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Yes the Children Are More Exposed to Radiofrequency Energy From Mobile Telephones Than Adults

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ABSTRACT Our reports of published research in several of the peer-reviewed journal articles in 1996, 2002, and 2004 have generated a lot of controversy over the last two decades, including the most recent publication by Foster and Chou. In this paper, we present arguments based on physics that the main reason for higher exposure of children (also women and men with smaller heads and likely thinner pinnae) to radiofrequency energy from mobile phones is the closer placement of the cell phone radiation source by several millimeters to the tissues of the head, e.g., the brain. Using heterogeneous anatomically derived shaped models of the head, we have previously reported that the exposure increases by a compounding rate of 10%–15% for every single millimeter of closer location of the radiating antenna. This is similar to the report of ∼20% increase for every millimeter in the Foster and Chou's paper from their (1) even though their simplistic (1) is valid only for a homogenous tissue slab of infinite size and the radiation source that is a wire dipole rather than a mobile telephone. Both of their assumptions for (1) are obviously not applicable for human exposures to mobile telephones. Actually, the physical reason for such a rapid drop off of coupled energy is that the radiofrequency electromagnetic fields close to a radiating source in the so-called near-field region reduce in strength very rapidly with every millimeter of distance, even faster than in the far-field region, where the electromagnetic fields reduce inversely with the square of the distance from the source.

INDEX TERMS Mobile telephones, exposure of children, antennas and radiation, EM compatibility.

I. INTRODUCTION AND BACKGROUND

To their credit, the authors Foster and Chou [1] recognize in their abstract that the discussion for this topic can be ''limited to dosimetric issues'' including possible agerelated differences in the heads of mobile phone users (sic children, women and people with smaller heads and thinner pinnae (''the fleshy outside part of the ear'' [1]). And yet they muddle up our claims in published literature [2]–[6] dating back to 1996 that children, women, and men with smaller heads would absorb higher radiofrequency energy in the head including the brain by presenting a bombastic roster of 23 studies using a variety of complex head models in [1, Table 2] leading to their insinuating caption, ''Are children more exposed to RF energy from mobile phones than adults?''.

In this paper, we will present logical arguments based on easy-to-understand physical concepts that led to the conclusions presented in our papers [2]–[6] that children, women, and people with smaller heads with thinner pinnae will absorb more RF energy as compared to adult males with larger heads and thicker pinnae. The physical arguments that have often been very helpful in dosimetric evaluations do not and need not depend on complex models used by a roster of 23 individual authors itemized in Table 2 of the Foster and Chou article [1].

While Foster and Chou mention some of our published papers [2], [3], [6] they do not mention our other papers [4], [5] that address the important role of reduced distance of the radiofrequency (RF) radiating source of the mobile telephone for individuals with thinner pinnae in drastically increasing the SAR measure of RF absorption by 10-15% for every single millimeter of closer placement of the cell phone source of radio frequency radiation for such individuals.

In [4] we have studied, both experimentally and computationally, the peak spatial (ps) average 1- and 10-g SAR for three commercial mobile phones and a fourth canonical telephone of dimensions typical of a mobile phone for increasing separations of 2-8 millimeters from a flat phantom (of dimensions 30 × 30 cm suggested by FCC for testing of laptop devices) and a sphere phantom of diameter 21.2 cm similar to the dimensions of the adult head.

The highlights of the results presented in [4] are the following:

1. The psSAR both for 1-g and 10-g tissues increases at a compounding rate of 10-15% for each millimeter closer placement of a radiating telephone for the flat phantom as well as the sphere phantom [4] and even for the heterogeneous anatomically based head models [5]. Shown in Figures 1a, b, and c are the variations of the peak 1- or 10-g psSAR for both "the Visible Man Model" and the Utah Anatomic Model derived from MRI (magnetic resonance images of a male volunteer) as a function of separation (0, 2, 4, and 6 millimeters) from the absorptive tissues for two different monopole antennas on assumed handsets of dimensions typical of mobile phones [5]. For each of the cases in Figures 1a, b, and c, the psSAR increases monotonically at the rate of 10-15% for each millimeter closer placement of the radiating antennas from the anatomically based models.

