Study of Hot Spots by Oncological Patients with Metal Implants in Head and Neck Region

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Abstract— The purpose of this contribution is to study the risk of unwanted hotspots around metallic implants in head and neck area of the new waveguide applicator system. Metallic implants may interact with the EM field. The reaction rate depends on the implants dimensions.

1. INTRODUCTION

Metal implants like wires, titan screws or stents are often considered as contraindication for microwave hyperthermia. Metal implants can cause some phenomena that affect and impair microwave hyperthermia treatment. The main goal of microwave hyperthermia is distribution of electromagnetic energy in tumor. High frequency energy causes tumor heating. For effective treatment it is necessary to heat tumor to the temperature range 42–45°C [1]. The presence of metallic implants in the treated area may cause two types of complications. First complication is when high frequency microwave field exposes metallic implants. Energy heat metal and this can result in local extreme temperature. Due to good thermal conductivity of metal the temperature simply spread to the tissue. If this temperature exceeds 60°C we can call it ablation. The second complication is that metal implants affect the expected electromagnetic field distribution. A way how to reduce this type of interaction between implants and electromagnetic field is the applicator setting in the way that the vector of electric field intensity is turned perpendicularly to metal implant [1]. This condition is difficult to meet, because in biological tissue vector of electrical field is rotated due to many reflections and transitions between different tissues. In this contribution we study the behavior of a given type of metal implants in high frequency electromagnetic field as much heats the tissue around them and how it affects the distribution of electromagnetic filed in treatment targets and sensitive tissues like brain and spinal cord.

2. APPLICATOR SYSTEM

We developed a new applicator system (see Figure 1) intended for microwave hyperthermia in head and neck area (applicator system is partially adopted from [2]). The applicator system is constructed from four equal waveguide applicators intended for superficial hyperthermia. They are water filled waveguide applicators with strip line horn aperture. Each applicator has 100 × 50 mm effective aperture and as the main conductive material aluminum is used. The suitable working frequency for this type of applications is 434 MHz. By amplitude and phase combination of each applicator we are able to steer the field and cover the most of treated tissue. Whole system can be rotate around the patient to find the best possible position for treatment. In the center of microwave radiation is the treatment target. Other part of the system is circular water bolus, which is 240 mm in diameter. The purpose of the water bolus is to cool patient skin and thereby reduce the risk of hotspots.

3. NUMERICAL PHANTOM

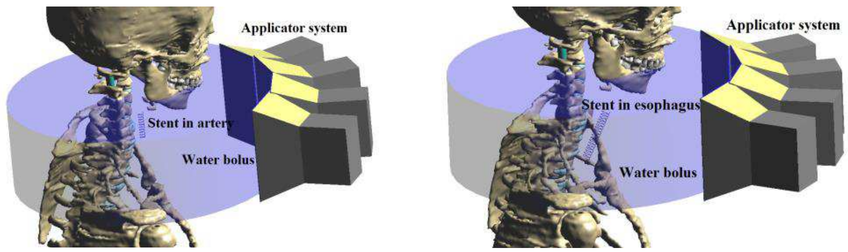
For simulation purposes the human model part of the SEMCAD X models database was used. Specifically model the Ella from Virtual Family 1.2 was utilized [3]. All dielectric parameters were taken from IT'IS foundation material database [4]. Around neck or head we placed the applicator system in a position to meet the practical use conditions (see Figures 1 and 2). For comparison and evaluation specific absorption rate [W/kg] (further SAR) is used. Metal implants were placed in a way that they are close enough to the applicator system. In the following paragraphs used metallic implants are discussed.

3.1. Stent in Artery

A Stent in the carotid artery is used in case of artery stenosis (constriction). The stent has a shape memory. Stent will ensure smooth supply of brain blood and reduce the risk of brain stroke. Stents are made from stainless steel. In the Figure 1(a) there is numerical model with stent in carotid artery. The stent is 30 mm in length and 3 mm in diameter.

3.2. Stent in Esophagus

It is used in case of constriction in esophagus. This constriction could be cause by tumor or injury. The stent has a similar function as stent intended for artery. In the Figure 1(b) one can see position of stent in numerical model. The stent is located in place where esophagus passes behind the thyroid gland. The stent is 20 mm in diameter and 50 mm in length.



