Ushuaia, 9 de Enero del 2024.-

A la Pdte. del Concejo Deliberante de la ciudad Ushuaia

Vice intendente Sra. Gabriela Muñiz Sicardi

A todos los Bloques Legislativos

Al Intendente de la Municipalidad De Ushuaia

Don Walter Vouto

A la Pdte. De la Legislatura de la Provincia de Tierra del Fuego, Antártida e Islas del Atlántico Sur

Sra. Mónica Susana Urquiza

A todos los Bloques Legislativos

S / D

De nuestra consideración:

Las que suscriben Aleth Sandra Lede DNI 14677063 y Alejandra Guerrero DNI 24173436, Referentes de Corte Tierra del fuego (Ciudadanos organizados para regular las telecomunicaciones), elevamos la presente en virtud de las declaraciones que se han hecho públicas del Sr. Concejal Nicolás Pelloli y de la Sra. Belén Montes de Oca, respecto a la revisión de la ordenanza sancionada N 6317/23 de fecha 6 de diciembre de 2023 y promulgada mediante decreto N 2593/ 2023, haciendo hincapié de la importancia de la conectividad en la ciudad mediante radiación electromagnética no Ionizante artificial de quinta generación (5G) y sucesivas.

Queremos manifestar y poner en conocimiento de todos los señores concejales y de toda la población de Tierra del Fuego que la tramitación para la sanción de la misma, se hizo acreditando 22000 pruebas científicas en un compendio de 225 páginas elaborado por un comité de investigadores del **Grupo para el Futuro de la Ciencia y la Tecnología (STOA)** del Parlamento Europeo https://www.europarl.europa.eu/RegData/etudes/STUD/2021/690012/EPRS_STU(2021)690012_ES.pdf . Cómo así también se presentaron estudios realizados y/o reunidos, leyes, etc. , por profesionales, investigadores de CoRTe de la Argentina, cómo también, se ha citado, con acreditación de hechos, la terrible situación acontecida en la ciudad de Güemes- Salta https://www.fm899.com.ar/noticias/salta-1/tras-siete-anios-de-lucha-quitaran-las-antenas-de-telefonia-en-guemes-86953 , donde murieron 80 personas luego de la instalación de tres Antenas de telefonía inalámbrica con un dictamen judicial que ordenó el retiro de las mismas

Todas las pruebas presentadas pueden ser chequeadas por cualquiera que quiera verificar la veracidad de las mismas (son informes científicos por miles y otros)

En virtud de las muchas pruebas indubitables presentadas y de la Ley Nacional de medio ambiente N 25675 la que en su artículo 4 establece que las autoridades están obligadas a tomar medidas de preservación del medio ambiente -medida precautoria (sólo con tener sospechas que algo puede ser perjudicial para el ambiente como para las personas animales etc.), es que se firmó la citada ordenanza. Y Aquí no hay sospecha, HAY

CERTEZA que el uso de los campos electromagnéticos artificiales para brindar Internet inalámbrico, producen radiaciones no Ionizantes que pueden provocar muchas enfermedades.

Además y a pedido del señor presidente del Concejo Deliberante Sr. Juan Carlos Pino, fueron invitados a participar, debatir y presentar información al respecto, a través de las minutas correspondientes y antes de la sanción a:

1) Ministerio de salud

2) Enacom

3) Ministerio de Comunicación

4) Ministerio de Ambiente

5) Secretaria de Gabinete de la Municipalidad de Ushuaia

A través de la Comisión de Calidad de Vida y Turismo, y ninguno se hizo presente, ni respondió por escrito a la convocatoria.

En caso de que resuelvan presentar el proyecto de derogación de la ordenanza, solicitamos participar del debate que corresponde realizar, previo a tomar cualquier resolución. Estando dispuestos a participar en forma presencial o vía zoom investigadores, científicos y profesionales en la materia, para que puedan informarse con verdad sobre este tema, aportando todas las pruebas científicas que respaldan las declaraciones que se han realizado y se realizarán, situación que resulta en extremo peligroso para la salud y la vida de todos los vecinos., por lo cual se debería tomar todos los recaudos pertinentes para tomar las mejores decisiones.

Amerita la seriedad de este grave problema, que aquellos que declaran no haber evidenciado problemas sobre la salud de la población irradiada con energía electromagnética provenientes de la tecnología de quinta generación y sucesivas, acrediten con pruebas científicas indubitables y reproducibles por pares, la total inocuidad de las mismas. "Condición indispensable para considerar válidas las declaraciones"

Además adjuntamos a la presente:

1) Estudio Observacional de campo de Muestras de Sangre expuestas a Radiación de Microondas (moo) proporcionada por la Dra. Marcela Witt
2) Fundamentos y estudios proporcionados por el Dr. en Radioqímica Rodolfo Touzet (asesor de CNEA)
3) Fundamentos de: Dr. en Física de la UBA Andrés Ozols
4) Mail de la Premio Nobel de la Paz 2007 Dra. Devra Davis

Asimismo queremos aclarar que no estamos oponiéndonos al desarrollo de las comunicaciones sino que éstas se realicen con el conocimiento y precaución para la preservación de la Salud y vida de todos los vecinos.

En caso que se instale este servicio de telefonía inalámbrica de quinta generación (5G) mediante el uso de energía electromagnética no ionizante artificial NO habrá lugar ni persona, cualquiera sea su actividad o posición social, que pueda evitar las radiaciones electromagnéticas no ionizantes dado que estarán en todo lugar, sufriendo las consecuencias sobre la salud y la vida aun para los señores y señoras concejales y sus propias familias.

Hacemos una breve síntesis de los problemas de salud que producen las radiaciones mencionada y que por desconocimiento no se tiene en cuenta, ante una excesiva exposición a los campos electromagnéticos de radiofrecuencia: dolores de cabeza, zumbidos en los oídos, insomnio, cansancio, etc., y bajo exposición crónica: miocarditis, neumonías bilaterales, turbo cánceres, enfermedades del sistema inmunológicas, agravamiento de enfermedades sistémicas, etc.

Por último queremos llevar a la reflexión de cada uno de los concejales, que una buena decisión trae buenas consecuencias y una mala decisión trae malas consecuencias. En Caso de derogar la ordenanza traería una grave situación de pérdida de salud para la población y en muchos casos la de la vida misma, siendo ustedes responsables en caso que tomaran esa determinación.

Qué Dios y los vecinos se lo demanden.

Quedamos a vuestra disposición.

Saludamos a Ustedes atentamente.

Alejandra E. Guerrero
DNI 24173436

Adjunto 112 fojas

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tel 2901 534357

Gmail **FDM Imprenta <fdmimprenta@gmail.com>**

Fwd: Ushuaia; Argentina
1 mensaje

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alejandra guerrero <alejandraguerrero1974@gmail.com> 8 de enero de 2024, 3:39 p.m.
CC: "fdmimprenta@gmail.com" <fdmimprenta@gmail.com>

---------- Forwarded message ---------
De: **Devra Davis** <ddavis@ehtrust.org>
Date: dom, 7 ene 2024 a las 3:05
Subject: Re: Ushuaia; Argentina
To: alejandra guerrero <alejandraguerrero1974@gmail.com>
Cc: Kent Chamberlin <kent.chamberlin@unh.edu>, Rodolfo Touzet <rodolfotouzet@gmail.com>, DGI <All@dgicomm.com>

"5G has not been tested for safety before a widespread network is being proposed. Emissions from existing 4G antennas are not routinely monitored, or measured. Environmental Health trust is calling for real time reporting of electromagnetic field emissions from existing antennas with appropriate averaging times and a complete moratorium on 5G until it has been adequately evaluated, consistent with your legislation.

This call is also consistent with recommendations from the international commission on the biological effects of EMF, and the New Hampshire Commission on 5G and other expert groups that recognize the need for policies that reduce exposures and especially protect children, who will bear the consequences throughout their lives.

We applaud the efforts of Ushuaia, Argentina, Commune of Lechmann (Santa Fe), Azul (Buenos Aires) and Capilla del Monte (Córdoba), resolving not to permit 5G antennas without evidence that 5G radiation will not adversely impact the health or physical environment of the community and wildlife.

The expanded new edition of our book Disconnect – – a scientist's solutions for safer technology, provides additional supporting information.

There are videos of me and Prof. Chamberlin, copied here, discussing this on our website that you can easily find

Please let us know how we might be helpful. I am sure that Prof. Chamberlin would also be glad to elaborate on his relevant work.

Lo siento que l'informacion no esta traducido en espanol.

Traducción del mail enviado por la Dra. Devra Davis

"5G has not been tested for safety before a widespread network is being proposed. Emissions from existing 4G antennas are not routinely monitored, or measured. Environmental Health trust is calling for real time reporting of electromagnetic field emissions from existing antennas with appropriate averaging times and a complete moratorium on 5G until it has been adequately evaluated, consistent with your legislation.

This call is also consistent with recommendations from the international commission on the biological effects of EMF, and the New Hampshire Commission on 5G and other expert groups that recognize the need for policies that reduce exposures and especially protect children, who will bear the consequences throughout their lives.

"No se ha probado la seguridad del 5G antes de proponer una red generalizada. Las emisiones de las antenas 4G existentes no se controlan ni miden de forma rutinaria. Environmental Health Trust pide informes en tiempo real de las emisiones de campos electromagnéticos de las antenas existentes con tiempos promedio adecuados y una moratoria completa sobre 5G hasta que haya sido evaluado adecuadamente, de acuerdo con su legislación.

Este llamado también es consistente con las recomendaciones de la comisión internacional sobre los efectos biológicos de los CEM, y la Comisión de New Hampshire sobre 5G y otros grupos de expertos que reconocen la necesidad de políticas que reduzcan la exposición y protejan especialmente a los niños, quienes soportarán las consecuencias a lo largo de su vida. vidas.

Dear Dr. Davis:

We thank you for the time and dedication in sending us this email with your words, since it is of utmost importance, as you are a global reference. Sincerely Alejandra Guerrero

We applaud the efforts of Ushuaia, Argentina, Commune of Lechmann (Santa Fe), Azul (Buenos Aires) and Capilla del Monte (Córdoba), resolving not to permit 5G antennas without evidence that 5G radiation will not adversely impact the health or physical environment of the community and wildlife.

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Please let us know how we might be helpful. I am sure that Prof. Chamberlin would also be glad to elaborate on his relevant work.

Aplaudimos los esfuerzos de Ushuaia, Argentina, Comuna de Lechmann (Santa Fe), Azul (Buenos Aires) y Capilla del Monte (Córdoba), resolviendo no permitir antenas 5G sin evidencia de que la radiación 5G no impactará negativamente la salud o el medio ambiente físico. de la comunidad y la vida silvestre.

La nueva edición ampliada de nuestro libro Disconnect: soluciones científicas para una tecnología más segura proporciona información de apoyo adicional.

Hay videos míos y del Prof. Chamberlin, copiados aquí, discutiendo esto en nuestro sitio web que puede encontrar fácilmente.

Háganos saber cómo podríamos ser útiles. Estoy seguro de que el Prof. Chamberlin también estará encantado de ampliar su importante trabajo.

Señor Walter Vouto 7 de enero de 2024

Intendente de la Ciudad de Ushuaia

De mi mayor consideración

Yo, Andrés Ozols, Dr. en física del Instituto de Ingeniería Biomédica de la Universidad de Buenos Aires, me remito a Usted por el solo hecho de ser un hombre consciente, que se preocupa por la salud del prójimo.

Me apena profundamente la decisión de la derogación de la Ordenanza de prohibición de la instalación de la tecnología 5G en vuestra Ciudad.
La insistencia respecto a los daños a la salud provocados por la radiación electromagnética (**RE**) no es un capricho o exageración de un conjunto de ciudadanos que responden a caprichos.

Los efectos de la RE se remontan a la instalación del tendido eléctrico, como ocurrió en España en 1917.

La intensa radicación generó un cuadro inflamatorio con síntomas similares a una influenza, que erróneamente fueron atribuidos a un virus. Esta intoxicación externa provoca como otras intoxicaciones la formación de exosomas, secreciones de las células, alterando el potencial de membrana celular. Somos seres eléctricos, como son el cerebro y corazón. Esta perturbación no vivida anteriormente provocó la muerte de 20 millones de españoles en la denominada Fiebre Española de 1918.

La instalación de nuevas tecnologías de distribución eléctrica y sistemas de comunicación incrementaron la exposición a mayor diversidad de campos electromagnéticos operados a frecuencias cada vez mayores, a nivel mundial, provocaron la cronificación de enfermedades, de acuerdo a estudios epidemiológicos, asociándolo a virus o patógenos externos, que hasta el día de hoy no fueron aislados. La teoría de la infección nunca fue probada científicamente.

Wuhan en la República China, tenia la mayor cantidad de tecnología 5G y a principios del 2020 denuncian casos de inflación aguda pulmonar, SARS COV-2, atribuido a un virus, que hasta el día de hoy no fue aislado. Las autopsias realizadas en Italia, demostraron cuadros trombóticos en los vasos capilares de los pulmones. Esto impedía el intercambio de oxígeno, la disminución de la saturación de oxígeno, y finalmente la muerte al insistir con protocolo médicos errados.

¿Parece casualidad?

Los antecedentes relativos al efecto a las radiaciones electromagnéticas lo resumo a continuación:

A finales de la década de 1990, la FCC y la ICNIRP adoptaron límites de exposición a la radiación de radiofrecuencia (RFR) para proteger al público y a los trabajadores de los efectos adversos de la RFR. Estos límites se basaron en los resultados de estudios de comportamiento realizados en la década de 1980 que involucraron exposiciones de 40 a 60 minutos en 5 monos y 8 ratas, y luego aplicaron factores de seguridad arbitrarios a una tasa de absorción específica (SAR) de umbral aparente de 4 W/kg. Los límites también se basaron en dos supuestos principales: cualquier efecto biológico se debía a un calentamiento excesivo de los tejidos y no se producirían efectos por debajo del umbral putativo de SAR, así como doce supuestos que no fueron especificados ni por la FCC ni por la ICNIRP. En este artículo, mostramos cómo los últimos 25 años de investigación exhaustiva sobre RFR demuestran que los supuestos subyacentes a los límites de exposición de la FCC y la ICNIRP no son válidos y continúan presentando un daño para la salud pública. Los efectos adversos observados en exposiciones por debajo del umbral supuesto de SAR incluyen inducción no térmica de especies reactivas de oxígeno, daño en el ADN, miocardiopatía, carcinogenicidad, daño en los espermatozoides y efectos neurológicos, incluida la hipersensibilidad electromagnética. Además, múltiples estudios en humanos han encontrado asociaciones estadísticamente significativas entre la exposición a RFR y un mayor riesgo de cáncer de cerebro y tiroides. Sin embargo, en 2020, y a la luz del conjunto de pruebas revisadas en este artículo, la FCC y la ICNIRP reafirmaron los mismos límites que se establecieron en la década de 1990. En consecuencia, estos límites de exposición, que se basan en suposiciones falsas, no protegen adecuadamente a los trabajadores, los niños, las personas hipersensibles y la población en general de las exposiciones a RFR a corto o largo plazo. Por lo tanto, se necesitan con urgencia límites de exposición que protejan la salud de los seres humanos y el medio ambiente. Estos límites deben basarse en pruebas científicas y no en suposiciones erróneas, especialmente teniendo en cuenta la creciente exposición mundial de las personas y el medio ambiente a la RFR, incluidas las nuevas formas de radiación de las telecomunicaciones 5G para las que no existen estudios adecuados sobre los efectos en la salud (Comisión Internacional sobre los Efectos Biológicos de los Campos Electromagnéticos (ICBE-EMF), *Salud Ambiental, 2022, 21:92* https://doi.org/10.1186/s12940-022-00900-9)

Creo que tomarà conciencia que mi preocupación no carece de fundamentos científicos y evidencias clínicas.

Piense que sus propios vecinos le podrán demandar explicaciones en el futuro.

Desde ya estor a vuestra disposición para proporcionarle todo información que considere pertinente.

Lo saluda ate.

Dr. Andrés Ozols
Grupo de Biomateriales para Prótesis e Ingeniería de Tejidos
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<u>INFORME sobre Ordenanzas que limitan el despliegue 5G</u>

Con relación a las Ordenanzas de varias ciudades que han limitados las dosis de los Campos Electromagnéticos o que no permiten el despliegue 5G, se debe informar a la comunidad médica y a la población de cuatro cosas:

1 - Existe una <u>Normativa Internacional</u> reciente (OMS-ICNIRP-OIT-ICRP) que establece medidas de Radioprotección de las personas y el Medio ambiente que deben respetarse y ya muchos países lo han hecho (Suiza, Italia, Polonia, Bélgica, Rusia, N. Zelandia, Australia, Canadá, etc.)

2 - Existen miles de <u>Trabajos científicos</u> de los efectos para la salud producidos por especialistas en la materia que deben ser conocidos por la comunidad médica y por la población.

3 - En el caso de algunas frecuencias <u>5G los riesgos son mucho mayores</u> debido a una mayor dosis de radiación, los efectos sobre el sistema inmune y la falta de estudios específicos suficientes.

4 - La Radioprotección salva vidas mejorando la comunicación y el acceso a internet.

1 - <u>Normativa Internacional de Consenso</u> (participaron todas las organizaciones competentes)

a) En el año 2020 se reúne la Comisión Internacional de Protección de las Radiaciones No Ionizantes (ICNIRP) con representantes de la Asociación Internacional de Protección Radiológica (IRPA), creadora del ICNIRP, La Comisión Internacional de Protección Radiológica (ICRP), La Organización Internacional del Trabajo (OIT), El Comité Científico de Naciones Unidas sobre efectos de las Radiaciones (UNSCEAR) y La Organización Mundial de la Salud (OMS) y se emiten en forma consensuada **"Los Principios del ICNIRP-2020"** (ver Ref. 1) donde se crea un "Marco Único de Radioprotección para todo el Espectro de Radiaciones", Ionizantes y no ionizantes, y se establece como "Documento de Referencia" el ICRP-103, que es el documento que ya usa la Autoridad Regulatoria Argentina (ARN) Esta decisión conjunta es significativa pues determina que **no debe haber diferencias de criterio en las medidas de control, y se debe usar la misma norma y se deben aplicar los mismos criterios de radioprotección que se aplican a las Radiaciones Ionizantes (Justificación, Optimización y Límites de dosis).**

b) La responsable de la Organización Mundial de la Salud (OMS) para el control de los Campos Electromagnéticos, la Dra. Emilie Van Deventer, en un documento emitido el año pasado, junto con representantes de la Organización Internacional del Trabajo (OIT), la Asociación Internacional de Protección Radiológica (IRPA) y otros expertos, reconoce que **"No existe un marco coherente y global para la protección de la salud de la población de las radiaciones no ionizantes"** (ver Ref-2) razón por la cual se recomienda a todos los gobiernos establecer Políticas Nacionales con objetivos claros de Salud y Seguridad, a semejanza de las políticas establecidas para la protección de las radiaciones ionizantes.

Propone además, este proyecto de la OMS, que se establezca **una Comisión Multidisciplinaria que incluya a médicos, biólogos, epidemiólogos, físicos y otros especialistas**, para aplicar los 3 Principios de Radioprotección del ICRP. La carencia de un Sistema de Protección para las RNI supone un enorme riesgo para la población. Esto fue señalado por el CIPRACEM y la delegación argentina en el Congreso IRPA-15 de Radioprotección celebrado en Seúl, Corea, en el 2021, (ver Ref-3)

c) Los 3 Principios de Radioprotección ICRP-103 (ver Ref 4) se aplican a las radiaciones ionizantes desde hace casi 100 años en forma exitosa, habiéndose disminuido las dosis y los riesgos de la población y de los trabajadores de nuestro país en forma continua. El ICRP-103 fue traducido al español por profesionales de la Comisión Nacional de Energía Atómica (CNEA) y de la Autoridad Regulatoria Nuclear (ARN), y se cuenta con personas de experiencia en su aplicación en la CNEA, la ARN, la NA-SA, la Superintendencia de Riesgos de Trabajo (SRT) en la Sociedad Argentina de Radioprotección (SAR), en la Sociedad Argentina de Física Médica (SAFIM) y en sociedades médicas que trabajan con radiaciones ionizantes como la de Radiología y la de Medicina Nuclear. En síntesis, se puede cumplir con la Normativa Internacional e implementar la propuesta de la OMS y otros organismos internacionales de manera adecuada. Por otra parte el **ICRP-103 requiere establecer una "Autoridad Regulatoria" independiente de las empresas comerciales**, de la misma forma que ocurre con la ARN para las radiaciones ionizantes, y las autoridades competentes deben tomar las medidas necesarias para asegurar su independencia y competencia, siguiendo las recomendaciones de la OMS.

En síntesis, establecer un Sistema de Protección para las RNI y cumplir con los Principios del ICNIRP y el ICRP-103, siguiendo las recomendaciones de la OMS, es un objetivo posible y sustentable, y continuar el despliegue 5G sin designar antes una <u>Autoridad de Control</u> es exponerse a múltiples riesgos inaceptables para la población y el medio ambiente.

2 - Los efectos sobre la salud

a) La Comisión Internacional de efectos biológicos de los Campos Electromagnéticos (ICBF-EMF), integrada por prestigiosos expertos del IARC y otros especialistas destacados, afirma que los límites de exposición actuales no son válidos y significan un grave riesgo para la salud pública..! (ver Ref 5)

b) Efectos adversos a la salud que incluyen un mayor riesgo de abortos espontáneos (ver Ref 6)

c) un mayor riesgo de enfermedades y cáncer en la vecindad de las antenas base (ver Ref 7)

d) la inducción de especies reactivas de oxígeno y daño en el ADN (ver Ref 8),

e) efectos neurológicos y enfermedades neurodegenerativas como el Alzheimer (ver Ref 9),

f) daño a nuestro sistema inmunológico, particularmente importante durante la pandemia dado que se ha observado que el número de muertes por Covid en los distritos y estados de USA con 5G fue el doble o el triple de los estados con 3G o 4G (ver Ref-10), lo que determinó medio millón de muertos injustificados.

g) un mayor riesgo de tumores cerebrales (ver Ref 11) y otros daños como pérdida de motilidad en los espermatozoides, tumores de tiroides, colon y recto, diabetes y osteoporosis, etc.

Muchos de estos daños a la salud constituyen "Efectos Determinísticos" que deben ser totalmente evitados de acuerdo a las recomendaciones del ICRP-103

Todo esto demuestra la necesidad de establecer un Sistema de Control de las RNI semejante al utilizado para las radiaciones ionizantes, tal como se propone en los Principios del ICNIRP-2020 para evitar diferencias entre los trabajadores y entre la población

3 – El 5G y sus propios riesgos

a) el trabajo de Kavindra Kesari y J. Behari sobre el efecto de las ondas de 50 GHz (5G) en el cerebro de las ratas, que muestra como la exposición prolongada puede causar la ruptura de la doble cadena del ADN y hacer cambios en las enzimas antioxidantes en el sistema neurológico de las ratas debido a la formación de radicales libres. También confirma que el posible sitio de acción de dicha radiación milimétrica es el hipocampo, la región responsable del control del aprendizaje y la memoria localizado en el centro de nuestro cerebro.(ver Ref 12). Esto descarta la hipótesis de que los efectos son solo en la piel.

b) El Servicio de Investigaciones del Parlamento Europeo (EPRS) ha producido un informe (Ref-13), donde se afirma que la literatura "no contiene estudios adecuados" para excluir el riesgo de que se produzcan tumores y efectos adversos sobre la reproducción y el desarrollo tras la exposición a 5G, o excluir la posibilidad de algunas interacciones sinérgicas entre 5G y otras frecuencias que ya se están utilizando. Esto hace que **la introducción de 5G esté llena de incertidumbre respecto a ambos problemas de salud, lo que justifica el llamado a una moratoria sobre 5G, hasta que se complete toda la investigación necesaria.**

c) Se adjunta como complemento el Informe del CIPRACEM a la comunidad médica sobre 5G.

4 - Finalmente se debe destacar que proteger la salud no implica dificultar la comunicación que debe ser más rápida y potente y libre para toda la comunidad sin excepción, como ocurre con las radiciones ionizantes con las que se prestan servicios pero sin causar muertes como ocurre con las radiaciones elctromagnéticas cuando se descuida la salud de la gente.

Dr. Rodolfo Touzet (CNEA-ARN-SAR-ANM-INC-IRPA)
Presidente del CIPRACEM

CIPRACEM
Comisión Interamericana de Protección contra la Radiación Electromagnética

ADJUNTOS:

1 - ICNIRP Principles 2020 (Health Phys 118 (5):477–482; 2020):
2 - Marco de Protección para las RNI (OMS) 12 /01/ 2022 en inglés y español
3 - Protection against IR vis-a-vis NIR (IRPA-15) A. González y R. Touzet
4 - ICRP - 103 (traducción al español de la APCNEAN)
5 - International Commission on the Biological Effects of EMF (ICBE-EMF)
6 - Exposición a RNI de Embarazadas (Calif)
7 - Riesgo de las antenas base – Balmori et al
8 - H. Lai RFR-oxidative effect-study abstracts
9 - M. Pall - CEM y Enfermedad de Alzheimer
10 - Magda Havas 5G y Sistema Inmunológico
11 - Hardell - Bradford Hill Tumores cerebrales
12 - K. Kesari y J. Behari sobre el efecto de las ondas milimétricas (5G)
13 - Informe sobre 5G del Servicio de Investigaciones del Parlamento Europeo (EPRS)
14 - Informe CIPRACEM a la comunidad médica sobre 5G

Rodolfo Touzet

Dr. en Radioquímica (Universidad de la Sorbona) especialista en Seguridad Radiológica y Nuclear

Asesor de la Comisión Nacional de Energía Atómica (CNEA) en Seguridad Radiológica y Nuclear

Fue Gerente de Licenciamiento de la Autoridad Regulatoria Nuclear (ARN)

Miembro electo del Comité Ejecutivo de la International Radiological Protection Association (IRPA)

Miembro de la Federación Latinoamericana de Protección Radiológica (FRALC) (past-president)

Miembro de la Comisión Independiente para el estudio de los efectos de las radiaciones no ionizantes (CIPERNI)

Presidente de la Comisión Interamericana de Prot. Radiológica de Campos Electromagnéticos y Radiaciones no ionizantes (CIPRACEM)

Miembro de la Comisión Internacional de Seguridad Electromagnética (ICEMS)

Miembro de la Comisión de Certificación de Profesionales Médicos de la Academia Nacional de Medicina

Miembro del Consejo Consultivo del Instituto Nacional del Cáncer (INC)

Miembro del Comité de Salud del Organismo Argentino de Acreditación (OAA)

Coordinador del Programa Nacional de Protección Radiológica del Paciente

Socio fundador de la Sociedad Argentina de Radioprotección (SAR)

Miembro del comité del IRAM (TC-85) en Protección Radiológica

Miembro electo de la Asociación Argentina de Tecnología Nuclear (AATN)

Miembro del Comité Premio Nacional a la Calidad (ex-Juez del Premio Nacional a la Calidad)

Actividades docentes...

Docente del Curso de Post-Grado en Seguridad Radiológica de la Autoridad Regulatoria Nuclear.

Docente de la Tecnicatura en Medicina Nuclear del Instituto Dan Beninson (CNEA)

Docente de la Facultad de Ciencias Exactas de la UBA, de la Universidad de San Martín, de la UCA y otras

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Comunicado 1 del CIPRACEM a la comunidad médica sobre los riesgos de los Campos Electromagnéticos (CEM) para la salud de las personas

La Comisión Interamericana de Protección Radiológica de Campos Electromagnéticos y Radiaciones No Ionizantes (CIPRACEM) desea hacer llegar alguna información sobre los riesgos de la exposición de las personas a los campos electromagnéticos (CEM) a todos los médicos y a todas las organizaciones médicas de nuestro país y ofrecerles todo el apoyo y la documentación que puedan requerir para actuar adecuadamente frente a esta nueva problemática.

La situación actual, generalidades:

Las empresas de telecomunicaciones con el apoyo de los gobiernos, están desplegando la red inalámbrica de quinta generación (5G) para tener hogares "inteligentes", y ciudades "inteligentes". Todo lo que poseamos desde refrigeradores hasta pañales para bebés, tendrán antenas y microchips y se conectarán de manera inalámbrica a Internet. Lo que no se reconoce es que esto tendrá como resultado un impacto muy fuerte en la salud de la gente y el medio ambiente a escala mundial.

Incluso antes de que se propusiera la red 5G, docenas de peticiones y declaraciones firmadas por científicos internacionales, incluyendo la Declaración de Friburgo, firmada por más de 3.000 médicos, pedían el cese de la expansión de la tecnología inalámbrica y una moratoria a las nuevas estaciones base, hasta tanto se investigaran todas sus consecuencias..!

En 2015, 215 científicos de 41 países comunicaron a las Naciones Unidas (ONU) y a la Organización Mundial de la Salud (OMS), que más de 10.000 estudios científicos publicados, con revisión de pares, demostraban fuertes daños a la salud humana por radiación de RF. Los efectos incluían: Alteración del ritmo cardiaco, Cambio en la expresión genética, Cánceres, Diabetes, Deterioro cognitivo, Enfermedades cardiovasculares, Daños en el ADN, Aumento de los radicales libres, Alteraciones en la calidad de los espermatozoides, Abortos espontáneos, Daños neurológicos, Enfermedad de Alzheimer y Estrés oxidativo celular y en los niños incluye Autismo, trastorno por déficit de atención con hiperactividad (TDAH) y asma.

Los daños van mucho más allá de los seres humanos, ya que hay abundante evidencia de daños a plantas y vida silvestre y a animales de laboratorio, que incluye Aves, Mamíferos, Abejas, Insectos, Ranas, Ratas, Plantas, Árboles y Bosques.

Los niveles proyectados de radiación de radiofrecuencias, serán decenas o cientos de veces mayores que los que existen actualmente..!!, sin posibilidad de escapar en ninguna parte del planeta, por lo que los daños actuales a la salud crecerán en forma exponencial. Se puede agregar que en 5G se planifica ampliar las frecuencias de operación hasta 100 GHz, desconociéndose si esas frecuencias provocan daños a la salud humana por no haberse realizado aún investigaciones serias e independientes al respecto.,!!

Algunos problemas más relevantes:

1 - Se observó el crecimiento por factor 4 o 5 de la frecuencia de los tumores cerebrales, de mayor malignidad, en aquellos países que cuentan con estadísticas epidemiológicas, como es el caso de Francia, Suecia, Australia, Inglaterra y Brasil. Se estima que solo por tumores cerebrales la exposición a los CEM han producido ya más de 4 millones de fallecimientos. Para determinar "la Causalidad" dos expertos del IARC (los Dres. C. Portier y L. Hardell) aplicaron los 9 criterios de Sir Bradford Hill obteniendo una muy fuerte evidencia de la causalidad atribuida a la exposición a los CEM. En Argentina lamentablemente no contamos aún con estadísticas nacionales y ya ha sido comunicada esta necesidad al Instituto Nacional

del Cáncer. Se cuenta solo con algunos datos parciales procedentes de un servicio de cirugía que ha reportado que se quintuplicó, en solo 10 años, la frecuencia de los Neurinomas del acústico de grado 4, denominados gigantes,

2 – Se ha observado también un gran aumento de los tumores de tiroides, y de colon y recto en personas muy jóvenes en USA atribuido al uso de celulares en los bolsillos.

3 – Además del efecto carcinogénico se observa la Co-carcinogénesis en personas y animales, aumentando el número, volumen y agresividad de los tumores pre-existentes lo cual determina la necesidad inmediata de proteger a todos los pacientes con cáncer.

4 – Se observa una sensible debilitación del sistema inmunológico ocasionado por la inhibición de la Calcineurina sumada al aumento de la permeabilidad de la membrana hemato-encefálica, así como el cambio en la expresión de algunos oncogenes y cambios epigenéticos que producen una disminución de las defensas naturales del organismo, lo cual en el caso de una pandemia resulta doblemente grave.

5 - Hay otros efectos sobre la salud, que no se pueden describir aquí en detalle, que afectan el Sistema reproductor masculino y femenino, en personas y animales, incluyendo el aumento de los abortos espontáneos, también sobre el sistema endócrino y las hormonas, en particular sobre la melatonina, también sobre el Sistema de circulación sanguínea y sobre el Sistema nervioso con enfermedades neurológicas y psiquiátricas, el autismo y el aumento de la enfermedad de Alzheimer en personas muy jóvenes.

A diferencia de las radiaciones ionizantes cuyos efectos se observan solamente a valores de exposición muy superiores a los límites establecidos para el público y los trabajadores, en el caso de los CEM estos efectos ocurren frecuentemente a valores de exposición 100 veces por debajo de los límites establecidos.., razón por la cual se puede afirmar que el Poder Cancerígeno de los CEM es, como mínimo, 1000 veces superior al de las radiaciones ionizantes.

Normas para proteger a la población y el medio ambiente de los CEM

Afortunadamente disponemos de una normativa internacional y de una reciente iniciativa de la OMS que nos permiten disminuir fuertemente los riesgos, por factor 100 o 1000, aplicando los mismos principios que se utilizan para la protección de las Radiaciones Ionizantes..!! y en esta tarea hay varias sociedades médicas, que forman parte del Programa de Protección Radiológica del paciente, que ya tienen experiencia en la aplicación de los 3 Principios de Radioprotección del ICRP para disminuir las dosis de radiación recibidas por los pacientes.

a) En el año 2020 la Comisión Internacional de Protección de Radiaciones No Ionizantes (ICNIRP), emite Los Principios del ICNIRP que fueron aprobados por la Organización Internacional del Trabajo (OIT) y la Organización Mundial de la Salud (OMS), y establecen que:

Se deben cumplir los 3 Principios de Radioprotección, la Justificación, la Optimización y los Límites de Dosis, de forma exactamente igual como se hace con las radiaciones Ionizantes y de hecho el Documento de Referencia propuesto es el ICRP-103

b) En enero de este año la OMS inicia un Proyecto (Marco de Protección de RNI) que Insta a los Gobiernos a establecer un Sistema de Protección (multisectorial) que incluya médicos y físicos para cumplir los 3 Principios de Radioprotección.

c) Dado que no existe experiencia previa, ni especialistas, en la aplicación de los 3 Principios de Radioprotección del ICRP a los Campos Electromagnéticos (CEM) esta

Comisión Interamericana de Protección Radiológica de los Campos Electromagnéticos y las Radiaciones No Ionizantes (CIPRACEM) desarrolló una Guía Informativa justamente para la aplicación de los Principios de Radioprotección a las Radiaciones no Ionizantes y los CEM.., que puede brindar alguna ayuda para encontrar soluciones prácticas para proteger a la población de los dispositivos tecnológicos usados en las comunicaciones inalámbricas. (recomendamos a las autoridades leerla atentamente)
d) La medida fundamental que propone la OMS es el establecimiento de un "Sistema de Control Regulatorio" Independiente de las Empresas y de carácter Multisectorial. Entendemos que esta recomendación debe ser cumplida a la brevedad para proteger la población en forma inmediata.

Por tratarse de una problemática que afecta muy fuertemente a la salud, la comunidad médica debe estar informada en forma muy especial para poder proteger a la población y en particular a los individuos más sensibles como pueden ser los niños, las mujeres embarazadas, los enfermos de cáncer, las personas con hipersensibilidad electromagnética y los pacientes con cuadros que puedan ser agravados por la exposición a los CEM.

Dado los grandes intereses puestos en juego sería necesario que la sociedad civil y en particular la comunidad médica a través de sus organizaciones soliciten e insten a las autoridades competentes el cumplimiento de una normativa que asegure la protección adecuada de la población.

Aunque es un tema muy complejo y extenso no queremos extendernos demasiado en este comunicado pero quedamos a vuestra total disposición para aportar toda la documentación que les resulte necesaria.., por vía mail, a cualquier médico o sociedad médica que nos lo requiera..!!

Quedan a vuestra total disposición los miembros argentinos del CIPRACEM, el Dr. Daniel Orfila (Director Médico del IC-EM -Implantes Cocleares Equipo Multicéntrico), el Ing. Walter Fano (Profesor responsable de Antenas y Propagación Electromagnética de la Facultad de Ingeniería de la UBA), el Dr. Eduardo Legaspe (Bioquímico, especialista en Radioprotección de poblaciones vulnerables por efectos de las radiaciones no ionizantes), la Dra. Mariana Lofeudo (abogada especialista en salud y ambiente. Docente de grado y posgrado en la Facultad de Derecho de la UBA, a cargo del dictado del tema Contaminación Electromagnética), el Ing. Guillermo Defays (Master of Sciences en Sistemas de Comunicaciones de la Universidad de Essex, Inglaterra), el Bioing. Mag. Esteban Rossi (Profesor titular, Investigador de la Fac. de Ingeniería de la UNER), el Ing. Abel González (ARN-SAR-UNSCEAR-IAEA), el Dr. Rodolfo Touzet (CNEA-SAR-FRALC-IRPA), Ing. Jorge Ferrari (†-in memorial)

Muy atentamente, quedamos a vuestra total disposición,

CIPRACEM

Comisión Interamericana de Protección Radiológica de los Campos Electromagnéticos y las Radiaciones no Ionizantes

Se adjuntan al mail, a modo de ejemplo, solo 3 documentos:
1) La Guía Informativa CIPRACEM que incluye una Bibliografía de 1500 trabajos,
2) Un muy reciente trabajo de Martin Pall sobre Enfermedad de Alzheimer y
3) Un artículo de Nature sobre los efectos en la mujer embarazada.

(Hay mucha más documentación disponible a los que nos lo requieran..)

Comunicado N° 2 del CIPRACEM a la comunidad médica sobre Diagnóstico y tratamiento de personas con Hipersensibilidad Electromagnética (EHS)

1) Casuística: La OMS considera que la tasa de personas electrohipersensibles en países industrializados se acerca al 5% de la población y está aumentando en forma exponencial. En Suecia, que posee muy buenas estadísticas, la cantidad de personas que manifiestan tener hipersensibilidad electromagnética eran un 1.5 % en 1996, pasó al 3% en el 2000 y al 9% en el 2004. En Austria pasó del 1.5% en 1995 al 13% en el 2002 o sea que en solo 7 años se multiplicó por 10.

Se adjunta un informe que en base a los datos de diferentes países, estiman que actualmente un 50% de la población mundial puede ser EHS con diferentes grados de sensibilidad, desde los que no pueden soportar un CEM y deben aislarse hasta los que poseen sólo síntomas leves.

El Observatorio de Contaminación Electromagnética de Estados Unidos afirma que actualmente el porcentaje de la población estadounidense que padece de electro sensibilidad es de un 10%.

O sea que la información estadística es muy variada de un país a otro y del nuestro no tenemos aún una estadística a nivel nacional.

Un caso particular, se informa que dos investigadores suecos, Österdalh y Högstedt, afirman que las personas que poseen reparaciones bucales con amalgamas, tienen mayor riesgo de ser EHS porque esas amalgamas funcionan como antenas.

2) Discapacidad: En varios países los tribunales han reconocido los reclamos por discapacidad a personas con sensibilidad electromagnética, caso de Australia, Francia, España y Estados Unidos. En Suecia, gracias al trabajo del científico Olle Johansson y su equipo del Instituto Karolinska, la Electrosensibilidad ha sido reconocida oficialmente como una discapacidad, e incluso se dan ayudas económicas a los afectados para que puedan proteger sus viviendas de los campos electromagnéticos.

Los datos indicarían que la situación es cada vez más seria y el aumento de los casos graves es cada vez más frecuente por lo que se considera la conveniencia de que una junta médica especializada establezca los criterios que deberán aplicarse en estos casos. Los padecimientos que sufren algunas personas son realmente graves y ha habido casos de suicidios. Es un tema social que los médicos deben considerar y las autoridades deben prevenir.

3) Diagnóstico y tratamiento: Se dispone de las Directrices del Colegio de Médicos de Austria para el diagnóstico y tratamiento de enfermedades y problemas de salud relacionados con los campos electromagnéticos (síndrome de los CEM) que han sido traducidas al español, y que indica cómo proceder en estos caso, las pruebas diagnósticas a realizar y las medidas a tomar.

El principal método de tratamiento debe consistir obviamente en la prevención o reducción de la exposición a los CEM, teniendo cuidado de reducir o eliminar, de ser posible, todas las fuentes de CEM existentes. Muchos casos han demostrado que estas medidas pueden resultar eficaces. Por otra parte se deben tomar las medidas sintomáticas correspondientes.

Hay otros 2 trabajos de diagnóstico más recientes y muy importantes que se adjuntan (de Belpomme y de Heuser), y que utilizan técnicas diagnósticas muy elaboradas de tomografía cerebral ultrasónica, ecografía Doppler transcraneal y

escáneres cerebrales de resonancia magnética, así como el uso de "biomarcadores" para la detección de diversas alteraciones y trastornos patológicos tales como el estrés oxidativo celular, la apertura de la membrana hematoencefálica, la respuesta autoinmune y la disminución de la concentración de melatonina, todos ellos son efectos determinísticos muy adversos originados por la exposición intensa y prolongada a los CEM.

4) Trastornos relacionados: Es muy importante destacar que el trabajo de Belpomme demuestra claramente que en la mayoría de los casos de hipersensibilidad electromagnética se han observado y medido un conjunto de "trastornos funcionales fisiopatológicos" que evidencian que el cuadro clínico EHS no es originado en un simple descenso del umbral de sensibilidad del paciente sino más bien en la aparición de un conjunto de alteraciones patológicas originadas por los CEM que constituyen una única, bien-definida e identificable nueva enfermedad neurológica que no puede ser confundida ni tratada como un trastorno psicosomático ni por efecto nocebo.

5) Conclusión: con el fin de aumentar la conciencia científica de esta entidad patológica en la comunidad médica y el público en general, se deberá fomentar la investigación y capacitar a los médicos para diagnosticar, tratar y prevenir de manera eficiente los casos de hipersensibilidad electromagnética (EHS), que de hecho constituye una única, bien-definida e identificable nueva enfermedad neurológica.

Por otra parte es importante destacar que se deberán tomar las medidas necesarias para prevenir la ocurrencia de estos casos estableciendo límites adecuados de dosis de irradiación que prevengan la ocurrencia de efectos determinísticos tal como establecen los criterios del ICRP-103 que es el documento de referencia adoptado por la comunidad internacional al aprobar en forma consensuada los principios del ICNIRP-2020.

Para las radiaciones no ionizantes se deben aplicar exactamente los mismos principios que se aplican a las radiaciones ionizantes por lo que se debe impedir la ocurrencia de todo tipo de efectos determinísticos en las personas y los animales.

La aplicación de los Principios de Radioprotección tal como establece el ICNIRP-2020 y recomienda el nuevo proyecto de la OMS, es una herramienta efectiva para disminuir las dosis de radiación de la población a niveles que prevengan o disminuyan la frecuencia de casos de EHS.

6) Asociaciones de personas EHS: En muchos países las personas con Hipersensibilidad Electromagnética se agrupan en sociedades u ONG para defender sus derechos y reclamar para que se establezcan lugares protegidos de los CEM, se dicten normas que impidan el uso indebido y se capacite a la población y se realicen campañas informativas sobre los riesgos de los CEM y cómo prevenirlos. Una medida importante es tener disponibles materiales de protección de las personas y las viviendas, tales como pinturas, ropa, cortinas, tules, láminas transparentes para vidrios y todo material que ayude a construir cajas de faraday para protegerse de los CEM.