   It is interesting to note that our observation of 10-15% reduction of psSAR in Figures 1a, b, and c is similar to the nearly 20% reduction calculated from Eq.1 in the Foster and Chou article [1] for each millimeter distal placement of the radiator even though they have used a simplistic semi-infinite block of homogenous tissue material and a dipole radiating antenna rather than mobile phones with handsets. Both of these gross assumptions are certainly not representative of the human head nor the mobile phone. As mentioned in the abstract of this paper, the main reason or such a drastic reduction of SAR is that the electromagnetic fields of an antenna drop off very rapidly in the so-called "near-field" region of the antenna faster even than in the "far-field" where the fields drop off as the square of the distance from the source.

   Nevertheless the Foster and Chou observation in [1] of nearly 20% reduction in psSAR is interesting and qualitatively similar to 10-15% reduction of psSAR reported in [3]–[5] which led us to conclude that "smaller heads of children (and women and leaner adults) are often accompanied by thinner pinnae (and skulls) which leads to a closer placement of the source of radiofrequency radiation to the tissues of the head, e.g., the brain, hence larger absorption of radiofrequency energy radiated by mobile telephones.

2. To address the issue of possible agerelated changes in the dielectric properties of human tissues, in [3] we have also studied the variation of psSAR with the dielectric properties of the various tissues of the head. In [7] and [8] it has been reported that the dielectric properties of the various tissues are substantially higher (by 50% or more) for

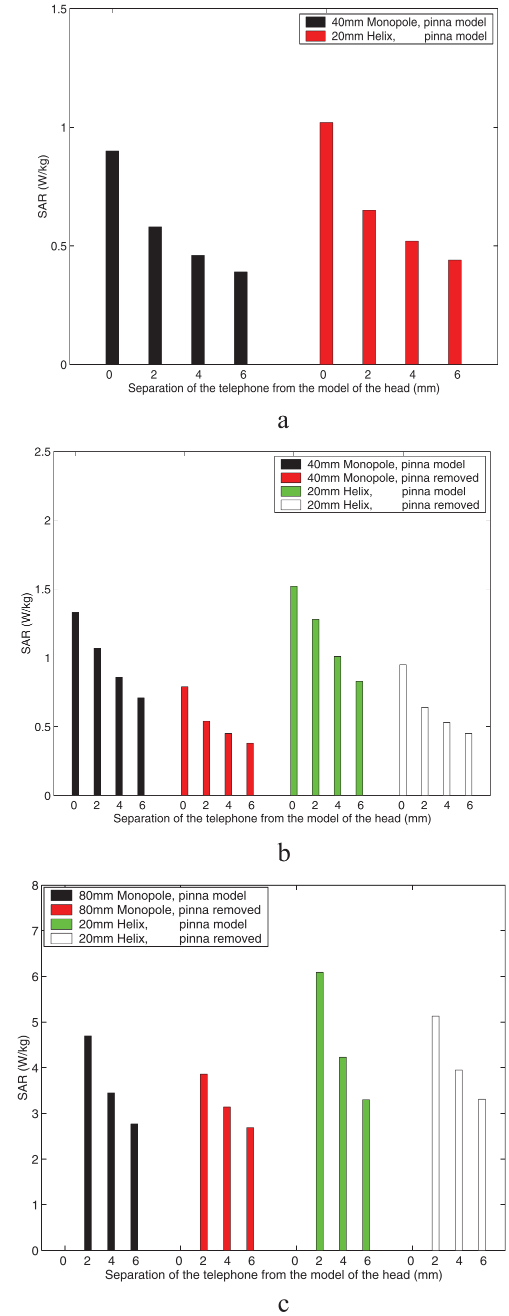

FIGURE 1. Variation of peak 1- or 10-g SAR as a function of separation from the absorptive tissues. Handset of dimensions 22 × 42 × 122 mm. (Excerpted from Gandhi and Kang [5].) a. 10-g SAR, "Visible Man" Model, cheek position, frequency = 1900 MHz, radiated power = 125 mW. b. 10-g SAR, Utah Model, 15°-tilted position, frequency = 1900 MHz, radiated power = 125 mW. c. 1-g SAR, Utah Model, 15°-tilted position, frequency = 835 MHz, radiated power = 600 mW.

