
<td>1.007±0.005</td>
</tr>
<tr>
<td>Ectopia of the cylindrical epithelium</td>
<td>0.97±0.06</td>
<td>0.96±0.07</td>
<td>0.96±0.08</td>
</tr>
<tr>
<td>Dysplasia of the cervix</td>
<td>0.99±0.07</td>
<td>0.98±0.09</td>
<td>0.99±0.10</td>
</tr>
<tr>
<td>Carcinoma of uterine cervix</td>
<td>0.99±0.04</td>
<td>0.99±0.03</td>
<td>0.98±0.04</td>
</tr>
</tbody>
</table>

The comparison of the characteristics of the average electroconductivity of the cervix in the normal state and during the pathology shows the slight increase of electroconductivity having dysplasia and the carcinoma of uterine cervix in comparison with the electroconductivity of the cervix in the normal state of the menstruated women. But the difference is not statistically trustworthy (p>0.05). There is no statistically trustworthy difference in various scanning levels during both pathology and the normal state (p>0.05). But the clear difference appear while estimating the electroconductivity of the hypoimpedance zone of the external fauces, table 3, which corresponds to the two borders between two types of epitheliums and, as a rule, the place where the pathology of the cervix is situated.
Table 3. The characteristics of the electroconductivity of the zone of the external fauces of the cervix in the normal state and the pathology at the different scanning depth, M±SD.

<table>
<thead>
<tr>
<th>1 phase</th>
<th>2 level (5 mm)</th>
<th>3 level (8 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.16±0.03</td>
<td>1.13±0.04</td>
<td>1.04±0.06</td>
</tr>
<tr>
<td>1.050±0.006</td>
<td>1.05±0.10</td>
<td>1.050±0.006</td>
</tr>
<tr>
<td>1.20±0.06</td>
<td>1.14±0.02</td>
<td>1.07±0.05</td>
</tr>
<tr>
<td>1.27±0.03</td>
<td>1.17±0.01</td>
<td>1.06±0.08</td>
</tr>
<tr>
<td>1.300±0.005</td>
<td>1.280±0.006</td>
<td>1.14±0.02</td>
</tr>
</tbody>
</table>

During the second phase of the menstrual cycle the electroconductivity of the zone of the external fauces is less than in the first one on the first two scanning levels (p<0.01) and doesn’t differ at different depth (p>0.05). In the normal stage at the first phase of the menstrual cycle and at any pathology the characteristics of the electroconductivity of the zone of the external fauces statistically are positively less (p<0.01) at the deeper scanning level. There is a statistically trustworthy difference in the characteristics of the electroconductivity in disease in comparison with the normal state at a scanning depth of 2 mm (p<0.01, p<0.05) and a statistically trustworthy increase of electroconductivity having the cancer of the cervix at a depth of 5 and 8 mm in comparison with the normal state and beginning pathology. The difference in the characteristics of the electroconductivity of the zone of the external fauces depends on the invasion degree and the degree of the epithelium transformation.

4. Conclusions

In spite of the absence of significant difference in the characteristics of the average electrical conductivity of the cervix uteri in the normal state and the pathology, there are clear differences in the characteristics of the electrical conductivity of the zone of the external fauces which can be the criteria of the diagnosis of different pathology of the cervix uteri.

Method of the electrical impedance tomography of the cervix meets all the requirements to the screening diagnostic technique of the precancerous disease: it is simple, accessible, noninvasive, has no any restrictions for repetition of examination tests, doesn't require any special patient’s preparation, unlike other methods allows to detect the pathological changes of the cervix at the depth of up to 8 mm without an operative intervention. Because of its safety, it is possible to use the method during pregnancy and for the young nullipara women when biopsy of the cervix uteri is undesirable.

References