Para mayor información, se adjuntan las los sitios web de las asociaciones de EHS en diferentes países con información específica de mucha utilidad. (En América latina no conocemos asociaciones de personas EHS)

Australia	https://anres.org/information-for-individuals/
Belgium	https://www.bbemg.uliege.be/electrosensitivity-ehs/
Canada	http://www.weepinitiative.org/index.html
Denmark	https://EHSF.dk
Finland	https://sahkoherkkyyssaatio.fi/in-english/
France	https://www.electrosensible.org/b2/
Germany	https://www.buergerwelle.de/
Ireland	https://es-ireland.com/about-2/
Italy	https://www.elettrosensibili.it/
Netherlands	http://www.stichtingehs.nl/
Norway	https://www.felo.no/nyheter/
Portugal	http://antenasaquinao.blogspot.com/
Spain	https://www.avaate.org/
Sweden	https://eloverkanslig.org/
Switzerland	https://www.buergerwelle-schweiz.org/
United Kingdom	https://www.es-uk.info/
USA	https://wearetheevidence.org/

Nuevamente quedan a vuestra disposición por toda información complementaria los miembros argentinos del CIPRACEM, el Dr. Daniel Orfila (Director Médico del IC-EM -Implantes Cocleares Equipo Multicéntrico), el Ing. Walter Fano (Profesor responsable de Antenas y Propagación Electromagnética de la Facultad de Ingeniería de la UBA), el Dr. Eduardo Legaspe (Bioquímico, especialista en Radioprotección de poblaciones vulnerables por efectos de las radiaciones no ionizantes), la Dra. Mariana Lofeudo (abogada especialista en salud y ambiente. Docente de grado y posgrado en la Facultad de Derecho de la UBA, a cargo del dictado del tema Contaminación Electromagnética), el Ing. Guillermo Defays (Master of Sciences en Sistemas de Comunicaciones de la Universidad de Essex, Inglaterra), el Bioing. Mag. Esteban Rossi (Profesor titular, Investigador de la Fac. de Ingeniería de la UNER), el Ing. Abel González (ARN-SAR-UNSCEAR- IAEA), el Dr. Rodolfo Touzet (CNEA-SAR-FRALC-IRPA),

Se adjuntan 4 documentos para el diagnóstico y tratamiento de los EHS.

Muy atentamente, quedan a vuestra total disposición

CIPRACEM

Comisión Interamericana de Protección Radiológica de los Campos Electromagnéticos y las Radiaciones no Ionizantes

Adjuntos al comunicado CIPRACEM Nº 2:

- **Directrices para EHS del Colegio de Médicos de Austria**
- **Diagnóstico tratamiento de (EHS) - D. Belpomme**
- **Uso de MRI en pacientes con EHS - Gunnar Heuser**
- **Tendencia mundial de crecimiento de los EHS - O. Hallberg**

Comunicado 3 del CIPRACEM a la comunidad médica sobre los riesgos de la proximidad de las Antenas base para la salud de las personas

La Comisión Interamericana de Protección Radiológica de Campos Electromagnéticos y Radiaciones No Ionizantes (CIPRACEM) desea hacer llegar a la comunidad médica información sobre los riesgos de las personas que viven en la proximidad de las antenas base de telefonía celular y ofrecer el apoyo y documentación necesaria para actuar frente a esta problemática.

1 – Revisión de la literatura científica sobre los efectos sobre la salud de las antenas de estaciones base de celular:

a) El grupo de A. Balmori hizo una revisión completa de estudios realizados en 39 países diferentes, en condiciones urbanas reales, y en más del 70% se encontró que provocaban enfermedades, cambios en los parámetros biológicos como rotura del ADN, aumento de la frecuencia de cáncer que en algunos casos llega a ser 5 veces mayor que los valores en poblaciones alejadas de las antenas. Esta revisión de A. Balmori es la más reciente y completa y se recomienda leerla atentamente. Es importante señalar que además hay muchos estudios realizados en animales y árboles cerca de las antenas "que obviamente no pueden ser conscientes de su proximidad" por lo que nunca se les pueden atribuir efectos psicosomáticos.

Estos efectos son esperables dadas las experiencias realizadas con seres humanos (CERENAT, Interphone, INTEROCC) y las experiencias realizadas con animales de laboratorio en USA (NTP) y en Italia (Instituto Ramazzini) que demostraron que aumenta la frecuencia de cáncer por la exposición a teléfonos celulares y antenas hasta valores de 3% con relación a los animales no expuestos. Se adjunta este trabajo completo como Ref. 3.1a.

b) Hay otro estudio, realizado en los Estados Unidos, que analiza el impacto de las antenas base y de wifi sobre las personas expuestas. Destaca en el caso de Israel, que la frecuencia de cáncer en mujeres es 10 veces más alta en las zonas cercanas a las antenas que en el resto de la ciudad, y además se observó un aumento significativo de la frecuencia en un período de solo un año.!!, lo cual indicaría, considerando los períodos de latencia, "un fenómeno de aceleración de casos latentes o co-carcinogénesis", que ya fue observado en el estudio INTEROCC, Francia.

Las personas que utilizan dispositivos inalámbricos deben saber que cada emisión de voz o datos contribuye al deterioro, la enfermedad y el sufrimiento de personas y animales dentro del alcance de la antena. Se afirma que no existe una autoridad federal, estatal o local en los EE. UU que esté monitoreando y calculando la radiación emitida por millones de antenas y sus riesgos. Los expertos del Comité Nacional Ruso de Protección contra la Radiación No Ionizante (RNCNIRP) afirman que la mayoría de las señales de radiofrecuencia que se utilizan en los sistemas de comunicación no han sido probados en condiciones reales..!! dado que no se consideran los efectos de "los cócteles de radiaciones electromagnéticas", que incluyen un conjunto de parámetros físicos variables, como polarización (vertical u horizontal), densidades de potencia, campos pulsados con variaciones de ancho, forma y amplitud de pulso, etc., etc., para cientos de canales de frecuencia diferentes que pueden estar presentes en un sitio determinado...!!

Dice este informe que el Dr. Dietrich Klinghardt M.D., especialista en la Enfermedad de Lyme, LD, está "convencido de que el aumento de la virulencia de esta enfermedad (LD), que se está viendo en USA con cientos de miles de casos, está relacionado al aumento exponencial de los campos electromagnéticos (CEM)" y por lo tanto, el tratamiento de la enfermedad de Lyme no será efectivo si no ocurre la disminución de los CEM. Estos son solo algunos puntos extraídos de este informe que es la Ref. 3.1b. y se recomienda leer en detalle.

c) Hay una tercera recopilación de efectos sobre la salud sobre más de 100 antenas en todo el mundo, donde se señalan diferentes daños, tales como: aumento de casos de cáncer y leucemia de acuerdo a la distancia a la antena, un riesgo elevado de neoplasia cerebral en niños con una exposición a CEM-RF superior a la mediana, mayor prevalencia de síntomas neuroconductuales adversos y/o cáncer en poblaciones que viven a distancias menores a 500 metros de las estaciones base, mayor riesgo de desarrollar problemas neuropsiquiátricos, efectos nocivos en la función del sistema nervioso central a través del estrés oxidativo celular, infertilidad irreversible, aumento de la tasa de mortalidad de ratas con mortalidad en los grupos expuestos de casi el doble del valor observado en el grupo de exposición simulada, etc., etc. Ver Ref. 3.1c.

Del análisis de estas 3 recopilaciones se desprende que las Antenas base producen en sus cercanías efectos determinísticos y un aumento de la frecuencia de efectos estocásticos que son incompatibles con las recomendaciones del ICRP-103 que corresponde aplicar. Si cualquiera de estos efectos fuera observado en la proximidad de una instalación radiactiva o una Central Nuclear la misma sería puesta "fuera de servicio" por la Autoridad Regulatoria correspondiente (ARN).

2 – Experiencia realizada en Bello Horizonte, Brasil:

En este estudio se realiza una comparación entre la frecuencia y la mortalidad por cáncer en relación a la cercanía de las estaciones base. Este estudio fue complementado por una evaluación detallada, casa por casa, de las dosis que efectivamente recibían los residentes de dichas casas.

Como resultado del estudio que se realizó entre 1996 y 2016, se encontró que las tasas de mortalidad y el riesgo relativo fueron mayores para los residentes dentro de un radio de 500 m desde las antenas de estaciones base, en comparación con la tasa de mortalidad promedio de toda la ciudad, y se observó además una disminución del gradiente de dosis-respuesta para los residentes que vivían mucho más lejos. Ver el trabajo completo en Ref. 3.2

3 – Evidencia clara de "efectos determinísticos": (efectos en linfocitos de sangre periférica humana de personas que residen en las cercanías de estaciones base de telefonía móvil):

Para complementar los 4 trabajos de campo realizados en cercanías de antenas de estaciones base de telefonía celular, se adjunta el resumen de un trabajo donde se observa daño en el ADN de linfocitos de sangre periférica (LSP) de las personas que residen en las cercanías de estaciones base de telefonía móvil y son comparados con controles sanos. Los grupos de estudio se emparejaron según varios datos demográficos, como edad, género, patrón dietético, hábito de fumar, consumo de alcohol, duración del uso del teléfono móvil y uso promedio diario del teléfono móvil. La densidad de potencia de RF de los individuos expuestos fue significativamente mayor ($p < 0,0001$) en comparación con el grupo de control que residían a 300 metros. Se cultivaron los LSP y se evaluó el daño del ADN mediante ensayo de micronúcleos. Los análisis de los datos del grupo expuesto ($n = 40$), que residían dentro de un perímetro de 80 m de las estaciones base móviles, mostraron una frecuencia significativamente mayor ($p < 0,0001$) de micronúcleos en comparación con el grupo de control, que residía a 300 m de la estación/es base móvil/es.

Esta experiencia muestra que los residentes cercanos a las antenas base pueden sufrir efectos determinísticos, que como se ha dicho previamente es incompatible con las recomendaciones del ICRP-103, que es el "Documento de Referencia" establecido en el estándar ICNIRP-2020 que fuera consensuado internacionalmente, Ver Ref. 3.3

4 – Constancia de la Causalidad de los efectos estocásticos:

Es importante destacar que cuando "se afirma que todos los efectos observados son causados por la exposición a los Campos Electromagnéticos" se fundamenta esta afirmación en la aplicación explícita de los 9 Criterios formulados por Sir Bradford Hill (1965) que son imprescindibles para determinar la "Causalidad". En los Principios del ICNIRP-2020 se establece que antes de tomar determinaciones y/o establecer requisitos regulatorios es necesario que los "efectos estén científicamente comprobados" y para lograr que "los efectos estén científicamente comprobados" es necesaria la aplicación de los 9 Criterios formulados por Sir Bradford Hill (1965) que son imprescindibles para determinar la "Causalidad"(esto dice textualmente el ICNIRP-2020)

En síntesis, las decisiones no pueden ser tomadas sobre la base de solo algunos trabajos, sino "sobre el conjunto de toda la información existente" utilizando los 9 Criterios formulados por Sir Bradford Hill.

Esta tarea ha sido realizada por dos prestigiosos expertos del IARC: los doctores Lennart Hardell y Christopher J. Portier, que han considerado la totalidad de la información científica que incluye trabajos in vitro, estudios de casos, estudios sobre animales, estudios estadísticos, etc. y ambos han concluido que las pruebas de Causalidad de los campos electromagnéticos en los casos de tumores cerebrales como los gliomas y los Neurinomas del acústico son muy fuertes, razón por la cual la causalidad está debidamente demostrada.

Para comprobar esta afirmación se adjunta el trabajo de Lennart Hardell "Uso de los puntos de vista de Bradford Hill para evaluar la fuerza de la evidencia del riesgo de tumores cerebrales asociados con el uso de teléfonos móviles e inalámbricos. Ref. 3.4

5 – La penetración de las ondas milimétricas producidas por el 5G:

La penetración de los campos electromagnéticos en inversamente proporcional a la frecuencia, o sea a mayor frecuencia menor será el alcance y la penetración dentro de la piel y los tejidos biológicos. En base a esta circunstancia algunas publicaciones han aprovechado para afirmar que para las frecuencias de los GHz (denominadas milimétricas por su longitud de onda), la penetración es menor que las radiofrecuencias de MHz y por lo tanto: <u>"No van a producir mayores daños en la salud de las personas expuestas.." Por lo que podemos quedarnos tranquilos..!!</u>

Si bien es correcto que hay un menor alcance, "Se ha comprobado experimentalmente que la radiación de microondas de 50 GHz (milimétrica) penetra profundamente en el cerebro de ratas Wistar y produce serios daños en el hipocampus que está precisamente en el centro del cerebro..!!" (lo que indicaría que o tienen acceso a través del canal auditivo o los lagrimales o a través de los poros de la piel o mediante la exposición de la sangre periférica que circula por los capilares superficiales que luego accede a los vasos internos, etc.)

En la experiencia de Kumar Kesari y J. Behari los animales fueron expuestos, durante solo 2 h al día, durante 45 días de forma continua a una densidad de potencia de 0,86 $\mu W/cm^2$ con una tasa de absorción específica nominal de 8,0 × 10^{-4} W/kg.. O sea, a valores de exposición 100 veces por debajo de los límites establecidos..!! y no obstante los efectos fueron muy graves.

La exposición crónica a estas radiaciones provocó la ruptura de la doble cadena del ADN y una disminución de las actividades de las enzimas antioxidantes y de un protector tumoral (PKC). Se concluye que estas radiaciones milimétricas pueden tener un efecto muy significativo en todo el cerebro, por lo que se debe evitar exponer a las personas a las mismas. El hipocampo es probablemente un sitio preferencial para la biointeracción de los CEM y esto está en línea con otros informes que refieren que una exposición crónica a la radiación electromagnética afecta las funciones de aprendizaje y memoria al afectar el hipocampo. Ver Ref. 3.5

Conclusión: De la revisión de muchos trabajos y los estudios complementarios parece adecuado concluir que las Antenas base producen en sus cercanías efectos determinísticos y un aumento de la frecuencia de efectos estocásticos incompatibles con las recomendaciones del ICRP-103 que corresponde aplicar. Afortunadamente disponemos de una normativa internacional (ICNIRP-2020) y de una reciente iniciativa de la OMS que propone el establecimiento de un "Sistema de Control Regulatorio" de carácter Multisectorial que nos permiten disminuir fuertemente los riesgos, aplicando los mismos principios que se utilizan para la protección de las Radiaciones Ionizantes..!! y en esta tarea hay varias sociedades médicas, que forman parte del Programa de Protección Radiológica del paciente, que ya tienen experiencia en la aplicación de los 3 Principios de Radioprotección del ICRP para disminuir las dosis de radiación recibidas por los pacientes.

Hay varios estudios que muestran que el poder cancerígeno de los Campos Electromagnéticos es muy superior al poder cancerígeno de las radiaciones ionizantes, razón por la cual las medidas de prevención deben ser aun más estrictas.

Quedan a vuestra disposición los miembros argentinos del CIPRACEM, el Dr. Daniel Orfila (Director Médico del IC-EM -Implantes Cocleares Equipo Multicéntrico), el Ing. Walter Fano (Profesor responsable de Antenas y Propagación Electromagnética de la Facultad de Ingeniería de la UBA), el Dr. Eduardo Legaspe (Bioquímico, especialista en Radioprotección de poblaciones vulnerables por efectos de las radiaciones no ionizantes), la Dra. Mariana Lofeudo (abogada especialista en salud y ambiente. Docente de grado y posgrado en la Facultad de Derecho de la UBA, a cargo del dictado del tema Contaminación Electromagnética), el Ing. Guillermo Defays (Master of Sciences en Sistemas de Comunicaciones de la Universidad de Essex, Inglaterra), el Bioing. Mag. Esteban Rossi (Profesor titular, Investigador de la Fac. de Ingeniería de la UNER), el Ing. Abel González (ARN-SAR-UNSCEAR-IAEA), el Dr. Rodolfo Touzet (CNEA-SAR-FRALC-IRPA), Ing. Jorge Ferrari (†-in memorial)

Muy atentamente, quedamos a vuestra disposición,

CIPRACEM

Comisión Interamericana de Protección Radiológica de los Campos Electromagnéticos y las Radiaciones no Ionizantes

Adjuntos:

3.1a - Efectos de las Antenas (2022) - Revisión de Balmori
3.1b - The Kill Zones, Evaluación de los efectos de las antenas. USA
3.1c - Cell-Tower-Studies-updated (100 papers)
3.2 - Estudio de Bello Horizonte, Brasil - A. Dode
3.3 - Aberraciones cromosómicas en leucocitos de sangre periférica –Resumen
3.4 - Uso de los 9 criterios de Bradford Hill para demostrar la Causalidad – L. Hardell
3.5 - 50 GHz exposure Rats brain (K. Kesari y J. Behari)

Comunicado 4 del CIPRACEM a la comunidad médica sobre el impacto en la salud de las ondas milimétricas utilizadas en los sistemas 5G

Los sistemas de comunicación celular de quinta generación (5G), utilizan en algunos tramos, radiofrecuencias hasta ahora poco utilizadas para un despliegue masivo; las llamadas "ondas milimétricas". Debido al menor alcance y la menor penetración de las ondas milimétricas, se debe aumentar la cantidad de antenas 5G, para ponerlas más cerca de la gente para mantener la conectividad, por lo que la exposición del público crece muchísimo y, por ejemplo, el organismo de control de los Estados Unidos, la FCC, decidió aumentar 4 veces los límites permitidos para el público, de 1000 a 4000 $\mu W/cm^2$, y se colocaron antenas hasta en las luminarias de las calles. Todo esto produjo naturalmente un gran aumento de las dosis colectivas de la población expuesta y de los riesgos ligados a las mayores dosis.

En un primer momento, se especuló con que las ondas milimétricas, debido a su baja penetración, solo podían tener efectos superficiales en la piel humana. Pero esto no parece ser así. Se adjunta el trabajo de Kavindra Kesari y J. Behari del efecto de las ondas milimétricas en el cerebro de las ratas, que muestra como la exposición prolongada puede causar la ruptura de la doble cadena del ADN y hacer cambios en las enzimas antioxidantes en el sistema neurológico de las ratas debido a la formación de radicales libres. También confirma que el posible sitio de acción de dicha radiación milimétrica es el hipocampo, la región responsable del control del aprendizaje y la memoria localizado en el centro de nuestro cerebro. Este trabajo es muy importante para demostrar que no sería correcto afirmar que las ondas milimétricas afectan solo la piel.

Como conclusión, las nuevas frecuencias que 5G suma a la radiación existente, no hace más que potenciar y aumentar los efectos de las mismas sobre la salud humana, en particular, los efectos biológicos que disminuyen las defensas del organismo, como por ejemplo:

(1) La RF, a valores de exposición muy bajos, produce la apertura de los canales iónicos de la membrana celular y el ingreso abrupto de iones calcio que provocan una avalancha de reacciones bioquímicas que concluyen en "la inhibición de la Calcineurina" que es la enzima responsable del desarrollo y maduración de las células T, cuya función es la protección del organismo ante el ingreso de agentes extraños como microbios y virus.

(2) La exposición a la RF produce a bajas dosis y en un corto período de tiempo el aumento de la permeabilidad de la barrera hematoencefálica (BBB) lo que permite el ingreso al cerebro de moléculas de mayor tamaño, como la albúmina y toxinas que dañan las neuronas.

(3) La exposición a la RF provoca el estrés oxidativo celular y el aumento de los radicales libres lo que lleva a un aumento de la inflamación.

(4) La exposición a RF afecta la estructura de la hemoglobina, reduciendo su capacidad para unirse al oxígeno. Después de solo dos horas de exposición a un teléfono celular, la estructura de la hemoglobina humana cambia, disminuyendo su afinidad para unirse al oxígeno en los pulmones entre un 11 y un 12 %, lo que reduce la cantidad de oxígeno que se transporta desde los pulmones a los tejidos, contribuyendo a la hipoxia.

(5) La RF provoca cambios morfológicos en los eritrocitos, incluida la formación de equinocitos y "rouleaux" (pila de monedas), fenómeno que se observa al microscopio luego de solo 10 minutos de exposición a ondas milimétricas lo que contribuye a la formación de coágulos.

(6) Se ha demostrado que la exposición a RF reduce la producción glutatión. Las personas que residían cerca de una antena base de celular tenían niveles de glutatión muy inferiores a quienes vivían lejos de esa misma antena. Los bajos niveles de glutatión reducen los niveles de vitamina D y producen mayor riesgo de complicaciones por COVID-19 y el tratamiento con glutatión de pacientes con neumonía evitó con éxito la tormenta de citoquinas.

(7) La radiación RF afecta la cadena de transporte de electrones en las mitocondrias. Las mitocondrias suministran la energía a las células y consumen la mayor parte del oxígeno. La exposición a RF conduce a una disfunción mitocondrial que conduce a un menor consumo de oxígeno y a una menor producción de energía, lo que provocaría fatiga.

(8) La radiación RF afecta la expresión de los genes, incluyendo algunos oncogenes como el p53 que activa la apoptosis por la vía mitocondrial que es un mecanismo de defensa. etc., etc....

Estos efectos de reducción de las defensas, debido al aumento de la radiación que es provocada por las ondas milimétricas de los sistemas 5G que se suman a la radiación existente (debida sobre todo a los sistemas 3G y 4G) son más dañinos durante una epidemia o pandemia y pueden naturalmente aumentar el número de casos y el número de muertes. Queda claro que esto, "no significa que las tecnologías anteriores sean inocuas" muy por el contrario, son también muy dañinas y provocan enfermedades como se ha descripto en el anterior comunicado 3, sobre "los riesgos de la proximidad de las Antenas base para la salud de las personas".

El análisis de los efectos de radiaciones electromagnéticas durante una pandemia ha sido objeto de un estudio epidemiológico de gran detalle en los Estados Unidos, durante la reciente epidemia de Covid, por dos reconocidas investigadoras, las Dras. Magda Havas y Ángela Tsiang siendo aceptada su publicación por Medical Research Archives de la European Society of Medicine.

Los resultados del estudio mostraron que, en las mismas fechas, todas las ciudades que ya disponían de la tecnología 5G tenían una cantidad de casos/millón de habitantes y de muertos/millón de habitantes, significativamente mayores a las poblaciones que aun no disponían de la tecnología 5G. El número de casos y de muertes donde las ondas milimétricas se sumaban a las de 4G y 3G aumentaban significativamente y resultaban ser el doble o el triple de los lugares donde solo estaban en uso los sistemas anteriores.!

Es conveniente aclarar en este punto que estos resultados del trabajo científico, no tienen relación con ciertas teorías que identifican al sistema 5G como un factor determinante e intencional para el covid-2 y que, hasta llegan a negar la existencia del virus SARS-Cov-2.

El problema aquí son simplemente las ondas electromagnéticas de radiofrecuencia que, afectan a la salud humana por "la disminución de sus defensas" y que el sistema 5G, sumado al 3G y 4G lo que hace es aumentar las exposiciones de la población y aumentar los daños, sin que eso signifique que 5G sea particularmente dañino. Todas las radiofrecuencias son dañinas, hasta el wifi, el celular o el teléfono inalámbrico que tenemos en nuestros domicilios. Como uno de los efectos principales sobre la salud es disminuir las defensas del organismo, esto se manifiesta muy particularmente en situaciones donde hay enfermedades, como la última pandemia.

Se pone a consideración de la comunidad médica el estudio de Ángela Tsiang y Magda Havas que cuenta con una bibliografía importante para ser analizado por epidemiólogos, hematólogos y otros especialistas y permitan tomar las medidas preventivas y terapéuticas necesarias.

En los Estados Unidos se inició el despliegue de la tecnología 5G muy tempranamente, en el 2019, y cuando la OMS declara la pandemia en marzo del 2020, más de la mitad de los estados americanos ya disponían de antenas 5G y dispositivos que emitían frecuencias de GHz, las denominadas ondas milimétricas.

Esta circunstancia, tan especial, permitió contar con un Escenario único: que permitió comparar en un mismo país, el impacto de la pandemia en estados, ciudades y condados que ya disponían de 5G con otros que aún utilizaban tecnologías inalámbricas anteriores, como 1G/4G, pero con otras variables comparables como: el Sistema de Salud, el ingreso per cápita, la densidad poblacional, el clima, las costumbres, la calidad del aire, las etnias, etc. En las comparaciones entre diferentes países resulta necesario tener en cuenta todos estos factores que pueden afectar la causalidad.

En este estudio se compararon estados con estados, condados con condados e incluso en el caso de California, compararon condados con condados de un mismo estado..!!

Se compararon los máximos, los mínimos y los promedios, y en todos los casos el uso de la tecnología 5G y el denominado "Factor mmW" que indica cuantitativamente "La magnitud del uso de las ondas milimétricas" resultaron ser los factores determinantes y estadísticamente más significativos. En todas las comparaciones, sin excepción, el uso de la tecnología 5G fue el factor determinante y significó porcentualmente más casos de covid y más muertes por covid.

El estudio realiza también una comparación entre los países europeos de más de 2 millones de habitantes, en agosto del 2020, fecha en la cual ya se había desplegado la tecnología 5G en parte de Europa y los resultados de estas comparaciones dieron resultados equivalentes, los países con tecnología 5G tuvieron porcentualmente más casos de covid y más muertes por covid que aquellos que aun no habían realizado el despliegue de 5G.

Por otra parte, conviene recordar que la expansión inicial del virus que causó la pandemia de COVID-19, se produjo en Wuhan, China, donde ya se había implementado el sistema 5G en toda la ciudad.

En este estudio, se utilizó la literatura científica revisada por pares sobre los efectos biológicos perjudiciales de las radiaciones electromagnéticas y se identificaron varios mecanismos biológicos por los cuales la RF puede haber contribuido a la pandemia de COVID-19 como un cofactor ambiental tóxico. Hay evidencias de que la RF puede empeorar las arritmias cardíacas y los trastornos cardíacos.

La Comisión Interamericana de Protección contra la Radiación Electromagnética entiende que es muy necesario que las autoridades competentes designen un grupo de especialistas calificados, que evalúe la información científica disponible para proteger debidamente a la población de los riesgos derivados de la contaminación electromagnética.

El ICNIRP que es el organismo internacional reconocido en la materia, ha emitido una normativa, "los principios del ICNIRP-2020", que es necesario llevar a la práctica, así como el ICRP-103 que se ha designado como el documento de referencia.

La OMS ha puesto en marcha un proyecto para que los países apliquen los principios de radioprotección a las radiaciones electromagnéticas para lo cual la responsable del control de las radiaciones electromagnéticas, la Dra. E. Van Deventer, ha recomendado establecer un Organismo de Control Multidisciplinario integrado por médicos, biólogos, epidemiólogos, hematólogos, físicos, etc., para establecer las medidas de control necesarias para proteger a la población.

Solicitamos a las sociedades médicas el apoyo y el acompañamiento necesario para que el país cuente con un organismo de control semejante al que controla las radiaciones ionizantes.

Sería importante contar con el apoyo médico de un grupo de especialistas que abarcara todas las especialidades afectadas por las radiaciones electromagnéticas, que son muchas, a fin de poder evaluar toda la extensa bibliografía existente en forma sistemática y distribuida entre especialistas de cada área en particular. ("los temas médicos deben ser analizados por médicos")

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Se adjuntan los trabajos mencionados:

- Fifty-gigahertz Microwave Exposure Effect of Radiations on Rat Brain.
  Kavindra Kumar Kesari& J. Behari

- COVID-19 Attributed Cases and Deaths are Statistically Higher in States and Counties with 5th Generation Millimeter Wave Wireless Telecommunications in the United States.
  Ángela Tsiang and Magda Havas

Ambos trabajos disponen de una amplia bibliografía que puede ser consultada

Comunicado CIPRACEM Nº 5 sobre la necesidad de "Aplicar las Normas" para proteger la salud de la población de los Campos Electromagnéticos (de la misma forma que se protege la gente de las radiaciones ionizantes)

1 - Los daños producidos por el uso inadecuado* de los celulares y antenas: Recientemente se ha hecho una recopilación de cientos de estudios publicados en los últimos años, que muestran ***los efectos de las radiaciones electromagnéticas cuando no se usa la normativa apropiada***. Se han expuesto seres vivos y muestras de células y tejidos del organismo humano, así como de diversas especies de animales, como aves, conejos, ratas, ratones, aves, gusanos, moscas y diversas plantas. El resultado de estos estudios muestra que, en la mayoría de los estudios, (más del 90%) y a valores de exposición, incluso muy inferiores a los valores límites establecidos, se observan "daños biológicos"· producido por diversos mecanismos: como el Stress Oxidativo Celular por formación de productos hiperoxidantes (ROS), y de radicales libres, la rotura simple y doble del ADN, apoptosis, apoxia celular, cambios en la expresión genética, disminución de antioxidantes naturales presentes, como el glutatión, cambios histológicos y daño degenerativo en los órganos afectados, como cerebro, hipocampo, riñones, hígado, testículos y sangre; aglutinación de eritrocitos (ruleaux) y microcoagulación, disminución del transporte de oxígeno por la hemoglobina, disminución del número y motilidad de los espermatozoides. inhibición de la Calcineurina y disminución de células T, disfunción mitocondrial con menor consumo de oxígeno lo que provoca fatiga, cambios en la permeabilidad de la membrana celular o en la membrana hemato-encefálica, posibilitando el ingreso de toxinas, y un conjunto se otros efectos ***que en la práctica podrían ser disminuidos aplicando la normativa de Radioprotección que se aplica a las radiaciones ionizantes.*** (Las Normas de Radioprotección requieren la aplicación de los 3 principios del ICRP, La Justificación, La Optimización y Los Límites de Dosis)

Algunos de estos efectos se han observado a exposiciones muy bajas y solo luego de algunos pocos minutos de exposición., lo cual implica los graves riesgos que conlleva, incluso una comunicación muy breve, y se debe considerar que una irradiación más prolongada podría hacer que el estrés oxidativo sea permanente con todo lo que eso implica de daños en las biomoléculas. Como es de esperar, los efectos son siempre más marcados en el caso de células embrionales o células madre, en niños o crías de animales. También se observan mayores efectos en las exposiciones pulsadas.

La evidencia es muy notable por la cantidad y variedad de los estudios que se presentan (ver Ref. 1).

Estos efectos biológicos observados en la recopilación de H. Lai podrían ser la Primera etapa de un proceso que se inicia con un fenómeno primario de formación de radicales libres que da luego lugar al denominado "Stress Oxidativo Celular" y que de acuerdo a su desarrollo y ubicación anatómica dentro del organismo, podría ser el inicio de un conjunto de afecciones o enfermedades en personas y/o animales atribuidas a las radiaciones electromagnéticas y que ya han sido descriptas en otros comunicados y que ahora solo enunciaremos algunas más significativas.

2 - Crecimiento por factor 4 o 5 de la frecuencia de los tumores cerebrales, de mayor malignidad, en aquellos países que cuentan con estadísticas epidemiológicas, como es el caso de Francia, Suecia, Australia, Inglaterra y Brasil. Se estima que solo por tumores cerebrales la exposición a los CEM ha producido ya más de 4 millones de fallecimientos. Para determinar "la Causalidad" dos expertos del IARC (los Dres. C. Portier y L. Hardell) aplicaron los 9 criterios de Sir Bradford Hill obteniendo una muy fuerte evidencia de la causalidad atribuida a la exposición a los CEM-RF.
En la Argentina no tenemos estadísticas de estos tumores pero si tenemos información personal de uno de los servicios más importantes del país que atiende los "Neurinomas del Acústico" con la siguiente información: *En una década los tumores grado 4 (gigantes) se multiplicaron por 10 (de 23 pasaron a 212). Lo que equivale a un aumento de frecuencia del 25% /año..!! Y esto es muy coherente con los datos de aumento de frecuencia de tumores cerebrales grado 4 (glioblastoma) que se mencionaron.* (Ref. 2)

3 - Efectos sobre el Sistema nervioso con enfermedades neurológicas y psiquiátricas, el aumento en la frecuencia de autismo, el trastorno por déficit de atención con hiperactividad (TDAH), el deterioro cognitivo y en particular el aumento de la enfermedad de Alzheimer que se observa actualmente en personas muy jóvenes atribuido a un mecanismo que se inicia con la apertura del canal de calcio en la membrana celular provocado por los CEM (Ref. 3)

4 – Aumento de la presión arterial por la exposición a los campos electromagnéticos: En la revista de la Sociedad Europea de Cardiología, (el European Heart Journal), acaba de salir una nota relacionando la alta presión arterial. Según este estudio realizado sobre 220.000 personas voluntarias de entre 37 a 73 años, con solo 30 minutos por semana de uso del celular aumenta en un 12% el riesgo de alta presión y a mayor cantidad de minutos mayor es el riesgo de sufrir un ACV. (Ref. 4)

5 - Riesgos de la proximidad de las Antenas base para la salud: Se han realizado varias recopilaciones sobre este tema y la más amplia y reciente, que incluye a casi 40 países, es la de A. Balmori. Del análisis de estas recopilaciones (que incluyen la antena de Belo Horizonte, en Brasil) se desprende que las Antenas base producen en sus cercanías al 75% de la población algún tipo de efecto, sea la enfermedad por radiofrecuencia, aumento de la frecuencia de cáncer o cambios en los parámetros bioquímicos de su sangre. Algunos efectos determinísticos y el aumento de la frecuencia de efectos estocásticos son incompatibles con la aplicación de los principios de radioprotección del ICRP-103 que se considera el Documento de Referencia. Si estos fueran observados en los vecinos de una Central Nuclear suponemos que la misma sería puesta "fuera de servicio" por la Autoridad Regulatoria correspondiente, hasta tanto no se demuestre que los efectos no son ocasionados por la propia instalación. (Ref. 5)

6 - El riesgo del despliegue 5G:: El pasaje de la tecnología 4G a la 5G requiere aumentar la potencia de emisión de las antenas por factor 4 debido a su menor alcance, En un primer momento, se especuló con que las ondas milimétricas, debido a su baja penetración, solo podían tener efectos superficiales en la piel humana. Pero esto no parece ser así. El trabajo de Kavindra Kesari (Ref. 6) muestra como la exposición prolongada puede causar la ruptura de la doble cadena del ADN y. que el posible sitio de acción de dicha radiación milimétrica es el hipocampo, la región responsable del control del aprendizaje y la memoria localizado en el centro de nuestro cerebro. Como conclusión, las nuevas frecuencias que 5G suma a la radiación existente, no hace más que potenciar y aumentar los efectos de las mismas sobre la salud humana, y varios efectos biológicos que disminuyen las defensas más importantes del organismo.
Como consecuencia se pudo observar que en los Estados Unidos, debido al aumento simultaneo de las dosis y la disminución de las defensas del organismo las muertes por el virus durante la pandemia fueron el doble y el triple en aquellos lugares con 5G instalado en relación a los que aún tenían el 4G (Ref. 7)
El país no debiera tomar decisiones sobre cambios de tecnología ante de estudiar profundamente este caso.

7 – El riesgo particular de los niños y las mujeres embarazadas: Hay otros efectos sobre la salud, que afectan el Sistema reproductor masculino y femenino, en personas y animales, incluyendo la pérdida de motilidad de los espermatozoides y el descenso de la concentración de testosterona. En una población de mujeres embarazadas, controladas con dosímetros personales permanentes, se observó un aumento marcado de los abortos espontáneos en aquellas mujeres que habían recibido las dosis de radiación electromagnéticas más altas. (Ref. 8 y 9)

Hay muchos otros temas de igual importancia que no pudieron ser incluidos en este comunicado, como por ejemplo, el de las personas hipersensibles (EHS), los tumores de tiroides, y de colon y recto, la co-carcinogénesis, la diabetes, el deterioro cognitivo, la osteoporosis, la sinergia de los CEM con varios cancerígenos físicos y químicos, la protección necesaria de los animales y el medio ambiente, etc., pero consideramos que es más importante avanzar en la toma de medidas de radioprotección lo antes posible,

8 - Las Medidas de Radioprotección: Es muy conveniente destacar en este punto que el riesgo para la salud de la exposición a las radiaciones ionizantes es mucho menor que el de las radiaciones electromagnéticas para lo cual basta con un par de ejemplos. A) La probabilidad matemática de cáncer de un miembro del público de RI es de 5 en 100.000 (5%/Sv) en el caso de las ratas del NTP la tasa de cáncer fue del 3 en 100 o sea una relación de 1 en 1000. B) En la experiencia de Mokarram y Sheikihi con intestino de ratas, para determinar con biomarcadores de metilación el poder cancerígeno del Co-60 contra un celular en contacto. La efectividad de la exposición de 1 una hora de celular resultó ser equivalente a 1Gy, nuevamente 1 en 1000. C) La cohorte de Nagasaki e Hiroshima recibió una dosis promedio de aproximadamente 1000 mGy y las ratas utilizadas por Tillmann y por Lerchl para su experiencia sobre co-carcinogénesis en ratas recibieron hasta 100 veces menos de las dosis permitidas por lo que nuevamente la relación es de 1 en 1000 o aún mucho mayor.

Parece razonable por lo tanto utilizar para las radiaciones electromagnéticas un sistema de control de características similares o aún más estrictas que el usado para las radiaciones .ionizantes.

La Comisión Interamericana de Protección contra la Radiación Electromagnética entiende que es necesario que las autoridades competentes designen con la mayor urgencia un grupo de especialistas, que evalúe toda la información científica disponible para tomar las medidas necesarias para proteger debidamente a la población de los riesgos derivados de la contaminación electromagnética, aplicando sistemáticamente los tres principios de Radioprotección tal como indican los organismos internacionales, el ICNIRP, el ICRP y la OMS.

El ICNIRP que es el organismo internacional reconocido en la materia, ha emitido una normativa, "los principios del ICNIRP-2020", que es necesario llevar a la práctica, así como el ICRP-103 que se ha designado como el documento de referencia.

La OMS ha puesto en marcha un proyecto para que los países apliquen los principios de radioprotección a las radiaciones electromagnéticas para lo cual la responsable del control de las radiaciones electromagnéticas, la Dra. E. Van Deventer, ha recomendado establecer un Organismo de Control Multidisciplinario integrado por médicos, biólogos, epidemiólogos, hematólogos, físicos, etc., para establecer las medidas de control necesarias para proteger a la población.

Solicitamos a las sociedades médicas el apoyo y el acompañamiento necesario para que el país cuente con un organismo de control semejante al que controla las radiaciones ionizantes.

Sería importante contar con el apoyo médico de un grupo de especialistas que abarcara todas las especialidades afectadas por las radiaciones electromagnéticas, que son muchas, a fin de poder evaluar toda la extensa bibliografía existente en forma sistemática y distribuida entre los especialistas de cada área en particular.

Quedan a vuestra disposición los miembros argentinos del CIPRACEM, el Dr. Daniel Orfila (Director Médico del IC-EM -Implantes Cocleares Equipo Multicéntrico), el Ing. Walter Fano (Profesor responsable de Antenas y Propagación Electromagnética de la Facultad de Ingeniería de la UBA), el Dr. Eduardo Legaspe (Bioquímico, especialista en Radioprotección de poblaciones vulnerables por efectos de las radiaciones no ionizantes), la Dra. Mariana Lofeudo (abogada especialista en salud y ambiente. Docente de grado y posgrado en la Facultad de Derecho de la UBA, a cargo del dictado del tema Contaminación Electromagnética), el Ing. Guillermo Defays (Master of Sciences en Sistemas de Comunicaciones de la Universidad de Essex, Inglaterra), el Bioing. Mag. Esteban Rossi (Profesor titular, Investigador de la Fac. de Ingeniería de la UNER), el Ing. Abel González (ARN-SAR-UNSCEAR-IAEA), el Dr. Rodolfo Touzet (CNEA-SAR-FRALC-IRPA),

Muy atentamente, quedamos a vuestra disposición.

CIPRACEM

Comisión Iberoamericana de Protección Radiológica de los Campos Electromagnéticos y las Radiaciones no Ionizantes

Se adjuntan los documentos referenciados en el texto y las Normas de Aplicación que tienen consenso a nivel internacional y cuentan con especialistas en el país para su aplicación efectiva.

<u>Referencias adjuntas</u>

1 - Henry Lai RFR-oxidative effect-study absracts 2-4-2023
2 - Hardell - Bradford Hill
3 - Low Intensity EMF Cause Early Alzheimer's Disease. M. Pall
4 - Hipertensión y CEM
5 - Balmori Antenas Review-resaltado
6 - 50 GHz exposure Rats brain (Kesari)
7 - Magda Havas 5G y COVID
8 - Natura RNI y Embarazadas (Califa)
9- EMF and Children Devra Davis et al

Nor 1- ICNIRP Principles 2020
Nor 2- Marco de Proteccion para las RNI (OMS)
Nor 3- ICRP-103 en español

RESEARCH ARTICLE

COVID-19 Attributed Cases and Deaths are Statistically Higher in States and Counties with 5th Generation Millimeter Wave Wireless Telecommunications in the United States.

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Abstract
COVID-19-attributed case and death rates for the U.S.A. were analyzed through May 2020 in three ways – for all 50 states, the country's largest counties, and the largest counties in California – and found to be statistically significantly higher for states and counties *with* compared to those *without* 5G millimeter wave (mmW) technology. 5G mmW index was a statistically significant factor for the higher case and rates in all three analyses, while population density, air quality and latitude were significant for only one or two of the analyses. For *state averages*, cases per million were 79% higher ($p = 0.012$), deaths per million were 94% higher ($p = 0.049$), cases per test were 68% higher ($p = 0.003$) and deaths per test were 81% higher ($p = 0.025$) for states with vs. without mmW. For *county averages*, cases per million were 87% higher ($p = 0.005$) and deaths per million were 165% higher ($p = 0.012$) for counties with vs. without mmW. While higher population density contributed to the higher mean case and death rates in the mmW states and counties, exposure to mmW had about the same impact as higher density of mmW states on mean case and death rates and about three times as much impact as higher density for mmW counties on mean case and death rates. Based on multiple linear regression, if there was no mmW exposure, case and death rates would be 18-30% lower for 5G mmW states and 39-57% lower for 5G mmW counties. This assessment clearly shows exposure to 5G mmW technology is statistically significantly associated with higher COVID-19 case and death rates in the U.S.A. The mechanism–should this be a causal relationship–may relate to changes in blood chemistry, oxidative stress, an impaired immune response, an altered cardiovascular and/or neurological response.
Keywords: 5G; millimeter waves; radiofrequency; RF; microwave radiation; microwave sickness; wireless; electromagnetic fields; EMF; EMR; EMI; EHS; COVID-19; SARS-CoV-2

1. Introduction

The first documented case of COVID-19 was reported in Wuhan, China in December 2019. To prevent its spread, the U.S. blocked travel from China on January 31st and declared a National Emergency on March 13th, 2020. After the World Health Organization (WHO) declared it a pandemic on March 19, 2020, the U.S. began quarantine and stay-at-home orders to slow the virus' spread and to "flatten the curve". Despite these precautions, the virus spread quickly in the U.S. and around the globe.

The infectious agent was named *severe acute respiratory syndrome coronavirus 2* (SARS-CoV-2) due to genetic similarity to SARS-CoV that caused a pandemic in 2002-4. The disease associated with SARS-CoV-2 is COVID-19, which is an abbreviation for Coronavirus Disease 2019 associated with SARS-CoV-2.