younger rats compared to adult rats. The authors Peyman *et al.* [7], [8] hypothesize that the decrease in the dielectric properties with age may be due to changes in water and organic contents of the tissues. Even though the corresponding data are not available for the human tissues, the implications for the assessment of exposure of children may be quite significant.

In [3] we examine the effect of possible higher dielectric properties of the tissues of the head for the children (both the electrical permittivity and conductivity) at 835 and 1900 MHz to show that likely higher dielectric properties of the tissues will further increase the aforementioned higher SAR for children (because of more proximal placement by several millimeters of the RF radiation source to the heads of children).

3. To further understand the role of the head size, we have used in [3] two distinct head sizes, one based on the MRI scans of a Utah male volunteer, the so-called Utah Anatomic Model, and the "Visible Man Model" developed by the National Library of Medicine, Bethesda, MD, from MRI and CAT scans of a husky 105 kg (231 lb.) male cadaver [5]. For each of these two models, we postulated two additional models of the head size by using scaled larger or smaller models that are approximately 10% larger or 10% smaller for each of the dimensions and assumed various thicknesses for the pinna (6, 10, 14, and 20 millimeters) as well as the pinnae with lossless properties similar to the plastic spacer SAM accepted by FCC for SAR compliance testing [9]. Such head models are well within the variations in the head dimensions encountered for adult males and females. Furthermore, to generalize the conclusions, we assume diverse handset and antenna dimensions. Based on these studies we report in [5] that a model with thinner pinna of 6 mm thickness gives peak 1-g SAR that is up to 2.5 times higher at 1900 MHz and up to 1.7 times higher at 835 MHz as compared to the same model with thicker pinna of thickness 20 mm [see Figures 1a, b, and c reproduced from ref. 5 here].

CONCLUSIONS

Since the main reason why children, women, and people with thinner pinnae and skulls absorb more radiofrequency energy is because of the placement of the cell phone radiating source closer to the brain (increasing by 10-15% for every additional millimeter of reduced spacing, determined by using planar, spherical and head-shaped models [2], [5]), it is very hard to understand why the FCC allows the use of a large SAM model of dimensions derived from the 90th percentile head size of the U.S. Military recruits for psSAR compliance testing against safety guidelines. Furthermore, the FCC-accepted SAM model has a tapered smooth plastic spacer instead of actual tissue pinna which can artificially separate the radiofrequency radiation source of the mobile phone by up to 10 millimeters at some locations resulting in an underestimation of both 1- and 10-g psSAR for male heads and for children and women by two or more times [5].

In closing, it is fortuitous that several authors worldwide have now validated our original findings that children, women, and individuals with smaller heads absorb more radiofrequency energy from mobile telephones. Many of these independent findings are itemized in the lengthy Table 2 of the Foster and Chou article [1]. Of particular note are their references to Wiart et al. in France [their ref. 17; year 2005; ref.10 here], Keshvari and Lang in Finland [their ref. 16; year 2005; ref. 11 here], de Salles et al. in Brazil [their ref. 9; year 2006; ref.12 here], Christ et al. in Switzerland [their refs. 23, 32; years 2004 and 2010; refs. 13, 14 here], and Lu and Ueno in Japan [their ref. 25; year 2012; ref. 15 here] which corroborate our findings of higher radiofrequency absorbed energy for children (and women and leaner males) that is because of thinner pinna and skull which results in a closer placement of the radio frequency radiating source to the tissues of the head, e.g., brain.

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