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THE INFLUENCE OF COLD PLASMA ON DIELECTRIC PROPERTIES OF BIOLOGICAL TISSUE

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ABSTRACT

The purpose of this study was to verify the modifying effect of cold plasma on the dielectric permittivity of human skin samples. We fixed the shifts of dielectric properties of human skin specimens, which were specific for processing by non-ionized inert gases (argon and helium) and cold plasma. The dielectric permittivity of tissues was estimated using near-field resonant microwave sensing. It is established that the treatment of fragments of biological tissue (human skin) with the considered flows of non-ionized and ionized inert gases (helium and argon) has a significant effect on the dielectric characteristics of this biological object. At the same time, the identified effects are specific for each of these effects. Argon and argon cold plasma reduce the dielectric permittivity of the skin sample, and to a greater extent – non-ionized gas (on 24.3%). On the contrary, helium causes an increase in the studied parameter, but only in the form of cold plasma. This indicates the unequal influence of the considered physical factors on the morphological structure of the biological sample.

Keywords: near-field microwave sensing, biological tissue, dielectric properties

INTRODUCTION

The dielectric properties of biological objects have been studied for several decades [1-7]. To solve this problem, researchers use various approaches to sensing, which can be classified into active and passive [3, 6-8]. Such a wide range of diagnostic technologies still does not allow us to identify the optimal method of sensing and the frequency of electromagnetic field oscillations emitted by the generator [1-4, 7]. Thus, the latter ranges from 10 MHz to 35 GHz for various authors [1-7].

It should be noted that almost all studies relate to the use of microwave sensing technologies of biological tissues in vivo, whereas the method under consideration can be successfully used to assess the condition and characteristics of biological objects outside the body. In particular, individual publications have confirmed the possibility of evaluating the parameters of samples of a number of organs (liver [1], prostate gland [2], etc.) by their dielectric properties. This is consistent with the data of our previous studies [5, 6].

On this basis, the purpose of this study was to study the modifying effect of cold plasma on the dielectric permittivity of human skin samples.

MATERIAL AND METHODS

The experiment was performed on full-layer human skin samples removed intraoperatively during surgical interventions performed in Sechenov University clinics (n=11). Each sample was divided into 5 equal fragments, the first of which was a control (no manipulations were performed with it). The remaining four fragments were treated with gas streams containing non-ionized helium or argon, or cold helium or argon plasma. The treatment time was 1 minute, the duration of exposure was 5 minutes.

All samples were studied once by the method of near-field resonant microwave sounding using a hardware and software complex of its own design [5, 6]. The main evaluation indicator was the level of dielectric permittivity of a biological object [5, 6]. An applicator was used for probing, which allows integrally examining the dielectric properties of biological tissue at a depth of 5 mm, which corresponded to the size of the analyzed fragment. All biological tissue samples were obtained after the patients signed informed consent. The study was approved by Local Ethic Committee of Sechenov University.

Statistical processing of the obtained results was performed using the program Statistica 6.1 for Windows.

RESULTS

It is established that the dielectric properties of the studied samples change significantly under the influence of the tested gas flows (Fig. 1). Even non-ionized inert gases have an unequal effect on the dielectric permittivity of skin fragments ($p<0.05$). Thus, the treatment of biological tissue with a stream of helium does not shift the indicator under consideration relative to the control level, while the use of argon significantly reduces this parameter (by 24.3%; $p<0.05$). It can be assumed that argon treatment of a skin sample leads to a change in its degree of hydration, in contrast to the helium flow.

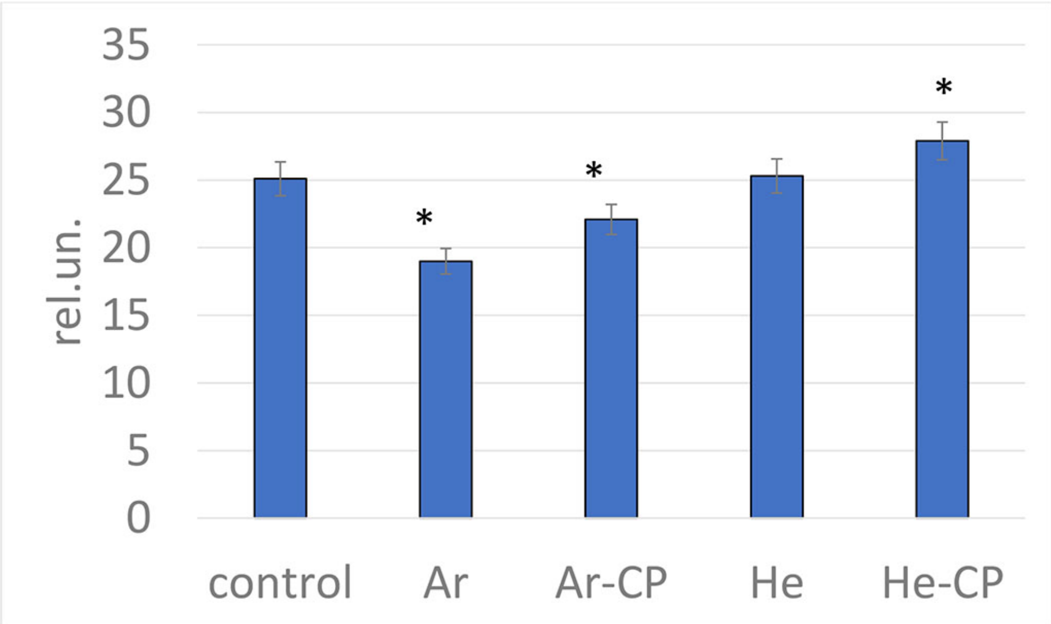

Figure 1. The dynamics of dielectric permittivity of biological samples under the action of inert gases and cold plasma; («» - level of statistical value (p<0.05)*

A variable dynamic was found when using cold plasma with various carrier gases (Fig. 1). It was revealed that for argon cold plasma, as for non-ionized argon, a decrease in the level of dielectric permittivity of a fragment of human skin is characteristic, but this trend is less pronounced (12.0% vs. 24.3% relative to an intact sample of biological tissue; $p<0.05$ for both effects).

On the contrary, the ionization of the helium flow leads to the formation of a modulating effect on the dielectric properties of human skin fragments, which was not observed for an unchanged inert gas. It was found that when treated with helium cold plasma, the dielectric permittivity of the studied object increases by 11.2% compared to the values characteristic of the control sample, with which no manipulations were performed ($p<0.05$).

CONCLUSION

The study made it possible to establish that the treatment of fragments of biological tissue (human skin) with the considered flows of non-ionized and ionized inert gases (helium and argon) has a significant effect on the dielectric characteristics of this biological object. At the same time, the identified effects are specific for each of these effects. In particular, argon and argon cold plasma reduce the dielectric permittivity of the skin sample, and to a greater extent – non-ionized gas. On the contrary, helium causes an increase in the studied parameter, but only in the form of cold plasma. This indicates the unequal influence of the considered physical factors on the morphological structure of the biological sample.

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