According to the U.S. Centers for Disease Control the epidemiological triangle for infectious diseases consists of the agent, the host and the environment. While attention has focused on the agent (genetics, modes of infection, etc.) and the host (age and comorbidities), little attention has focused on key environmental factors. These include but are not limited to air quality since this was initially identified as a respiratory illness, population density for person to person transmission, and electromagnetic radiation since COVID-19 appeared after 5G was implemented and many of the COVID-19 symptoms resemble those of microwave sickness.

As of September 18, 2020, according to Johns Hopkins University, the cases are not uniformly distributed globally (Figure 1). Many factors may account for this: testing differences, per capita income, standard of health care, population demographics, and environmental factors among others. This paper focuses on four environmental factors that may relate to the spread and fatality of this disease: population density, air pollution, latitude (which determines potential endogenous vitamin D production) and presence of 5G mmW technology, which is present in combination with frequencies used in previous generations of wireless communications from 1G to 4G and does not replace them. These data, along with COVID-19 case and death data, were readily available for the United States.

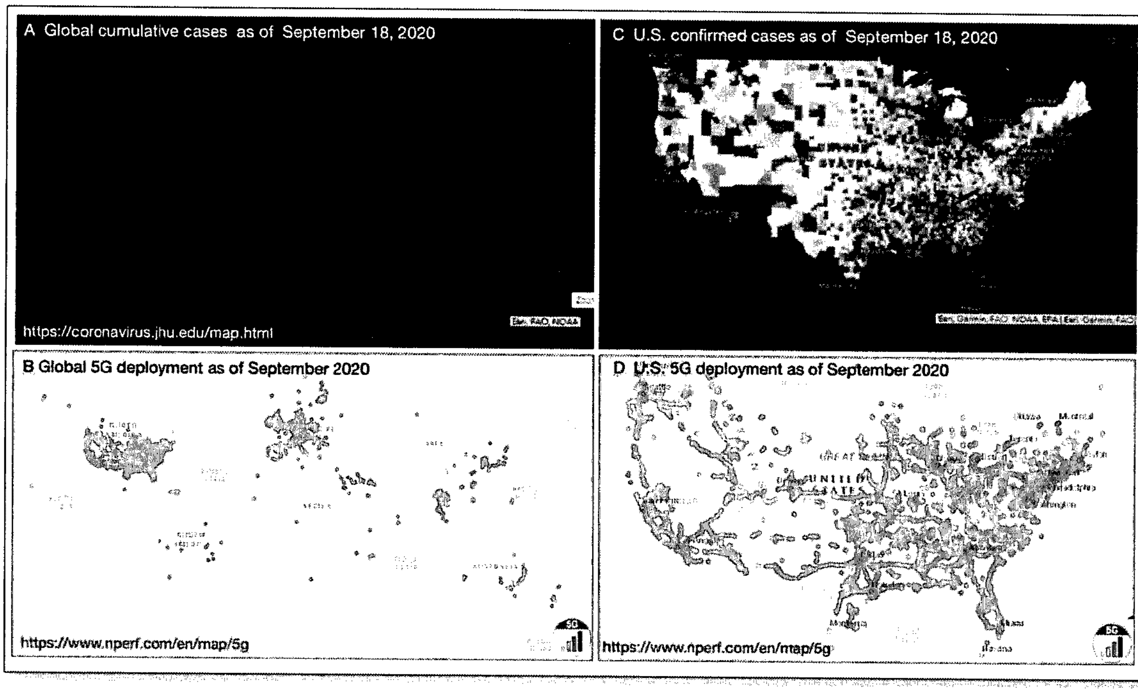

Figure 1. Data for COVID-19 (as of September 18, 2020) and rollout of 5G as of September 2020.

As of August 9, 2020, the U.S. was #1 out of 213 nations in the world for the highest number of total COVID-19 cases at 5.2 million, with 15,698 cases per million (9th highest) and 500 deaths per million (10th highest) [1].

The rollout of 5G technology is to support the Internet of things (IoT). As of January 2020, 31 countries had working 5G networks globally [2-5] In the top quartile of the highest ranking countries for COVID-19 deaths per million, 16 of them had working 5G networks; while only 7 countries had 5G in the 2nd highest quartile; 6 in the 3rd highest quartile and only 2 in the bottom quartile. In the top quartile, the 5G countries with higher deaths per million than the U.S. were San Marino (1238), Belgium (851), U.K. (686), Spain (610) and Italy (582). The other countries with 5G in the top quartile with fewer deaths per million than the U.S. were Ireland (358), Switzerland (229), South Africa (175), Romania (140), Germany (110), Denmark (106), Monaco (102), Oman (100), Bahrain (95), and Saudi Arabia (91).

Three radio frequency bands are used in 5th Generation (5G) wireless communications. The low band refers to frequencies below 1 GHz; the mid band to frequencies between 1 GHz and 6 GHz, and the high band to the millimeter waves (mmW), which are 24 GHz and above. The U.S. telecommunication companies began using mmW for 5G wireless communications in 2019 after their acquisition of the mmW spectrum, making the U.S. the first country in the world to use mmW for 5G. In June 2019, FCC's Auction 101 for 28 GHz sold for $700 million and Auction 102 for 24 GHz sold for $2 billion [6], and in March 2020, 37, 39 and 47 GHz bands in Auction 103 sold for $7.5 billion [7], generating a total of $10 billion for the U.S. government. As of February 2020, European countries were still not using mmW for 5G [8], and other countries have used only the low and mid band frequencies for 5G. To achieve higher speeds for 5G, densification of antennas has occurred worldwide. Also, because mmW have shorter wavelengths (higher frequencies) than that used for 1G to 4G, they are more susceptible to interference from obstructions, thus requiring more transmitters closer to users, which have been added to streetlamps and utility poles in some cities. The shorter distance and higher density of mmW antennas translates into higher radiation exposures, as acknowledged by the FCC's 2019 Notice of Proposed Rulemaking 19-126 [9] to increase the current RF exposure limits four-fold to accommodate 5G mmW devices and infrastructure.

If environmental exposure to 5G mmW increases the severity of COVID-19 or other viral infections, then the rapid rollout of 5G technology should be reconsidered.

2. Methods

2.1 COVID-19 Attributed Cases and Deaths

Data for number of cases, deaths, and tests for COVID-19 from Worldometer was assessed on April 22, 2020, May 15, 2020, and May 31, 2020 [1]. Data collection was stopped on May 31, 2020 because the nationwide quarantine effectively ended by that time as people in major cities all around the country broke quarantine when they gathered in crowds and some states began lifting their stay-at-home orders.

2.2 Variables: Air Quality Index, Latitude, Population Density and mmW Index

A mmW exposure index was calculated based on the sum of the total population of the cities serviced by mmW 5G by each provider in a county or state, divided by the total population of that county or state. This factor is not a calculation of the mmW exposure level but a differentiation between the different exposure levels in each state and county based on the number of mmW providers and the number of mmW cities and their population in those counties or states, which is necessary for statistical analysis.

Population density data were obtained from Wikipedia, which are calculated from population data from the U.S. Census divided by the area of the state or county. Air Quality Index (AQI) data from 2019 from the EPA were included in the analysis for states and counties. Latitude, which may relate to potential production of endogenous vitamin D associated with sun exposure, was also included in the analysis for counties.

2.3 States and Counties with and without 5G mmW Networks

Cities with 5G mmW networks were chosen for analysis because the most frequencies for wireless communications (5G mmW plus low and mid band 5G as well as frequencies from previous generations 1G to 4G) and the highest RF exposures due to the increased number of small cell antennas for 5G and their placement close to users would be present there. Even though urbanization and high density may be part of the criteria for choosing where to locate 5G mmW, and therefore it may seem appropriate to adjust the case and death rate data for urbanization and density, it is actually NOT appropriate to do so for this analysis. The higher the urbanization and density in an area, the higher the levels of RF radiation present because of the higher density of cell phone towers, Wi-Fi hot spots, cell phones and Wi-Fi routers present in highly urbanized or dense areas. To adjust the data for urbanization and density would therefore remove the effect of higher levels of RF radiation present in highly urbanized or dense areas. Therefore, case and death rate data and charts were not adjusted for density or urbanization. However, multi-variate analysis was done to determine if urbanization or density, along with AQI and latitude, were statistically significant factors in the case and death rates using multiple linear regression, and then their contributions relative to the contribution from 5G mmW to the case and death rates were calculated.

Counties and states with mmW 5G service were determined from the websites of the wireless providers AT&T [10], T-Mobile [11], and Verizon [12] which specified the cities that they service with mmW 5G (Table 1). There were no changes in the cities using mmW for 5G between April 22 and May 31, 2020.

The data were analyzed three ways to determine robustness: at the state level, at the county level, and for the largest counties in California.

In this analysis, 32 states were using mmW 5G and 18 states were not. All counties using mmW for 5G were included except for Hampton Roads, VA, because it spanned a combination of 16 counties and cities which made its analysis difficult; so, a total of 53 counties using mmW 5G were used.

The counties not using non-mmW were from the largest 120 cities in the U.S. according to the U.S. Census Bureau. After omitting the counties that contained cities with mmW 5G service, 49 counties were left that did not have mmW 5G technology. There are thousands of counties in the U.S., and because only the ones containing the 120 largest cities were included, some states were not represented in the county analysis. The states not represented in the county analysis (but included in the state analysis) are: VA, CT, DE, ME, MS, MT, NH, ND, RI, SC, VT, WY.

California, the most populated state in the U.S., has 60 counties in total and six counties with 5G mmW technology. The counties that did not use 5G mmW technology chosen for comparison included only those with a population of 500,000 or greater, of which there were 11.

Pearson's correlations were calculated for the case and death rates with the four variables population density, mmW index, AQI, and latitude. Two-sample t-test was used to compare case and death rates of 5G mmW states and counties to that of non-5G mmW states and counties, and statistical significance was defined to be $p < 0.05$ with alpha = 0.05. Regression analyses were performed to find regression equations for the case and death rates and identify statistically significant variables at $p < 0.05$. The numbers of cases per test and deaths per test were analyzed at the state level but not at the county level due to missing data.

3. Results

3.1 U.S. Compared to European Countries

Whereas none of the European countries was using mmW for 5G as of February 2020 and mmW spectrum was not even assigned to any European country except Italy [8], the U.S. began using mmW for 5G in 2019. Of the 10 European countries (with populations greater than 2 million) with the highest numbers of COVID-19 deaths per million through August 9, 2020 [1], deaths per million were significantly higher for those countries with 5G compared to non-5G and this difference was statistically significant (617 vs. 383, $p = 0.026$) (Table 2).

Table 1. Cities with mmW 5G Coverage and Provider from April 22 to May 31, 2020. Source: AT&T [10], T-Mobile [11], Verizon [12].

City	State	AT&T	T-Mobile	Verizon
Atlanta	GA	X	X	
Austin	TX	X		
Baltimore	MD	X		
Charlotte	NC	X		
Chicago	IL			X
Cincinnati	OH			X
Cleveland	OH	X	X	X
Columbus	OH			X
Dallas	TX	X	X	X
Denver	CO			X
Des Moines	IA			X
Detroit	MI	X		X
Grand Rapids	MI			X
Greensboro	NC			X
Hampton Roads	VA			X
Hoboken	NJ			X
Houston	TX	X		X
Indianapolis	IN			X
Jacksonville	FL	X		
Kansas City	MO			X
King of Prussia	PA	X		
Las Vegas	NV	X	X	
Little Rock	AR			X
Los Angeles	CA	X	X	X
Louisville	KY	X		
Memphis	TN			X
Menlo Pk, Rdwd City, San Bruno	CA	X		
Miami	FL	X		X
Miami Gardens (AT&T only)	FL	X		
Minneapolis	MN			X
Nashville	TN	X		
New York City	NY	X	X	X
Oakland	CA	X		
Ocean City	MD	X		
Oklahoma City	OK	X		
Omaha	NE			X
Orlando	FL	X		
Panama City	FL			X
Philadelphia	PA	X		
Phoenix	AZ	X		X
Raleigh	NC	X		
Salt Lake City	UT			X
San Antonio	TX	X		
San Diego	CA	X		
San Francisco	CA	X		
San Jose	CA	X		
Sioux Falls	SD			X
Spokane	WA			X
St. Paul	MN			X
Waco	TX	X		
Washington	DC			X
West Hollywood	CA	X		

Table 2. Top 10 Ranking European Countries for COVID-19 Deaths/Million for 5G * vs. Without 5G through August 9, 2020. Source: Worldometer [1]

Rank # Deaths per Million out of 213 Countries Worldwide	Rank # Deaths per Million out of European Countries (pop. > 2 million)	Country	Population	Total Deaths per Million
2	1	Belgium *	11,595,151	851
3	2	U.K. *	67,924,946	686
6	3	Spain *	46,756,796	610
7	4	Italy *	60,451,842	582
17	8	Ireland *	4,943,652	358
8	5	Sweden	10,106,111	570
12	6	France	65,289,486	464
16	7	Netherlands	17,139,065	359
22	9	Armenia	2,963,856	267
23	10	N. Macedonia	2,083,364	253
U.S. For Comparison		U.S.*	331,214,010	500
Mean 5G European Countries				617
Mean non-5G European Countries				383
p-value of T-test, with vs. without 5G				**0.0257***

The 500 deaths per million for the U.S. are within the range of the 5G European countries. Because of differences in testing and criteria for how cases are counted between U.S. and European countries, deaths per million is the most consistent number to use for comparison between countries. However, there are still other differences between the U.S. and European countries - per capita income, standard of health care, population demographics, quarantine measures, and environmental factors like air pollution - that complicate comparison between countries. Nevertheless, these data are provided to show how the U.S. compares to the top 10 European countries with the highest deaths per million, with and without 5G.

3.2 States with vs. without 5G mmW

There were 32 states with 5G mmW and 18 states without 5G mmW. Descriptive statistics for the cumulative data through April 22, which was just after the peak of daily deaths for COVID-19 had occurred on April 21 (Figure 2), can be found in Table 3. The average rate of cases and deaths was much higher for the mmW states compared to the non mmW states, and these differences were statistically significant with p-values between 0.005 to 0. 046 (Table 3 and Table 4A). There were almost twice as many cases per million (2,500 vs. 1,288, ratio 1.94) and more than twice as many deaths per million (126 vs. 55, ratio 2.29) for states with vs. without mmW technology. For mmW states compared to the non-mmW states, there were almost twice as many cases/test (15.5% vs. 8.82%, ratio 1.76) and twice as many deaths/test (0.721% vs. 0.364%, ratio 1.98). The fatality rate (deaths per case) was higher for the mmW states but was not statistically significant (4.13% vs. 3.50%, ratio 1.18, p = 0.081).

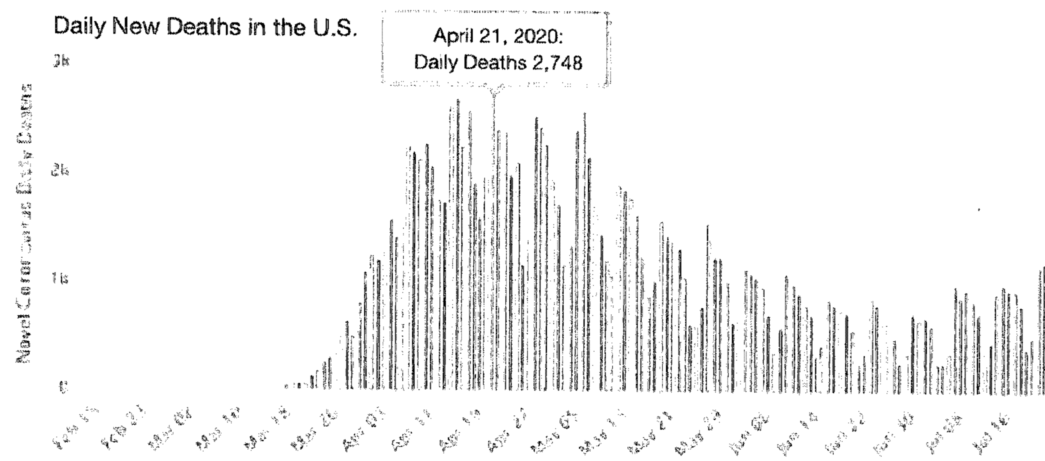

Figure 2. COVID-19 daily new deaths peaked at 2,748 on April 21, 2020 in the U.S. Source: Worldometer [1]

Table 3. Descriptive statistics through April 22, 2020 (after peak of daily deaths occurred) for states with and without 5G mmW for population, mmW index, COVID-19 tests, air quality index (AQI), and number of COVID-19 attributed cases and deaths. Statistical significance is indicated by * (p < 0.05) and ** (p < 0.01).

States	n		State Population	Population Density (people per sq. km)	mmW index	AQI	Tests per Million	Cases per Million	Deaths per Million	% Cases per Test	% Deaths per Test	% Deaths per Case
with 5G mmW		max	39,937,489	467	1.284	51.2	39,487	13,368	1037	51.60%	3.04%	8.30%
with 5G mmW	**32**	**mean**	**8,752,116**	**91.7**	**0.207**	**43.4**	**14,378**	**2500**	**126**	**15.50%**	**0.72%**	**4.13%**
with 5G mmW		min	903,027	4.29	0.006	33.5	7,224	492	10	4.50%	0.07%	0.47%
without 5G mmW		max	8,626,207	287	0	47.6	21,540	6274	431	32.10%	2.20%	6.90%
without 5G mmW	**18**	**mean**	**2,639,561**	**50.2**	**0**	**40.0**	**14,324**	**1288**	**55**	**8.80%**	**0.40%**	**3.50%**
without 5G mmW		min	567,025	0.502	0	21.2	6,567	412	8	2.30%	0.00%	1.30%
p-value of t-test			0.0002 **	0.062	7.3E-06 **	0.025 *	0.49	0.027 *	0.046 *	0.005 **	0.022 *	0.081
Ratio of means			3.32	1.83	N/A	1.09	1.00	1.99	2.33	1.77	1.81	1.18

Data from May 15 and May 31 show the same pattern as for April 22, with statistically significant higher cases/million, deaths/million, cases/test, and deaths/test for the mmW states compared to the non mmW states. For data cumulative through May 31, 2020, comparing mmW to non-mmW states, there were 5776 vs. 3220 cases per million (ratio 1.79, p = 0.012); 307 vs. 158 deaths per million (ratio 1.95, p = 0.049); 9.88% vs. 5.88% cases per test (ratio 1.68, p = 0.003); and 0.494% vs. 0.270% deaths per test (ratio 1.83, p = 0.025) (Table 4B & C; Figure 3A & B; Figure 4A & B).

Table 4. Case and death rates attributed to COVID-19 and Pearson's Correlations for population density, mmW index and their interaction for U.S. states for cumulative data through (A) April 22, 2020; (B) May 15, 2020; and (C) May 31, 2020. Statistical significance is indicated by * (p < 0.05) and ** (p < 0.01). NOTE: YTD is year to date.

A YTD through April 22, 2020	n	Total Tests per million	Total Cases per million	Total Deaths per million	% Cases per Test	% Deaths per Test	% Death per Case
Mean for States with mmW 5G	**32**	**14,378**	**2,500**	**126**	**15.5%**	**0.721%**	**4.13%**
Mean for States without mmW 5G	**18**	**14,324**	**1,288**	**55**	**8.82%**	**0.364%**	**3.50%**
mmW vs. non-mmW 5G		2%	99%	131%	77%	99%	18%
p-value for t-test mmW vs. non-mmW		0.49	**0.027 ***	**0.046 ***	**0.005 ****	**0.022 ***	**0.081**
Pearson Corr. to PopDensity (50 states)			**0.723**	**0.577**	**0.701**	**0.600**	**0.284**
Pearson Corr. to PopDensity*mmW (mmW states)			**0.700**	**0.783**	**0.434**	**0.559**	**0.360**
Pearson Corr. to mmW index (50 states)			**0.479**	**0.580**	**0.353**	**0.431**	**0.302**
Correlation between Population Density and mmW Factor's 0.072, i.e. they are independent of each other, no relationship.							
Pearson Correlation to Air Quality Index			0.094	0.047	0.282	0.183	0.085

B YTD through May 15, 2020	n	Total Tests per million	Total Cases per million	Total Deaths per million	% Cases per Test	% Deaths per Test	% Death per Case
Mean for States with mmW 5G	**32**	**34,606**	**4,595**	**248**	**12.26%**	**0.622%**	**4.60%**
Mean for States without mmW 5G	**18**	**33,932**	**2,459**	**123**	**7.24%**	**0.340%**	**3.97%**
mmW vs. non-mmW 5G		2%	87%	102%	69%	83%	15.9%
p-value for t-test mmW vs. non-mmW		0.44	**0.016 ***	**0.052**	**0.005****	**0.031 ***	**0.12**
Pearson Corr. to PopDensity (50 states)			**0.788**	**0.733**	**0.654**	**0.687**	0.439
Pearson Corr. to PopDensity*mmW (mmW states)			**0.656**	**0.681**	**0.400**	**0.485**	0.306
Pearson Corr. to mmW index (50 states)			**0.422**	**0.442**	**0.321**	**0.329**	0.213
Correlation between Population Density and mmW Factor is 0.073, i.e. they are independent of each other, no relationship.							
Pearson Correlation to Air Quality Index			0.152	0.121	0.284	0.237	0.162

C YTD through May 31, 2020	n	Total Tests per million	Total Cases per million	Total Deaths per million	% Cases per Test	% Deaths per Test	% Death per Case
Mean for States with mmW 5G	**32**	**54,805**	**5,776**	**307**	**9.88%**	**0.494%**	**4.57%**
Mean for States without mmW 5G	**18**	**53,506**	**3,220**	**158**	**5.88%**	**0.270%**	**3.91%**
mmW vs. non-mmW 5G		2%	79%	94%	68%	83%	17%
p-value for t-test mmW vs. non-mmW		0.42	**0.012***	**0.049***	**0.003****	**0.025***	**0.116**
Pearson Corr. to PopDensity (50 states)			**0.793**	**0.774**	**0.623**	**0.695**	**0.495**
Pearson Corr. to PopDensity*mmW (mmW states)			**0.625**	**0.665**	**0.350**	**0.453**	**0.332**
Pearson Corr. to mmW index (50 states)			**0.396**	**0.410**	**0.293**	**0.295**	**0.203**
Correlation between Population Density and mmW Factor is 0.073, i.e. they are independent of each other, no relationship.							
Pearson Correlation to Air Quality Index			0.181	0.143	0.319	0.257	0.169

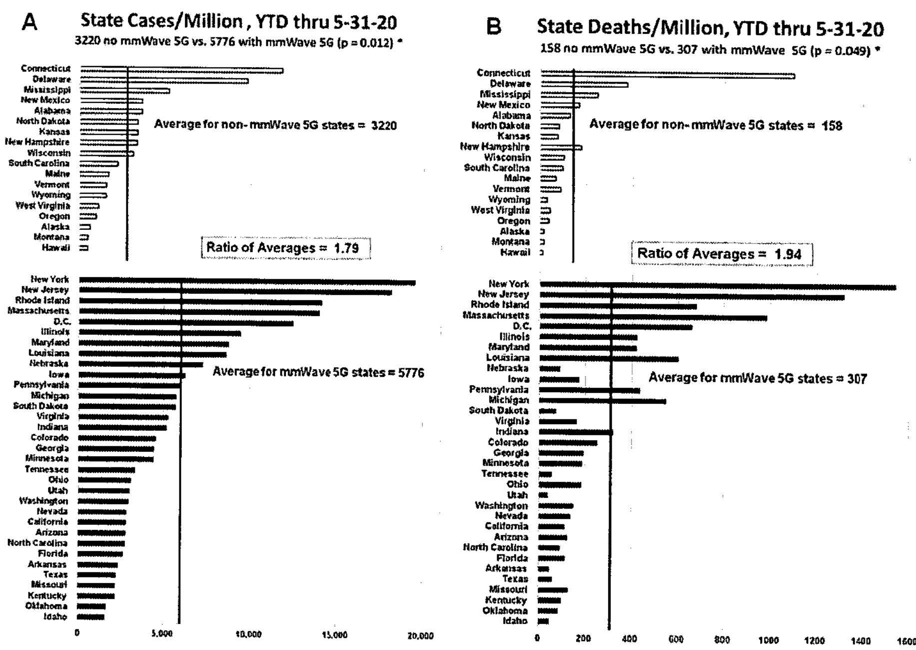

Figure 3. COVID-19 attributed case/million (A) and deaths/million (B) for states with and without 5G mmW for data through May 31, 2020.

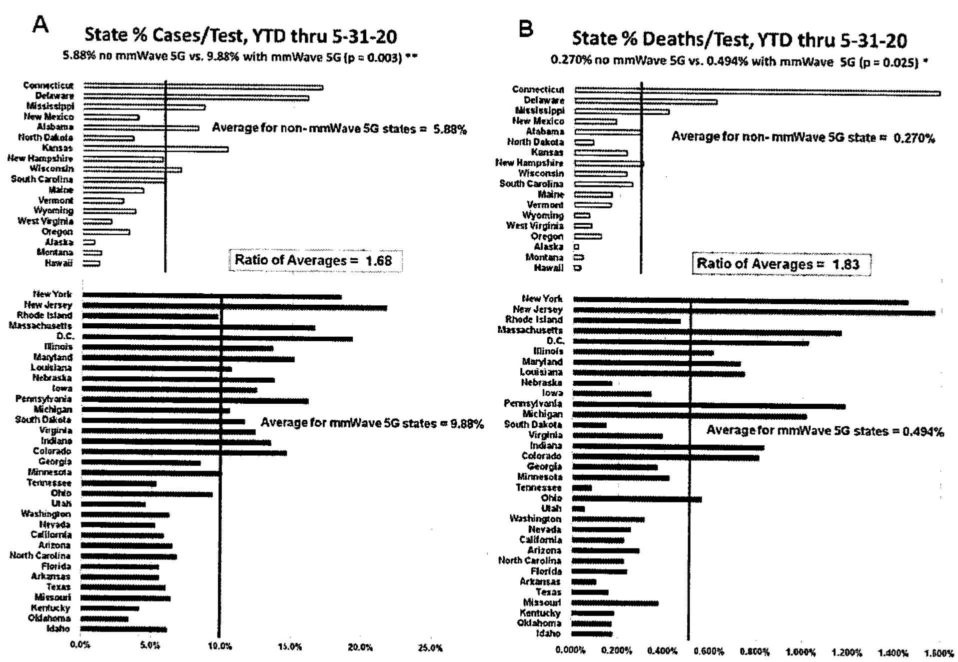

Figure 4. Percentage of COVID-19 attributed cases/test (A) and deaths/test (B) for states with and without 5G mmW technology for data through May 31, 2020. Note: different scale.

3.3 Counties with vs. without 5G mmW

Data for 53 counties with 5G mmW and 49 counties without 5G mmW were analyzed. Comparing mmW to non-mmW counties, there were 7100 vs. 3797 cases per million (ratio 1.87, $p = 0.005$) and 446 vs. 168 deaths per million (ratio 2.65, $p = 0.012$), and these differences were statistically significant. The fatality rate, which is deaths/cases, was higher for the mmW counties (4.70% vs. 4.07%, ratio 1.15), but this difference was not statistically significant (Table 5; Figures 5A and 5B).

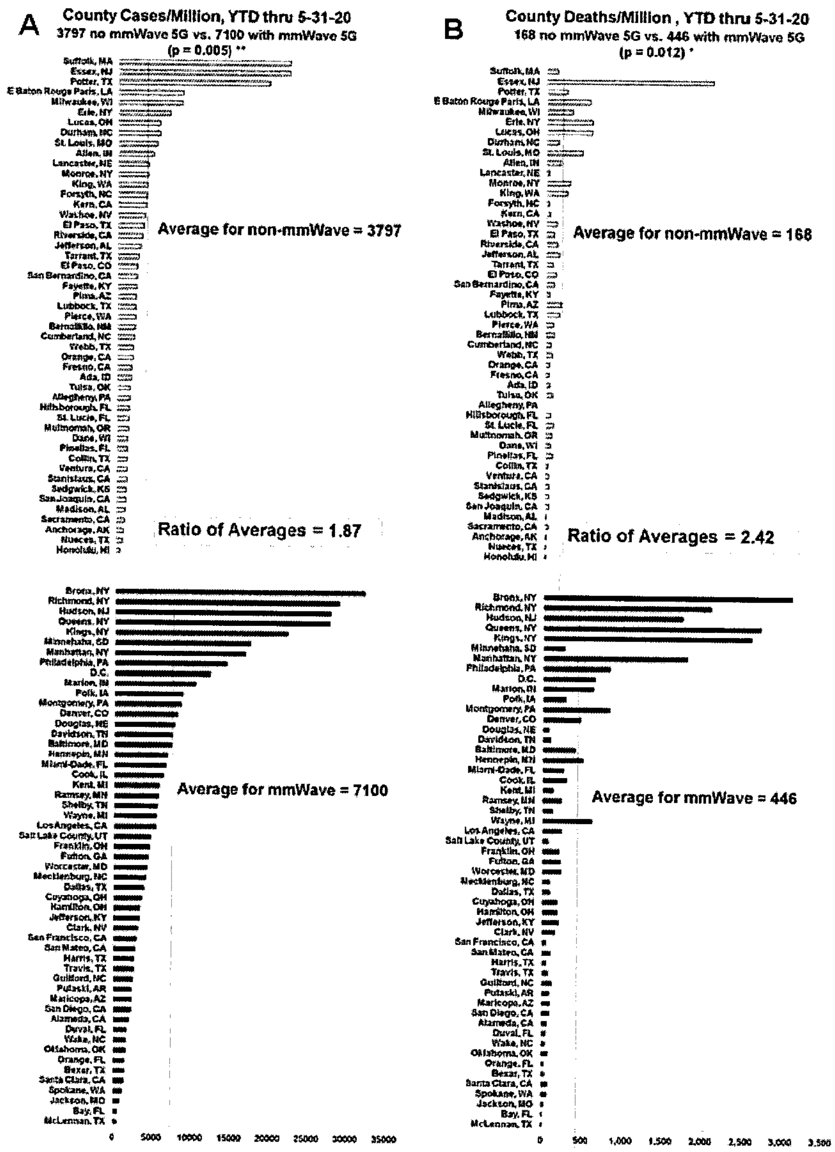

Figure 5. COVID-19 attributed cases/million (A) and deaths/million (B) for counties with and without 5G mmW technology through May 31, 2020. Note: different scale.

Table 5. Descriptive statistics and Pearson's Correlations for *U.S. counties* through May 31, 2020 with and without 5G mmW for population, population density, mmW index, air quality index (AQI), latitude and number of COVID-19 attributed case and death rates. Statistical significance is indicated by * ($p < 0.05$) and ** ($p < 0.01$).

Counties in U.S.	n		County Population	Population Density (people per sq. km)	mmW index	AQI	Latitude	Cases per Million	Deaths per Million	% Deaths per Case
with 5G mmW		max	10,105,518	26,822	3.00	71.0	47.7	32,064	3,105	11.7%
with 5G mmW	**53**	**mean**	**1,509,298**	**2,108**	**0.862**	**44.0**	**37.5**	**7,100**	**446**	**4.70%**
with 5G mmW		min	51,823	28.6	0.02	27.0	25.8	463	16	0.84%
without 5G mmW		max	3,185,968	5,360	0	80.0	61.2	22,141	2,081	10.7%
without 5G mmW	**49**	**mean**	**852,626**	**514**	**0**	**43.7**	**36.9**	**3,797**	**168**	**4.07%**
without 5G mmW		min	119,648	27	0	22.0	21.5	430	0	0.00%
p-value of t-test			0.005 **	0.007 **	3E-11 **	0.44	0.31	0.005 **	0.012 **	0.11
Ratio of means			1.77	4.11	N/A	1.01	1.02	1.87	2.66	1.15
Pearson's Correlation to Pop. Density								0.594	0.699	0.430
Pearson's Correlation to PopDensity*mmW								0.508	0.676	0.446
Pearson's Correlation to mmW								0.615	0.709	0.371
Pearson's Correlation to Air Quality Index								-0.212	-0.169	-0.072
Pearson's Correlation to Latitude								0.268	0.228	0.199

3.4 California Counties with vs. without 5G mmW

Data for six counties with 5G mmW and 11 counties with a population of 500,000 or greater without 5G mmW in California were analyzed. The six counties with 5G mmW technology were San Francisco, Los Angeles, San Diego, Alameda, Santa Clara, and San Mateo. The 11 counties that did not have 5G mmW technology were Orange, San Bernardino, Contra Costa, Sacramento, Riverside, Kern, Fresno, Ventura, San Joaquin, Stanslaus, and Sonoma. The mmW counties had higher average cases per million (2750 vs. 1679, ratio 1.64, p = 0.06) and significantly higher average deaths per million (102 vs. 52, ratio 1.96, p = 0.064 and higher fatality rate (3.75% vs. 3.01%, ratio 1.25, p = 0.131) than that of the non-mmW counties (Table 6).

3.5 Pearson's Correlations

A Pearson's correlation coefficient assesses the relationship between two variables. The correlation coefficient is considered very strong between ±0.7 and ±1; strong between ± 0.5 and ± 0.7, and moderate between ± 0.3 and ± 0.49.

Pearson's correlations of cases/million, deaths/million, cases/test, and deaths/test to air quality index, latitude population density, and mmW index were calculated. The results are in Table 4 for states, Table 5 for counties, and Table 6 for California.

Table 6. Descriptive statistics and Pearson's Correlations for *California counties* through May 31, 2020 with and without 5G mmW for population, population density, mmW index, air quality index (AQI), latitude and number of COVID-19 attributed case and death rates. Statistical significance is indicated by * ($p < 0.05$) and ** ($p < 0.01$).

Counties in California	n		County Population	Population Density (people per sq. km)	mmW index	AQI	Latitude	Cases per Million	Deaths per Million	% Deaths per Case
with 5G mmW		max	10,105,518	7,245	1.20	71	37.8	5,309	231	5.16%
with 5G mmW	**6**	**mean**	**3,117,676**	**1,653**	**0.61**	**48**	**36.2**	**2,750**	**102**	**3.75%**
with 5G mmW		min	769,545	262	0.22	35	32.8	1,409	46	1.62%
without 5G mmW		max	3,185,968	1,352	0	80	38.6	3,055	138	4.53%
without 5G mmW	**11**	**mean**	**1,367,642**	**400**	**0**	**54**	**36.2**	**1,679**	**52**	**3.01%**
without 5G mmW		min	499,942	38	0	34	33.9	909	8	0.73%
p-value of t-test, with vs. without 5G mmW			0.144	0.159	0.007 **	0.236	0.498	0.060	0.064	0.131
Ratio of means, with vs. without 5G mmW			2.28	4.13	N/A	0.89	1.00	1.64	1.98	1.25

	Cases per Million	Deaths per Million	% Deaths per Case
Pearson's Correlation to Pop. Density	0.250	-0.046	-0.292
Pearson's Correlation to PopDensity*mmW	0.294	-0.006	-0.296
Pearson's Correlation to mmW	0.705	0.591	0.157
Pearson's Correlation to Air Quality Index	0.512	0.557	0.305
Pearson's Correlation to Latitude	-0.470	-0.481	-0.210

3.5.1 Correlations of Case and Death Rates with Population Density

Population density is strongly correlated with the rates of cases/million, cases/test and deaths/million, and deaths/test in the 50 states (r =0.60 to 0.79 for April through May) (Table 4). Population density is an indicator of person to person contact as well as the amount of wireless radiation exposure. For example, in New York City, many reside in multi-level apartment buildings where they are exposed to many Wi-Fi routers and other wireless devices from closeby neighbors. In addition, Wi-Fi routers from certain providers have public Wi-Fi hot spots that provide service to other customers. These hot spots give off enough radiation to wirelessly connect anyone within a 100 meter radius [13]. Those living in an apartment complex in the middle of a large urban city are likely to be exposed to more Wi-Fi hotspots than those living in single family homes in the suburbs. So even though population density is a major factor in transmission, higher population density also inherently means higher wireless radiation exposure from neighbors (Table 4 for state data and Table 5 for county data).

At the county level, population density was also found to be strongly correlated with the case and death rates. Pearson's correlations between cases/million and population density was 0.594, between deaths/million and population density was 0.699, and between deaths/cases and population density was moderate, at 0.43 (Table 5). These correlations for population density are comparable to those reported in other studies. A study [14] found a Pearson's correlation of ~0.6 for public transit to COVID-19 cases per million, and a ~0.5 correlation for population density to COVID-19 cases per million. A Brazilian study reported a negative correlation between COVID-19 cases and temperature (r = -0.38) and a positive relationship between COVID-19 cases and population density (r = 0.51) [15].

3.5.2 Correlations of Case and Death Rates with Millimeter Wave Exposure

The mmW index is moderately to strongly correlated with cases per million, cases per test, deaths per million, and deaths per test for the 50 states. For cumulative data through April 22, 2020, the Pearson's correlations with the mmW index for the cases/million (r = 0.479) and deaths/million (r = 0.580) were the highest of the correlations from the data from April and May. From April to May, the same correlations trended downward slightly, but multiple linear regression with cumulative data through May 31, 2020 determined that mmW index was a statistically significant factor in the case and death rates, which is discussed later. The correlation between population density and mmW index is very low at 0.072, meaning that population density and mmW index are not correlated to each other, and that a high mmW index area is not necessarily a high density area. This is important, because it means that the higher rates of cases and deaths in mmW states are not solely because of the higher population density that may be present in those states.

At the county level, mmW exposure was also found to be strongly correlated with the case and death rates. Pearson's correlation for the mmW index and for cases/million was 0.615, for deaths/million it was 0.709, and for deaths/cases it was a moderate 0.371 (Table 5).

For California counties, there were strong correlations between the mmW exposure index and cases per million (r = 0.705) and deaths per million (r = 0.591), There were strong correlations also for the air quality index (AQI) and the cases (r = 0.512) and deaths (r = 0.557) per million (Table 6). However, population density and latitude were not well correlated with the cases and deaths per million for California counties.

3.5.3 Synergy between Population Density with mmW Exposure

There was a positive interaction between population density and the mmW index acting together that was greater than the effect of population density or mmW acting singularly on the deaths per million in the cumulative data through April 22. This is because the interaction of population density with mmW index (PopDensity*mmW) had a higher correlation (0.783) to deaths/million (Table 4A) than either the correlation of population density (0.577) or mmW index (0.580) alone did with deaths/million, meaning that the combined action of population density with mmW index had a stronger effect on deaths/million than either population density or mmW index did singularly.

3.5.4 Correlations of Case and Death Rates with Latitude and Vitamin D

Latitude is an indicator of potential sun exposure and vitamin D production. As latitude increases, the intensity of the radiation from the sun decreases, which reduces endogenous vitamin D production. Higher latitudes have been found to be partially associated with increased COVID-19 mortality rates [16]. Low vitamin D levels have been found to be a risk factor for the COVID-19 complications, which will be discussed later. Latitude was found to have a weak correlation with the case and death rates (0.199 to 0.268 in Table 5), however, based on regression analysis, which will be discussed later, latitude was a statistically significant factor in the case and death rates.

3.5.5 Correlations of Case and Death Rates with Air Quality Index (AQI)

AQI was found to have very little to weak correlation with the case and death rates in the state and county analysis for the U.S. For the states, the correlations ranged from 0.047 to 0.319 (Tables 4A–C), and at the county level, the correlations ranged from -0.212 to -0.072 (Table 5). For California counties, air quality was strongly correlated with the cases per million and deaths per million ($r = 0.512$ and $r = 0.557$ respectively, Table 6), and air quality was a statistically significant factor for the cases per million and deaths per million ($p = 0.0016$ and $p = 0.0031$ respectively, Table 7)

Air quality does have an impact on respiratory diseases. AQI ranges from 0-500, and air is considered unhealthy above 100, very unhealthy from 201-300, and hazardous at 301-500. The average AQI data for all states was between 21.2 to 51.2, indicating relatively clean air, which may be why AQI did not show up as a significant factor at the state level. Furthermore, the AQI used was a yearly average and not live data, and during the lockdowns emissions from cars and industry were significantly reduced, which likely made the actual air quality that people were exposed to better than the AQI data used.

3.6 Multi-Variate Analysis shows Population Density, Latitude, mmW Index are Statistically Significant Factors in the Case and Death Rates

According to multiple linear regression, at the state level, population density and mmW index were statistically significant contributors to the rates of cases and deaths; urbanization was found to not be a statistically significant factor compared to population density and mmW index. At the county level, population density, mmW index, and latitude were statistically significant contributors to the rates of cases and deaths. For California counties, only the AQI and mmW index were statistically significant contributors ($p<0.01$) to the case and death rates.

For case and death rates, the p-values for population density were between 1.02E-13 to 0.0064 for mmW states and counties; the p-values for mmW index were between 5.00E-06 to 0.026 for mmW states, counties, and California counties; the p-values for latitude were 0.014 and 0.045 for mmW counties; the p-values for AQI were 0.0016 and 0.0031 for California counties (Table 7). All regression equations and the p-values for density, mmW index, AQI, latitude are given in Table 7.

Multi-variate analysis using multiple linear regression showed the higher mean population density in the mmW states and counties is not the main reason for their higher case and death rates, that mmW index has at least as great an impact as the higher density. At the state level, the contribution of the mmW index is about the same as that from the higher density, but at the county level, the contribution from mmW index is at least three times higher than that from density (Table 8).

The regression equation for state cases/million (Table 7) is: Cases/million = 1418 + 32.54 state density + 7100 mmW index, with an adjusted R^2 of 0.732 , which means that 73.2% of the variation in cases/million is explained by the state population density and the mmW index, and the adjusted R^2 measures how close the data are to the fitted regression line. Both the state population density and the mmW index are statistically significant contributors to the cases/million ($p < 0.01$ for both, Table 7), and the regression equation is statistically significant with p-value = 1.35E-14, which is much less than $p < 0.01$ (Table 7). The increase in state population density between average mmW state and average non-mmW state is 91.7-50.2 = 41.5 (Table 3). So, the contribution to the mean case/million for mmW states from its higher average population density = 32.54*41.5 = 1350 (Table 8). The increase in mmW index between average mmW state and average non-mmW state is = 0.207 – 0 = 0.207 (Table 3). So, the contribution to the mean cases/million for mmW states from its mmW exposure index = 7100 * 0.207 = 1470 (Table 8). Therefore, the contribution to the mean cases/million for mmW states from mmW exposure is almost the same, but slightly higher than it is from the higher population density (1470 vs. 1350 out of the 5776 actual cases/million (Table 8). Thus, the higher mean cases/million for the mmW states is due to the higher average population density AND the mmW exposure of those states, with the contribution from each being about the same.

The regression equations also predict what the case and death rates would be if there was no mmW exposure. For example, the mean cases/million of the mmW states is 5776 cases/million; however, if there was no mmW in these states, the same regression equation predicts that the mean cases/million would be 24% lower, at 4403 cases/million (Table 8).

For all of the case and death rates for states, counties, and California, the contributions from the higher population density and from the mmW exposure of the mmW states and counties are given in Table 8, as well as what the predicted case and death rates would be if there was no mmW exposure.

Table 7. Regression Equations for data cumulative through May 31, 2020. Statistical significance is indicated by * ($p < 0.05$) and ** ($p < 0.01$).