(a) (b)

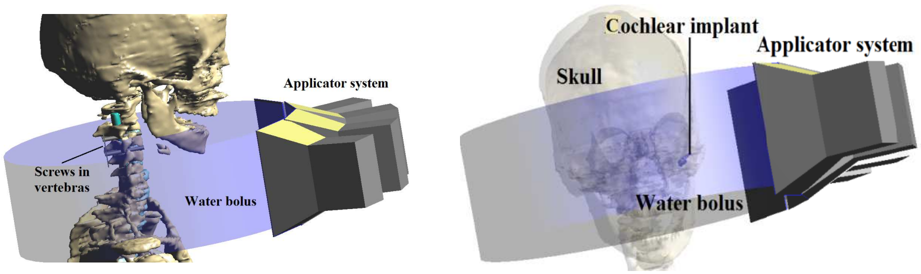
Figure 1: .Used numerical phantom, (a) stent in artery and (b) stent in esophagus.

3.3. Screws and Plate in Neck Vertebras

Plates and screws are used in case of injuries (fractures) of the cervical vertebras. The screws are drilled through vertebral body. For fixation of neck vertebras titan plate is used. In our numerical model the screws are drilled through 2nd and 3rd cervical vertebrae (total 4 screws). Screws are 40 mm long and 4 mm in diameter. The titan plate is fastened from the rear of the cervical vertebras. The plate has square shape with dimensions 35×35 mm.

3.4. Cochlear Implant

Cochlear implant is a part of device, which helps hearing-impaired people. Electrodes and signal transmission signals from the middle ear to the transmitter unit. In our numerical model we modeled only wire with electrodes in middle ear. The numerical model with cochlear implant is shown in the Figure 2(b).



(a) (b)

Figure 2: Used numerical phantom, (a) screws in vertebras and (b) part of cochlear implant.

4. SIMULATION RESULTS

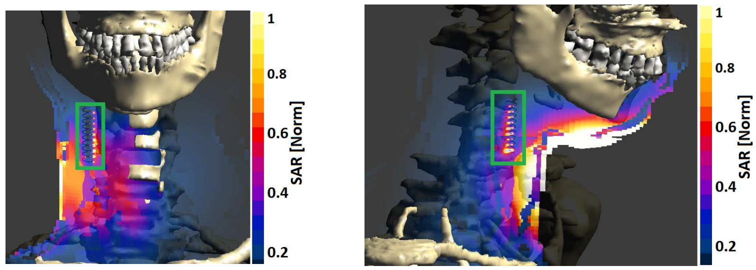
In the Figures 3–6 results of SAR distribution to the human numerical model ELLA in the presence of various metal implants are listed. All SAR values shown in the Figures are normalized. Following Equation (1) relates temperature, specific absorption rate and field intensity vector quantities:

$$SAR = \frac{\sigma}{2\rho}|E|^2 = c\frac{\Delta T}{\Delta t} \tag{1}$$

where SAR is specific absorption rate [W/kg], σ is tissue conductivity [S/m] at working frequency, ρ is tissue density [kg/m^3], E is vector of intensity field [V/m], c is specific heat capacity [J/kg/K], T is temperature [°C] and t is time [s].

4.1. Stent in Carotid Artery

Results for stent in carotid artery are in the Figure 3. The green rectangle is designated area, where the metal stent is. It is worth noticing that the maximum value of SAR values in the figure is located around the metal stent in carotid artery. Incurred hotspots are locally separated. This is caused by the relatively large distance between turns of stent.

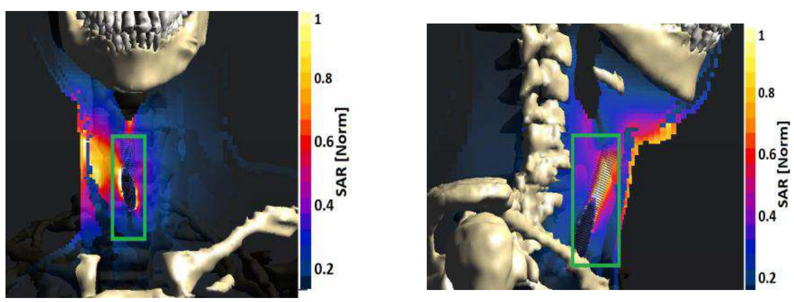


(a) (b)

Figure 3: SAR distribution in numerical phantom with stent in artery, (a) longitudinal and (b) transversal cross section.