	Regression R^2 adj	p-value for Regression (Sig. F)	p-value for Pop. Density	p-value for mmW index	p-value for latitude	p-value for AQI
States:		**	**	**		
Case/Million = 1418 + 32.54 State Density + 7100 mmW index	0.732	1.35E-14	1.0E-13	3E-05	not sig.	not sig.
Death/Million = 12.2 + 2.46 State Density + 577 mmW index	0.713	6.83E-14	7.2E-13	3E-05	not sig.	not sig.
		**	**	*		
Case/Test = 0.0534 + 0.000299 State Density + 0.0606 mmW index	0.427	7.89E-07	1.2E-06	2.6E-02	not sig.	not sig.
Death/Test = 0.00144 + 2.68E-05 State Density + 0.00480 mmW index	0.525	9.73E-09	1.3E-08	1.6E-02	not sig.	not sig.
Counties in US:		**	**	**	*	
Case/Million = -5080 + 0.576 Density + 218 Latitude + 3770 mmW index	0.448	2.80E-13	6.4E-03	2.5E-04	1.4E-02	not sig.
Death/Million = -435 + 0.0652 Density + 13.4 Latitude + 361 mmW index	0.587	2.10E-19	6.4E-05	5.0E-06	4.5E-02	not sig.
Counties in CA:		**		**		**
Case/Million = -268+ 36.6 AQI + 2012 mmW index	0.725	4.71E-05	not sig.	9.9E-05	not sig.	1.6E-03
Death/Million = -49.7 + 1.96 AQI + 83.1 mmW index	0.610	5.37E-04	not sig.	2.0E-03	not sig.	3.1E-03

Table 8. Predicted Values and Contributions from mmW index and higher mean density for mmW state or county for data cumulative through May 31, 2020.

	Actual Value	Predicted by Regression if no mmW	Predicted Change if no mmW	Predicted Contribution from mmW	Predicted Contribution from Higher Mean Density of mmW state or county	Ratio of Contribution mmW:Higher Mean Density of mmW state or county
mmW States:						
Mean Case/Million	5776	4403	-23.8%	1470	1350	1.09
Mean Death/Million	307	214	-30.4%	119	102	1.17
Mean Case/Test	9.88%	8.09%	-18.1%	1.25%	1.24%	1.01
Mean Death/Test	0.494%	0.390%	-21.1%	0.099%	0.111%	0.89
mmW Counties in US:						
Mean Case/Million	7100	4320	-39.2%	3260	918	3.55
Mean Death/Million	446	204	-54.3%	312	104	3.00
mmW Counties in CA:						
Mean Case/Million	2750	1487	-45.9%	1227	N/A	N/A
Mean Death/Million	102	44.4	-56.5%	50.7	N/A	N/A

Figure 6 shows that the mmW exposure factor is better correlated than the population density with the case and death rates, and this is also seen in the higher R^2 for the mmW exposure factor. For the cases/million, the R^2 was 0.501 for the mmW exposure as a predictor compared to the R^2 of 0.363 for population density, and for the deaths/million, the R^2 was 0.632 for the mmW exposure as a predictor compared to the R^2 of 0.526 for population density.

These R^2 for COVID-19 case and death rate regressions as a function of mmW exposure, population density, and latitude are better than those found by others. In New York a positive correlation between COVID-19 cases per million and population density was $R^2 = 0.17$, $p < 0.01$, and between cases per million and public transportation commute ratios, $R^2 = 0.25$, $p < 0.01$ [17].

4. Discussion

The world changed in March 2020 after the WHO classified COVID-19 as a pandemic and as countries closed their borders and initiated social distancing. Admittance to hospital intensive care units (ICU) reached an all-time high in some places and elderly patients were moved to nursing homes, where residents and staff quickly developed fatal symptoms of COVID-19.

Ventilators, commonly used for respiratory ailments, were not as effective as expected and doctors around the world were sharing their concerns about treatment protocols that were not working. Atypical cardiovascular complications were also being reported, including blood clots, hypoxia, arrhythmia, lower hemoglobin levels and strokes even in younger patients [18-19].

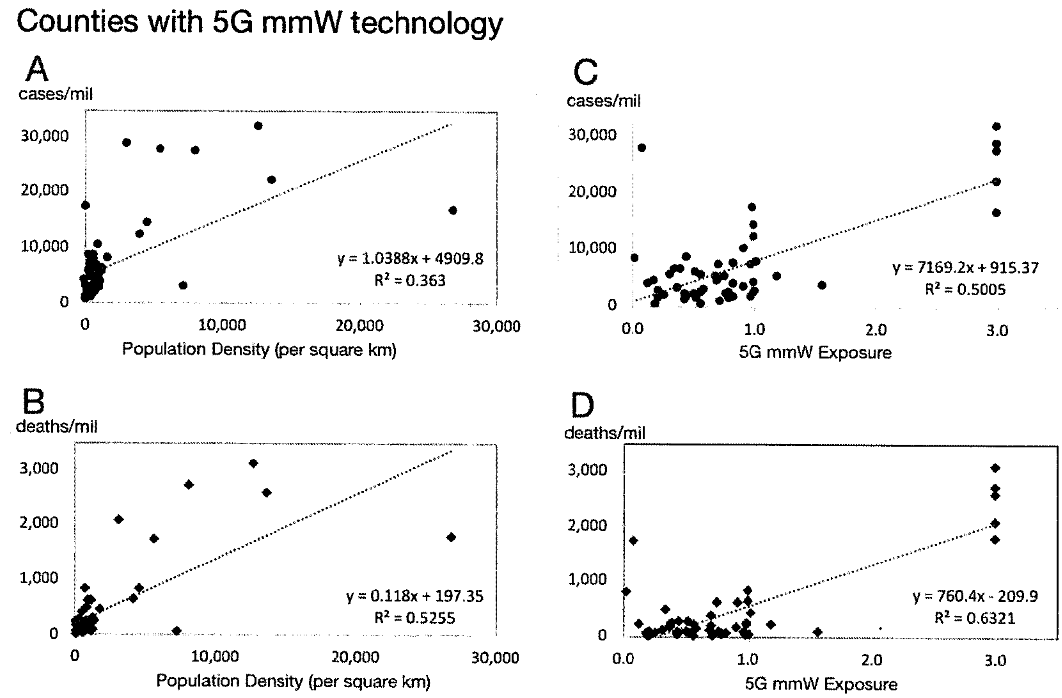

Figure 6. Regression plot for 53 counties with 5G mmW technology for COVID-19 attributed cases/million and deaths/million as a function of population density (A & B) and as a function of 5G mmW exposure (C & D) through May 31, 2020.

COVID-19 was clearly different than previous viral respiratory illnesses, and one theory was proffered that COVID-19 may be associated with the rollout of 5G mmW technology, which had occurred just prior to the first cases of COVID-19 in China [20].

Our results show a statistically significant increase between the COVID-19 attributed cases and deaths in states and counties in the U.S. with vs. without 5G mmW technology. States with 5G mmW technology had excess cases and excess deaths per million when compared to states without this technology, which was the case for three different dates: April 22, May 15 and May 30. When we examined U.S. counties, to determine how robust this relationship was, we got the same trend.

Multiple linear regression and Pearson's correlation coefficients have shown that the mmW index was statistically significant to the case and death rates in the analyses for states, counties, and California counties, i.e., in all three analyses, while population density was statistically significant for two of the analyses, and air quality index and latitude were statistically significant for only one of the analyses.

4.1 COVID-19 Anomalies and Wireless Radiation

There are some unique anomalies in COVID-19 that distinguish it from other viral infections. These anomalies are multiple blood clots that form in organs and blood vessels, severe inflammation, hypoxia and hypoxemia, and skin lesions even in those who test negative for SARS-CoV-2 (suggesting that their symptoms may be due to something other than SARS-CoV-2), and symptoms lingering for months after initial onset of the infection that resemble microwave sickness symptoms. The interesting thing about these anomalies are that RF exposure can exacerbate all of them.

Some COVID-19 patients report they have been sick for many months, despite testing negative for the SARS-CoV-2 virus, with numerous symptoms of microwave sickness. Microwave sickness, which the World Health Organization refers to as idiopathic environmental intolerance attributable to electromagnetic fields (IEI-EMF), is the medical term for the syndrome of symptoms that result from chronic exposure to non-ionizing radiation. It is also referred to as electromagnetic sensitivity per the Americans with Disabilities Act (ADA) or electrohypersensitivity (EHS) in some scientific studies. However, electromagnetic illness (EMI) is perhaps a more appropriate term since RFR exposure has the potential to affect all humans and not only those who are highly sensitive to this radiation. Most of the symptoms that these long COVID-19 patients have in common with microwave sickness are headaches, fatigue, difficulty concentrating, memory problems, insomnia, cardiovascular abnormalities like palpitations and tachycardia, tinnitus, anxiety, depression, and skin lesions according to a COVID-19 Survey Report by Indiana University School of Medicine [21]. At least 24 of the long COVID symptoms reported in the survey are also symptoms of microwave sickness, aka EHS [22] (Figure 7).

Wireless radiation is a toxic substance that degrades the immune system, and *"[e]xposure to myriad toxic substances degrades the immune system, whose dysfunction is then exploited by SARS-CoV-2 to result in COVID-19,"* [23]. A recent Russian study found a strong correlation between a country's exposure limits for RF radiation and COVID-19 deaths per million (r=0.577) and deaths per cases (r=0.551) [24].

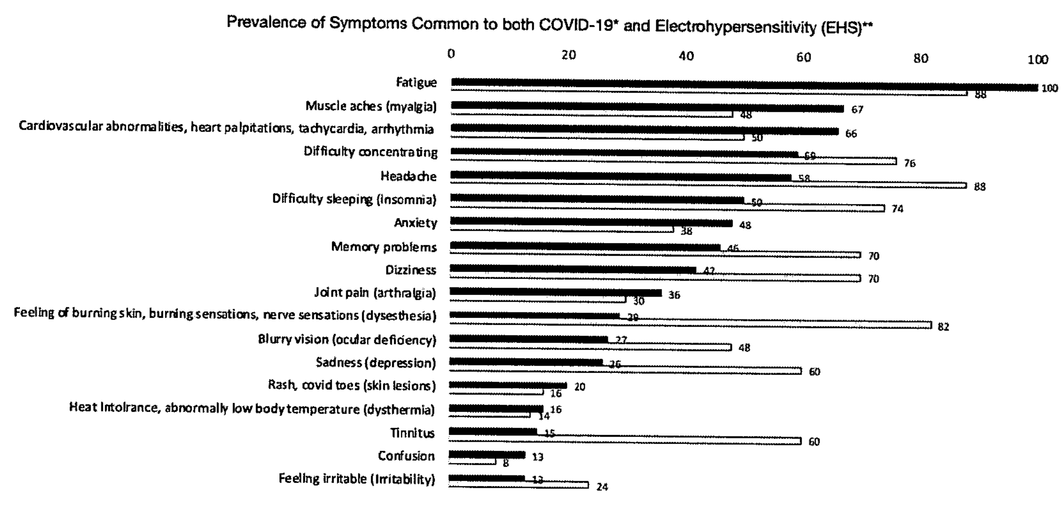

Figure 7. Prevalence of symptoms common to both COVID-19 and Electrohypersensitivity (EHS). Sources: *[21], **[22]

4.2 Common Mechanisms of Harm and Synergistic Effects between RF Radiation and COVID-19.

Radio frequency radiation (RFR) shares some mechanisms of harm with SARS-CoV-2 which could act synergistically with SARS-CoV-2 to promote and prolong infection. As explained below: (1) RFR impairs the immune system which would contribute to a greater number of people becoming infected and dying from disease [25-28]; (2) RFR is known to increase free-radicals and contribute to oxidative stress, leading to increased inflammation [29-33]; (3) RFR affects the blood, heart, and autonomic nervous system resulting in some combination of hypoxia, tachycardia, arrhythmia, rouleaux formation, and sympathetic up-regulation [34-36]; (4) RFR interferes with the body's repair mechanisms [37-39]; and (5) a growing population (between 1% – 10%) in developed countries is unable to tolerate current levels of RFR [40-41], developing symptoms of microwave sickness that are similar to those reported for long COVID-19 (Figure 7).

Microwave sickness is triggered by our increasing exposure to RFR emitted by mobile and cordless phones, cell phone base stations, radar, broadcast antennas, Wi-Fi, Bluetooth, smart meters, smart appliances, smart homes, smart light bulbs, wireless security systems, wireless personal assistants, wireless baby monitors, and wireless wearables, and now an increasing number of people are also exposed to 5G mmW.

Higher radiation exposures result from the shorter distance to people and higher density of antennas for 5G mmW. This is acknowledged by the FCC proposal in December 2019 to increase the current exposure limits four-fold to accommodate 5G mmW devices and infrastructure. The current exposure limit for the general population of 1000 $\mu W/cm^2$ averaged over a 30-minute period has been the guideline since 1996 per FCC 47 CFR Ch. I § 1.1310 and the FCC has proposed to increase that to 4000 $\mu W/cm^2$ indefinitely in its 2019 FCC Notice of Proposed Rulemaking 19-126 [9].

5G mmW have not been tested for their long-term biological effects and there is growing concern from the scientific and medical communities that this technology could have adverse biological consequences. Studies suggest that mmW can contribute to ocular damage, arrhythmias, antibiotic resistance among bacteria, teratogenic effects in drosophila, and impaired immunity in mice [42]. Even though mmW are absorbed mostly in the skin, systemic signaling in the skin from mmW can result in physiological effects on the nervous, cardiovascular and immune systems mediated through neuroendocrine mechanisms [42]. A compendium of 3800 studies showing a myriad of harmful biological effects from RFR at non-thermal levels (and below FCC's exposure limits) are contained in the 2012 BioInitiative Report [43].

4.3 Wireless Radiation affects the Immune System, increases Oxidative Stress and Inflammation

There is a common presumption that mmW are safer than the lower frequencies used in 4G and previous generations of wireless communications because mmW are mostly absorbed in the skin. However, biological responses to mmW irradiation can be initiated within the skin, and the subsequent systemic signaling in the skin can result in physiological effects on the nervous system, heart, and immune system [44]. The cities with 5G mmW would have the most varied and highest potential RF exposure levels because 5G mmW requires the use of multiple small cells in close proximity to users and all three bands of frequencies for 5G, in addition to radiation from previous generations of wireless communications..

Additionally, severe inflammation has been reported in COVID-19 cases, and oxidative stress is a cause of inflammation [45]. There are many studies showing that wireless radiation causes oxidative stress and generates free radicals [29-33, 46-48]. A review by an expert committee appointed by the Swiss government found that RF-EMF increased oxidative stress which can lead to changes in oxidative balance, and that those with pre-existing conditions (immune deficiencies or diseases such as diabetes and neurodegenerative diseases) that compromise the body's defense mechanisms (including antioxidative protection) can experience more severe health effects from EMF exposure; also, young and elderly individuals can react less efficiently to oxidative stress induced by EMF [49]. So chronic RF exposure creates oxidative stress and oxidative stress leads to inflammation. RF exposure has also been shown to directly increase inflammation by the production of pro-inflammatory cytokines that cause the immune system to overreact [50].

There are many studies showing the effect of wireless radiation on the immune system [27, 43]. A 2013 review found that wireless radiation has a stimulating effect on the immune system initially with short-term exposure, and an immunosuppressive effect with chronic exposure [26]. Cell phone radiation exposure for 1 hour per day for 30 days compromised the immune system of rats, resulting in a significant decrease in immunoglobulin levels, total leukocyte, lymphocyte, eosinophil and basophil counts; and a significant increase in neutrophil and monocyte counts [51]. Shielding from EMFs was found to significantly improve immune function and decrease inflammation in humans; lymphocyte NK (natural killer) cell activity increased by 30% after EMF exposure was reduced for two months [52]. In 2015, a significant discovery was made that the brain was directly connected to the immune system by lymphatic vessels [53], which would mean that the immune system can be affected directly by the brain and environmental influences that affect the brain, such as wireless radiation. A U.S. government study under the National Institute of Health found that cell phone radiation can affect the brain by increasing glucose metabolism in the brain [54] .

4.4 Wireless affects Vitamin D and Vitamin D Receptor

Vitamin D is essential to the proper functioning of the immune system. Low vitamin D levels have been associated with the most severe symptoms of COVID-19. Patients with low vitamin D are twice as likely to experience major complications from COVID-19 [55]. Another study found that 85% of severe COVID-19 patients had vitamin D insufficiency, and that 100% of ICU patients less than 75 years old had vitamin D insufficiency [56]. The case fatality rate of COVID-19 was highest in European countries with the highest incidence of severe vitamin D deficiency, and supplementation with vitamin D may reduce COVID-19 mortality [16].

Vitamin D deficiency can result from inflammation caused by chronic wireless radiation exposure [40]. Vitamin D supplementation was also found to reverse the negative effects of cell phone radiation on the immune system of rats [41]. Wireless radiation also lowers vitamin D receptor (VDR) activity by changing the shape of the VDR, thus impairing VDR activity and its ability to bind with vitamin D [28]. This is important because when a T-lymphocyte is exposed to a foreign pathogen, it extends a VDR to search for vitamin D, and if there is insufficient vitamin D, T-lymphocytes will not activate to destroy the invading pathogens [57].

4.5 Wireless Radiation depletes Glutathione which reduces Vitamin D and promotes Infection

There's evidence that low endogenous glutathione production has led to complications in COVID-19 and that low glutathione levels reduce vitamin D levels [58]. Vitamin D was also found to correlate positively with glutathione levels in type II diabetic patients [59], who have an increased risk for COVID-19 complications. Glutathione treatment of patients with COVID-19 pneumonia successfully prevented the cytokine storm in COVID-19 patients [60]. Several studies have shown reduced glutathione production from wireless radiation exposure. Glutathione was found to be at statistically significant lower levels in those living close to a cell tower (within 80 m) exposed to 100 times higher RF radiation compared to those living far from a cell tower (300 m or more) [37]. Another study found that radar workers in the military who had been working with radar for over 10 years had less than 50% of glutathione levels of non-radar workers, and this lower level was statistically significant [30].

4.6 Wireless Radiation lowers Oxygen Intake and damages Mitochondria

RF exposure also affects the structure of hemoglobin, reducing its ability to bind to oxygen. After just two hours of exposure to cell phone radiation, human hemoglobin structure changed, decreasing its affinity to bind to oxygen in the lungs between 11-12% [34] which reduces the amount of oxygen that would be carried from the lungs to the body's tissues, contributing to hypoxia. This is important because SARS CoV-2's ability to infect cells is enhanced when blood oxygen levels decline. The "furin cleavage" sequence in the virus activates increased ACE2 receptor attack and cellular invasion in low oxygen environments [61].

RF radiation also affects the electron transport chain in mitochondria. Mitochondria supply the energy in cells and consume the majority of oxygen in the cell. RF exposure leads to mitochondrial dysfunction, leading to lowered oxygen consumption in the cell and less energy production, which would cause fatigue. Wireless sources of EMF causing extensive electron leakage from the mitochondrial electron transport chain was attributed as the main cause of EMF damage in human reproductive cells, and wireless EMF exposure increased production of reactive oxygen species (ROS) by mitochondria [32].

4.7 Wireless Radiation promotes Blood Clotting

Vitamin D also has an anticoagulant effect, and low vitamin D levels have been shown to increase the chance of venous blood clots [62].

Formation of blood clots leading to strokes and other complications have been reported in COVID-19 cases in the young and middle-aged with no risk factors for clotting. In children, a condition associated with COVID-19 known as Multisystem Inflammatory Syndrome in Children (MIS-C) with symptoms including "COVID Toes" involves inflammation of the blood vessels and the formation of blood clots.

RF exposure can cause red blood cells to clump and stick together, known as rouleaux formation [35-36] (Figure 8). As early as 1978, effects of mmW on blood were found to cause a "tendency toward hypercoagulation" at an exposure of 1000 $\mu W/cm^2$ or less [63]; 1000 $\mu W/cm^2$ for 30 minutes is the current exposure limit for mmW for the public in the U.S.

Electromagnetic fields were found to increase the risk for blood clot formation [64]. Other studies have also shown changes in blood viscosity and rouleaux formation with frequencies of 2 kHz [65]. Frequencies in the 0-3 kHz range are found in wireless communications in the form of pulsation and modulation, and there is significant evidence that the biological effects from wireless communications is because of these electric fields; in addition, the application of pulsed electromagnetic fields (PEMF) for short periods of time have therapeutic effects [44] such as the stimulation of bone growth [66]. The right modulation in pulsating electrostatic field therapy can reduce rouleaux formation [67]. Electromagnetic fields have been used for over a hundred years therapeutically, and PEMF devices, approved by the FDA, have been used in animals and humans to reduce inflammation, increase circulation and reduce pain [68]. The fact that RF radiation at non-thermal levels is used in medical therapy means that there are biological effects of RF radiation at non-thermal levels. In addition, mmW are used in medical therapy, including cancer therapy. At power density levels far exceeding the FCC permissible levels for wireless communications of 1000 $\mu W/cm^2$, mmW have been used to stimulate immune cell activity suppressed by anti-cancer drugs [69-70]. Chronic RF radiation exposure within the FCC permissible levels disturbs immune function through stimulation of various allergic and inflammatory responses; for example, RFR increases mast cells in the skin, morphologically alters immune cells, and interferes with tissue repair processes [25]. Anti-inflammatory effects of mmW, achieved only with specific modulation frequencies for certain mmW carrier frequencies, have been used therapeutically also; but without the correct modulation frequency, certain carrier mmW frequencies were "ineffective" [71]. Therefore, it is not just the mmW carrier frequency, but also its combination with pulsation and modulation frequencies that determine biological effects. Medical therapy using RF and mmW radiation is achieved only under controlled conditions, with specific carrier and pulsation and modulation frequencies at specific power densities over a specific and relatively short period of time. The RF radiation that we are exposed to from wireless communications is constant and random, with varying power densities, layered with many frequencies from different sources that use pulsation and modulation frequencies needed to enable wireless communications without consideration of biological effects. Consequently, medical mmW and telecommunication mmW have very different biological impacts due to different exposure parameters.

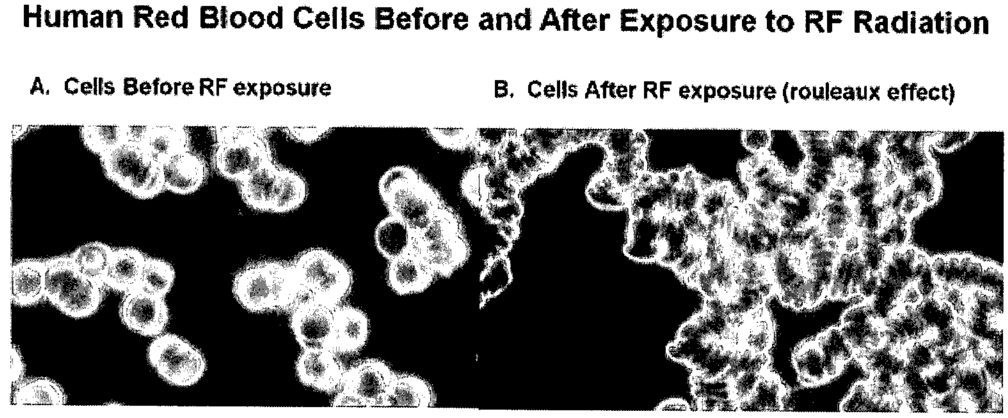

Figure 8. In A., red blood cells are not aggregated prior to RF radiation exposure. In B., blood cells from the same patient after 10 minutes of exposure to 2.45 GHz Wi-Fi aggregate and exhibit rouleaux effect.

4.8 Both Wireless Radiation and SARS-CoV-2 interfere with Calcium Channels in the Cell Membrane

Cell membranes are considered the major target for the interaction between mmW and biological systems, and the waves may alter structural and functional properties of membranes [72]. The cell membrane becomes more permeable from RF exposure from cell phones due to changes in the phospholipid composition at exposure levels well under the current FCC exposure limit. This increased cell membrane permeability altered the expression of 178 genes significantly ($p < 0.05$), affecting processes such as DNA replication and repair, cell signalling and calcium signalling, nervous system function, immune system response, lipid metabolism, and carcinogenesis [38]. Voltage gated calcium channels (VGCC's) located in cell membranes control intracellular calcium ion (Ca^{2+}) concentrations, and exposure to electromagnetic fields has been shown to increase intracellular Ca^{2+} concentration in human lymphocyte cells between approximately 25–50%, and this higher intracellular Ca^{2+} concentration in human lymphocyte cells increases allergic reactions [73]. Increasing intracellular Ca^{2+} concentrations have a myriad of health effects, from headaches to cancer in humans [66].

A related virus, porcine deltacoronavirus, attacks host cells by opening their voltage gated calcium channels (VGCCs) in the cell membrane, which increases the calcium ion (Ca^{2+}) concentration inside host cells which increases virus replication. Reducing the intracellular calcium by blocking VGCC's reduced the infection [74]. Anti-viral medications work by inhibiting VGCC activation to reduce intracellular Ca^{2+} to inhibit the viral replication [75].

4.9 Both Wireless Radiation and SARS-CoV-2 interfere with Cell Signalling via p38/MAPK and mTOR Pathways

SARS-CoV-2 takes over a human host cell by interfering with phosphorylation cell signalling and altering the phosphorylation of 40 human proteins and 49 kinase enzymes, involving the p38/MAPK and mTOR pathways among others. This takeover of the human host cells by the virus prevents the host cell from replicating and provides a stable environment for viral replication [76]. Signals from wireless communications have also been found to interfere with cell signalling and phosphorylation in the p38/MAPK and mTOR pathways, which were associated with an increased permeability in cell membranes due to changes in its phospholipid composition following exposure to radiofrequency radiation [38]. There have been many studies on the interaction of EMFs with cell signalling systems; interference with cell signalling and phosphorylation was reported in an earlier study that found that pulsed EMFs rapidly activates the mTOR signalling pathway [77].

For all the above reasons, environmental exposure to 5G mmW can increase cases and severity of COVID-19.

5. Conclusion

While 5G did not cause COVID-19, statistical analysis showed that exposure to 5G mmW (which is present in combination with 1G-4G and other RFR sources like Wi-Fi) is a statistically significant factor associated with higher COVID-19 case and death rates in the U.S. The higher population densities in the 5G mmW states or counties is another statistically significant factor but it does not entirely account for the higher case and death rates in those states and counties. Population density is an indicator not only of person to person contact, but also of wireless radiation exposure from neighbours. Latitude was also found to be a statistically significant factor that increases case and death rates for 5G mmW counties. Air quality was not found to be a statistically significant factor in the case and death rates except for California counties.

The higher case and death rates in the average mmW state or county compared to that of the average non-mmW state or county were statistically significant for multiple dates (April 22, May 15, May 31 2020) and for a variety of measurements (deaths/million, deaths/test, cases/million, cases/test).

Multiple linear regression found that at the state level, the mmW and the higher population density contributed almost equally to the increased case and death rates in the mmW states. Regression equations predicted that if the mmW states did not have mmW, the average cases per million for the mmW states would be reduced by 24%, and the deaths per million would be reduced by 30%.

At the county level, the mmW exposure contributed three times as much as the higher population density to the increased case and death rates in the mmW counties. Regression equations predicted that if the mmW counties did not have mmW exposure, the cases per million for the mmW counties would be reduced by 39%, and the deaths per million would be reduced by 54%.

For California counties, mmW and AQI were statistically significant contributors to the case and death rates while population density was not. Regression equations predicted that if the mmW counties did not have mmW, the cases per million would be reduced by 46%, and the deaths per million would be reduced by 57%.

It is not difficult to see how radiofrequency radiation could increase the case and death rates when wireless radiation and SARS-CoV-2 share common mechanisms of harm to human and animal cells and wireless radiation exposure produces conditions that enhance susceptibility to SARS-CoV-2. Both interfere with cell signalling via the phosphorylation pathways, increase intracellular calcium ion concentrations by activating VGCC's, and interfere with the actions of cell membranes. Radiofrequency radiation negatively impacts the immune system, reduces oxygen availability to blood cells and tissues, increases oxidative stress and inflammation, and reduces glutathione levels and vitamin D availability, all of which assist viral infection.

In this analysis, we compared 5G mmW areas with those that have RFR but do not yet have activated mmW technology. This is like comparing smokers to those exposed to second-hand smoke. Consequently, the difference between COVID-19 attributed case and death rates may be much higher had we compared areas with 5G mmW technology to areas with little or no RFR exposure, which is nearly impossible to do as few of these areas remain in the U.S.

The rollout of mmW 5G has been done without any testing to assess its safety, either singly or in combination with RF frequencies already present, such as 1G-4G and Wi-Fi. In fact, no long-term safety testing was done on any wireless technology before they were introduced to the market. Government presumption of safety on all wireless technology is that harmful effects can only happen at thermal levels and that effects at non-thermal levels do not exist, i.e. so as long as wireless devices and infrastructure do not emit enough energy to heat tissues, then there is nothing to be concerned about. However, thousands of studies have shown harmful biological effects at non-thermal levels, and medical devices using non-thermal levels of radiofrequency radiation have been used therapeutically for decades, which is concrete evidence of beneficial and adverse biological effects at non-thermal levels of non-ionizing radiation. Currently, mmW have been deployed for 5G in approximately 50 U.S. cities, but when 5G is fully rolled out, mmW will be everywhere. More than 400 scientists and doctors have signed the 5G Appeal [78] requesting a moratorium on the 5G rollout. Any economic benefits from 5G are likely to be outweighed by the risk of harm to the health of billions of people around the world.

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Competing Interests

None

References

1. Worldometer. COVID-19 Corona virus Pandemic. Worldometer. https://www.worldometers.info/coronavirus/#countries. Accessed April 22, May 15, May 31, August 9, 2020.
2. Fisher, T. 5G Availability Around the World. Lifewire. https://www.lifewire.com/5g-availability-world-4156244 Accessed September 1, 2020.
3. WorldTimeZone. 5G commercial network world coverage map. WorldTime Zone. https://www.worldtimezone.com/5g.html Accessed September 1, 2020.
4. European 5G Observatory. Announcements of Commercial Launches. European 5G Observatory. https://5gobservatory.eu/market-developments/5g-services/ Accessed September 1, 2020.
5. RT. Spain rolls out 5G network using Huawei gear despite US blacklisting Chinese tech giant. RT. https://www.rt.com/business/461954-spain-5g-network-huawei/ Accessed September 1, 2020.
6. Dano, M. Here Are the Big Winners in the FCC's 24GHz & 28GHz 5G Auctions. Lightreading. https://www.lightreading.com/mobile/5g/here-are-the-big-winners-in-the-fccs-24ghz-and-28ghz-5g-auctions/d/d-id/751903 Accessed May 1, 2020.
7. Fletcher, B. FCC mmWave auction brings in more than $7.5B as clock phase ends. Fierce Wireless. https://www.fiercewireless.com/regulatory/fcc-mmwave-auction-brings-more-than-7-5b-as-clock-phase-ends Accessed May 1, 2020.
8. Kinney, S. What's the outlook for millimeter wave 5G in the EU (and UK)? RCRWireless News. *https://www.rcrwireless.com/20200213/spectrum/millimeter-wave-5g-eu* Accessed September 1, 2020.
9. FCC. FCC-19-126 Resolution of Notice of Inquiry, Second Report and Order, Notice of Proposed Rulemaking, and Memorandum of Opinion and Order. 2019. https://docs.fcc.gov/public/attachments/FCC-19-126A1.pdf
10. AT&T. Coverage Map for 5G+. AT&T. https://www.att.com/5g/consumer/ Accessed April 22, May 31, 2020.
11. T-Mobile. Coverage Map for Samsung Galaxy S10 5G. T-Mobile. https://www.t-mobile.com/devices/samsung-galaxy-s10-5g. Accessed April 22, May 31, 2020.
12. Verizon. Explore Verizon 5G Ultra Wideband Coverage. Verizon. https://www.verizon.com/5g/coverage-map/ Accessed April 22, May 31, 2020.
13. Johansson O, Redmayne M. Exacerbation of demyelinating syndrome after exposure to wireless modem with public hotspot. *Electromagn Biol Med.* 2016;35:393–397. https://doi.org/10.3109/15368378.2015.1107839
14. Nair, S. COVID-19 and Social Impact. Forbes. https://www.forbes.com/sites/sorensonimpact/2020/04/10/covid-19-and-social-impact/?sh=6bec1132546b Accessed May 1, 2020.
15. Prata DN, Rodrigues W, Bermejo PH. Temperature significantly

changes COVID-19 transmission in (sub)tropical cities of Brazil. *Sci Total Environ.* 2020;729: 138862. https://doi.org/10.1016/j.scitotenv.2020.138862

16. Marik PE, Kory P, Varon J. Does vitamin D status impact mortality from SARS-CoV-2 infection? *Med Drug Discov.* 2020;100041. https://doi.org/10.1016/j.medidd.2020.100041
17. Soleimani, B, Nanda U, Ross S. Does Density Determine COVID-19 Destiny? Let's look at the Data. CADRE Research. https://medium.com/@cadre/does-density-determine-covid-19-destiny-lets-look-at-the-data-a43b60eac787 Accessed May 1, 2020.
18. Fifi JT, Mocco J. COVID-19 related stroke in young individuals. *Lancet Neuro.*2020;19:713–715. https://doi.org/10.1016/S1474-4422(20)30272-6
19. Lakhdari N, Tabet B, Boudraham L, Laoussati M, Aissanou S, Beddou L, Bensalem S, Bellik Y, Bournine L, Fatmi S, *et al.* M Red blood cells injuries and hypersegmented neutrophils in COVID-19 peripheral blood film. *medRxiv.* 2020;07.24.20160101. https://doi.org/10.1101/2020.07.24.20160101
20. Rubik B, Brown RR. Evidence for a Connection Between COVID-19 and Exposure to Radiofrequency Radiation from Wireless Telecommunications Including Microwaves and Millimeter Waves. *OSF Preprints.* 2021;01.04. https://doi.org/10.31219/osf.io/9p8qu
21. Lambert NJ, Survivor Corps. COVID-19 "Long Hauler" Symptoms Survey Report. Indiana University School of Medicine, 2020.
22. Belpomme D, Irigaray P. Electrohypersensitivity as a Newly Identified and Characterized Neurologic Pathological Disorder: How to Diagnose, Treat, and Prevent It. *Int J Mol Sci.* 2020;21(6),1915. https://doi.org/10.3390/ijms21061915
23. Kostoff RN, Briggs MB, Porter AL, Hernández AF, Abdollahi M, Aschner M, Tsatsakis A. The under-reported role of toxic substance exposures in the COVID-19 pandemic. *Food Chem Toxicol.* 2020;145:111687. https://doi.org/10.1016/j.toxlet.2020.01.020
24. Mordachev VI. Correlation Between the Potential Electromagnetic Pollution Level and the Danger of COVID-19. 4G/5G/6G Can Be Safe for People. *Dokl Bguir.* 2020;18. http://dx.doi.org/10.35596/1729-7648-2020-18-4-96-112
25. Johansson O. Disturbance of the immune system by electromagnetic fields—A potentially underlying cause for cellular damage and tissue repair reduction which could lead to disease and impairment. *Pathophysiology.* 2009; Electromagnetic Fields (EMF) Special Issue 16:157–177. https://doi.org/10.1016/j.pathophys.2009.03.004
26. Szmigielski S. Reaction of the immune system to low-level RF/MW exposures. *Sci Total Environ.* 2013;454–455:393–400. https://doi.org/10.1016/j.scitotenv.2013.03.034
27. Belyaev I, Dean A, Eger H, Hubmann G, Jandrisovits R, Kern M, Kundi M, Moshammer H,

Lercher P, Muller K, *et al.* EUROPAEM EMF Guideline 2016 for the prevention, diagnosis and treatment of EMF-related health problems and illnesses. *Rev Environ Health.* 2016;31(3):363-97. https://doi.org/10.1515/reveh-2016-0011

28. Marshall TG, Heil TJR. Electrosmog and autoimmune disease. *Immunol Res.* 2017;65,129–135. https://doi.org/10.1007/s12026-016-8825-7

29. Aydin B, Akar A. Effects of a 900-MHz electromagnetic field on oxidative stress parameters in rat lymphoid organs, polymorphonuclear leukocytes and plasma. *Arch Med Res.* 2011;42:261–267. https://doi.org/10.1016/j.arcmed.2011.06.001

30. Garaj-Vrhovac V, Gajski G, Pažanin S, Šarolić A, Domijan AM, Flajs D, Peraica M. Assessment of cytogenetic damage and oxidative stress in personnel occupationally exposed to the pulsed microwave radiation of marine radar equipment. *Int J Hyg Environ Health.* 2011;214:59–65. https://doi.org/10.1016/j.ijheh.2010.08.003

31. Yakymenko I, Tsybulin O, Sidorik E, Henshel D, Kyrylenko O, Kyrylenko S. Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation. *Electromagn Biol Med.* 2015;19:1–16. https://doi.org/10.3109/15368378.2015.1043557

32. Santini SJ, Cordone V, Falone S, Mijit M, Tatone C, Amicarelli F, Di Emidio G. Role of Mitochondria in the Oxidative Stress Induced by Electromagnetic Fields: Focus on Reproductive Systems. *Oxid Med Cell Longev.* 2018; 5076271. https://doi.org/10.1155/2018/5076271

33. Alkis ME, Bilgin HM, Akpolat V, Dasdag S, Yegin K, Yavas MC, Akdag M. Effect of 900-, 1800-, and 2100-MHz radiofrequency radiation on DNA and oxidative stress in brain. *Electromagn Biol Med.* 2019;38:32–47. https://doi.org/10.1080/15368378.2019.1567526

34. Mousavy SJ, Riazi GH, Kamarei M, Aliakbarian H, Sattarahmady N, Sharifizadeh A, Safarian S, Ahmad F, Moosavi-Movahedi AA. Effects of mobile phone radiofrequency on the structure and function of the normal human hemoglobin. *Int J Biol Macromol.* 2009;44:278–285. https://doi.org/10.1016/j.ijbiomac.2009.01.001

35. Havas M. Radiation from wireless technology affects the blood, the heart, and the autonomic nervous system. *Rev Environ Health.* 2013;28:5–84. https://doi.org/10.1515/reveh-2013-0004

36. Rubik B. Does Short-term Exposure to Cell Phone Radiation Affect the Blood? *Wise Traditions in Food, Farming and the Healing Arts.* 2014;15(4):19-28. https://www.westonaprice.org/health-topics/does-short-term-exposure-to-cell-phone-radiation-affect-the-blood/

37. Zothansiama, Zosangzuali M, Lalramdinpuii M, Jagetia GC. Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations.

Electromagn Biol Med. 2017;36:295–305. https://doi.org/10.1080/15368378.2017.1350584

38. Fragopoulou AF, Polyzos A, Papadopoulou MD, Sansone A, Manta AK, Balafas E, Kostomitsopoulos N, Skouroliakou A, Chatgilialoglu C, Georgakilas A, *et al.* Hippocampal lipidome and transcriptome profile alterations triggered by acute exposure of mice to GSM 1800 MHz mobile phone radiation: An exploratory study. *Brain Behav.* 2018;8:e01001. https://doi.org/10.1002/brb3.1001
39. De Luca C, Thai JC, Raskovic D, Cesareo E, Caccamo D, Trukhanov A, Korkina L. Metabolic and genetic screening of electromagnetic hypersensitive subjects as a feasible tool for diagnostics and intervention. *Mediators Inflamm.* 2014;924184. https://doi.org/10.1155/2014/924184
40. Belpomme D, Campagnac C, Irigaray P. Reliable disease biomarkers characterizing and identifying electrohypersensitivity and multiple chemical sensitivity as two etiopathogenic aspects of a unique pathological disorder. *Rev Environ Health.* 2015;30:251–271. https://doi.org/10.1515/reveh-2015-0027
41. Johansson O. Electrohypersensitivity: a functional impairment due to an inaccessible environment. *Rev Environ Health.* 2015;30(4):311-21. https://doi.org/10.1515/reveh-2015-0018.
42. Russell CL. 5 G wireless telecommunications expansion: Public health and environmental implications. *Environ Res.* 2018;165:484–495. https://doi.org/10.1016/j.envres.2018.01.016
43. BioInitiative Working Group, Sage C, Carpenter D (Eds.). BioInitiative Report: A Rationale for Biologically-Based Public Exposure Standards for Electromagnetic Radiation at 2012, 2012. www.bioinitiative.org
44. Kostoff RN, Heroux P, Aschner M, Tsatsakis A. Adverse health effects of 5G mobile networking technology under real-life conditions. *Toxicol Lett.* 2020;323:35–40. https://doi.org/10.1016/j.toxlet.2020.01.020
45. Reuter S, Gupta SC, Chaturvedi MM, Aggarwal BB. Oxidative stress, inflammation, and cancer: How are they linked? *Free Radic Biol Med.* 2010;49:1603–1616. https://doi.org/10.1016/j.freeradbiomed.2010.09.006
46. Dauda Usman J, Isyaku UM, Magaji RA, Fasanmade AA. Assessment of electromagnetic fields, vibration and sound exposure effects from multiple transceiver mobile phones on oxidative stress levels in serum, brain and heart tissue. *Sci Afr.* 2020;7:e00271. https://doi.org/10.1016/j.sciaf.2020.e00271
47. Kıvrak EG, Yurt KK, Kaplan A, Alkan I, Altun G. Effects of electromagnetic fields exposure on the antioxidant defense system. *J Microsc Ultrastruct.* 2017;5:167–176. https://doi.org/10.1016/j.jmau.2017.07.003
48. Usselman RJ, Hill I, Singel DJ, Martino CF. Spin Biochemistry Modulates Reactive Oxygen Species (ROS) Production by Radio Frequency Magnetic Fields. *PLOS*

ONE. 2014;9(3):e93065. https://doi.org/10.1371/journal.pone.0093065

49. BERENIS January 2021 Newsletter, 2021. https://www.bafu.admin.ch/dam/bafu/en/dokumente/elektrosmog/fachinfo-daten/newsletter_berenis_sonderausgabe_januar_2021.pdf.download.pdf/Newsletter%20BERENIS%20-%20Special%20Issue%20January%202021.pdf
50. Wyszkowska J, Jędrzejewski T, Piotrowski J, Wojciechowska A, Stankiewicz M, Kozak W. Evaluation of the influence of in vivo exposure to extremely low-frequency magnetic fields on the plasma levels of pro-inflammatory cytokines in rats. *Int J Radiat Biol* 2018;94:909–917. https://doi.org/10.1080/09553002.2018.1503428
51. El-Gohary OA, Said MA. Effect of electromagnetic waves from mobile phone on immune status of male rats: possible protective role of vitamin D. *Can J Physiol Pharmacol.* 2017; 95(2):151-156. https://doi.org/10.1139/cjpp-2016-0218.
52. Díaz-Del Cerro E, Vida C, Martínez de Toda I, Félix J, De la Fuente M. The use of a bed with an insulating system of electromagnetic fields improves immune function, redox and inflammatory states, and decrease the rate of aging. *Environ Health.* 2020; Nov 23;19(1):118. https://doi.org/10.1186/s12940-020-00674-y
53. Louveau A, Smirnov I, Keyes TJ, Eccles JD, Rouhani SJ, Peske JD, Derecki NC, Castle D, Mandell JW, Lee KS, *et al.* Structural and functional features of central nervous system lymphatic vessels. *Nature.* 2015;523:337–341. https://doi.org/10.1038/nature14432
54. Volkow ND, Tomasi D, Wang GJ, Vaska P, Fowler JS, Telang F, Alexoff D, Logan J, Wong C. Effects of Cell Phone Radiofrequency Signal Exposure on Brain Glucose Metabolism. *JAMA.* 2011;305:808–813. https://doi.org/10.1001/jama.2011.186
55. Daneshkhah A, Agrawal V, Eshein A, Subramanian H, Roy HK, Backman V. The Possible Role of Vitamin D in Suppressing Cytokine Storm and Associated Mortality in COVID-19 Patients. *medRxiv.* 2020;2020.04.08.20058578. https://doi.org/10.1101/2020.04.08.20058578
56. Lau FH, Majumder R, Torabi R, Saeg F, Hoffman R, Cirillo JD, Greiffenstein P. Vitamin D Insufficiency is Prevalent in Severe COVID-19. *medRxiv.* 2020;2020.04.24.20075838. https://doi.org/10.1101/2020.04.24.20075838
57. Von Essen M, Kongsbak M, Schjerling P, Olgaard K, Ødum N, Geisler C. Vitamin D controls T cell antigen receptor signaling and activation of human T cells. *Nat Immunol.* 2010;11:344–9. https://doi.org/10.1038/ni.1851
58. Polonikov A. Endogenous Deficiency of Glutathione as the Most Likely Cause of Serious Manifestations and Death in COVID-19 Patients. ACS Infect Dis 6: 1558–1562, 2020. https://doi.org/10.1021/acsinfecdis.0c00288
59. Jain S, Micinski D, Huning L, Kahlon G, Bass PF, Levine SN. Vitamin D and L-cysteine levels

correlate positively with GSH and negatively with insulin resistance levels in the blood of type 2 diabetic patients. *Eur J.Clin.Nutr.* 2014;68: 1148–1153. https://doi.org/10.1038/ejcn.2014.114

60. Horowitz RI, Freeman PR, Bruzzese J. Efficacy of glutathione therapy in relieving dyspnea associated with COVID-19 pneumonia: A report of 2 cases. *Respir Med Case Rep.* 2020;30:101063. https://doi.org/10.1016/j.rmcr.2020.101063
61. McMahon S, Grondin F, McDonald PP, Richard DE, Dubois CM. Hypoxia-enhanced Expression of the Proprotein Convertase Furin Is Mediated by Hypoxia-inducible Factor-1 IMPACT ON THE BIOACTIVATION OF PROPROTEINS. *J Biol Chem.* 2005;280:6561–6569. https://doi.org/10.1074/jbc.M413248200
62. Khademvatani K, Seyyed-Mohammadzad MH, Akbari M, Rezaei Y, Eskandari R, Rostamzadeh A. The relationship between vitamin D status and idiopathic lower-extremity deep vein thrombosis. *Int J Gen Med.* 2014;7:303–309. https://doi.org/10.2147/IJGM.S64812
63. Zalyubovskaya NP, Kiselev R. Effect of Radio Waves of a Millimeter Frequency Range on the Body of Man and Animals. *Gigiyena Sanit.* 1978;8:35-39.
64. Caprani A, Richert A, Flaud P. Experimental evidence of a potentially increased thrombo-embolic disease risk by domestic electromagnetic field exposure. *Bioelectromagnetics* 2004;25: 313–315. https://doi.org/10.1002/bem.20022
65. Antonova N, Riha P. Studies of electrorheological properties of blood. *Clin. Hemorheol Microcirc.* 2006;35:19–29. https://doi.org/10.3933/APPLRHEOL-24-35190
66. Pall ML. Electromagnetic fields act via activation of voltage-gated calcium channels to produce beneficial or adverse effects. *J Cell Mol Med.* 2013;17:958–965. https://doi.org/10.1111/jcmm.12088
67. De Lorenzo A, Martinoli R, Carbonelli MG, Monteleone G, Di Lorenzo N, Di Daniele N. Resting metabolic rate incremented by pulsating electrostatic field (PESF) therapy. *Diabetes Nutr Metab.* 2004;17:309–312.
68. Gaynor JS, Hagberg S, Gurfein BT. Veterinary applications of pulsed electromagnetic field therapy. *Res Vet Sci.* 2018;119:1–8. https://doi.org/10.1016/j.rvsc.2018.05.005
69. Logani M., Alekseev S, Bhopale MK, Slovinsky WS, Ziskin MC. Effect of millimeter waves and cyclophosphamide on cytokine regulation. *Immunopharmacol Immunotoxicol.* 2012;34: 107–112. https://doi.org/10.3109/08923973.2011.583252
70. Makar V, Logani M, Szabo I, Ziskin M. Effect of millimeter waves on cyclophosphamide induced suppression of T cell functions. *Bioelectromagnetics.* 2003;24:356–365. https://doi.org/10.1002/bem.10106
71. Gapeyev AB, Mikhailik EN, Chemeris NK. Features of anti-inflammatory effects of modulated extremely high-frequency electromagnetic radiation.

Bioelectromagnetics. 2009;30:454–461. https://doi.org/10.1002/bem.20499

72. Ramundo-Orlando A. Effects of Millimeter Waves Radiation on Cell Membrane - A Brief Review. *J Infrared Milli Terahz Waves.* 2010;31:1400–1411. https://doi.org/10.1007/s10762-010-9731-z
73. Puri BK, Segal DR, Monro JA. The effect of successful low-dose immunotherapy ascertained by provocation neutralization on lymphocytic calcium ion influx following electric field exposure. *J Complement Integr Med.* 2019;17:20170156. https://doi.org/10.1515/jcim-2017-0156
74. Bai D, Fang L, Xia S, Ke W, Wang J, Wu X, Fang P, Xiao S. Porcine deltacoronavirus (PDCoV) modulates calcium influx to favor viral replication. *Virology.* 2020;539:38–48. https://doi.org/10.1016/j.virol.2019.10.011
75. Chen X, Cao R, Zhong W. Host Calcium Channels and Pumps in Viral Infections. *Cells.* 2020;9:94. https://doi.org/10.3390/cells9010094
76. Bouhaddou M, Memon D, Meyer B, White KM, Rezelj VV, Correa Marrero M, Polacco BJ, Melnyk JE, Ulferts S, Kaake RM, *et al.* The Global Phosphorylation Landscape of SARS-CoV-2 Infection. Cell 2020;182:685-712.e19. https://doi.org/10.1016/j.cell.2020.06.034
77. Kovacic P, Somanathan R. Electromagnetic fields: Mechanism, cell signaling, other bioprocesses, toxicity, radicals, antioxidants and beneficial effects. *J Recept Signal Transduct Res.* 2010;30:214–26. https://doi.org/10.3109/10799893.2010.488650
78. Nyberg R, Hardell L. 5G Appeal http://www.5gappeal.eu/the-5g-appeal/ Accessed September 1, 2020.

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REVIEW ARTICLE

Evidence for a connection between coronavirus disease-19 and exposure to radiofrequency radiation from wireless communications including 5G

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ABSTRACT

Background and Aim: Coronavirus disease (COVID-19) public health policy has focused on the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) virus and its effects on human health while environmental factors have been largely ignored. In considering the epidemiological triad (agent-host-environment) applicable to all disease, we investigated a possible environmental factor in the COVID-19 pandemic: ambient radiofrequency radiation from wireless communication systems including microwaves and millimeter waves. SARS-CoV-2, the virus that caused the COVID-19 pandemic, surfaced in Wuhan, China shortly after the implementation of city-wide (fifth generation [5G] of wireless communications radiation [WCR]), and rapidly spread globally, initially demonstrating a statistical correlation to international communities with recently established 5G networks. In this study, we examined the peer-reviewed scientific literature on the detrimental bioeffects of WCR and identified several mechanisms by which WCR may have contributed to the COVID-19 pandemic as a toxic environmental cofactor. By crossing boundaries between the disciplines of biophysics and pathophysiology, we present evidence that WCR may: (1) cause morphologic changes in erythrocytes including echinocyte and rouleaux formation that can contribute to hypercoagulation; (2) impair microcirculation and reduce erythrocyte and hemoglobin levels exacerbating hypoxia; (3) amplify immune system dysfunction, including immunosuppression, autoimmunity, and hyperinflammation; (4) increase cellular oxidative stress and the production of free radicals resulting in vascular injury and organ damage; (5) increase intracellular Ca^{2+} essential for viral entry, replication, and release, in addition to promoting pro-inflammatory pathways; and (6) worsen heart arrhythmias and cardiac disorders.

Relevance for Patients: In short, WCR has become a ubiquitous environmental stressor that we propose may have contributed to adverse health outcomes of patients infected with SARS-CoV-2 and increased the severity of the COVID-19 pandemic. Therefore, we recommend that all people, particularly those suffering from SARS-CoV-2 infection, reduce their exposure to WCR as much as reasonably achievable until further research better clarifies the systemic health effects associated with chronic WCR exposure.

1. Introduction

1.1. Background

Coronavirus disease 2019 (COVID-19) has been the focus of international public health policy since 2020. Despite unprecedented public health protocols to quell the pandemic, the number of COVID-19 cases continues to rise. We propose a reassessment of our public health strategies.

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According to the Center for Disease Control and Prevention (CDC), the simplest model of disease causation is the epidemiological triad consisting of three interactive factors: the agent (pathogen), the environment, and the health status of the host [1]. Extensive research is being done on the agent, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Risk factors that make a host more likely to succumb to the disease have been elucidated. However, environmental factors have not been sufficiently explored. In this paper, we investigated the role of wireless communication radiation (WCR), a widespread environmental stressor.

We explore the scientific evidence suggesting a possible relationship between COVID-19 and radiofrequency radiation related to wireless communications technology including fifth generation (5G) of wireless communications technology, henceforth referred to as WCR. WCR has already been recognized as a form of environmental pollution and physiological stressor [2]. Assessing the potentially detrimental health effects of WCR may be crucial to develop an effective, rational public health policy that may help expedite eradication of the COVID-19 pandemic. In addition, because we are on the verge of worldwide 5G deployment, it is critical to consider the possible damaging health effects of WCR before the public is potentially harmed.

5G is a protocol that will use high frequency bands and extensive bandwidths of the electromagnetic spectrum in the vast radiofrequency range from 600 MHz to nearly 100 GHz, which includes millimeter waves (>20 GHz), in addition to the currently used third generation (3G) and fourth generation (4G) long-term evolution (LTE) microwave bands. 5G frequency spectrum allocations differ from country to country. Focused pulsed beams of radiation will emit from new base stations and phased array antennas placed close to buildings whenever persons access the 5G network. Because these high frequencies are strongly absorbed by the atmosphere and especially during rain, a transmitter's range is limited to 300 meters. Therefore, 5G requires base stations and antennas to be much more closely spaced than previous generations. Plus, satellites in space will emit 5G bands globally to create a wireless worldwide web. The new system therefore requires significant densification of 4G infrastructure as well as new 5G antennas that may dramatically increase the population's WCR exposure both inside structures and outdoors. Approximately 100,000 emitting satellites are planned to be launched into orbit. This infrastructure will significantly alter the world's electromagnetic environment to unprecedented levels and may cause unknown consequences to the entire biosphere, including humans. The new infrastructure will service the new 5G devices, including 5G mobile phones, routers, computers, tablets, self-driving vehicles, machine-to-machine communications, and the Internet of Things.

The global industry standard for 5G is set by the 3G Partnership Project (3GPP), which is an umbrella term for several organizations developing standard protocols for mobile telecommunications. The 5G standard specifies all key aspects of the technology, including frequency spectrum allocation, beam-forming, beam steering, multiplexing multiple in, multiple out schemes, as well as modulation schemes, among others. 5G will utilize from 64 to 256 antennas at short distances to serve virtually simultaneously a large number of devices within a cell. The latest finalized 5G standard, Release 16, is codified in the 3GPP published Technical Report TR 21.916 and may be downloaded from the 3GPP server at https://www.3gpp.org/specifications. Engineers claim that 5G will offer performance up to 10 times that of current 4G networks [3].

COVID-19 began in Wuhan, China in December 2019, shortly after city-wide 5G had "gone live," that is, become an operational system, on October 31, 2019. COVID-19 outbreaks soon followed in other areas where 5G had also been at least partially implemented, including South Korea, Northern Italy, New York City, Seattle, and Southern California. In May 2020, Mordachev [4] reported a statistically significant correlation between the intensity of radiofrequency radiation and the mortality from SARS-CoV-2 in 31 countries throughout the world. During the first pandemic wave in the United States, COVID-19 attributed cases and deaths were statistically higher in states and major cities with 5G infrastructure as compared with states and cities that did not yet have this technology [5].

There is a large body of peer reviewed literature, since before World War II, on the biological effects of WCR that impact many aspects of our health. In examining this literature, we found intersections between the pathophysiology of SARS-CoV-2 and detrimental bioeffects of WCR exposure. Here, we present the evidence suggesting that WCR has been a possible contributing factor exacerbating COVID-19.

1.2. Overview on COVID-19

The clinical presentation of COVID-19 has proven to be highly variable, with a wide range of symptoms and variability from case to case. According to the CDC, early disease symptoms may include sore throat, headache, fever, cough, chills, among others. More severe symptoms including shortness of breath, high fever, and severe fatigue may occur in a later stage. The neurological sequela of taste and smell loss has also been described.

Ing *et al.* [6] determined 80% of those affected have mild symptoms or none, but older populations and those with comorbidities, such as hypertension, diabetes, and obesity, have a greater risk for severe disease [7]. Acute respiratory distress syndrome (ARDS) can rapidly occur [8] and cause severe shortness of breath as endothelial cells lining blood vessels and epithelial cells lining airways lose their integrity, and protein rich fluid leaks into adjacent air sacs. COVID-19 can cause insufficient oxygen levels (hypoxia) that have been seen in up to 80% of intensive care unit (ICU) patients [9] exhibiting respiratory distress. Decreased oxygenation and elevated carbon dioxide levels in patients' blood have been observed, although the etiology for these findings remains unclear.

Massive oxidative damage to the lungs has been observed in areas of airspace opacification documented on chest radiographs and computed tomography (CT) scans in patients with SARS-CoV-2 pneumonia [10]. This cellular stress may indicate a biochemical rather than a viral etiology [11].

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Because disseminated virus can attach itself to cells containing an angiotensin-converting enzyme 2 (ACE2) receptor; it can spread and damage organs and soft tissues throughout the body, including the lungs, heart, intestines, kidneys, blood vessels, fat, testes, and ovaries, among others. The disease can increase systemic inflammation and induce a hypercoagulable state. Without anticoagulation, intravascular blood clots can be devastating [12].

In COVID-19 patients referred to as "long-haulers," symptoms can wax and wane for months [13]. Shortness of breath, fatigue, joint pain, and chest pain can become persistent symptoms. Post-infectious brain fog, cardiac arrhythmia, and new onset hypertension have also been described. Long-term chronic complications of COVID-19 are being defined as epidemiological data are collected over time.

As our understanding of COVID-19 continues to evolve, environmental factors, particularly those of wireless communication electromagnetic fields, remain unexplored variables that may be contributing to the disease including its severity in some patients. Next, we summarize the bioeffects of WCR exposure from the peer reviewed scientific literature published over decades.

1.3. Overview on bioeffects of WCR exposure

Organisms are electrochemical beings. Low-level WCR from devices, including mobile telephony base antennas, wireless network protocols utilized for the local networking of devices and internet access, trademarked as Wi-Fi (officially IEEE 802.11b Direct Sequence protocol; IEEE, Institute of Electrical and Electronic Engineers) by the Wi-Fi alliance, and mobile phones, among others, may disrupt regulation of numerous physiological functions. Non-thermal bioeffects (below the power density that causes tissue heating) from very low-level WCR exposure have been reported in numerous peer-reviewed scientific publications at power densities below the International Commission on Non-Ionizing Radiation Protection (ICNIRP) exposure guidelines [14]. Low-level WCR has been found to impact the organism at all levels of organization, from the molecular to the cellular, physiological, behavioral, and psychological levels. Moreover, it has been shown to cause systemic detrimental health effects including increased cancer risk [15], endocrine changes [16], increased free radical production [17], deoxyribonucleic acid (DNA) damage [18], changes to the reproductive system [19], learning and memory defects [20], and neurological disorders [21]. Having evolved within Earth's extremely low-level natural radiofrequency background, organisms lack the ability to adapt to heightened levels of unnatural radiation of wireless communications technology with digital modulation that includes short intense pulses (bursts).

The peer-reviewed world scientific literature has documented evidence for detrimental bioeffects from WCR exposure including 5G frequencies over several decades. The Soviet and Eastern European literature from 1960 to 1970s demonstrates significant biological effects, even at exposure levels more than 1000 times below 1 mW/cm^2, the current guideline for maximum public exposure in the US. Eastern studies on animal and human subjects were performed at low exposure levels (<1 mW/cm^2) for long durations (typically months). Adverse bioeffects from WCR exposure levels below 0.001 mW/cm^2 have also been documented in the Western literature. Damage to human sperm viability including DNA fragmentation by internet-connected laptop computers at power densities from 0.0005 to 0.001 mW/cm^2 has been reported [22]. Chronic human exposure to 0.000006 – 0.00001 mW/cm^2 produced significant changes in human stress hormones following a mobile phone base station installation [23]. Human exposures to cell phone radiation at 0.00001 – 0.00005 mW/cm^2 resulted in complaints of headache, neurological problems, sleep problems, and concentration problems, corresponding to "microwave sickness" [24,25]. The effects of WCR on prenatal development in mice placed near an "antenna park" exposed to power densities from 0.000168 to 0.001053 mW/cm^2 showed a progressive decrease in the number of newborns and ended in irreversible infertility [26]. Most US research has been performed over short durations of weeks or less. In recent years, there have been few long-term studies on animals or humans.

Illness from WCR exposure has been documented since the early use of radar. Prolonged exposure to microwaves and millimeter waves from radar was associated with various disorders termed "radio-wave sickness" decades ago by Russian scientists. A wide variety of bioeffects from nonthermal power densities of WCR were reported by Soviet research groups since the 1960s. A bibliography of over 3700 references on the reported biological effects in the world scientific literature was published in 1972 (revised 1976) by the US Naval Medical Research Institute [27,28]. Several relevant Russian studies are summarized as follows. Research on *Escherichia coli* bacteria cultures show power density windows for microwave resonance effects for 51.755 GHz stimulation of bacterial growth, observed at extremely low power densities of 10^{-13} mW/cm^2 [29], illustrating an extremely low level bioeffect. More recently Russian studies confirmed earlier results of Soviet research groups on the effects of 2.45 GHz at 0.5 mW/cm^2 on rats (30 days exposure for 7 h/day), demonstrating the formation of antibodies to the brain (autoimmune response) and stress reactions [30]. In a long-term (1 – 4 year) study comparing children who use mobile phones to a control group, functional changes, including greater fatigue, decreased voluntary attention, and weakening of semantic memory, among other adverse psychophysiological changes, were reported [31]. Key Russian research reports that underlie the scientific basis for Soviet and Russian WCR exposure guidelines to protect the public, which are much lower than the US guidelines, have been summarized [32].

By comparison to the exposure levels employed in these studies, we measured the ambient level of WCR from 100 MHz to 8 GHz in downtown San Francisco, California in December, 2020, and found an average power density of 0.0002 mW/cm^2. This level is from the superposition of multiple WCR devices. It is approximately 2×10^{10} times above the natural background.

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Pulsed radio-frequency radiation such as WCR exhibits substantially different bioeffects, both qualitatively and quantitatively (generally more pronounced) compared to continuous waves at similar time-averaged power densities [33-36]. The specific interaction mechanisms are not well understood. All types of wireless communications employ extremely low frequency (ELFs) in the modulation of the radiofrequency carrier signals, typically pulses to increase the capacity of information transmitted. This combination of radiofrequency radiation with ELF modulation(s) is generally more bioactive, as it is surmised that organisms cannot readily adapt to such rapidly changing wave forms [37-40]. Therefore, the presence of ELF components of radiofrequency waves from pulsing or other modulations must be considered in studies on the bioeffects of WCR. Unfortunately, the reporting of such modulations has been unreliable, especially in older studies [41].

The BioInitiative Report [42], authored by 29 experts from ten countries, and updated in 2020, provides a scholarly contemporary summary of the literature on the bioeffects and health consequences from WCR exposure, including a compendium of supporting research. Recent reviews have been published [43-46]. Two comprehensive reviews on the bioeffects of millimeter waves report that even short-term exposures produce marked bioeffects [47,48].

2. Methods

An ongoing literature study of the unfolding pathophysiology of SARS-CoV-2 was performed. To investigate a possible connection to bioeffects from WCR exposure, we examined over 250 peer-reviewed research reports from 1969 to 2021, including reviews and studies on cells, animals, and humans. We included the world literature in English and Russian reports translated to English, on radio frequencies from 600 MHz to 90 GHz, the carrier wave spectrum of WCR (2G to 5G inclusive), with particular emphasis on nonthermal, low power densities (<1 mW/cm^2), and long-term exposures. The following search terms were used in queries in MEDLINE® and the Defense Technical Information Center (https://discover.dtic.mil) to find relevant study reports: radiofrequency radiation, microwave, millimeter wave, radar, MHz, GHz, blood, red blood cell, erythrocyte, hemoglobin, hemodynamic, oxygen, hypoxia, vascular, inflammation, pro-inflammatory, immune, lymphocyte, T cell, cytokine, intracellular calcium, sympathetic function, arrhythmia, heart, cardiovascular, oxidative stress, glutathione, reactive oxygen species (ROS), COVID-19, virus, and SARS-CoV-2. Occupational studies on WCR exposed workers were included in the study. Our approach is akin to Literature-Related Discovery, in which two concepts that have heretofore not been linked are explored in the literature searches to look for linkage(s) to produce novel, interesting, plausible, and intelligible knowledge, that is, potential discovery [49]. From analysis of these studies in comparison with new information unfolding on the pathophysiology of SARS-CoV-2, we identified several ways in which adverse bioeffects of WCR exposure intersect with COVID-19 manifestations and organized our findings into five categories.

Table 1. Bioeffects of Wireless Communication Radiation (WCR) exposure in relation to COVID-19 manifestations and their progression

Wireless communications radiation (WCR) exposure bioeffects	COVID-19 manifestations
Blood changes	**Blood changes**
Short-term: rouleaux, echinocytes	Rouleaux, echinocytes
Long-term: reduced blood clotting time, reduced hemoglobin, hemodynamic disorders	Hemoglobin effects; vascular effects
	→ Reduced hemoglobin in severe disease; autoimmune hemolytic anemia; hypoxemia and hypoxia
	→ Endothelial injury; impaired microcirculation; hypercoagulation; disseminated intravascular coagulopathy (DIC); pulmonary embolism; stroke
Oxidative stress	**Oxidative stress**
Glutathione level decrease; free radicals and lipid peroxide increase; superoxide dismutase activity decrease; oxidative injury in tissues and organs	Glutathione level decrease; free radical increase and damage; apoptosis
	→ Oxidative injury; organ damage in severe disease
Immune system disruption and activation	**Immune system disruption and activation**
Immune suppression in some studies; immune hyperactivation in other studies	Decreased production of T-lymphocytes; elevated inflammatory biomarkers.
Long-term: suppression of T-lymphocytes; inflammatory biomarkers increased; autoimmunity; organ injury	→ Immune hyperactivation and inflammation; cytokine storm in severe disease; cytokine-induced hypo-perfusion with resulting hypoxia; organ injury; organ failure
Increased intracellular calcium	**Increased intracellular calcium**
From activation of voltage-gated calcium channels on cell membranes, with numerous secondary effects	→ Increased virus entry, replication, and release
	→ Increased NF-κB, pro-inflammatory processes, coagulation, and thrombosis
Cardiac effects	**Cardiac effects**
Up-regulation of sympathetic nervous system; palpitations and arrhythmias	Arrhythmias
	→ Myocarditis; myocardial ischemia; cardiac injury; cardiac failure

Supportive evidence including study details and citations are provided in the text under each subject heading, i.e., blood changes, oxidative stress, etc.

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3. Results

Table 1 lists the manifestations common to COVID-19 including disease progression and the corresponding adverse bioeffects from WCR exposure. Although these effects are delineated into categories — blood changes, oxidative stress, immune system disruption and activation, increased intracellular calcium (Ca^{2+}), and cardiac effects — it must be emphasized that these effects are not independent of each other. For example, blood clotting and inflammation have overlapping mechanisms, and oxidative stress is implicated in erythrocyte morphological changes as well as in hypercoagulation, inflammation, and organ damage.

3.1. Blood changes

WCR exposure can cause morphologic changes in blood readily seen through phase contrast or dark-field microscopy of live peripheral blood samples. In 2013, Havas observed erythrocyte aggregation including rouleaux (rolls of stacked red blood cells) in live peripheral blood samples following 10 min human exposure to a 2.4 GHz cordless phone [50]. Although not peer reviewed, one of us (Rubik) investigated the effect of 4G LTE mobile phone radiation on the peripheral blood of ten human subjects, each of whom had been exposed to cell phone radiation for two consecutive 45-min intervals [51]. Two types of effects were observed: increased stickiness and clumping of red blood cells with rouleaux formation, and subsequent formation of echinocytes (spiky red blood cells). Red blood cell clumping and aggregation are known to be actively involved in blood clotting [52]. The prevalence of this phenomenon on exposure to WCR in the human population has not yet been determined. Larger controlled studies should be performed to further investigate this phenomenon.

Similar red blood cell changes have been described in peripheral blood of COVID-19 patients [53]. Rouleaux formation has been observed in 1/3 of COVID-19 patients, whereas spherocytes and echinocyte formation is more variable. Spike protein engagement with ACE2 receptors on cells lining the blood vessels can lead to endothelial damage, even when isolated [54]. Rouleaux formation, particularly in the setting of underlying endothelial damage, can clog the microcirculation, impeding oxygen transport, contributing to hypoxia, and increasing the risk of thrombosis [52]. Thrombogenesis associated with SARS-CoV-2 infection may also be caused by direct viral binding to ACE2 receptors on platelets [55].

Additional blood effects have been observed in both humans and animals exposed to WCR. In 1977, a Russian study reported that rodents irradiated with 5 – 8 mm waves (60 – 37 GHz) at 1 mW/cm^2 for 15 min/day over 60 days developed hemodynamic disorders, suppressed red blood cell formation, reduced hemoglobin, and an inhibition of oxygen utilization (oxidative phosphorylation by the mitochondria) [56]. In 1978, a 3-year Russian study on 72 engineers exposed to millimeter wave generators emitting at 1 mW/cm^2 or less showed a decrease in their hemoglobin levels and red blood cell counts, and a tendency toward hypercoagulation, whereas a control group showed no changes [57]. Such deleterious hematologic effects from WCR exposure may also contribute to the development of hypoxia and blood clotting observed in COVID-19 patients.

It has been proposed that the SARS-CoV-2 virus attacks erythrocytes and causes degradation of hemoglobin [11]. Viral proteins may attack the 1-beta chain of hemoglobin and capture the porphyrin, along with other proteins from the virus catalyzing the dissociation of iron from heme [58]. In principle this would reduce the number of functional erythrocytes and cause the release of free iron ions that could cause oxidative stress, tissue damage, and hypoxia. With hemoglobin partially destroyed and lung tissue damaged by inflammation, patients would be less able to exchange carbon dioxide (CO_2) and oxygen (O_2), and would become oxygen depleted. In fact, some COVID-19 patients show reduced hemoglobin levels, measuring 7.1 g/L and even as low as 5.9 g/L in severe cases [59]. Clinical studies of almost 100 patients from Wuhan revealed that the hemoglobin levels in the blood of most patients infected with SARS-CoV-2 are significantly lowered resulting in compromised delivery of oxygen to tissues and organs [60]. In a meta-analysis of four studies with a total of 1210 patients and 224 with severe disease, hemoglobin values were reduced in COVID-19 patients with severe disease compared to those with milder forms [59]. In another study on 601 COVID-19 patients, 14.7% of anemic COVID-19 ICU patients and 9% of non-ICU COVID-19 patients had autoimmune hemolytic anemia [61]. In patients with severe COVID-19 disease, decreased hemoglobin along with elevated erythrocyte sedimentation rate (ESR), C-reactive protein, lactate dehydrogenase, albumin [62], serum ferritin [63], and low oxygen saturation [64] provide additional support for this hypothesis. In addition, packed red blood cell transfusion may promote recovery of COVID-19 patients with acute respiratory failure [65].

In short, both WCR exposure and COVID-19 may cause deleterious effects on red blood cells and reduced hemoglobin levels contributing to hypoxia in COVID-19. Endothelial injury may further contribute to hypoxia and many of the vascular complications seen in COVID-19 [66] that are discussed in the next section.

3.2. Oxidative stress

Oxidative stress is a non-specific pathological condition reflecting an imbalance between an increased production of ROS and an inability of the organism to detoxify the ROS or to repair the damage they cause to biomolecules and tissues [67]. Oxidative stress can disrupt cell signaling, cause the formation of stress proteins, and generate highly reactive free radicals, which can cause DNA and cell membrane damage.

SARS-CoV-2 inhibits intrinsic pathways designed to reduce ROS levels, thereby increasing morbidity. Immune dysregulation, that is, the upregulation of interleukin (IL)-6 and tumor necrosis factor α (TNF-α) [68] and suppression of interferon (IFN) α and IFN β [69] have been identified in the cytokine storm accompanying severe COVID-19 infections and generates oxidative stress [10]. Oxidative stress and mitochondrial dysfunction may further perpetuate the cytokine storm, worsening tissue damage, and increasing the risk of severe illness and death.

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Similarly low-level WCR generates ROS in cells that cause oxidative damage. In fact, oxidative stress is considered to be one of the primary mechanisms in which WCR exposure causes cellular damage. Among 100 currently available peer-reviewed studies investigating oxidative effects of low-intensity WCR, 93 of these studies confirmed that WCR induces oxidative effects in biological systems [17]. WCR is an oxidative agent with a high pathogenic potential especially when exposure is continuous [70].

Oxidative stress is also an accepted mechanism causing endothelial damage [71]. This may manifest in patients with severe COVID-19 in addition to increasing the risk for blood clot formation and worsening hypoxemia [10]. Low levels of glutathione, the master antioxidant, have been observed in a small group of COVID-19 patients, with the lowest level found in the most severe cases [72]. The finding of low glutathione levels in these patients further supports oxidative stress as a component of this disease [72]. In fact, glutathione, the major source of sulfhydryl-based antioxidant activity in the human body, may be pivotal in COVID-19 [73]. Glutathione deficiency has been proposed as the most likely cause of serious manifestations in COVID-19 [72]. The most common co-morbidities, hypertension [74]; obesity [75]; diabetes [76]; and chronic obstructive pulmonary disease [74] support the concept that pre-existing conditions causing low levels of glutathione may work synergistically to create the "perfect storm" for both the respiratory and vascular complications of severe infection. Another paper citing two cases of COVID-19 pneumonia treated successfully with intravenous glutathione also supports this hypothesis [77].

Many studies report oxidative stress in humans exposed to WCR. Peraica *et al.* [78] found diminished blood levels of glutathione in workers exposed to WCR from radar equipment (0.01 mW/cm^2 – 10 mW/cm^2; 1.5 – 10.9 GHz). Garaj-Vrhovac *et al.* [79] studied bioeffects following exposure to non-thermal pulsed microwaves from marine radar (3 GHz, 5.5 GHz, and 9.4 GHz) and reported reduced glutathione levels and increased malondialdehyde (marker for oxidative stress) in an occupationally exposed group [79]. Blood plasma of individuals residing near mobile phone base stations showed significantly reduced glutathione, catalase, and superoxide dismutase levels over unexposed controls [80]. In a study on human exposure to WCR from mobile phones, increased blood levels of lipid peroxide were reported, while enzymatic activities of superoxide dismutase and glutathione peroxidase in the red blood cells decreased, indicating oxidative stress [81].

In a study on rats exposed to 2450 MHz (wireless router frequency), oxidative stress was implicated in causing red blood cell lysis (hemolysis) [82]. In another study, rats exposed to 945 MHz (base station frequency) at 0.367 mW/cm^2 for 7 h/day, over 8 days, demonstrated low glutathione levels and increased malondialdehyde and superoxide dismutase enzyme activity, hallmarks for oxidative stress [83]. In a long-term controlled study on rats exposed to 900 MHz (mobile phone frequency) at 0.0782 mW/cm^2 for 2 h/day for 10 months, there was a significant increase in malondialdehyde and total oxidant status over controls [84]. In another long-term controlled study on rats exposed to two mobile phone frequencies, 1800 MHz and 2100 MHz, at power densities 0.04 – 0.127 mW/cm^2 for 2 h/day over 7 months, significant alterations in oxidant-antioxidant parameters, DNA strand breaks, and oxidative DNA damage were found [85].

There is a correlation between oxidative stress and thrombogenesis [86]. ROS can cause endothelial dysfunction and cellular damage. The endothelial lining of the vascular system contains ACE2 receptors that are targeted by SARS-CoV-2. The resulting endotheliitis can cause luminal narrowing and result in diminished blood flow to downstream structures. Thrombi in arterial structures can further obstruct blood flow causing ischemia and/or infarcts in involved organs, including pulmonary emboli and strokes. Abnormal blood coagulation leading to micro-emboli was a recognized complication early in the history of COVID-19 [87]. Out of 184 ICU COVID-19 patients, 31% showed thrombotic complications [88]. Cardiovascular clotting events are a common cause of COVID-19 deaths [12]. Pulmonary embolism, disseminated intravascular coagulation (DIC), liver, cardiac, and renal failure have all been observed in COVID-19 patients [89].

Patients with the highest cardiovascular risk factors in COVID-19 includ males, the elderly, diabetics, and obese and hypertensive patients. However, increased incidence of strokes in younger patients with COVID-19 has also been described [90].

Oxidative stress is caused by WCR exposure and is known to be implicated in cardiovascular disease. Ubiquitous environmental exposure to WCR may contribute to cardiovascular disease by creating a chronic state of oxidative stress [91]. This would lead to oxidative damage to cellular constituents and alter signal transduction pathways. In addition, pulse-modulated WCR can cause oxidative injury in liver, lung, testis, and heart tissues mediated by lipid peroxidation, increased levels of nitric oxides, and suppression of the antioxidant defense mechanism [92].

In summary, oxidative stress is a major component in the pathophysiology of COVID-19 as well as in cellular damage caused by WCR exposure.

3.3. Immune system disruption and activation

When SARS-CoV-2 first infects the human body, it attacks cells lining the nose, throat, and upper airway harboring ACE2 receptors. Once the virus gains access to a host cell through one of its spike proteins, which are the multiple protuberances projecting from the viral envelope that bind to ACE2 receptors, it converts the cell into a virus self-replicating entity.

In response to COVID-19 infection, both an immediate systemic innate immune response as well as a delayed adaptive response has been shown to occur [93]. The virus can also cause a dysregulation of the immune response, particularly in the decreased production of T-lymphocytes. [94]. Severe cases tend to have lower lymphocyte counts, higher leukocyte counts and neutrophil-lymphocyte ratios, as well as lower percentages of monocytes, eosinophils, and basophils [94]. Severe cases of COVID-19 show the greatest impairment in T-lymphocytes.

In comparison, low-level WCR studies on laboratory animals also show impaired immune function [95]. Findings

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include physical alterations in immune cells, a degradation of immunological responses, inflammation, and tissue damage. Baranski [96] exposed guinea pigs and rabbits to continuous or pulse-modulated 3000 MHz microwaves at an average power density of 3.5 mW/cm^2 for 3 h/day over 3 months and found nonthermal changes in lymphocyte counts, abnormalities in nuclear structure, and mitosis in the erythroblastic cell series in the bone marrow and in lymphoid cells in lymph nodes and spleen. Other investigators have shown diminished T-lymphocytes or suppressed immune function in animals exposed to WCR. Rabbits exposed to 2.1 GHz at 5mW/cm^2 for 3 h/day, 6 days/week, for 3 months, showed suppression of T-lymphocytes [97]. Rats exposed to 2.45 GHz and 9.7 GHz for 2 h/day, 7 days/week, for 21 months showed a significant decrease in the levels of lymphocytes and an increase in mortality at 25 months in the irradiated group [98]. Lymphocytes harvested from rabbits irradiated with 2.45 GHz for 23 h/day for 6 months show a significant suppression in immune response to a mitogen [99].

In 2009, Johansson conducted a literature review, which included the 2007 Bioinitiative Report. He concluded that electromagnetic fields (EMF) exposure, including WCR, can disturb the immune system and cause allergic and inflammatory responses at exposure levels significantly less than current national and international safety limits and raise the risk for systemic disease [100]. A review conducted by Szmigielski in 2013 concluded that weak RF/microwave fields, such as those emitted by mobile phones, can affect various immune functions both *in vitro* and *in vivo* [101]. Although the effects are historically somewhat inconsistent, most research studies document alterations in the number and activity of immune cells from RF exposure. In general, short-term exposure to weak microwave radiation may temporarily stimulate an innate or adaptive immune response, but prolonged irradiation inhibits those same functions.

In the acute phase of COVID-19 infection, blood tests demonstrate elevated ESR, C-reactive protein, and other elevated inflammatory markers [102], typical of an innate immune response. Rapid viral replication can cause death of epithelial and endothelial cells and result in leaky blood vessels and pro-inflammatory cytokine release [103]. Cytokines, proteins, peptides, and proteoglycans that modulate the body's immune response, are modestly elevated in patients with mild-to-moderate disease severity [104]. In those with severe disease, an uncontrolled release of pro-inflammatory cytokines--a cytokine storm--can occur. Cytokine storms originate from an imbalance in T-cell activation with dysregulated release of IL-6, IL-17, and other cytokines. Programmed cell death (apoptosis), ARDS, DIC, and multi-organ system failure can all result from a cytokine storm and increase the risk of mortality.

By comparison, Soviet researchers found in the 1970s that radiofrequency radiation can damage the immune system of animals. Shandala [105] exposed rats to 0.5 mW/cm^2 microwaves for 1 month, 7 h/day, and found impaired immune competence and induction of autoimmune disease. Rats irradiated with 2.45 GHz at 0.5 mW/cm^2 for 7 h daily for 30 days produced autoimmune reactions, and 0.1 – 0.5 mW/cm^2 produced persistent pathological immune reactions [106]. Exposure to microwave radiation, even at low levels (0.1 – 0.5 mW/cm^2), can impair immune function, causing physical alterations in the essential cells of the immune system and a degradation of immunologic responses [107]. Szabo *et al.* [108] examined the effects of 61.2 GHz exposure on epidermal keratinocytes and found an increase in IL-1b, a pro-inflammatory cytokine. Makar *et al.* [109] found that immunosuppressed mice irradiated 30 min/day for 3 days by 42.2 GHz showed increased levels of TNF-α, a cytokine produced by macrophages.

In short, COVID-19 can lead to immune dysregulation as well as cytokine storms. By comparison, exposure to low-level WCR as observed in animal studies can also compromise the immune system, with chronic daily exposure producing immunosuppression or immune dysregulation including hyperactivation.

3.4. Increased intracellular calcium

In 1992, Walleczek first suggested that ELF electromagnetic fields (<3000 Hz) may be affecting membrane-mediated Ca^{2+} signaling and lead to increased intracellular Ca^{2+} [110]. The mechanism of irregular gating of voltage-gated ion channels in cell membranes by polarized and coherent, oscillating electric or magnetic fields was first presented in 2000 and 2002 [40,111]. Pall [112] in his review of WCR-induced bioeffects combined with use of calcium channel blockers (CCB) noted that voltage-gated calcium channels play a major role in WCR bioeffects. Increased intracellular Ca^{+2} results from the activation of voltage-gated calcium channels, and this may be one of the primary mechanisms of action of WCR on organisms.

Intracellular Ca^{2+} is essential for virus entry, replication, and release. It has been reported that some viruses can manipulate voltage-gated calcium channels to increase intracellular Ca^{2-} thereby facilitating viral entry and replication [113]. Research has shown that the interaction between a virus and voltage-gated calcium channels promote virus entry at the virus-host cell fusion step [113]. Thus, after the virus binds to its receptor on a host cell and enters the cell through endocytosis, the virus takes over the host cell to manufacture its components. Certain viral proteins then manipulate calcium channels, thereby increasing intracellular Ca^{2+}, which facilitates further viral replication.

Even though direct evidence has not been reported, there is indirect evidence that increased intracellular Ca^{2+} may be involved in COVID-19. In a recent study, elderly hospitalized COVID-19 patients treated with CCBs, amlodipine or nifedipine, were more likely to survive and less likely to require intubation or mechanical ventilation than controls [114]. Furthermore, CCBs strongly limit SARS-CoV-2 entry and infection in cultured epithelial lung cells [115]. CCBs also block the increase of intracellular Ca^{2+} caused by WCR exposure as well as exposure to other electromagnetic fields [112].

Intracellular Ca^{2+} is a ubiquitous second messenger relaying signals received by cell surface receptors to effector proteins involved in numerous biochemical processes. Increased intracellular Ca^{2+} is a significant factor in upregulation of transcription nuclear factor KB (NF-κB) [116], an important regulator of pro-inflammatory cytokine production as well as coagulation and thrombotic cascades. NF-κB is hypothesized to be a key factor underlying severe clinical manifestations of COVID-19 [117].

In short, WCR exposure, therefore, may enhance the infectivity of the virus by increasing intracellular Ca^{2+} that may also indirectly contribute to inflammatory processes and thrombosis.

3.5. Cardiac effects

Cardiac arrhythmias are more commonly encountered in critically ill patients with COVID-19 [118]. The cause for arrhythmia in COVID-19 patients is multifactorial and includes cardiac and extra-cardiac processes [119]. Direct infection of the heart muscle by SARS-CoV-19 causing myocarditis, myocardial ischemia caused by a variety of etiologies, and heart strain secondary to pulmonary or systemic hypertension can result in cardiac arrhythmia. Hypoxemia caused by diffuse pneumonia, ARDS, or extensive pulmonary emboli represent extra-cardiac causes of arrhythmia. Electrolyte imbalances, intravascular fluid imbalance, and side effects from pharmacologic regimens can also result in arrhythmias in COVID-19 patients. Patients admitted to ICUs have been shown to have a higher increase in cardiac arrhythmias, 16.5% in one study [120]. Although no correlation between EMFs and arrhythmia in COVID-19 patients has been described in the literature, many ICUs are equipped with wireless patient monitoring equipment and communication devices producing a wide range of EMF pollution [121].

COVID-19 patients commonly show increased levels of cardiac troponin, indicating damage to the heart muscle [122]. Cardiac damage has been associated with arrhythmias and increased mortality. Cardiac injury is thought to be more often secondary to pulmonary emboli and viral sepsis, but direct infection of the heart, that is, myocarditis, can occur through direct viral binding to ACE2 receptors on cardiac pericytes, affecting local, and regional cardiac blood flow [60].

Immune system activation along with alterations in the immune system may result in atherosclerotic plaque instability and vulnerability, that is, presenting an increased risk for thrombus formation, and contributing to development of acute coronary events and cardiovascular disease in COVID-19.

Regarding WCR exposure bioeffects, in 1969 Christopher Dodge of the Biosciences Division, U.S. Naval Observatory in Washington DC, reviewed 54 papers and reported that radiofrequency radiation can adversely affect all major systems of the body, including impeding blood circulation; altering blood pressure and heart rate; affecting electrocardiograph readings; and causing chest pain and heart palpitations [123]. In the 1970s Glaser reviewed more than 2000 publications on radiofrequency radiation exposure bioeffects and concluded that microwave radiation can alter the electrocardiogram, cause chest pain, hypercoagulation, thrombosis, and hypertension in addition to myocardial infarction [27,28]. Seizures, convulsions, and alteration of the autonomic nervous system response (increased sympathetic stress response) have also been observed.