4.2. Stent in Esophagus

Stent in esophagus behave similarly as stents in carotid artery. In the Figure 4 the results from simulation are listed (green rectangle indicate stent position in the cross section). Hot spots are located around the stent turns. The hot spots are fuse together. This is due to less distance between turns.

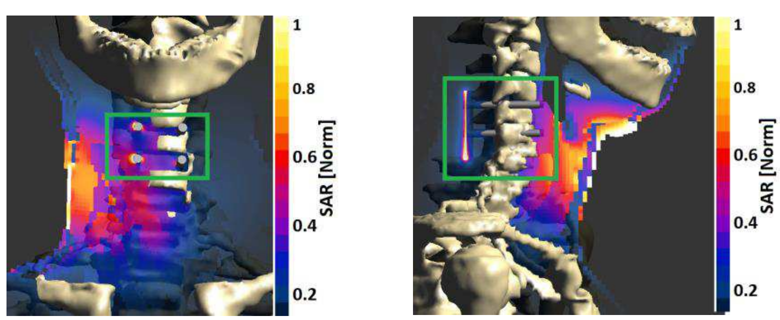


(a) (b)

Figure 4: SAR distribution in numerical phantom with stent in esophagus, (a) longitudinal and (b) transversal cross section.

4.3. Screws in Neck Vertebras

In the next Figure 5 the results in case of the screws and plate in the cervical spine are shown. In the Figure 5(a) there is a cross section where the screws begin. The unwanted hotspots have



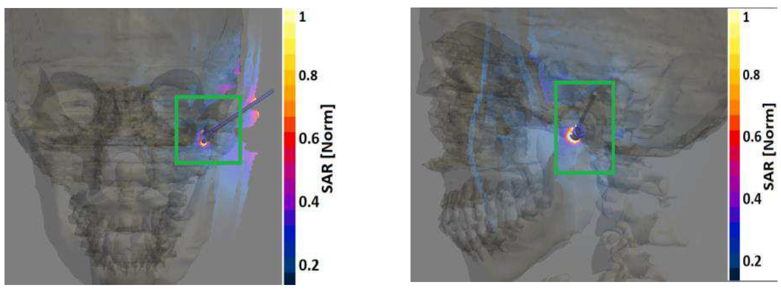
(a) (b)

Figure 5: SAR distribution in numerical phantom with screws in cervical vertebras, (a) longitudinal and (b) transversal cross section.

highest values in the cross section. In the Figure 5(b) there is longitudinal cross section, where in the green box is showing the hot spot formation on the titanium plate. Hot spots around screws in cervical vertebras are locally increasing temperature in spinal cord.

4.4. Cochlear Implant

Another examined metal implant is cochlear implant. The implant consists two parts. The first part is a conductor, which provide signal from the middle ear. On this wire there is no significant or critical SAR value. This is because the conductor is perpendicular to the electric field intensity. The second part of used cochlear implant is a conductor with electrodes, which is headed by a spiral in the middle ear. According to our numerical simulations the results are shown in the Figure 6. There is a very significant hotspot formation just in this part of implant. At the place where implant.



(a) (b)

Figure 6: SAR distribution in numerical phantom with cochlear implant, (a) longitudinal and (b) transversal cross section.

5. CONCLUSION

Metal implants behave similarly like an antenna. When we exposed metal implant to high frequency electromagnetic field the heating due to current flows was caused. If patients with metal implants underwent hyperthermic treatment of head and neck region by our hyperthermic applicator system, there would be large heating implants. We formulate this conclusion for all tested implants. Some implants (cochlear implant or screws in the cervical spine) can significantly compromise patient health and irreparably damage the organ in the implant nearby. The only possibility how to reduce the risk of unwanted hotspot is to ensure that the intensity of electric field is perpendicular to the metal implants. It is not so easy, because the electrical fields in biological tissue are extremely complicated.

ACKNOWLEDGMENT

This study was supported by the COST Action TD1301: "Development of a European-based Collaborative Network to Accelerate Technological and as well as by the Student Grant System of the Czech Technical University in Prague by student's project SGS 2014, with number SGS14/189/OHK3/3T/13: "Interactions of EM field with biological systems and theirs applications in medicine.".

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