Since then, many other researchers have concluded that WCR exposure can affect the cardiovascular system. Although the nature of the primary response to millimeter waves and consequent events are poorly understood, a possible role for receptor structures and neural pathways in the development of continuous millimeter wave-induced arrhythmia has been proposed [47]. In 1997, a review reported that some investigators discovered cardiovascular changes including arrhythmias in humans from long-term low-level exposure to WCR including microwaves [124]. However, the literature also shows some unconfirmed findings as well as some contradictory findings [125]. Havas *et al.* [126] reported that human subjects in a controlled, double-blinded study were hyper-reactive when exposed to 2.45 GHz, digitally pulsed (100 Hz) microwave radiation, developing either an arrhythmia or tachycardia and upregulation of the sympathetic nervous system, which is associated with the stress response. Saili *et al.* [127] found that exposure to Wi-Fi (2.45 GHz pulsed at 10 Hz) affects heart rhythm, blood pressure, and the efficacy of catecholamines on the cardiovascular system, indicating that WCR can act directly and/or indirectly on the cardiovascular system. Most recently, Bandara and Weller [91] present evidence that people who live near radar installations (millimeter waves: 5G frequencies) have a greater risk of developing cancer and experiencing heart attacks. Similarly, those occupationally exposed have a greater risk of coronary heart disease. Microwave radiation affects the heart, and some people are more vulnerable if they have an underlying heart abnormality [128]. More recent research suggests that millimeter waves may act directly on the pacemaker cells of the sinoatrial node of the heart to change the beat frequency, which may underlie arrhythmias and other cardiac issues [47].

In short, both COVID-19 and WCR exposure can affect the heart and cardiovascular system, directly and/or indirectly.

4. Discussion

Epidemiologists, including those at the CDC, consider multiple causal factors when evaluating the virulence of an agent and understanding its ability to spread and cause disease. Most importantly, these variables include environmental cofactors and the health status of the host. Evidence from the literature summarized here suggests a possible connection between several adverse health effects of WCR exposure and the clinical course of COVID-19 in that WCR may have worsened the COVID-19 pandemic by weakening the host and exacerbating COVID-19 disease. However, none of the observations discussed here prove this linkage. Specifically, the evidence does not confirm causation. Clearly COVID-19 occurs in regions with little wireless communication. Furthermore, the relative morbidity caused by WCR exposure in COVID-19 is unknown.

We recognize that many factors have influenced the pandemic's course. Before restrictions were imposed, travel patterns facilitated the seeding of the virus, causing early rapid global spread. Population density, higher mean population age, and socioeconomic factors certainly influenced early viral spread. Air pollution, especially particulate matter $PM_{2.5}$ (2.5

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micro-particulates), likely increased symptoms in patients with COVID-19 lung disease [129].

We postulate that WCR possibly contributed to the early spread and severity of COVID-19. Once an agent becomes established in a community, its virulence increases [130]. This premise can be applied to the COVID-19 pandemic. We surmise that "hot spots" of the disease that initially spread around the world were perhaps seeded by air travel, which in some areas were associated with 5G implementation. However, once the disease became established in those communities, it was able to spread more easily to neighboring regions where populations were less exposed to WCR. Second and third waves of the pandemic disseminated widely throughout communities with and without WCR, as might be expected.

The COVID-19 pandemic has offered us an opportunity to delve further into the potential adverse effects of WCR exposure on human health. Human exposure to ambient WCR significantly increased in 2020 as a "side effect" to the pandemic. Stay-at-home measures designed to reduce the spread of COVID-19 inadvertently resulted in greater public exposure to WCR, as people conducted more business and school related activities through wireless communications. Telemedicine created another source of WCR exposure. Even hospital inpatients, particular ICU patients, experienced increased WCR exposure as new monitoring devices utilized wireless communication systems that may exacerbate health disorders. It would potentially provide valuable information to measure ambient WCR power densities in home and work environments when comparing disease severity in patient populations with similar risk factors.

The question of causation could be investigated in future studies. For example, a clinical study could be conducted in COVID-19 patient populations with similar risk factors, to measure the WCR daily dose in COVID-19 patients and look for a correlation with disease severity and progression over time. As wireless device carrier frequencies and modulations may differ, and the power densities of WCR fluctuate constantly at a given location, this study would require patients to wear personal microwave dosimeters (monitoring badges). In addition, controlled laboratory studies could be conducted on animals, for example, humanized mice infected with SARS-CoV-2, in which groups of animals exposed to minimal WCR (control group) as well as medium and high power densities of WCR could be compared for disease severity and progression.

A major strength of this paper is that the evidence rests on a large body of scientific literature reported by many scientists worldwide and over several decades--experimental evidence of adverse bioeffects of WCR exposure at nonthermal levels on humans, animals, and cells. The Bioinitiative Report [42], updated in 2020, summarizes hundreds of peer-reviewed scientific papers documenting evidence of nonthermal effects from exposures ≤ 1 mW/cm^2. Even so, some laboratory studies on the adverse health effects of WCR have sometimes utilized power densities exceeding 1mW/cm^2. In this paper, almost all of the studies that we reviewed included experimental data at power densities ≤ 1 mW/cm^2.

A potential criticism of this paper is that adverse bioeffects from nonthermal exposures are not yet universally accepted in science. Moreover, they are not yet considered in establishing public health policy in many nations. Decades ago, Russians and Eastern Europeans compiled considerable data on nonthermal bioeffects, and subsequently set guidelines at lower radiofrequency radiation exposure limits than the US and Canada, that is, below levels where nonthermal effects are observed. However, the Federal Communications Commission (FCC, a US government entity) and ICNIRP guidelines operate on thermal limits based on outdated data from decades ago, allowing the public to be exposed to considerably higher radiofrequency radiation power densities. Regarding 5G, the telecommunication industry claims that it is safe because it complies with current radiofrequency radiation exposure guidelines of the FCC and ICNIRP. These guidelines were established in 1996 [131], are antiquated, and are not safety standards. Thus, there are no universally accepted safety standards for wireless communication radiation exposure. Recently international bodies, such as the EMF Working Group of the European Academy of Environmental Medicine, have proposed much lower guidelines, taking into account nonthermal bioeffects from WCR exposure in multiple sources [132].

Another weakness of this paper is that some of the bioeffects from WCR exposure are inconsistently reported in the literature. Replicated studies are often not true replications. Small differences in method, including unreported details, such as prior history of exposure of the organisms, non-uniform body exposure, and other variables can lead to inadvertent inconsistency. Moreover, not surprisingly, industry-sponsored studies tend to show less adverse bioeffects than studies conducted by independent researchers, suggesting industry bias [133]. Some experimental studies that are not industry-sponsored have also shown no evidence of harmful effects of WCR exposure. It is noteworthy, however, that studies employing real-life WCR exposures from commercially available devices have shown high consistency in revealing adverse effects [134].

WCR bioeffects depend on specific values of wave parameters including frequency, power density, polarization, exposure duration, modulation characteristics, as well as the cumulative history of exposure and background levels of electromagnetic, electric and magnetic fields. In laboratory studies, bioeffects observed also depend on genetic parameters and physiological parameters such as oxygen concentration [135]. The reproducibility of bioeffects of WCR exposure has sometimes been difficult due to failure to report and/or control all of these parameters. Similar to ionizing radiation, the bioeffects of WCR exposure can be subdivided into deterministic, that is, dose-dependent effects and stochastic effects that are seemingly random. Importantly, WCR bioeffects can also involve "response windows" of specific parameters whereby extremely low-level fields can have disproportionally detrimental effects [136]. This nonlinearity of WCR bioeffects can result in biphasic responses such as immune suppression from one range of parameters, and immune hyperactivation from another range of parameters, leading to variations that may appear inconsistent.

In gathering reports and examining existing data for this paper, we looked for outcomes providing evidence to support a proposed connection between the bioeffects of WCR exposure and

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COVID-19. We did not make an attempt to weigh the evidence. The radiofrequency radiation exposure literature is extensive and currently contains over 30,000 research reports dating back several decades. Inconsistencies in nomenclature, reporting of details, and cataloging of keywords make it difficult to navigate this enormous literature.

Another shortcoming of this paper is that we do not have access to experimental data on 5G exposures. In fact, little is known about population exposure from real-world WCR, which includes exposure to WCR infrastructure and the plethora of WCR emitting devices. In relation to this, it is difficult to accurately quantify the average power density at a given location, which varies greatly, depending on the time, specific location, time-averaging interval, frequency, and modulation scheme. For a specific municipality it depends on the antenna density, which network protocols are used, as, for example, 2G, 3G, 4G, 5G, Wi-Fi, WiMAX (Worldwide Interoperability for Microwave Access), DECT (Digitally Enhanced Cordless Telecommunications), and RADAR (Radio Detection and Ranging). There is also WCR from ubiquitous radio wave transmitters, including antennas, base stations, smart meters, mobile phones, routers, satellites, and other wireless devices currently in use. All of these signals superimpose to yield the total average power density at a given location that typically fluctuates greatly over time. No experimental studies on adverse health effects or safety issues of 5G have been reported, and none are currently planned by the industry, although this is sorely needed.

Finally, there is an inherent complexity to WCR that makes it very difficult to fully characterize wireless signals in the real world that may be associated with adverse bioeffects. Real world digital communication signals, even from single wireless devices, have highly variable signals: variable power density, frequency, modulation, phase, and other parameters changing constantly and unpredictably each moment, as associated with the short, rapid pulsations used in digital wireless communication [137]. For example, in using a mobile phone during a typical phone conversation, the intensity of emitted radiation varies significantly each moment depending on signal reception, number of subscribers sharing the frequency band, location within the wireless infrastructure, presence of objects and metallic surfaces, and "speaking" versus "non-speaking" mode, among others. Such variations may reach 100% of the average signal intensity. The carrier radiofrequency constantly changes between different values within the available frequency band. The greater the amount of information (text, speech, internet, video, etc.), the more complex the communication signals become. Therefore, we cannot estimate accurately the values of these signal parameters including ELF components or predict their variability over time. Thus, studies on the bioeffects of WCR in the laboratory can only be representative of real-world exposures [137].

This paper points to the need for further research on nonthermal WCR exposure and its potential role in COVID-19. Moreover, some of the WCR exposure bioeffects that we discuss here — oxidative stress, inflammation, and immune system disruption — are common to many chronic diseases, including autoimmune disease and diabetes. Thus, we hypothesize that WCR exposure may also be a potential contributing factor in many chronic diseases.

When a course of action raises threats of harm to human health, precautionary measures should be taken, even if clear causal relationships are not yet fully established. Therefore, we must apply the Precautionary Principle [138] regarding wireless 5G. The authors urge policymakers to execute an immediate worldwide moratorium on wireless 5G infrastructure until its safety can be assured.

Several unresolved safety issues should be addressed before wireless 5G is further implemented. Questions have been raised about 60 GHz, a key 5G frequency planned for extensive use, which is a resonant frequency of the oxygen molecule [139]. It is possible that adverse bioeffects might ensue from oxygen absorption of 60 GHz. In addition, water shows broad absorption in the GHz spectral region along with resonance peaks, for example, strong absorption at 2.45 GHz that is used in 4G Wi-Fi routers. This raises safety issues about GHz exposure of the biosphere, since organisms are comprised of mostly water, and changes in the structure of water due to GHz absorption have been reported that affect organisms [140]. Bioeffects from prolonged WCR exposure of the whole body need to be investigated in animal and human studies, and long-term exposure guidelines need to be considered. Independent scientists in particular should conduct concerted research to determine the biological effects of real-world exposure to WCR frequencies with digital modulation from the multiplicity of wireless communication devices. Testing could also include real-life exposures to multiple toxins (chemical and biological) [141], because multiple toxins may lead to synergistic effects. Environmental impact assessments are also needed. Once the long-term biological effects of wireless 5G are understood, we can set clear safety standards of public exposure limits and design an appropriate strategy for safe deployment.

5. Conclusion

There is a substantial overlap in pathobiology between COVID-19 and WCR exposure. The evidence presented here indicates that mechanisms involved in the clinical progression of COVID-19 could also be generated, according to experimental data, by WCR exposure. Therefore, we propose a link between adverse bioeffects of WCR exposure from wireless devices and COVID-19.

Specifically, evidence presented here supports a premise that WCR and, in particular, 5G, which involves densification of 4G, may have exacerbated the COVID-19 pandemic by weakening host immunity and increasing SARS-CoV-2 virulence by (1) causing morphologic changes in erythrocytes including echinocyte and rouleaux formation that may be contributing to hypercoagulation; (2) impairing microcirculation and reducing erythrocyte and hemoglobin levels exacerbating hypoxia; (3) amplifying immune dysfunction, including immunosuppression, autoimmunity, and hyperinflammation; (4) increasing cellular oxidative stress and the production of free radicals exacerbating vascular injury and organ damage; (5) increasing intracellular Ca^{2+} essential for viral entry, replication, and release, in addition to promoting pro-

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inflammatory pathways; and (6) worsening heart arrhythmias and cardiac disorders.

WCR exposure is a widespread, yet often neglected, environmental stressor that can produce a wide range of adverse bioeffects. For decades, independent research scientists worldwide have emphasized the health risks and cumulative damage caused by WCR [42,45]. The evidence presented here is consistent with a large body of established research. Healthcare workers and policymakers should consider WCR a potentially toxic environmental stressor. Methods for reducing WCR exposure should be provided to all patients and the general population.

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Conflict of Interest

The authors declare that they have no conflicts of interest in preparing and publishing this manuscript. No competing financial interests exist.

References

[1] Centers for Disease Control and Prevention. Epidemiological Triad. Atlanta, Georgia: Centers for Disease Control and Prevention; 2020.

[2] Balmori A. Electromagnetic Pollution from Phone Masts. Effects on Wildlife. Pathophysiology 2009;16:191-9.

[3] Lin JC. 5G Communications Technology and Coronavirus Disease. IEEE Microw Mag 2020;21:16-9.

[4] Mordachev VI. Correlation between the Potential Electromagnetic Pollution Level and the Danger of COVID-19. 4G/5G/6G can be Safe for People. Doklady BGUIR 2020;18:96-112.

[5] Tsiang A, Havas M. COVID-19 Attributed Cases and Deaths are Statistically Higher in States and Counties with 5th Generation Millimeter Wave Wireless Telecommunications in the United States. Med Res Arch 2021;9:2371.

[6] Ing AJ, Cocks C, Green JP. COVID-19: In the Footsteps of Ernest Shackleton. Thorax 2020;75:693-4.

[7] Garg S, Kim L, Whitaker M, O'Halloran A, Cummings C, Holstein R, *et al.* Hospitalization Rates and Characteristics of Patients Hospitalized with Laboratory-Confirmed Coronavirus Disease 2019 COVID-NET, 14 States, March 1-30, 2020. MMWR Morb Mortal Wkly Rep 69:458-64.

[8] Wu C, Chen X, Cai Y, Xia J, Zhou X, Xu S, *et al.* Risk Factors Associated with Acute Respiratory Distress Syndrome and Death in Patients with Coronavirus Disease. JAMA Intern Med 2020;180:934-43.

[9] Gattinoni L, Chiumello D, Caironi P, Busana M, Romitti F, Brazzi L, *et al.* COVID-19 Pneumonia: Different Respiratory Treatments for Different Phenotypes: Intensive Care Med 2020;46:1099-102.

[10] Cecchini R, Cecchini AL. SARS-CoV-2 Infection Pathogenesis is Related to Oxidative Stress as a Response to Aggression. Med Hypotheses 2020;143:110102.

[11] Cavezzi A, Troiani E, Corrao S. COVID-19: Hemoglobin, Iron, and Hypoxia Beyond Inflammation, a Narrative Review. Clin Pract 2020;10:1271.

[12] Bikdeli B, Madhavan MV, Jimenez D, Chuich T, Dreyfus I, Driggin E, Nigoghossian C, *et al.* Global COVID-19 Thrombosis Collaborative Group, Endorsed by the ISTH, NATF, ESVM, and the IUA, Supported by the ESC Working Group on Pulmonary Circulation and Right Ventricular Function. COVID-19 and Thrombotic or Thromboembolic Disease: Implications for Prevention, Antithrombotic Therapy, and Follow-Up: JACC State-of-the-Art Review. JACC 2020;75:2950-73.

[13] Carfi A, Bernabei R, Landi F. Persistent Symptoms in Patients after Acute COVID-19. JAMA 2020;324:603-5.

[14] ICNIRP. International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines for Limiting Exposure to Electromagnetic Fields (100 kHz to 300 GHz). Health Phys 2020;118:483-524.

[15] Bortkiewicz A, Gadzicka E, Szymczak W. Mobile Phone Use and Risk for Intracranial Tumors and Salivary Gland Tumors A Meta-analysis. Int J Occup Med Environ Health 2017;30:27-43.

[16] Sangün Ö, Dündar B, Çömlekçi S, Büyükgebiz A. The Effects of Electromagnetic Field on the Endocrine System in Children and Adolescents. Pediatr Endocrinol Rev 2016;13:531-45.

[17] Yakymenko I, Tsybulin O, Sidorik E, Henshel D, Kyrylenko O, Kyrylenko S. Oxidative Mechanisms of Biological Activity of Low-intensity Radiofrequency Radiation. Electromagn Biol Med 2016;35:186-202.

[18] Ruediger HW. Genotoxic Effects of Radiofrequency Electromagnetic Fields. Pathophysiology 2009;16:89-102.

[19] Asghari A, Khaki AA, Rajabzadeh A, Khaki A. A Review on Electromagnetic Fields (EMFs) and the Reproductive System. Electron Physician 2016;8:2655-62.

[20] Zhang J, Sumich A, Wang GY. Acute Effects of Radiofrequency Electromagnetic Field Emitted by Mobile Phone on Brain Function. Bioelectromagnetics 2017;38:329-38.

[21] Pall ML. Microwave Frequency Electromagnetic Fields (EMFs) Produce Widespread Neuropsychiatric Effects Including Depression. J Chem Neuroanat 2016;75:43-51.

[22] Avendano C, Mata A, Sanchez Sarmiento CA, Doncei GF. Use of Laptop Computers Connected to Internet through Wi-Fi Decreases Human Sperm Motility and Increases Sperm DNA Fragmentation. Fertil Steril 2012;97:39-45.

[23] Buchner K, Eger H. Changes of Clinically Important Neurotransmitters under the Influence of Modulated RF Fields a Long-term Study Under Real-life Conditions Umwelt Medizin Gesellschaft 2011;24:44-57.

[24] Navarro EA, Segura J, Portoles M, Gomez-Perretta C. The Microwave Syndrome: A Preliminary Study in Spain. Electromagn Biol Med 2003;22:161-9.

[25] Hutter HP, Moshammer H, Wallner P, Kundi M. Subjective Symptoms, Sleeping Problems, and Cognitive Performance in Subjects Living Near Mobile Phone Base Stations. Occup Environ Med 2006;63:307-13.

[26] Magras IN, Xenos TD. RF Radiation-induced Changes in the Prenatal Development of Mice. Bioelectromagnetics 1997;18:455-61.

[27] Glaser ZR. Bibliography of Reported Biological Phenomena ('Effects') and Clinical Manifestations Attributed to Microwave and Radio-Frequency Radiation, Research Report. Project MF12.524.015-00043, Report No. 2. Bethesda, MD: Naval Medical Research Institute; 1972. p. 1-103.

[28] Glaser ZR, Brown PF, Brown MS. Bibliography of Reported Biological Phenomena (Effects) and Clinical Manifestations Attributed to Microwave and Radio-Frequency Radiation: Compilation and Integration of Report and Seven Supplements. Bethesda, MD: Naval Medical Research Institute; 1976. p. 1-178.

[29] Belyaev IY, Shcheglov VS, Alipov YD, Polunin VA. Resonance Effect of Millimeter Waves in the Power Range from 10(-19) to 3 x 10(-3) W/cm2 on *Escherichia coli* Cells at Different Concentrations. Bioelectromagnetics 1996;17:312-21.

[30] Grigoriev YG, Grigoriev OA, Ivanov AA, Lyaginskaya AM, Merkulov AV, Shagina NB, *et al.* Confirmation Studies of Soviet Research on Immunological Effects of Microwaves: Russian Immunology Results. Bioelectromagnetics 2010;31:589-602.

[31] Grigoriev Y. Mobile Communications and Health of Population: The Risk Assessment, Social and Ethical Problems. Environmentalist 2012;32:193-200.

[32] Repacholi M, Grigoriev Y, Buschmann J, Pioli C. Scientific Basis for the Soviet and Russian Radiofrequency Standards for the General Public. Bioelectromagnetics 2012;33:623-33.

[33] Pakhomov A, Murphy M. A Comprehensive Review of the Research on Biological Effects of Pulsed Radiofrequency Radiation in Russia and the Former Soviet Union; 2011.

[34] Belyaev IY. Dependence of Non-thermal Biological Effects of Microwaves on Physical and Biological Variables: Implications for Reproducibility and Safety Standards. Eur J Oncol 2010;5:187-218.

[35] Franzen J. Wideband Pulse Propagation in Linear Dispersive Bio-Dielectrics Using Fourier Transforms. United States Air Force Research Laboratory, Report No. AFRL-HE-BR-TR-1999-0149, February; 1999.

[36] Albanese R, Penn J, Medina R. Short-rise-time Microwave Pulse Propagation through Dispersive Biological Media. J Opt Soc Am A 1989;6:1441-6.

[37] Lin-Liu S, Adey WR. Low Frequency Amplitude Modulated Microwave Fields Change Calcium Efflux Rates from Synaptosomes. Bioelectromagnetics 1982;3:309-22.

[38] Penafiel LM, Litovitz T, Krause D, Desta A, Mullins MJ. Role of Modulation on the Effect of Microwaves on Ornithine Decarboxylase Activity in L929 Cells. Bioelectromagnetics 1997;18:132-41.

[39] Huber R, Treyer V, Borbely AA, Schuderer J, Gottselig JM, Landolt HP, Werth E, *et al.* Electromagnetic Fields, Such as Those from Mobile Phones, Alter Regional Cerebral Blood Flow and Sleep and Waking EEG. J Sleep Res 2002;11:289-95.

[40] Panagopoulos DJ, Karabarbounis A, Margaritis LH. Mechanism of Action of Electromagnetic Fields on Cells. Biochem Biophys Res Commun 2002;298:95-102.

[41] Panagopoulos DJ. Comments on Pall's Millimeter (MM) Wave and Microwave Frequency Radiation Produce Deeply Penetrating Effects: The Biology and the Physics. Rev Environ Health 2021;2021:165.

[42] Sage C, Carpenter DO. BioInitiative Working Group, BioInitiative Report: A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Radiation. Updated 2014-2020; 2012. http://www.bioinitiative.org

[43] Belpomme D, Hardell L, Belyaev I, Burgio E, Carpenter DO. Thermal and Non-thermal Health Effects of Low Intensity Non-ionizing Radiation: An International Perspective (Review). Environ Pollut 2018;242:643-58.

[44] Di Ciaula A. Towards 5G Communication Systems: Are there Health Implications? Int J Hyg Environ Health 2018;221:367-75.

[45] Russell CL. 5G Wireless Telecommunications Expansion: Public Health and Environmental Implications. Environ Res 2018;165:484-95.

[46] Miller AB, Sears ME, Morgan LL, Davis DL, Hardell L, Oremus M, *et al.* Risks to Health and Well-being from Radio-frequency Radiation Emitted by Cell Phones and Other Wireless Devices. Public Health Front 2019;7:223.

[47] Pakhomov AG, Akyel Y, Pakhomova ON, Stuck BE, Murphy MR. Current State and Implications of Research on the Biological Effects of Millimeter Waves. Bioelectromagnetics 1998;19:393-413.

[48] Betskii OV, Lebedeva NN. Low-intensity Millimeter Waves in Biology and Medicine. In: Clinical Application of Bioelectromagnetic Medicine. New York: Marcel Decker; 2004. p. 30-61.

[49] Kostoff RN, Block JA, Solka JL, Briggs MB, Rushenberg RL, Stump JA, *et al.* Literature-Related Discovery: A Review. Report to the Office of Naval Research; 2007. p. 1-58.

DOI: http://dx.doi.org/10.18053/jctres.07.202105.007

[50] Havas M. Radiation from Wireless Technology Affects the Blood, Heart, and the Autonomic Nervous System. Rev Environ Health 2013;28:75-84.

[51] Rubik B. Does Short-term Exposure to Cell Phone Radiation Affect the Blood? Wise Trad Food Farm Heal Arts 2014;15:19-28.

[52] Wagner C, Steffen P, Svetina S. Aggregation of Red Blood Cells: From Rouleaux to Clot Formation. Comput Rendus Phys 2013;14:459-69.

[53] Lakhdari N, Tabet B, Boudraham L, Laoussati M, Aissanou S, Beddou L, *et al.* Red Blood Cells Injuries and Hypersegmented Neutrophils in COVID-19 Peripheral. medRxiv 2020;2020:20160101.

[54] Lei Y, Zhang J, Schiavon CR, He M, Chen L, Shen H, *et al.* SARS-CoV-2 Spike Protein Impairs Endothelial Function Via Downregulation of ACE2. Circ Res 2021;128:1323-6.

[55] Zhang S, Liu Y, Wang X, Yang L, Li H, Wang Y, *et al.* SARS-CoV-2 Binds Platelet ACE2 to Enhance Thrombosis in COVID-19. J Hematol Oncol 2020;13:120.

[56] Zalyubovskaya NP. Biological Effect of Millimeter Radiowaves. Vrachebnoye Delo 1977;3:116-9.

[57] Zalyubovskaya NP, Kiselev RI. Effects of Radio Waves of a Millimeter Frequency Range on the Body of Man and Animals. Gigiyna I Sanitaria 1978;8:35-9.

[58] Wenzhong L, Li H. COVID-19 Attacks the 1-beta Chain of Hemoglobin and Captures the Porphyrin to Inhibit Heme Metabolism. ChemRxiv 2020;2020:26434.

[59] Lippi G, Mattiuzzi C. Hemoglobin Value May be Decreased in Patients with Severe Coronavirus Disease 2019. Hematol Transfus Cell Ther 2020;42:116-7.

[60] Chen L, Li X, Chen M, Feng Y, Xiong C. The ACE2 Expression in Human Heart Indicates New Potential Mechanism of Heart Injury among Patients Infected with SARS-CoV-2. Cardiovasc Res 2020;116:1097-100.

[61] Algassim, AA, Elghazaly AA, Alnahdi AS, Mohammed-Rahim OM, Alanazi AG, Aldhuwayhi NA, *et al.* Prognostic Significance of Hemoglobin Level and Autoimmune Hemolytic Anemia in SARS-CoV-2 Infection. Ann Hematol 2021;100:37-43.

[62] Ghahramani S, Tabrizi R, Lankarani KB, Kashani SMA, Rezaei S, Zeidi N, *et al.* Laboratory Features of Severe vs. Non-severe COVID-19 Patients in Asian Populations: A Systematic Review and Meta-analysis. Eur J Med Res 2020;25:30.

[63] Cheng L, Li HL, Li C, Liu C, Yan S, Chen H, *et al.* Ferritin in the Coronavirus Disease 2019 (COVIDvirus A Systematic Review and Meta-etaemati. J Clin Lab Anal 2020;34:e23618.

[64] Tobin MJ, Laghi F, Jubran A. Why COVID-19 Silent Hypoxemia is Baffling to Physicians. Am J Respir 2020;202:356-60.

[65] Ejigu T, Patel N, Sharma A, Vanjarapu JMR, Nookala V. Packed Red Blood Cell Transfusion as a Potential Treatment Option in COVID-19 Patients with Hypoxemic Respiratory Failure: A Case Report. Cureus 2020;12:e8398.

[66] Varga Z, Flammer AJ, Steiger P, Haberecker M, Andermatt R, Zinkernagel AS, *et al.* Endothelial Cell Infection and Endotheliitis in COVID-19. Lancet 2020;395:1417-8.

[67] Betteridge DJ. What is Oxidative Stress? Metabolism 2000;49 2 Suppl 1:3-8.

[68] Giamarellos-Bourboulis E, Netea MG, Rovina N, Akinosoglou K, Antoniadou A, Antonakos N, *et al.* Complex Immune Dysregulation in COVID-19 Patients with Severe Respiratory Failure. Cell Host Microbe 2020;27:992-1000.

[69] Hadjadj J, Yatim N, Barnabei L, Corneau A, Boussier J, Smith N, *et al.* Impaired Type 1 Interferon Activity and Inflammatory Responses in Severe COVID-19 Patents. Science 2020;369:718-24.

[70] Dasdag S, Akdag MZ. The Link between Radiofrequencies Emitted from Wireless Technologies and Oxidative Stress. J Chem Neuroanat 2016;75:85-93.

[71] Higashi Y, Noma K, Yoshizumi M, Kihara Y. Endothelial Function and Oxidative Stress in Cardiovascular Diseases. Circ J 2009;73:411-8.

[72] Polonikov A. Endogenous Deficiency of Glutathione as the Most Likely Cause of Serious Manifestations and Death in COVID-19 Patients. ACS Infect Dis 2020;6:1558-62.

[73] Guloyan V, Oganesian B, Baghdasaryan N, Yeh C, Singh M, Guilford F, *et al.* Glutathione Supplementation as an Adjunctive Therapy in COVID-19. Antioxidants (Basel, Switzerland) 2020;9:914.

[74] Marushchak M, Maksiv K, Krynytska I, Dutchak O, Behosh N. The Severity of Oxidative Stress in Comorbid Chronic Obstructive Pulmonary Disease (COPD) and Hypertension: Does it Depend on ACE and AGT Gene Polymorphisms? J Med Life 2019;12:426-34.

[75] Choromanska B, Mysiliwiec P, Luba M, Wojskowicz P, Mysliwiec H, Choromanska K, *et al.* The Impact of Hypertension and Metabolic Syndrome on Nitrosative Stress and Glutathione Metabolism in Patients with Morbid Obesity. Oxid Med Cell Longev 2020;2020:1057570.

[76] Lutchmansingh FK, Hsu JW, Bennett FI, Badaloo AV, Mcfarlane-Anderson N, Gordon-Strachan GM, *et al.* Glutathione Metabolism in Type 2 Diabetes and its Relationship with Microvascular Complications and Glycemia. PLoS One 2018;13:e0198626.

[77] Horowitz RI, Freeman PR, Bruzzese J. Efficacy of Glutathione Therapy in Relieving Dyspnea Associated with COVID-19 Pneumonia: A Report of 2 Cases. Respir Med 2020;30:101063.

[78] Peraica M, Marijanovic AM, Flajs D, Domijan AM, Gajski G, Garaj-Vrhovac G. Oxidative Stress in Workers

DOI: http://dx.doi.org/10.18053/jctres.07.202105.007

Occupationally Exposed to Microwave Radiation. Toxicol Lett 2008;180:38-9.

[79] Garaj-Vrhovac V, Gajski G, Pazanin S, Sarolic A, Domijan D, Flajs D, *et al.* Assessment of Cytogenetic Damage and Oxidative Stress in Personnel Occupationally Exposed to the Pulsed Microwave Radiation of Marine Radar Equipment. Int J Hyg Environ Health 2011;214:59-65.

[80] Zothansiama, Zosangzuali M, Lalramdinpuii M, Jagetia GC. Impact of Radiofrequency Radiation on DNA Damage and Antioxidants in Peripheral Blood Lymphocytes of Humans Residing in the Vicinity of Mobile Phone Base Stations. Electromagn Biol Med 2017;36:295-305.

[81] Moustafa YM, Moustafa RM, Belacy A, Abou-El-Ela SH, Ali FM. Effects of Acute Exposure to the Radiofrequency Fields of Cellular Phones on Plasma Lipid Peroxide and Anti-oxidase Activities in Human Erythrocytes. J Pharm Biomed Anal 2001;26:605-8.

[82] Hassan NS, Rafaat BM, Aziz SW. Modulatory Role of Grape Seed Extract on Erythrocyte Hemolysis and Oxidative Stress Induced by Microwave Radiation in Rats. Int J Integr Biol 2010;10:106-11.

[83] Yurekli AI, Ozkan M, Kalkan T, Saybasili H, Tuncel H, Atukeren P, *et al.* GSM Base Station Electromagnetic Radiation and Oxidative Stress in Rats. Electromagn Biol Med 2006;25:177-88.

[84] Dasdag S, Bilgin HM, Akdag MZ, Celik H, Aksen F. Effect of Long-term Mobile Phone Exposure on Oxidative-antioxidative Processes and Nitric Oxide in Rats. Biotechnol Biotechnol Equip 2008;22:992-7.

[85] Alkis ME, Akdag MZ, Dasdag S. Effects of low-intensity Microwave Radiation on Oxidant-antioxidant Parameters and DNA Damage in the Liver of rats. Bioelectromagnetics 2021;42:76-85.

[86] Loscalzo J. Oxidant Stress: A Key Determinant of Atherothrombosis. Biochem Soc Trans 2003;31:1059-61.

[87] Tang N, Li D, Wang X, Sun Z. Abnormal Coagulation Parameters are Associated with Poor Prognosis in Patients with Novel Coronavirus Pneumonia. J Thromb Haemost 2020;18:844-7.

[88] Klok FA, Kruip MJ, Van der Meer NJ, Arbous MS, Gommers DA, Kant KM, *et al.* Incidence of Thrombotic Complications in Critically ill ICU Patients with COVID-19. Thromb Res 2020;191:145-7.

[89] Zaim S, Chong JH, Sankaranarayanan V, Harky A. COVID-19 and Multi-Organ Response. Curr Probl Cardiol 2020;2020:100618.

[90] Yaghi S, Ishida K, Torres J, Mac Grory B, Raz E, Humbert K, *et al.* SARS-CoV-2 and Stroke in a New York Healthcare System. Stroke 2020;51:2002-11.

[91] Bandara P, Weller S. Cardiovascular Disease: Time to Identify Emerging Environmental Risk Factors. Eur J Prev Cardiol 2017;24:1819-23.

[92] Esmekaya MA, Ozer C, Seyhan N. 900 MHz Pulse-modulated Radiofrequency Radiation Induces Oxidative Stress on Heart, Lung, Testis, and Liver Tissues. Gen Physiol Biophys 2011;30:84-9.

[93] Cao X. COVID-19: Immunopathology and its Implications for Therapy. Nat Rev Immunol 2020;20:269-70.

[94] Qin C, Zhou L, Hu Z, Zhang S, Yang S, Tao Y, *et al.* Dysregulation of Immune Response in Patients with Coronavirus 2019 (COVID-19) in Wuhan, China. Clin Infect Dis 2020;71:762-8.

[95] McRee DI. Soviet and Eastern European Research on Biological Effects of Microwave Radiation. Proc IEEE 1980;68:84-91.

[96] Baranski S. Effect of Chronic Microwave Irradiation on the Blood Forming System of Guinea Pigs and Rabbits. Aerosp Med 1971;42:1196-9.

[97] Nageswari KS, Sarma KR, Rajvanshi VS, Sharan R, Sharma M, Barathwal V, *et al.* Effect of Chronic Microwave Radiation on T Cell-mediated Immunity in the Rabbit. Int 1991;35:92-7.

[98] Adang D, Remacle C, Vander Vorst A. Results of a Long-term Low-level Microwave Exposure of Rats. IEEE Trans Microw Theory Tech 2009;57:2488-97.

[99] McRee DI, Faith R, McConnell EE, Guy AW. Long-term 2450-MHz cw Microwave Irradiation of Rabbits: Evaluation of Hematological and Immunological Effects. J Microw Power Electromagn Energy 1980;15:45-52.

[100] Johansson O. Disturbance of the Immune System by Electromagnetic Fields a Potentially Underlying Cause for Cellular Damage and Tissue Repair Reduction which Could Lead to Disease and Impairment. Pathophysiology 2009;16:157-77.

[101] Szmigielski S. Reaction of the Immune System to Low-level RF/MW Exposures. Sci Total Environ 2013;454-455:393-400.

[102] Zhou F, Ting Y, Du R, Fan G, Liu Y, Liu Z, *et al.* Clinical Course and Risk Factors for Mortality of Adult Inpatients with COVID-19 in Wuhan, China: A Retrospective Cohort Study. Lancet 2020;395:1054-62.

[103] Yang M. Cell Pyroptosis, a Potential Pathogenic Mechanism of 2019-nCoV Infection. ScienceOpen; 2020.

[104] Upadhyay J, Tiwari N, Ansari MN. Role of Inflammatory Markers in Corona Virus Disease (COVID-19) Patients: A Review. Exp Biol Med 2020;245:1368-75.

[105] Shandala MG, Rudnev MI, Vinogradov GK, Belonoshko NC, Goncharova NM. Immunological and hematological effects of microwaves at low power densities. In: Proceedings of International Union of Radio Science Symposium on Biological Effects of Electromagnetic Waves Vol. 84. Airlie, VA; 1977.

[106] Grigoriev YG, Ivanov AA, Lyaginskaya AM, Merkulov AV, Stepanov VS, Shagina NB. Autoimmune Processes after

DOI: http://dx.doi.org/10.18053/jctres.07.202105.007

Long-term Low-level Exposure to Electromagnetic Fields (Experimental Results). Part I. Mobile Communications and Changes in Electromagnetic Conditions for the Population. Need for Additional Substantiation of Existing Hygienic Standards. Biophysics 2010;551041-5.

[107] Grigoriev YG. Evidence for Effects on the Immune System. Immune System and EMF RF. Bioinitiative Rep 2012;8:1-24.

[108] Szabo I, Rojavin MA, Rogers, TJ, Ziskin MC. Reactions of Keratinocytes to *In Vitro* Millimeter Wave Exposure. Bioelectromagnetics 2001;22:358-64.

[109] Makar V, Logani M, Szabo I, Ziskin M. Effect of Millimeter Waves on Cyclophosphamide Induced Suppression of T Cell Functions. Bioelectromagnetics 2003;24:356-65.

[110] Walleczek J. Electromagnetic Field Effects on Cells of the Immune System: The Role of Calcium Signaling. FASEB J 1992;6:3177-85.

[111] Panagopoulos DJ, Messini N, Karabarbounis A, Filippetis AL, Margaritis LH. A Mechanism for Action of Oscillating Electric Fields on Cells. Biochem Biophys Res Commun 2000;272:634-40.

[112] Pall ML. Electromagnetic Fields Act Via Activation of Voltage-gated Calcium Channels to Produce Beneficial or Adverse Effects. J Cell Mol Med 2013;17:958-65.

[113] Chen X, Cao R, Zhong W. Host Calcium Channels and Pumps in Viral Infections. Cells 2019;9:94.

[114] Solaimanzadeh I. Nifedipine and Amlodipine are Associated with Improved Mortality and Decreased Risk for Intubation and Mechanical Ventilation in Elderly Patients Hospitalized for COVID-19. Cureus 2020;12:e8069.

[115] Straus MR, Bidon M, Tang T, Whittaker GR, Daniel S. FDA Approved Calcium Channel Blockers Inhibit SARS-CoV-2 Infectivity in Epithelial Lung Cells. BioRxiv 2020;2020:214577.

[116] Sen CK, Roy S, Packer L. Involvement of Intracellular Ca^{2+} in Oxidant-Induced NF-κB Activation. FEBS Lett 1996;385:58-62.

[117] Do LA, Anderson J, Mulholland EK, Licciardi PV. Can Data from Paediatric Cohorts Solve the COVID-19 Puzzle? PLoS Pathog 2020;16:e1008798.

[118] Atri D, Siddiqi HK, Lang JP, Nauffal V, Morrow DA, Bohula EA. COVID-19 for the Cardiologist: Basic Virology, Epidemiology, Cardiac Manifestations, and Potential Therapeutic Strategies. JACC Back Transl Sci 2020;5:518-36.

[119] Dherange P, Lang J, Qian P, Oberfeld B, Sauer WH, Koplan B, *et al.* Arrhythmias and COVID-19: A Review. JACC Clin Electrophysiol 2020;6:1193-204.

[120] Colon CM, Barrios JG, Chiles JW, McElwee SK, Russell DW, Maddox WR, *et al.* Atrial Arrhythmias in COVID-19 Patients. JACC Clin Electrophysiol 2020;6:1189-90.

[121] Gökmen N, Erdem S, Toker KA, Ocmen E, Ozkure A. Analyzing Exposures to Electromagnetic Fields in an Intensive Care Unit. Turk J Anaesthesiol Reanim 2016;44:236-40.

[122] Sandoval Y, Januzzi JL, Jaffe AS. Cardiac Troponin for Assessment of Myocardial Injury in COVID-19. J Am Coll Cardiol 2020;76:1244-58.

[123] Dodge CH. Clinical and Hygienic Aspects of Exposure to Electromagnetic Fields. Biological Effects and Health Implications of Microwave Radiation. A Review of the Soviet and Eastern European Literature. In: Symposium Proceedings, Richmond, VA 1969 Sep 17.

[124] Jauchem JR. Exposure to Extremely Low Frequency Electromagnetic Fields and Radiofrequency Radiation: Cardiovascular Effects in Humans. Int Arch Occup Environ Health 1997;70:9-21.

[125] Black DR, Heynick LN. Radiofrequency Effects on Blood Cells, Cardiac, Endocrine, and Immunological Functions. Bioelectromagnetics 2003;6:S187-95.

[126] Havas M, Marrongelle J, Pollner B, Kelley E, Rees CRG, Tully L. Provocation Study Using Heart Rate Variability Shows Microwave Radiation from 2.4GHz Cordless Phone Affects Autonomic Nervous System. Eur J Oncol Library 2010;5:271-98.

[127] Saili L, Hanini A, Smirani C, Azzouz I, Sakly M, Abdelmelek H, *et al.* Effects of Acute Exposure to WIFI Signals (2.45GHz) on Heart Variability and Blood Pressure in Albino Rabbits. Environ Toxicol Pharmacol 2015;40:600-5.

[128] Cleary SF. Biological Effects and Health Implications of Microwave Radiation. A Review of the Soviet and Eastern European Literature. In: Symposium Proceedings, Richmond, VA 1969 Sep 17. BRH/DBE Report No. 70-2; 1970.

[129] Fiasca F, Minelli M, Maio D, Minelli M, Vergallo I, Necozione S, *et al.* Associations between COVID-19 Incidence Rates and the Exposure to PM2.5 and NO_2: A Nationwide Observational Study in Italy. Int J Environ Res Public Health 2020;17:9318.

[130] Hoyt JR, Langwig KE, Sun K, Parise KL, Li A, Wang Y, *et al.* Environmental Reservoir Dynamics Predict Global Infection Patterns and Population Impacts for the Fungal Disease White-nose Syndrome. PNAS 2020;117:7255-62.

[131] Federal Communications Commission (FCC). Guidelines for Evaluating the Environmental Effects of Radiofrequency Radiation. FCC96-326; ET Docket No. 93-62; 1996.

[132] Belyaev I, Dean A, Eger H, Hubmann G, Jandrisovits R, Kern M, *et al.* EUROPAEM EMF Guideline 2016 for the Prevention, Diagnosis and Treatment of EMF-related Health Problems and Illnesses. Rev Environ Health 2016;31:363-97.

[133] Huss A, Egger M, Hug K, Huwiler-Muntener K, Roosli M. Source of Funding and Results of Studies of Health Effects of Mobile Phone Use: Systematic Review of Experimental Studies. Environ Health Perspect 2007;115:14.

[134] Panagopoulos DJ. Comparing DNA Damage Induced by Mobile Telephony and Other Types of Man-made Electromagnetic Fields. Mutat Res 2019;781:53-62.

[135] Belyaev IY, Shcheglov VS, Alipov ED, Ushalov VD. Nonthermal Effects of Extremely High-frequency Microwaves on Chromatin Conformation in cells *In Vitro* Dependence on Physical, Physiological, and Genetic Factors. IEEE Trans Microw Theory Techn 2000;48:2172-9.

[136] Blackman CF, Kinney LS, Houyse DE, Joines WT. Multiple Power-density Windows and their Possible Origin. Bioelectromagnetics 1989;10:115-28.

[137] Panagopoulos DJ, Cammaerts MC, Favre D, Balmori A. Comments on Environmental Impact of Radiofrequency Fields from Mobile Phone Base Stations. Crit Rev Environ Sci Technol 2016;46:885-903.

[138] Kriebel D, Tickne J, Epstein P, Lemons PJ, Levins R, Loechler EL, *et al.* The Precautionary Principle in Environmental Science. Environ Health Perspect 2001;109:871-6.

[139] Tretyakov MY, Koshelev MA, Dorovskikh VV, Makarov DS, Rosenkranz PW. 60-GHz Oxygen Band: Precise Broadening and Central Frequencies of Fine-Structure Lines, Absolute Absorption Profile at Atmospheric Pressure, and Revision of Mixing Coefficients. J Mol Spectrosc 2005;231:1-14.

[140] Torgomyan H, Kalantaryan V, Trchounian A. Low Intensity Electromagnetic Irradiation with 70.6 and 73 GHz Frequencies Affects *Escherichia coli* Growth and Changes Water Properties. Cell Biochem Biophys 2011;60:275-81.

[141] Kostoff RN, Heroux P, Aschner M, Tsatsakis A. Adverse Health Effects of 5G Mobile Networking Technology Under Real-life Conditions. Toxicol Lett 2020;323:35-40.

DOI: http://dx.doi.org/10.18053/jctres.07.202105.007

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Effects of mobile phone radiofrequency on the structure and function of the normal human hemoglobin

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ABSTRACT

Widespread use of mobile phones has increased the human exposure to electromagnetic fields (EMFs). It is required to investigate the effect of EMFs on the biological systems. In this paper the effect of mobile phone RF (910 MHz and 940 MHz) on structure and function of HbA was investigated. Oxygen affinity was measured by sodium dithionite with UV–vis spectrophotometer. Structural changes were studied by circular dichroism and fluorescence spectroscopy. The results indicated that mobile phone EMFs altered oxygen affinity and tertiary structure of HbA. Furthermore, the decrease of oxygen affinity of HbA corresponded to the EMFs intensity and time of exposure.

1. Introduction

Nowadays, more than 2.5 billion people utilize cell phones and base stations constituting the cell network. The global system for mobile communication (GSM) which being used in most of the countries has a frequency of either 900 or 1800 MHz (pulsed at 217 Hz, band width of 200 kHz). The spectrum of 900 MHz has two bands: 890–915 MHz which is specific for handset, and 935–960 MHz which is specific for base station antenna. The development of mobile communication has aroused a deep interest in people and has stimulated wide and often controversial discussions in the scientific community about potential damages induced by exposure to low-level radiation emitted in the microwave (MW) region [1].

There are several works on the effect of electromagnetic fields (EMFs) on proteins. The possibility that RF radiation may cause changes in protein conformation and hence biological properties has been reported in Refs. [2–9]. George et al. [10] studied citrate synthase unfolding by the effect of EMFS, and concluded that microwaves have effect on protein conformation that could take the form of a direct interaction of the electromagnetic fields with the protein or its water of hydration. In another work Mancinelli et al. [11] also showed the same result, exploring a potential role of MW-EMFs exposure in affecting folding process and/or determining the misfolding of polypeptide chains. Exposure to cell phone radiation up-regulates apoptosis of genes in primary cultures of neurons and astrocytes [12], and in human endothelial cell lines [13]. Also expression of Hsp70 [14,15]; early gene, c-fos [16]; G1 phase-regulating proteins [17]; tumor suppressor p53 [18]; up-regulating P27Kip1 [19] affected by microwave irradiation.

It has reported the change in the activity of enzymes upon exposure by microwave EMFs, e.g., extracellular-signal-regulated kinase [20]; antioxidative enzyme activities [21]; trichoderma reesei cellulase [22]; Na, K-ATPase [23]; acetylcholinesterase [24,25]; soluble and insoluble peroxidase [26]; cerebral cytochrome *c* oxidase [27].

Schirmacher et al. [28] reported the influence of high frequency EMFs on the permeability of an in vitro model of the blood–brain barrier (BBB). They concluded that on exposure to EMFs the permeability of ^{14}C-sucrose increased significantly compared to that of the unexposed samples.

In light of what happen to biological systems by exposing to the EMFs, there are some evidences for possible effects of EMF via involving in electron transfer reactions. These were extensively

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reported by Blank and coworkers [9,23,29–39]. Blank and Soo [34] were also examined the EM field effects on electron transfer by using simple system, the classic oscillating Belousov-Zhabotinski (BZ) reaction. They concluded that EM fields accelerate all linked redox reactions. In other work [39] they concluded that 60 Hz magnetic fields accelerate electron transport from cytochrome *c* to the enzyme, cytochrome oxidase. In other studies, they demonstrated the effects of low frequency electric and magnetic fields on several biochemical systems, including the Na,K-ATPase, and indicate that EMFs interact with electrons [23,33]. In recent review paper, Blank [9] was considered examples of direct effects of electric and magnetic fields on charge transfer in biological systems, and reported the structural changes driven by such effects. Blank [9] also concluded that conformational changes that arise from alterations in charge distribution play a key role in membrane transport proteins, including ion channels, and probably account for DNA stimulation to initiate protein synthesis. In conclusion it appears likely that weak EMFs can control and amplify biological processes through their effects on charge distribution.

Behind these works there are also several papers showed that the EMFs had no effects on biological systems. Schwarz et al. [40] reported the genotoxic effects of Radiofrequency EMFs (GSM, 1950 MHz) in vitro in human fibroblasts but not in lymphocytes. They concluded that GSM exposure may cause genetic alterations in some but not in all human cells in vitro. Martino et al. [41] showed that pulsed EMFs did not affect on the metabolic activity and cell number of SaOS-2 osteoblast-like cells. Mobile phone exposure does not induce apoptosis on spermatogenesis in rats which were reported by Dasdag et al. [42]. Stefanics et al. [43] reported a single 10 min exposure of 900 MHz EMFs emitted by a commercial mobile phone does not produce measurable immediate effects in the latency of auditory brainstem waves I, III and V. Leadbeater et al. [44] showed that microwave irradiation on the lipase-catalysed transesterification reaction of methyl acetoacetate does not have a noticeable effect on reaction rate or product conversion. Mobile phone base station-emitted radiation does not induce phosphorylation of Hsp27 reported by Hirose et al. [45]. Ferreira et al. [46] showed that high frequency EMFs exposure on the central nervous system of rats is not able to produce detectable oxidative stress. Zeng et al. [47] reported that RF EMFs exposure under experimental conditions cannot produce distinct effects on gene and protein expression in the MCF-7 cells. Thorlin et al. [48] suggested that exposure of cultured astroglial and microglial brain cells to 900 MHz microwave radiation does not provide evidence for any effect. Bismuto et al. [1] showed that Measurements of absorption spectroscopy, circular dichroism and fluorescence emission decay in the frequency domain do not exhibit any influence of the microwave radiation on the native structural state of myoglobin. Li et al. [49] reported that 837 MHz microwave exposure of TP53 tumor suppressor protein in normal human fibroblasts do not change significantly.

Normal hemoglobin (HbA) is an essential component of the circulatory system of vertebrates. Its chief physiological function is to transport oxygen from the lungs to the tissues [50]. Hemoglobin (molecular weight 64,500) is roughly spherical, with a diameter of nearly 5.5 nm. It is a tetrameric protein containing four heme prosthetic groups, each one associated with each polypeptide chain. Adult hemoglobin contains two types of globin, two α chains (141 residues each) and two β chains (146 residues each). Although, fewer than half of the amino acid residues in the polypeptide sequences of α- and β-globins subunits are identical, the three-dimensional structures of the two types of subunits are very similar.

In arterial blood passing from the lungs through the heart to the peripheral tissues, hemoglobin is about 96% saturated with oxygen [51,52]. In the venous blood returning to the heart, hemoglobin is only about 64% saturated [52]. Hemoglobin, with its multiple subunits and O_2-binding sites, is better suited to oxygen transport. Interactions among the subunits in hemoglobin caused conformational changes that alter the affinity of the protein for oxygen [53,54]. The modulation of oxygen binding allows the O_2-transport protein to respond to changes in oxygen demand by tissues. Hemoglobin must bind oxygen efficiently in the lungs, where the pO_2 is about 13.3 kPa, and release oxygen in the tissues, where the pO_2 is about 4 kPa. Myoglobin, or any protein that binds oxygen, and this binding is described by a hyperbolic binding curve, would be ill suited to this function. A protein that binds O_2 with high affinity would bind it efficiently in the lungs but would not release much of it in the tissues. If the protein that binds oxygen with a sufficiently low affinity to release it in the tissues, it would not pick up much oxygen in the lungs. Hemoglobin solves the problem by undergoing a transition from a low-affinity state (the T state) to a high-affinity state (the R state) as more O_2 molecules are bound. As a result, hemoglobin has a hybrid S-shaped, or sigmoid, binding curve for oxygen [55].

In addition to carrying nearly all the oxygen required by cells from the lungs to the tissues, hemoglobin carries two end products of cellular respiration (H^+ and CO_2) from the tissues to the lungs and the kidneys, where they are excreted. Carbon dioxide must be hydrated and therefore results an increase in the H^+ concentration (a decrease in pH) in the tissues. The binding of oxygen by hemoglobin is profoundly influenced by pH and CO_2 concentration, so the interconversion of CO_2 and bicarbonate is of a great importance to the regulation of oxygen binding and release in the blood. Hemoglobin transports about 40% of the total H^+ and 15–20% of the CO_2 formed in the tissues to the lungs and the kidneys. The binding of H^+ and CO_2 is inversely related to the binding of oxygen. At the relatively low pH and high CO_2 concentration of peripheral tissues, the affinity of hemoglobin for oxygen decreases as H^+ and CO_2 are bound, and O_2 is released to the tissues. Conversely, in the capillaries of the lung, as CO_2 is excreted and the blood pH consequently rises, the affinity of hemoglobin for oxygen increases and the protein binds more O_2 for transport to the peripheral tissues. This effect of pH and CO_2 concentration on the binding and release of oxygen by hemoglobin is called the Bohr effect, after Christian Bohr, the Danish physiologist who discovered it in 1904. The O_2–saturation curve of hemoglobin is influenced by the H^+ concentration. Both O_2 and H^+ are bound by hemoglobin, but with inverse affinity. When the oxygen concentration is high, as in the lungs, hemoglobin binds O_2 and releases protons. When the oxygen concentration is low, as in the peripheral tissues, H^+ is bound and O_2 is released. Oxygen and H^+ are not bound at the same sites in hemoglobin. Oxygen binds to the iron atoms of the hemes, whereas H^+ binds to any of several amino acid residues in the protein [51,55–58].

2,3-disphosphoglycerate (DPG) is another molecule which contribute in hemoglobin function. DPG is known to greatly reduce the affinity of hemoglobin for oxygen. There is an inverse relationship between the binding of O_2 and the binding of DPG and binds at a site distant from the oxygen-binding site and regulates the O_2-binding affinity of hemoglobin in relation to the pO_2 in the lungs [55,59].

In this research we attempted to study the effect of mobile phone EMFs on the oxygen affinity and structure of HbA, because of the importance of hemoglobin as a sole oxygen transporter in blood.

2. Materials and methods

2.1. Materials

All chemicals were purchased from Merck (Germany). These were of analytical grade and were used without further purification.

All measurements were made in triplicate at 37.0 ± 0.1 °C unless otherwise indicated.

2.2. Methods

2.2.1. Preparation of hemoglobin

Human adult hemoglobin (HbA) was prepared from human red blood cells of healthy donors. The heparinized blood was centrifuged to remove plasma components. The packed red cells were washed three times in an isotonic saline solution (0.9% NaCl) and red cells were osmetically lysed with cold double distilled water. Membrane components were removed by low-speed centrifugation (3000 rpm). The soluble Hb was centrifuged at least two additional times at high speed to remove any insoluble materials (10,000 rpm). The hemoglobin solution was then brought to 20% saturation with ammonium sulfate, left standing for about 15 min, and centrifuged at 20,000 × g for 1 h at 2 °C. The supernatant contained HbA [60].

2,3-diphosphoglycerate was removed by method of Benesch et al. [61]. HbA samples were dialyzed at least three times in 50 mM phosphate buffer (pH 7.5) for 24 h. The hemoglobin concentration was determined spectrophotometrically using a millimolar extinction coefficient of 13.5 (monomer basis) at 541 nm for oxyhemoglobin [62]. Additionally, the samples were analyzed by conventional sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) for purity.

2.2.2. Exposure setup

Exposure of HbA to the RF 910 MHz and 940 MHz EMF were carried by a spiral antenna (frequency range: 800 MHz to 12 GHz) in a temperature controlled incubator in the shielded room of the Antenna Laboratory of the University of Tehran (see Fig. 1).

If the sample is situated far from the antenna, it can be assumed that the incident signal is a plane wave. The electric field intensity (EFI) in the location of the sample has been measured using an E-field probe and a calibrated spectrum analyzer at 37.0 ± 0.1 °C.

RF continuous wave without any modulation is generated by the HP 8657A signal generator. As the output power level of the signal generator is limited to 15 dBm (decibel referenced to mW), a high power WicomTech GSM amplifier is added to guarantee the power requirements.

The HbA sample (3 mL of solution) in a polystyrene tube was exposed to the 910 MHz or 940 MHz EMF. Temperature was controlled to within ± 0.1 °C by the incubator manufactured by PERSSOJEN CO (Iran). The treated sample was matched with unexposed control which was kept in the same experimental conditions, except this was isolated in a 10-mm thickness aluminum sample holder with an aluminum cap.

The cable carries the signal from the E-field probe to the spectrum analyzer, which has 2.5 dBm losses. Observed power by the spectrum analyzer (e.g., 21 dBm) shows that power on the sample is equal to 23.5 dBm or 233.87 mW. Assuming the dipole antenna (probe) has a resistance, with $R = 50\,\Omega$ and length, $L = 6.1$ cm, the electric field intensity of 37.7 dBV/m or 77 V/m was determined on the sample, which is equal to 2 dBm/cm^2 or 15.7 W/m^2 using the relation:

$$U = \frac{E^2}{\eta} \text{ Or } U_{dB} = 2E_{dB} - 25.7_{dB} \tag{1}$$

where E is the electric field intensity (EFI), η is the free space characteristic impedance (377 Ω), and U is the power density.

The hemoglobin sample is holded inside the plastic tube with 5 cm in length and 1 cm in diameter. The change of temperature inside the tube upon interaction with mobile phone radiation is calculated and it was negligible.

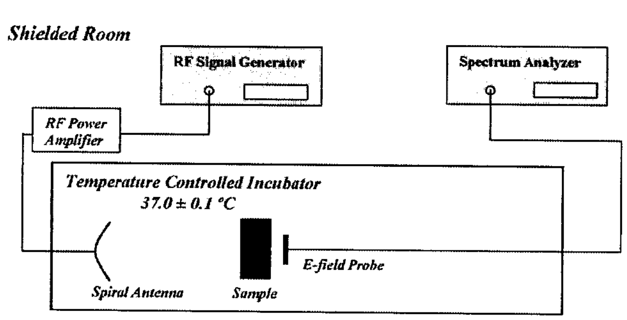

Fig. 1. A block diagram for exposing the HbA samples.

2.2.3. Measurements of the oxygen affinity of HbA

Oxygen affinity of hemoglobin was measured on the basis of differences in spectral characteristics between the two pigments, oxyhemoglobin and deoxyhemoglobin as described by Tietz [63]. Absorbance of 800 µL HbA in 10 mM phosphate buffer (pH 7.4) was determined at 548 and 577 nm. These were designated $A_{548(o)}$ and $A_{577(o)}$, respectively, where subscript o represents oxygenated protein. 100 µL of sodium dithionite ($Na_2S_2O_4$) solution [3 mg/mL] was added to these oxygenated solutions, mixed gently, and then absorbance was measured at 548 and 577 nm. Which are designated as $A_{548(r)}$ and $A_{577(r)}$, respectively, where the subscript r represents the deoxygenated HbA. Ratio of R_o and R_r as well as constants K_4 and K_5 were calculated as follows [63]:

$$R_o = \frac{A_{548(o)}}{A_{577(o)}} \tag{2}$$

$$R_r = \frac{A_{548(r)}}{A_{577(r)}} \tag{3}$$

$$K_4 = \frac{100}{(R_o - R_r)} \tag{4}$$

$$K_5 = \frac{100 R_r}{(R_o - R_r)} \tag{5}$$

The fresh HbA solution (800 µL) was placed into the cell of spectrophotometer and absorbance at 548 and 577 nm was read. This solution was titrated with several addition of 5 µL solution of sodium dithionite. During each addition, solution was mixed gently and absorbance was measured at 548 and 577 nm after 3 min. The titration was carried out till all oxygen was removed from HbA. Percent saturation of HbA with O_2 for each step was calculated as follows:

$$\text{Percent saturation} = K_4 \left(\frac{A_{577}}{A_{548}}\right) - K_5 \tag{6}$$

Molar concentration of sodium dithionite [SDT], required for 50% saturation of HbA, is designated as $[SDT]_{50}$. This is practically equivalent to P_{50} in oxygen dissociation curve of Hb [55]. The absorbance was recorded in Shimadzu model UV-3100 spectrophotometer whose temperature was maintained at 37.0 ± 0.1 °C by circulating water from an external Haak D8 water bath. All samples were kept in an air-shielded cuvette.

2.2.4. Circular dichroism spectropolarimetry

Circular dichroism (CD) spectra in the far-UV regions (190–260 nm) were obtained in J-810 Jasco spectropolarimeter using 1 mm path cell at 25 °C. Protein concentration (monomer basis) was 21 µM (0.2 mg/mL) in the presence of 10 mM sodium phosphate buffer, pH 7.4. Protein secondary structure was determined by CDNN program, version 2.1.0.223. The visible-CD (350–600 nm) was measured in an Aviv 215 spectropolarimeter at 25 °C. The CD measurement was performed using a 10-mm path length quartz cuvette and a protein concentration of 11 µM.

2.2.5. Fluorescence measurements

A Cary Eclipse Varian Australia spectrofluorescence that was equipped with a temperature controller bath model Cary was used for the intrinsic fluorescence experiments. The excitation wavelength was adjusted to 285 nm, which was specific for the excitation of tryptophan (Trp) residues of the protein structure. Emission spectra were recorded between the wavelengths of 290 and 400 nm at the bandwidth of 10 nm. Hemoglobin samples were 10.3 μM (monomer basis) in a phosphate buffer (10 mM, pH 7.4).

1-anilinonaphthalene-8-sulfonate (ANS) is a small organic compound that be used to probe for the accessibility of hydrophobic patches in proteins. In this study, protein solution (10.3 μM, monomer basis) was prepared in 1 ml of phosphate buffer (10 mM, pH 7.4) with 10 μL of ANS (2 mM). Emission scans were then obtained from 365 to 600 nm using an excitation wavelength of 355 nm.

2.2.6. Aggregation assays

Time courses of thermal aggregation of HbA solutions (11.3 μM, monomer basis) were followed by measuring absorbance at 360 nm in Cary-100 Bio VARIAN spectrophotometer using a 10-mm path length quartz cuvette [64]. Temperatures were controlled within ±0.1 °C by a Cary temperature controller. Aggregation was followed for 300 min at 60 °C. It is important to note exposed and unexposed hemoglobin samples were in solution at 37 °C and not aggregated.

2.2.7. Thermal denaturation measurements

Thermal denaturation of HbA solutions (10.4 μM, monomer basis) was followed at 280 nm in a Cary-100 Bio VARIAN spectrophotometer using a 10-mm path length quartz cuvette [64]. Temperatures were controlled to within ±0.1 °C by a Cary temperature controller. Absorbance at 280 nm was obtained in temperature range 25–85 °C with a scan rate of 0.5 °C/min. This scan rate was found to provide adequate time for equilibration.

Thermal unfolding of HbA solutions (10.4 μM, monomer basis) was also monitored in J-810 Jasco spectropolarimeter using 2 mm path cell by measuring the decrease in ellipticity at 222 nm with increasing temperature. The dynode voltage changes that occurred with changes in temperature were also recorded and were used as a criterion of protein aggregation [65,66]. Circular dichroism and dynode voltage at 222 nm was obtained in temperature range 25–85 °C with a scan rate of 0.5 °C/min.

3. Results and discussion

3.1. Oxygen affinity

More than 1000 variants of Hb have been reported, some with altered oxygen affinity, either higher or lower while maintaining the stability of Hb. Individuals with low oxygen affinity hemoglobin show mild anemia, whereas individuals with high oxygen affinity hemoglobin shows symptoms associated with polycythemia [67].

Sodium dithionite ($Na_2S_2O_4$) is a powerful reducing agent used to deoxygenate hemoglobin, and it is extensively used for this purpose [68–74]. The reaction takes place between one molecule of dithionite and one of oxygen, with the production of H_2O_2:

$$Na_2S_2O_4 + O_2 + 2H_2O \leftrightarrows 2NaHSO_3 + H_2O_2 \quad (7)$$

We have used this reagent for deoxygenating of HbA.

Fig. 2 shows the percent saturation of HbA in 10 mM phosphate buffer (pH 7.4) in the absence and presence of 940 MHz with an EFI of 77 V/m as a function of [SDT]. We have analyzed each curve using a non-linear least-squares method of $[SDT]_{50}$, the molar concentration of SDT at which HbA is 50% saturated with O_2. These values of $[SDT]_{50}$ were used to determine α, defined as

$$\alpha = 100([SDT]_{50}\text{unexposed} - [SDT]_{50}\text{exposed})/[SDT]_{50}\text{unexposed} \quad (8)$$

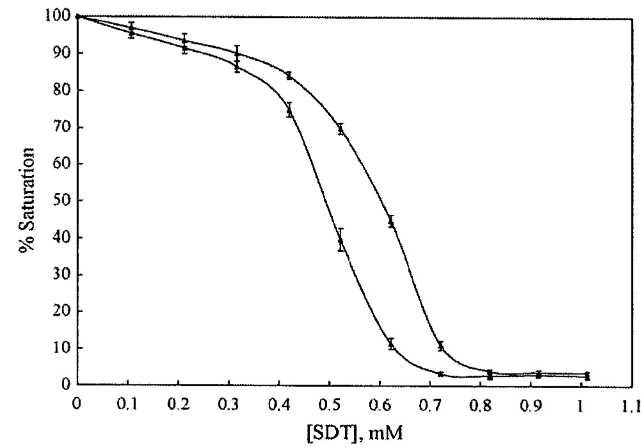

Fig. 2. Effect of 940 MHz with EFI of 77 V/m on HbA. Protein in 10 mM phosphate buffer exposed (Δ), and unexposed (▲). Experimental conditions: [HbA] = 32.5 μM, exposure time = 1 h and pH 7.4. The effect of 910 MHz is resembled to 940 MHz, data not shown. The error bars indicate of triplicate repeating experiments.

We have also determined α value of HbA in the absence and presence of 940 MHz with EFI of 21.7, 30.6, 48.6 at 10 mM phosphate buffer from the measurements such as shown in Fig. 2 (this figure is plotted for 77 V/m as a typical, other electric field intensity are resemble to Fig. 2). These values are tabulated in Table 1. It is seen in this table that dependence of α on EMFs is not linear; suggesting that α of HbA depends on factor(s) as well. It worth noting that Tkalec et al. [75] suggest the effects of radio frequency fields are frequency dependent and are not linear over the whole field intensity spectrum. Furthermore, several workers have also reported the nonlinearity responses of biological systems to radiofrequency exposure [76–81].

Results presented and discussed above led us to conclude that the O_2 binding ability of HbA is affect by the EMFs intensity. We wanted to know whether the duration to which HbA is exposed to particular EMFs is also important. We have therefore designed experiments in which HbA is exposed to 940 MHz with EFI of 77 V/m (about 1.6 mW/cm^2) for five fixed times (15, 30, 60, 90 and 120 min) and measured % saturation as a function of [SDT]. These results were analyzed for α value for different times of exposure, and are shown in Fig. 3. It is seen in this figure that α increase with an increase in time of exposure. Then exposure of HbA with electric field intensity for long time has more effect on the retardation of the O_2-binding ability of the time.

All the O_2-binding results suggested that EMFs has its effect on the binding ability of HbA. We wanted to know whether there is any relation between this decreased binding ability of HbA and structure of the protein. In order to understand this we carried out structural studies using UV/vis, CD and fluorescence measurements. It should be noted that all structural studies were carried out at 940 MHz with electric field intensity of 77 V/m.

Table 1

Values of α (see Eq. (8)) of HbA in 10 mM phosphate buffer (pH 7.4). The protein was exposed to 940 MHz with different electric field intensities (EFI) at 37 °C. The protein concentration was 32 μM.

$\alpha \pm$ S.D.[a]	EFI (V/m)
−2.20 ± 0.70	21.7
13.46 ± 3.58	30.6
16.46 ± 5.54	48.6
17.01 ± 2.45	77.0

[a] Standard deviation.

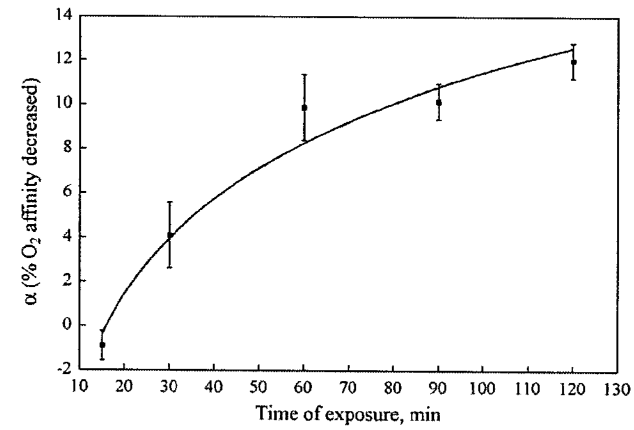

Fig. 3. Time-dependence of the effect of 940 MHz with EFI of 77 V/m on HbA. Experimental conditions: [HbA] = 32 μM in 10 mM phosphate buffer, pH 7.4, at 37 °C. The error bars indicate of triplicate repeating experiments.

3.2. Circular dichroism studies

Fig. 4 shows the far-UV CD spectra of unexposed and exposed HbA in 10 mM sodium phosphate buffer with 940 MHz and EFI of 77 V/m. It is seen in this figure that the exposed protein has slightly more secondary structure. This finding seems to suggest that the secondary structure has no significant role to play in the altered binding ability of HbA under these experimental conditions.

Fig. 5 shows CD spectra of HbA in the Soret band region under same experimental conditions used to obtain results shown in Fig. 4. It may be seen in this figure that globin–heme interaction is affected by an exposure to the radiation. The Soret CD spectra of HbA, which results from the $\pi-\pi^*$ transition of the heme chromophore, and this transition is influenced by the surrounding aromatic amino acids. Therefore, the Soret CD spectral changes can reflect the changes not only in the electronic state of the heme but also in its environment [82,83]. Visible circular dichroism spectra of the HbA exposed to 940 MHz with EFI of 77 V/m is shown in Fig. 5. The spectral difference in the Soret region indicates that tertiary structure of the protein is significantly changed on the exposure of HbA to EMFs.

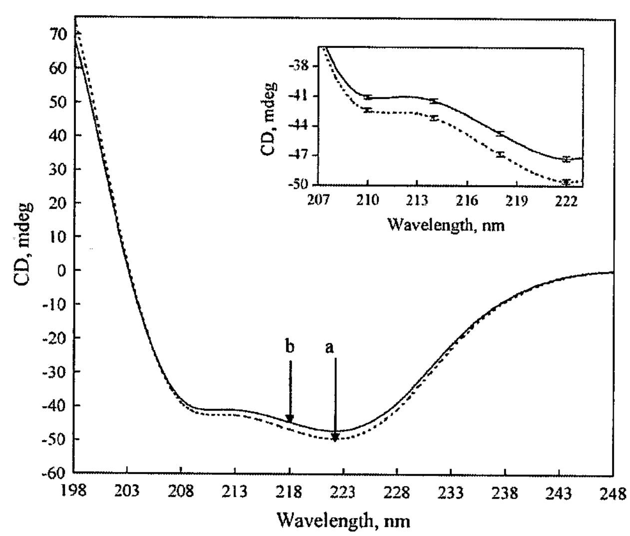

Fig. 4. The far-UV CD spectra of the HbA in 10 mM phosphate buffer (pH 7.4). CD spectra of the exposed (a) and unexposed (b) HbA at 940 MHz with EFI of 77 V/m for 1 h. The HbA concentration was 21 μM. The inset shows error bars of spectra for triplicate repeating experiments and high reproducibility of measurements.

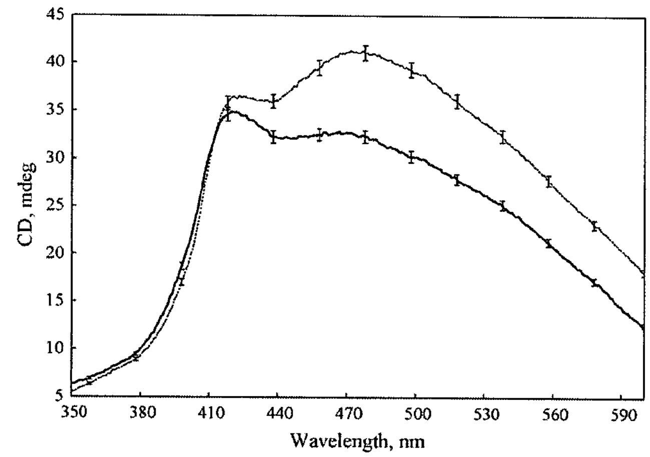

Fig. 5. The visible CD spectra of the HbA at 37 °C. CD spectra of the exposed (a) and unexposed (b) HbA at 940 MHz, 77 V/m for 1 h. The HbA concentration was 11 μM dissolved in 10 mM phosphate buffer at pH 7.4. The error bars of spectra indicate triplicate of repeating experiments and high reproducibility of measurements.

This finding is possibly due to a difference in the tightness of the heme attachment [84], leading to a change in the binding ability of the protein on exposure to the electric field.

3.3. Fluorescence measurements

The Hb molecule is assembled from two symmetrical (αβ) dimmers. Each (αβ) dimmer contains three tryptophan (Trp) residues, adding to a total of six Trp residues in the tetramer. Fluorescence of hemoglobin tetramer is mainly due to the six tryptophan residues [85].

Fig. 6 shows fluorescence spectrum of HbA solution in 10 mM phosphate buffer exposed to 940 MHz with EFI of 77 V/m and compare it with that of the unexposed HbA. This figure shows a quenching of Trp fluorescence with 4 nm blue shift. It is known that a shift of maximum emission wavelength corresponds to a polarity change around the chromophore residues. A red shift always indicates that Trp residues are, on average, more exposed to the solvent and these is a decrease in the fluorescence intensity. On the other hand, a blue shift is a consequence of transferring Trp residues into a more hydrophobic environment and there is an increase in the

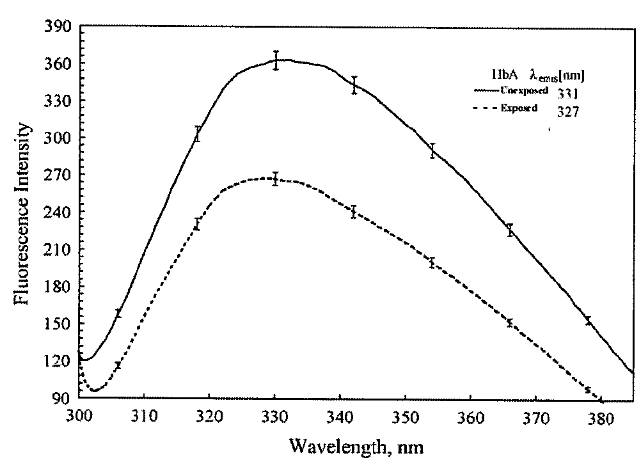

Fig. 6. Fluorescence spectra of HbA in 10 mM phosphate buffer (pH 7.4) at 37 °C. Unexposed (—) and exposed (- - -) proteins. Experimental conditions: [HbA] = 10.2 μM, 940 MHz of EFI = 77 V/m, and exposure time = 1 h. The error bars of spectra indicate of triplicate repeating experiments and high reproducibility of measurements.

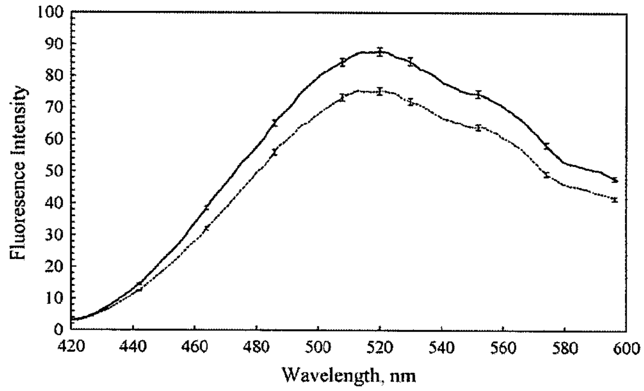

Fig. 7. Fluorescence spectra of ANS binding with exposed (- - -) and unexposed (—) HbA (excitation wavelength was 355 nm). The HbA concentration was 10.3 μM dissolved in 10 mM phosphate buffer (pH 7.4). The protein was exposed with 940 MHz, EFI of 77 V/m for 1 h at 37 °C. The error bars of spectra indicate of triplicate repeating experiments and high reproducibility of measurements.

fluorescence intensity. However, it is observed that although there is a blue shift indicating that Trp is transferred to a more hydrophobic environment, yet fluorescence intensity is decreased (see Fig. 6). This could be due to quenching of the Trp fluorescence by the heme. Our results do suggest that the tertiary structure of the protein is altered on exposure to the EMFs.

The fluorescence probe ANS has often been used for research on biosystems. ANS exhibits a large fluorescence enhancement on binding to the exposed hydrophobic patches of proteins [85]. Fluorescence of ANS in exposed HbA is less than unexposed HbA (see Fig. 7). This finding suggests that the untreated HbA has more hydrophobic patches exposed to solvent than the EMFs exposed protein. Thus, the exposure of HbA to EMFs leads to a more compact structure of the protein.

3.4. Aggregation measurements

Fig. 8 shows the change in A_{360} (a probe for measuring aggregation) of HbA in 10 mM phosphate buffer solution exposed to 940 MHz with EFI of 77 V/m as a function of time at 60 °C. It is seen in this figure that aggregation process of the exposed and unexposed of HbA is similar until 175 min. After that, aggregation of the exposed HbA reached a plateau, but aggregation process of unexposed HbA continued. So, it could be concluded that the extent of aggregation of the exposed HbA is smaller than normal condition. This could be due to the less exposed hydrophobic surface on the protein exposed to the radiation. This observation is in agreement with the intrinsic and ANS fluorescence measurements (see Figs. 6 and 7).

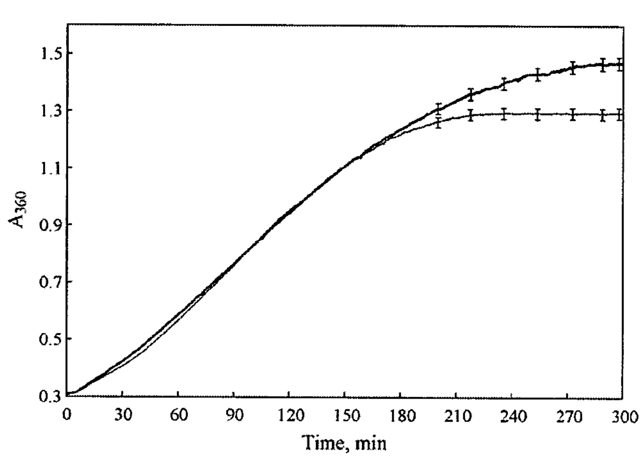

Fig. 8. Time courses for aggregation of HbA in 10 mM phosphate buffer (pH 7.4) at 60 °C. Exposed (a) and unexposed (b) protein. Protein (11.3 μM) was exposed to radiation (940 MHz, EFI = 77 V/m and exposure time = 1 h, at 37 °C) and measurements of absorbance at 360 nm was carried out at 60 °C. The error bars indicate triplicate repeating experiments and high reproducibility of measurements.

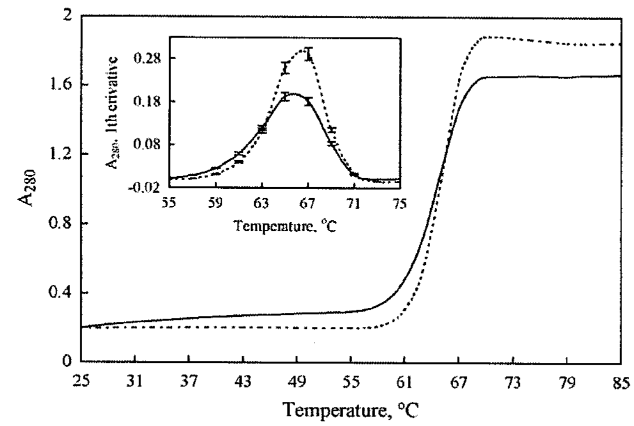

Fig. 9. Heat-induced denaturation of the exposed (- - -) and unexposed (—) HbA in 10 mM phosphate buffer (pH 7.4). Experimental conditions: [HbA] = 10.4 μM, 940 MHz, EFI = 77 V/m, exposure time = 1 h and at 37 °C. Denaturation was monitored by change in absorbance at 280 nm with a heating rate of 0.5 °C/min. The inset shows first derivative of plots of A_{280} vs. temperature. The error bars were showed in the inset indicates of triplicate repeating experiments and high reproducibility of measurements.

3.5. Thermal profiles

Fig. 9 shows thermal denaturation profiles of HbA in 10 mM phosphate buffer unexposed and exposed to 940 MHz with electric field intensity of 77 V/m. This figure indicated the thermal profiles induced by tertiary structure which obtained by UV spectrometer at 280 nm. The inset shows the first derivative of each curve. The maximum in this profile occurs at T_m [86]. It has been observed that the exposed HbA shows 2 °C increasing in T_m suggesting that the exposed HbA structure is slightly more thermal stability relative to the unexposed protein. This finding is also consistent with the fluorescence measurements.

It should be noted that each curve shown in this figure (see Fig. 9) describes at least two phenomena, namely denaturation and aggregation. We wanted to know which of these phenomena are affected by EMFs that exerted in our experiments. Thus, we need to discriminate these two different phenomena (unfolding and aggregation). For this reason we carried out another experiment based on the method used by Benjwal et al. [65]. This method is carried out by circular dichroism (CD) experiments and then used CD data along with dynode voltage data to discriminate between the heat-induced protein unfolding and aggregation. To discriminate these two phenomena we also used this technique.

Fig. 10 shows thermal unfolding and aggregation profiles of HbA in 10 mM phosphate buffer unexposed and exposed to 940 MHz with electric field intensity of 77 V/m used Far-UV circular dichroism spectropolarimetry (accordance to secondary structure of protein). Fig. 10a represents unfolding process and show that onset of unfolding of unexposed protein is resembled with the exposed sample. The figure also indicates that the whole thermal unfolding profile of exposed protein is postponed relative to unexposed sample. Fig. 10b represents aggregation process of HbA that is obtained by dynode voltage at 222 nm as a criterion of aggregation profile. It has been observed in this figure that onset of aggregation

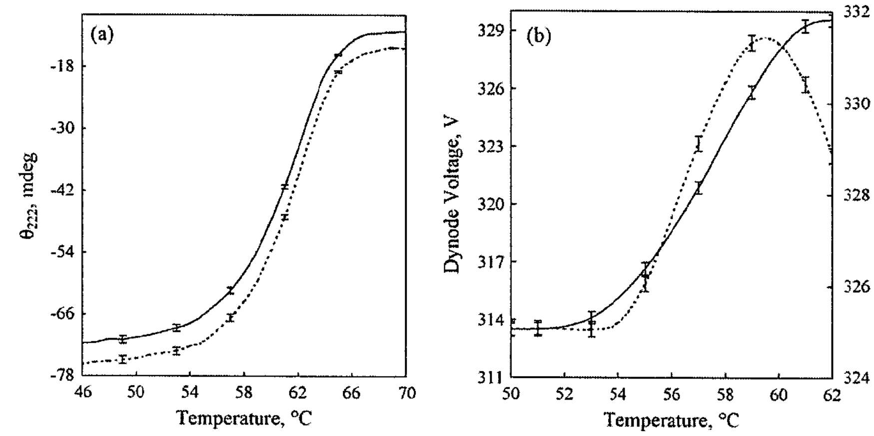

Fig. 10. Thermal unfolding and aggregation of the exposed (- - -) and unexposed (—) HbA in 10 mM phosphate buffer (pH 7.4) monitored by CD and turbidity. (a) CD melting curves, θ_{222} (T), recorded at 222 nm report on a-helical unfolding. (b) Turbidity (dynode voltage) melting curves, V (T), recorded at 222 nm report on the heat-induced increase in the particle size due to protein aggregation. Experimental conditions: [HbA] = 10.4 μM, 940 MHz, EFI = 77 V/m, exposure time = 1 h and at 37 °C. Circular dichroism and dynode voltage at 222 nm was obtained in temperature range 25–85 °C with a scan rate of 0.5 °C/min. The error bars indicate triplicate repeating experiments and high reproducibility of measurements.

of unexposed HbA is about 52 °C but those of exposed protein is at 54 °C. This difference indicates that the structure of the exposed HbA is slightly late aggregate and therefore is more thermal stable relative to the unexposed protein.

The results from Figs. 9 and 10 indicate the thermal conformational change for hemoglobin started near 60 and 55 °C for tertiary and secondary structures, respectively and not any conformational change occurred at near 37 °C for exposed and unexposed hemoglobin. We conducted all other experiments at 37 °C where there is no aggregation, to avoid any possible interference of sample turbidity with spectrophotometrically measurements.

4. Conclusions

Our in vitro experiments led us to the following conclusions. The mobile phone frequencies of 910 and 940 MHz affect the O_2-binding ability of HbA (we have shown the data and figures relative to 940 MHz as a typical). The data relative to 910 MHz is resembled to 940 MHz (data not shown). In fact, Hb of a healthy human exposed to these frequencies bind less O_2 in the lung and releases more O_2 in the tissue. This change in the functional activity of HbA is due to changes in the tertiary structure of the protein at 37 °C. The alteration of structure of exposed HbA is accordance with diminishing and late aggregation process relative to unexposed sample.

Acknowledgements

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References

[1] E. Bismuto, F. Mancinelli, G. d'Ambrosio, R. Massa, Eur. Biophys. J. 32 (2003) 628–634.
[2] J.A. Laurence, P.W. French, R.A. Lindner, D.R. McKenzie, J. Theor. Biol. 206 (2000) 291–298.
[3] J.A. Laurence, D.R. McKenzie, K.R. Foster, J. Theor. Biol. 222 (2003) 403–405.
[4] H. Bohr, J. Bohr, Bioelectromagnetics 2 (2000) 68–72.
[5] H. Bohr, J. Bohr, Phys. Rev. E61 (2000) 4310–4314.
[6] R.D. Astumian, Phys. Rev. Lett. 91 (2003) 1181021–1181024.
[7] D.I. de Pomerai, B. Smith, A. Dawe, K. North, T. Smith, D.B. Archer, I.R. Duce, D. Jones, E.P. Candido, FEBS Lett. 543 (2003) 93–97.
[8] A.B. Copty, Y. Neve-Oz, I. Barak, M. Golosovsky, D. Davidov, Biophys. J. 91 (2006) 1413–1423.
[9] M. Blank, Electromagn. Biol. Med. 27 (2008) 3–23.
[10] D.F. George, M.M. Bilek, D.R. McKenzie, Bioelectromagnetics 29 (2008) 324–330.
[11] F. Mancinelli, M. Caraglia, A. Abbruzzese, G. d'Ambrosio, R. Massa, E. Bismuto, J. Cell. Biochem. 93 (2004) 188–196.
[12] T.Y. Zhao, S.P. Zou, P.E. Knapp, Neurosci. Lett. 412 (2007) 34–38.
[13] R. Nylund, D. Leszczynski, Proteomics 6 (2006) 4769–4780.
[14] M. Lantow, M. Lupke, J. Frahm, M.O. Mattsson, N. Kuster, M. Simko, Radiat. Environ. Biophys. 45 (2006) 55–62.
[15] M. Simkó, C. Hartwig, M. Lantow, M. Lupke, M.O. Mattsson, Q. Rahman, J. Rollwitz, Toxicol. Lett. 161 (2006) 73–82.
[16] J.W. Finnie, Pathology 37 (2005) 231–233.
[17] S. Lange, T. Viergutz, M. Simkó, Cell Prolif. 37 (2004) 337–349.
[18] J. Czyz, K. Guan, Q. Zeng, T. Nikolova, A. Meister, F. Schönborn, J. Schuderer, N. Kuster, A.M. Wobus, Bioelectromagnetics 25 (2004) 296–307.
[19] K. Yao, K.J. Wang, Z.H. Sun, J. Tan, W. Xu, L.J. Zhu, D.Q. Lu, Mol. Vis. 10 (2004) 138–143.
[20] J. Friedman, S. Kraus, Y. Hauptman, Y. Schiff, R. Seger, Biochem. J. 405 (2007) 559–568.
[21] K. Zwirska-Korczala, J. Jochem, M. Adamczyk-Sowa, P. Sowa, R. Polaniak, E. Birkner, M. Latocha, K. Pilc, R. Suchanek, J. Physiol. Pharmacol. 56 (2005) 101–108.
[22] S. Zhu, Y. Wu, Z. Yu, X. Zhang, H. Li, M. Gao, Bioresour. Technol. 97 (2006) 1964–1968.
[23] M. Blank, Bioelectromagnetics 26 (2005) 677–683.
[24] T. Vukova, A. Atanassov, R. Ivanov, N. Radicheva, Med. Sci. Monit. 11 (2005) BR50–BR56.
[25] M. Barteria, A. Palab, S. Rotellaa, Biophys. Chem. 113 (2005) 245–253.
[26] M. Portaccio, P. De Luca, D. Durante, S. Rossi, U. Bencivenga, P. Canciglia, M. Lepore, A. Mattei, A. De Maio, D.G. Mita, Bioelectromagnetics 24 (2003) 449–456.
[27] M. Ammari, A. Lecomte, M. Sakly, H. Abdelmelek, R. de-Seze, Toxicology 250 (2008) 70–74.
[28] A. Schirmacher, S. Winters, S. Fischer, J. Goeke, H.J. Galla, U. Kullnick, E.B. Ringelstein, F. Stögbauer, Bioelectromagnetics 21 (2000) 338–345.
[29] M. Blank, R. Goodman, Bioelectromagnetics 18 (1997) 111–115.
[30] H. Lin, L. Han, M. Blank, M. Head, R. Goodman, J. Cell. Biochem. 70 (1998) 297–303.
[31] M. Blank, R. Goodman, J. Cell. Biochem. 73 (1999) 369–374.
[32] M. Blank, R. Goodman, J. Cell. Biochem. 81 (2001) 689–692.
[33] M. Blank, L. Soo, Bioelectrochemistry 53 (2001) 171–174.
[34] M. Blank, L. Soo, J. Cell. Biochem. 81 (2001) 278–283.
[35] R. Goodman, M. Blank, J. Cell. Physiol. 192 (2002) 16–22.
[36] M. Blank, L. Soo, Bioelectrochemistry 61 (2003) 93–97.
[37] M. Blank, R. Goodman, J. Cell. Physiol. 199 (2004) 359–363.
[38] M. Blank, R. Goodman, J. Cell. Physiol. 214 (2008) 20–26.
[39] M. Blank, L. Soo, Bioelectrochem. Bioenerg. 45 (1998) 253–259.
[40] C. Schwarz, E. Kratochvil, A. Pilger, N. Kuster, F. Adlkofer, H.W. Rüdiger, Int. Arch. Occup. Environ. Health 81 (2008) 755–767.
[41] C.F. Martino, D. Belchenko, V. Ferguson, S. Nielsen-Preiss, H.J. Qi, Bioelectromagnetics 29 (2008) 125–132.
[42] S. Dasdag, M.Z. Akdag, E. Ulukaya, A.K. Uzunlar, D. Yegin, Arch. Med. Res. 39 (2008) 40–44.
[43] G. Stefanics, L. Kellényi, F. Molnár, G. Kubinyi, G. Thuróczy, I. Hernádi, BMC Public Health 12 (2007) 325–1325.
[44] N.E. Leadbeater, L.M. Stencel, E.C. Wood, Org. Biomol. Chem. 7 (2007) 1052–1055.
[45] H. Hirose, N. Sakuma, N. Kaji, K. Nakayama, K. Inoue, M. Sekijima, T. Nojima, J. Miyakoshi, Bioelectromagnetics 28 (2007) 99–108.

[46] A.R. Ferreira, F. Bonatto, M.A. de Bittencourt Pasquali, M. Polydoro, F. Dal-Pizzol, C. Fernández, A.A. de Salles, J.C. Moreira, Bioelectromagnetics 27 (2006) 487–493.
[47] Q. Zeng, G. Chen, Y. Weng, L. Wang, H. Chiang, D. Lu, Z. Xu, Proteomics 6 (2006) 4732–4738.
[48] T. Thorlin, J.M. Rouquette, Y. Hamnerius, E. Hansson, M. Persson, U. Björklund, L. Rosengren, L. Rönnbäck, M. Persson, Radiat. Res. 166 (2006) 409–421.
[49] J.R. Li, C.K. Chou, J.A. McDougall, G. Dasgupta, H.H. Wu, R.L. Ren, A. Lee, J. Han, J. Mom, Radiat. Res. 151 (1999) 710–716.
[50] J.A. Lukin, C. Ho, Chem. Rev. 104 (2004) 1219–1230.
[51] R.E. Dickerson, I. Geis, Hemoglobin: Structure, Function, Evolution, Pathology, Benjamin/Cummings Pub. Co. Inc, Redwood City, USA, 1983.
[52] E. Bennett-Guerrero, T.H. Veldman, A. Doctor, M.J. Telen, T.L. Ortel, T.S. Reid, M.A. Mulherin, H. Zhu, R.D. Buck, R.M. Califf, T.J. McMahon, Proc. Natl. Acad. Sci. U. S. A. 104 (2007) 17063–17068.
[53] S. Pin, C.A. Royer, E. Gratton, B. Alpert, G. Weber, Biochemistry 29 (1990) 9194–9202.
[54] N. Ramadas, J.M. Rifkind, Biophys. J. 76 (1999) 1796–1811.
[55] D.L. Nelson, M.M. Cox, Lehninger Principles of Biochemistry, Worth Publisher, New York, USA, 2005.
[56] M. Blank, J. Theor. Biol. 51 (1975) 127–134.
[57] G. di Prisco, S.G. Condo, M. Tamburrlnl, B. Giardlna, Trends Biochem. Sci. 16 (1991) 471–474.
[58] Y. Takashi, P. Sunglck, T. Antonio, I. Kiyohiro, K. Kenji, J. Biol. Chem. 277 (2002) 34508–34520.
[59] E.M. Castilho, M.L. Glass, J.C. Manço, Braz. J. Med. Biol. Res. 36 (2003) 731–737.
[60] A. Rossi-Fanelli, E. Antonini, A. Caputo, J. Biol. Chem. 236 (1961) 391–396.
[61] R.E. Benesch, R. Benesch, C.I. Yu, Biochemistry 8 (1969) 2567–2571.
[62] E. Antonini, M. Brunori, Annu. Rev. Biochem. 39 (1970) 977–1042.
[63] N.W. Tietz, Textbook of Clinical Chemistry, W.B. Saunders Co, Philadelphia, USA, 1986.
[64] N. Rezaei-Ghaleh, H. Ramshini, A. Ebrahim-Habibi, A.A. Moosavi-Movahedi, M. Nemat-Gorgani, Biophys. Chem. 132 (2008) 23–32.
[65] S. Benjwal, S. Verma, K.H. Röhm, O. Gursky, Protein Sci. 15 (2006) 635–639.
[66] A. Barzegar, A.A. Moosavi-Movahedi, S. Rezaei-Zarchi, A.A. Saboury, M.R. Ganjali, P. Norouzi, G.H. Hakimelahi, F.Y. Tsai, Biotechnol. Appl. Biochem. 49 (2008) 203–211.
[67] T. Shirasawa, M. Izumizaki, Y. Suzuki, A. Ishihara, T. Shimizu, M. Tamaki, F. Huang, K. Koizumi, M. Iwase, H. Sakai, E. Tsuchida, K. Ueshima, H. Inoue, H. Koseki, T. Senda, T. Kuriyama, I. Homma, J. Biol. Chem. 278 (2003) 5035–5043.
[68] J.M. Salhany, Biochemistry 47 (2008) 6059–6072.
[69] T.R. Weiland, S. Kundu, J.T. Trent III, J.A. Hoy, M.S. Hargrove, J. Am. Chem. Soc. 126 (2004) 11930–11935.
[70] B.C. Vu, A.D. Jones, J.T. Lecomte, J. Am. Chem. Soc. 124 (2002) 8544–8545.
[71] B. Widdop, Ann. Clin. Biochem. 39 (2002) 378–391.
[72] L. Kiger, C. Poyart, M.C. Marden, Biochemistry 37 (1998) 14643–14650.
[73] S.L. Archer, V. Hampl, D.P. Nelson, E. Sidney, D.A. Peterson, E.K. Weir, Circ. Res. 77 (1995) 174–181.
[74] E.J. van Kampen, W.G. Zijlstra, Adv. Clin. Chem. 8 (1965) 141–185.
[75] M. Tkalec, K. Malaric, B. Pevalek-Kozlina, Bioelectromagnetics 26 (2005) 185–193.
[76] L.J. Challis, Bioelectromagnetics Supplement 7 (2005) S98–S106.
[77] A.A. Marinot, C. Frilot, Bioelectromagnetics 24 (2003) 70–72.
[78] R.K. Adair, Bioelectromagnetics 24 (2003) 440–441.
[79] Q. Balzano, Bioelectromagnetics 23 (2002) 278–287.
[80] Q. Balzano, Bioelectromagnetics 24 (2003) 483–488.
[81] Q. Balzano, A. Shepherd, Bioelectromagnetics 24 (2003) 473–482.
[82] Y. Sugita, I. Nagai, Y. Yoneyama, J. Biol. Chem. 246 (1971) 383–388.
[83] C. Liu, A. Bo, G. Cheng, X. Lin, S. Dong, Biochim. Biophys. Acta 1385 (1998) 53–60.
[84] H. Hamaguchi, A. Isomoto, H. Nakajima, Biochem. Biophys. Res. Commun. 35 (1969) 6–11.
[85] S. De, A. Girigoswami, J. Colloid. Interf. Sci. 296 (2006) 324–331.
[86] K.W. Olsen, Methods Enzymol. 231 (1994) 514–524.

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Fifty-gigahertz Microwave Exposure Effect of Radiations on Rat Brain

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Abstract The object of this study is to investigate the effects of 50-GHz microwave radiation on the brain of Wistar rats. Male rats of the Wistar strain were used in the study. Animals of 60-day age were divided into two groups—group 1, sham-exposed, and group 2, experimental (microwave-exposed). The rats were housed in a temperature-controlled room (25 °C) with constant humidity (40–50%) and received food and water ad libitum. During exposure, rats were placed in Plexiglas cages with drilled ventilation holes and kept in an anechoic chamber. The animals were exposed for 2 h a day for 45 days continuously at a power level of 0.86 $\mu W/cm^2$ with nominal specific absorption rate 8.0×10^{-4} w/kg. After the exposure period, the rats were killed and homogenized, and protein kinase C (PKC), DNA double-strand break, and antioxidant enzyme activity [superoxides dismutase (SOD), catalase, and glutathione peroxidase (GPx)] were estimated in the whole brain. Result shows that the chronic exposure to these radiations causes DNA double-strand break (head and tail length, intensity and tail migration) and a significant decrease in GPx and SOD activity (p=<0.05) in brain cells, whereas catalase activity shows significant increase in the exposed group of brain samples as compared with control (p=<0.001). In addition to these, PKC decreased significantly in whole brain and hippocampus ($p<0.05$). All data are expressed as mean ± standard deviation. We conclude that these radiations can have a significant effect on the whole brain.

Keywords Glutathione peroxidase · Superoxidase · Catalase · Microwave radiation · Protein kinase C

Introduction

Microwaves may affect biological systems by increasing free radicals, which may enhance lipid peroxidation, and by changing the antioxidative activities of the brain cells, thus

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leading to oxidative damage. The effect of microwave radiations on biological systems is primarily identified as due to an increase in temperature, i.e., thermal [1], though nonthermal effects have also been identified [2, 3]. The present study was designed to determine the effects of 50 GHz nonthermal microwave radiation on rat brain. This frequency was chosen because 50 GHz has a very small penetration depth, which may cause an increase in the random molecular motion due to free-radical processes within the cell. So far, most of the investigations are confined to a frequency up to 10 GHz. Above-range frequencies will have limited penetration into the body, and their mode of interaction with the system, including those at cellular and molecular levels, will be interesting to examine. It will be of further interest to establish their commonality with after-exposure parameters at comparatively lower frequencies. The study also aims to spread over the electromagnetic field (EMF) effect over a wider band of nonionizing electromagnetic spectrum.

Protein kinase C (PKC) and antioxidant enzymes play an important role in functioning of the central nervous system. PKC plays a key role in a variety of pathologic states, including oncogenesis [4, 5]. This may affect the cellular responses to extracellular stimuli participated in cell differentiation and apoptosis [6]. PKC modulates ion conductance by phosphorylating membrane proteins such as channels, pumps, and ion exchange proteins mobilization into the cytosol. This has been implicated in phosphorylation of several neuronal proteins, which are thought to regulate neurotransmitter release and long-term potentiation in memory formation [7]. The activation of this enzyme is thought to be biochemically dependent on Ca^{2+}. Tumor-promoting phorbol esters, such as 12,O-tetradecanoyl phorbol-13-acetate (TPA), have a structure very similar to diacylglycerol and activate PKC directly, both in vitro and in vivo [8]. TPA has a specific membrane receptor in the cell membrane [9, 10]. In order to stimulate cell proliferation in cells, growth factor and PKC are needed to induce the signal pathways. Furthermore, tumor promoters TPA have a membrane receptor in the membrane of all cells. This receptor is considered to be calcium phospholipid-dependent protein kinase (PKC). It is involved in the regulation of a variety of cellular events, including modulation of receptor functions for major hormones and certain enzymes such as adenylate cyclase and ornithine decarboxylase.

In the present investigation, PKC has been estimated in hippocampus, whole brain, and the remaining portion. The hippocampus is understood to be responsible for learning and memory. In addition to this, antioxidant enzyme estimation has also been performed. It is well known that these enzymes play a major role in protecting the cells by removal of free radicals, which are generated by microwave radiations. It has been established that the overproduction of reactive oxygen species (ROS) comes through free radicals formation and may change the levels of superoxides dismutase (SOD), glutathione peroxidase (GPx), and catalase (CAT) activity in the whole brain. These parameters were undertaken to determine the possible site of the EMF biointeraction with ROS. Very recently, Mahfouz et al. [11] reported that microwave/radiofrequency radiation may lead to oxidative stress due to overproduction of ROS. Others workers, several from our laboratory, have shown that these radiations affect cholenergic systems, brain Na+–K+ ATPase activity [12, 13], growth-related enzymes [14], PKC activity [3], single-strand DNA breaks in brain cells [15, 16], and reduced infertility in male rats [17].

In continuation, DNA double-strand breaks were observed and comet scoring was carried out with tail and head-length migration and intensity. The first study of DNA strand break was observed by Lai and Singh [18] in rat brain cells at continuous and pulsed RF radiation. These field exposures induced the formation of DNA–protein and DNA–DNA cross-links in brain cells of rats [19], which could be the result of free-radical damage involving iron cations [20, 21]. The results of Ivancsits et al. [22–25] indicate that the interaction of these fields with DNA is quite complicated and apparently depends on many factors, such as the mode of exposure, the type of cells, and the intensity and duration of exposure. Some researchers found conflicting results; some observed that there is no effect of radio frequency radiation exposure in DNA strand break of mammalian somatic cells [26, 27]. To support these data and to confirm their pathological implications, we have measured the activities of antioxidant enzymes, namely, SOD, CAT, and GPx and tumor promoter PKC in rat brain cells.

Material and Methods

Material

The GPx (catalog No. 703102), CAT (catalog No. 707002), and SOD (CAT No. 706002) antioxidant enzyme kit was purchased from the Cayman Chemical Company, Ann Arbor, MI, USA. P^{32} radioactive labeled ATP was purchased from BRIT, Hyderabad, India. The rest of the chemicals were purchased from Thomas Baker Chemicals Limited, Marine Drive, Mumbai, India.

Animals Exposure

Male Wistar rats (60 days old and 190±20 g body weight) were obtained from the animal facility of Jawaharlal Nehru University, New Delhi. They were divided into two groups, a sham-exposed group ($n=6$) and an experimental group (n=6). In the animal exposure and subsequent experimentation, a blind study was conducted, where the experimental and control code was not disclosed before the data analysis. All animals were housed in an air-conditioned room, where the temperature was maintained at 25 °C with constant humidity (40–50%). The air circulation was constantly maintained to keep it in equilibrium with the room temperature. The animals were provided with standard food pallets (prepared by Brook Bond India, Mumbai, India) and water ad libitum.

The protocol and study method was approved by the Institutional Animal Ethical Committee and the Committee for Purpose of Control and Supervision of Experimental on Animal.

Exposure Chamber

Two rats at a time were placed in a Plexiglas cage, which was quite ventilated with holes of 1-cm diameter. The dimension of the exposure cage was made in such a way that animals moved freely. The chamber is lined with radar-absorbing material (attenuation, 40 db) to minimize the possibility of any reflections. At far field distance from the horn antenna, it was found that the field is homogeneous in the vertical plane midline of the beam. Rats were exposed with 50 GHz continuous source through the antenna, 2 h a day for 45 days (Fig. 1). The power density at receiving end was measured (0.86 $\mu W/cm^2$) and the nominal specific absorption rate (SAR) value was calculated (8.0×10^{-4} w/kg). The animals faced E filed orientation parallel to the exposure chamber. Since the free space wavelength at this frequency is 0.6 cm, it is assumed that the exposure is limited to the subcutaneous surface. Every day, the cage was placed in the same position facing the horn antenna and the same number of rat positions was filled.

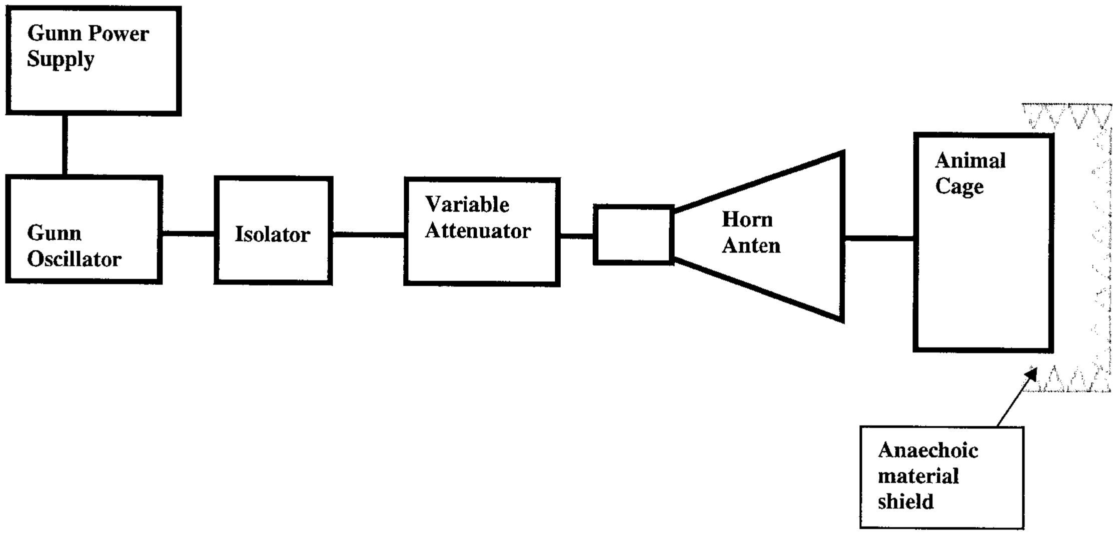

Fig. 1 Schematic diagram of 50-GHz radiation source

Sample Preparation and Tissue Homogenate

In the present investigations, enzyme assay was used to determine the enzyme activity (SOD, GPx, and CAT) in exposed Wistar rats. Immediately after exposure, animals were killed by overdose of anesthesia and the brain was collected in ice-cold buffer. The brain was homogenized in cold buffer (50 mM Tris–HCl, pH 7.5, 5 mM EDTA, and 1 mM DTT per gram tissue) for GPx, 5–10 ml HEPES buffer for SOD, and (50 mM potassium phosphate, pH 7.0, containing 1 mM EDTA per gram tissue) for CAT. The sample was centrifuged at 10,000×*g* for 15 min at 4 °C. Supernatant was collected and enzyme assay was performed. Different sets of animals with the same age group were taken for given parameters (DNA strand break, PKC, and antioxidant enzyme).

Estimation of GPx Activity

One hundred twenty microliters of assay buffer and 50 µl cosubstrate mixture were added in nonenzymatic wells. One hundred microliters of assay buffer, 50 µl of cosubstrate mixture, and 20 µl of diluted GPx were added in other wells as control samples, whereas the same amount of assay buffer and cosubstrate including 20 µl of brain sample in place of GPx were added in all the wells. Immediately, reaction was initiated by adding 20 µl of cumene hydroperoxide to all the wells being used. Finally, the well plate was placed in a microplate reader spectrophotometer, and the absorbances of the samples were taken at 340 nm

Estimation of Superoxidase Activity

Twenty microliters of SOD standard was diluted with 1.98 ml of sample buffer. SOD standard wells were prepared by using 200 µl of the diluted radical detector and 10 µl of diluted standard. Sample wells were also prepared by adding 200 µl of the diluted radical detector and 10 µl of sample to the wells. The reaction was initiated by adding 20 µl of diluted xanthine oxidase to all the wells. The sample plate was kept in microplate reader temperature, and absorbance was taken at 450 nm.

Estimation of CAT Activity

One hundred microliters of assay buffer, 30 μl of methanol, and 20 μl of standard were added to wells, which contained 10 μl of formaldehyde and 9.99 ml of sample buffer and formaldehyde wells were prepared. Control wells were prepared by adding 100 μl of diluted assay buffer, 30 μl of methanol, and 20 μl of diluted CAT. Thirdly, the sample wells were prepared by adding 100 μl of diluted assay buffer, 30 μl of methanol, and 20 μl of tissue samples. The reaction was initiated by adding 20 μl of diluted hydrogen peroxide to all the wells. Sample plate was incubated for 20 min at room temperature and 30 μl of potassium hydroxide was added to terminate the reaction. Thirty microliters of purpald (chromogen) was added to each well and thereafter incubated for 10 min at room temperature on a shaker. Ten microliters of potassium periodate was added to each well, incubated for 5 min at room temperature on shaker, and the absorbance of samples was taken at 540 nm.

Calcium-dependent Protein Kinase (PKC) Assay

After 45 days of exposure, the animals were killed with rat cocktail anesthesia (Ketamine, Xylazine; IP) and then decapitated. Brain tissue was taken out from the cranial cavity immediately and put into a deep freezer for a short while to become tissue hard. The hippocampus was taken out and assays were performed in three sets as follows: (1) hippocampus, (2) whole brain minus hippocampus (remaining brain), (3) whole brain.

Each brain tissue was homogenized separately in 40 vol of ice-cold, 1-mM sodium bicarbonate (pH 7.5). The homogenate was centrifuged at 600 g for 10 min at 4 °C. The supernatants were centrifuged at 20,000×*g* for 30 min at 4 °C. The pellet was pipetted with ice-cold, 1-mM sodium bicarbonate and centrifuged at 20,000×*g* for 30 min at 4 °C. The pellet was resuspended in incubation buffer (100 mM HEPES, 120 mM NaCl, 1.2 mM MgSO4, 2.5 mM KCl, 15 mM NaHCO3, 10 mM glucose, 1 mM EDTA, pH 7.4) and protein concentration was measured by Lowry's method [28]. Protein kinase activity was assayed in a total volume of 0.5 ml incubation medium [50 mM HEPES, 10 mM MgCl2, 0.5 mM CaCl2, and 0.2 mM EGTA (free calcium level of 0.1 mM), pH 7] with a total protein concentration of 100 μg. P^{32}-labeled ATP (specific activity 3,000 Ci/mmol ATP) was added to initiate the reaction and then incubated at 25 °C. Fifty-microliter samples were taken out and pipetted upon 3-mm filter discs (pretreated with 10% trichloroacetic acid, 20 mM sodium pyrophosphate, and 10 mM EDTA). These filter discs were dropped into 500 ml of the TCA mixture (10% trichloroacetic acid, 20 mM sodium pyrophosphate, and 10 mM EDTA) and left overnight at 4 °C. Filters were washed once in 5% TCA, heated to 90 °C for 15 min in 10% TCA. Furthermore, 5% TCA wash was extracted in hot ethanol/ ether (3:1 v/v) before drying. Radioactivity was measured in a Hewlett Packard scintillation counter

DNA Double-strand Breaks Estimation

In the present investigations, comet assay (also referred to as single-cell gel electrophoresis) is used to determine DNA damage (DNA strand break). Assay was performed according to the technique of Singh [29]. Immediately after the exposure period, one rat at a time was anesthetized by placing it in a glass jar containing cotton dipped in anesthetized ether. Animals were killed and brain was homogenized in phosphate buffer and a single-cell suspension was made by using pipette. From the suspension, 10 μl of its suspension was mixed with 0.2 ml, 0.7% agarose. Agarose was suspended in phosphate buffered saline with 3:1 agarose higher resolution and kept at 37 °C to maintain physiological conditions [18]. The mixture was pipetted out and poured onto a fully frosted slide, immediately covered with coverglass (24×60 mm). These slides were kept in an ice-cold steel tray on ice for 1 min to allow the agarose to gel. Again, a layer was made over the gel with 100 µl of agarose as before, after removing the coverglass [29, 30]. These slides were immersed in ice-cold lysing solution with the addition of DNAase free proteinase K (0.5 mg/ml) and kept overnight at 4 °C. After lysing overnight, the slides were removed and placed in a horizontal slab of an electrophoresis assembly. One liter of electrophoresis buffer was gently poured into the assembly. After 20 min to allow for unwinding, electrophoresis was started at 250 mA (12 V) for 30 min. The slides were removed from the electrophoresis apparatus and placed in coplin jar containing neutralizing buffer. After 30 min, the slides were transferred to another jar of neutralizing solution. After one more change of 30 min, the slides were left vertical at room temperature to dry and stained with ethidium bromide (EtBr of 0.05 mg/ml) covered with a 24×60-mm coverglass. Microscopic slides were prepared with each individual animal separately.

Images were taken at 100× magnification using a charge-coupled device camera GW525x (Genwac, Orangeburg, NY, USA) attached to Leica DMLB fluorescence microscope (Leica, Wetzlar, Germany) with an excitation filter of 490 nm, a 500-nm dichroic filter, and an emission filter of 515 nm. The images of double strand DNA break in brain cells were recorded with fluorescence microscope.

Comet Scoring

Slides were assayed for double-strand DNA breaks. Twenty cells were selected from each slide. Therefore, from each animal, 40 cells (two slides) were scored. Head and tail length (µm), intensity (%), and tail migration (µm) from the beginning of the nuclear area to the last five pixels of DNA perpendicular to the direction of migration at the leading edge were measured. Tail and head length, migration, and intensity of individual cells were measured. The scoring of comet assay was done by using Comet assay IV 4.2 version software (Perceptive Instrument, Haverhill, UK). Data are presented as mean ± standard deviation. The difference between exposed and control groups was tested for significance by using one-way analysis of variance (ANOVA). A difference at $p<0.05$ was considered statistically significant.

Results

Antioxidant Enzymatic Activity in Brain Cells

Compared with the control group (16.82±2.96), those exposed to the 50-GHz showed a significant decrease (12.66±0.87 nmol min^{-1} ml^{-1}; $p<0.001$) in GPx activity (Fig. 2a). The exposed group also showed a significant decrease of SOD activity (169.09± 15.34 U/ml; $p<0.006$) as compared to the control group (189.50±13.13) (Fig. 2b). However, the exposed group of animals showed a significant increase in CAT activity (9.81±1.60 nmol min^{-1} ml^{-1}; $p<0.001$) as compared to the control group (6.86±0.76) (Fig. 2c). The results occulting significant changes occurring in the exposed group of brain cells in all antioxidants enzymatic activities of GPx SOD and CAT are shown in Fig. 2a–c.

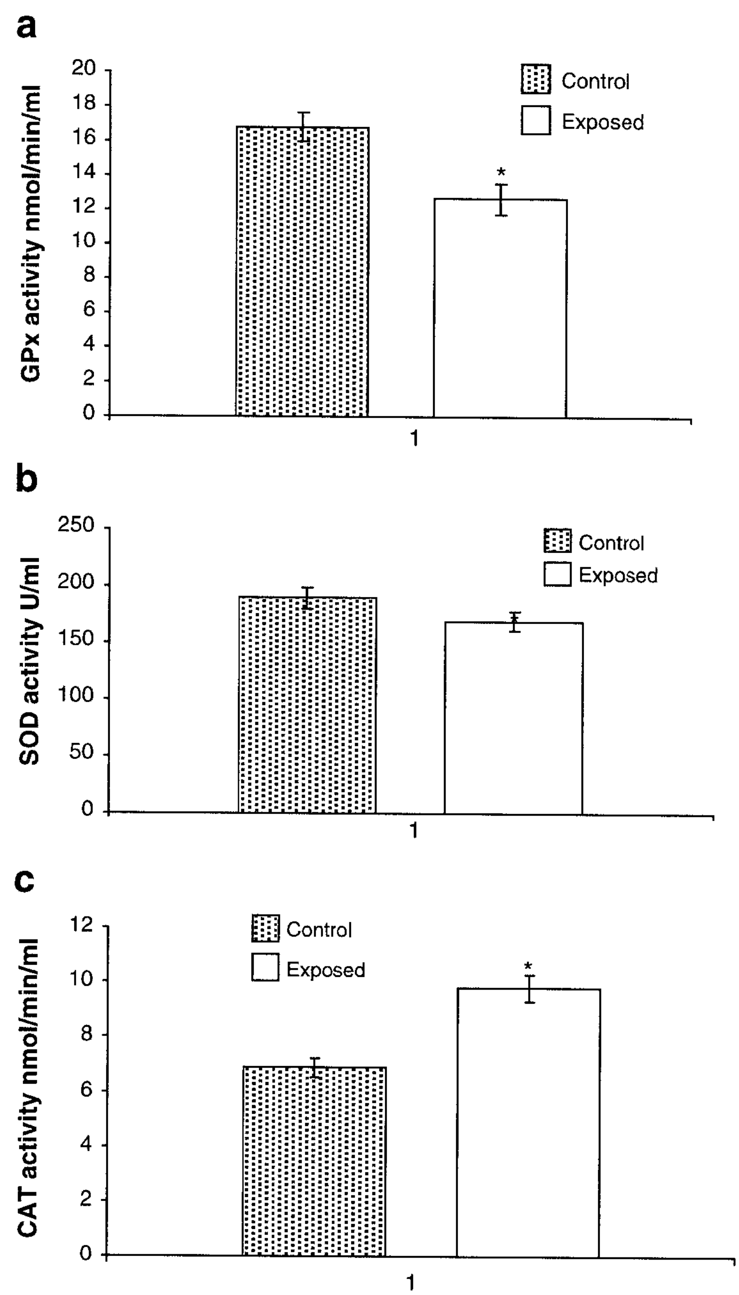

Fig. 2 Antioxidant enzyme activities in rat brain cells in 50 GHz exposed Wistar rats. Result shows significant decrease in exposed group of brain GPx (**a**) and SOD (**b**). However, the exposed group shows significantly increased brain CAT enzyme activity compared to control (**c**). Data are expressed as mean ± standard deviation (SD). *$p<0.05$ vs control group

PKC Activity

The important role of PKC is the transduction for the activation of many cellular functions and control of cell proliferation. Cells, which are subjected to prolonged exposure to tumor promoter phorbol esters, showed depletion in PKC level. PKC activity in whole brain is reduced significantly ($p<0.005$) in the chronically exposed group (3,198.0±1,259.28/mg protein), as compared to their sham exposed counterpart (6,321.33±2,141.55/mg protein) (Fig. 3a). In the hippocampus group, the experimental results also show a significant decline. For the sham-exposed group, it was 3,990.0±1,494.27/mg protein, and for the exposed group, it was 2,703.0±1,213.46/mg protein ($p<0.03$) (Fig. 3b).

However, in the remaining brain, the experimental data do not show a significant difference when compared to the sham-exposed group ($p>0.05$). For the sham-exposed group, we measured 6,455.33±4,061.20/mg protein, whereas for the exposed group, it

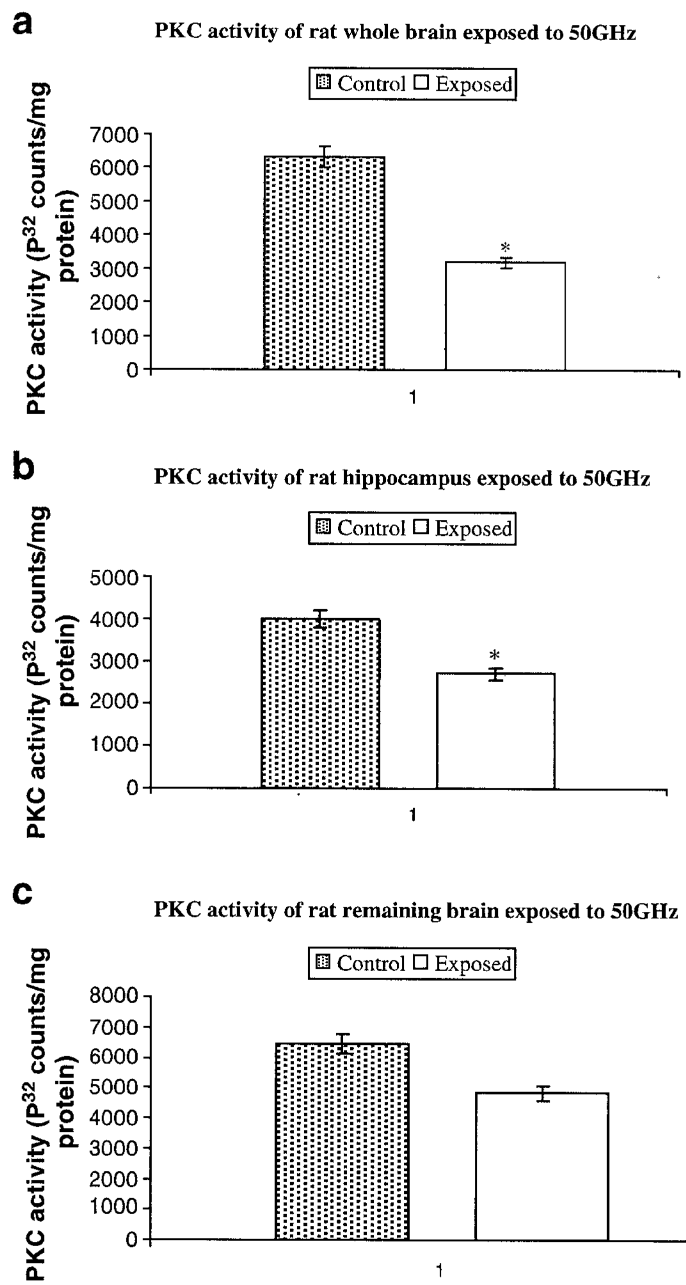

Fig. 3 Effect of chronic exposure to 50 GHz microwave radiation on PKC activity in whole brain (**a**), hippocampus (**b**) was statistically significant ($p<0.05$) as compared to sham-exposed group. However, whole brain minus hippocampus (remaining brain) (**c**) shows no significant result. *Asterisks* show significant results

was 4,850±4,119.14/mg protein (Fig. 3c). All statistical work was done by one-way ANOVA.

DNA Double-strand Break

In the qualitative picture of DNA double-strand break, it is shown that more tail migration has taken place in the exposed brain (Fig. 4) as compared to control (Fig. 5). Our results show that the prolonged chronic exposure to 50 GHz causes reproducible increase in double-strand DNA breaks in brain cells of rats in all the exposed-group animals. The average values of head and tail length, intensity, and tail migration of rat brain cells exposed to 50-GHz continuous wave are given in Table 1. It shows that there is a significant increase in the head and tail length of DNA, and tail migration was also recorded as compared to the control group. A comparison for the control group, the average values of

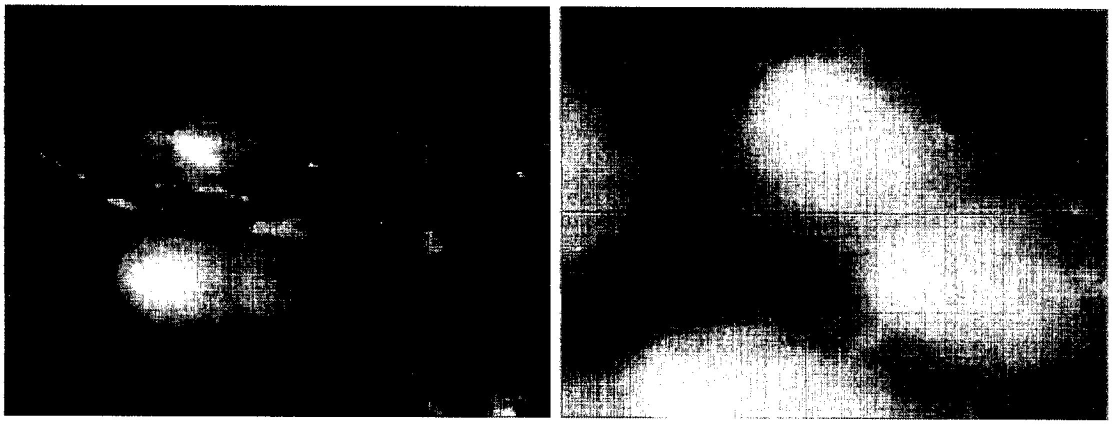

Fig. 4 DNA double-strand break of exposed rat brain cells observed in fluorescent microscope at 40×

head length (93.26±0.41 μm), tail length (66.26±0.69 μm), and tail migration (19.63± 0.70 μm), was recorded, whereas for the exposed group, it was head length (109.17±1.13 μm; $p<0.01$), tail length (176.56±2.35 μm; $p=0.0023$), and tail migration (122.23±2.19 μm; $p<0.005$). At the same time, the total average value of head and tail intensity was also recorded. A significant decrease was observed in head intensity, whereas significant increase was observed in tail intensity of the exposed group. For the control group, the average value of head intensity (87.05±1.2%) and tail intensity (12.94±1.20%) was scored. Alternatively, in the exposed group, the average values in head intensity (49.76± 1.04%; $p<0.03$) and tail intensity (48.24±2.00%; $p<0.02$) were recorded. The present study was aimed to find out the effect of chronic exposure of radiation. Data obtained show that prolonged (45 days) exposure to microwave radiation (50 GHz) causes double-strand DNA break in brain cells.

Discussions

SOD and GPx play a key role in the biological system protecting the body from destructive free-radical activity. An absence or decrease in activity of these enzymes may have noxious metabolic outcomes. The mechanism of detoxication is not confined to the SOD alone, but a product of SOD activity is also a strong inhibitor of this enzyme [31]. It is suggested that an effective detoxication of active oxygen takes place with concordant SOD and CAT action. CAT is involved in the detoxification of hydrogen peroxide (H_2O_2), a ROS.

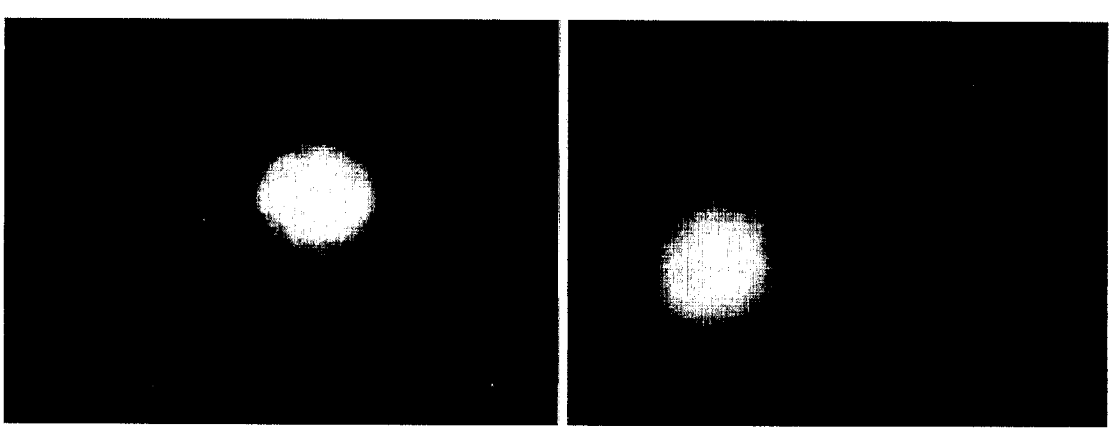

Fig. 5 No DNA double-strand break of exposed rat brain cells observed in fluorescent microscope at 40×

Table 1 Average value of six animals were scored by using comet assay IV 4.2 version (Perceptive Instrument) has presented in mean ± SD (standard deviation).

	Head length	Tail length	Tail migration	Head intensity	Tail intensity
Control	93.26±0.41	66.26±0.69	19.63±0.70	87.05±1.2	12.94±1.20
Exposed	109.17±1.13	176.56±2.35	122.23±2.19	49.76±1.04	48.24±2.00
p Value	$p<0.01$	0.0023	0.005	$p<0.03$	$p<0.02$

In our study, SOD and GPx activities were significantly decreased ($p<0.05$) due to the effect of EMF on the brain, whereas CAT activity was significantly increased in the exposed group ($p<0.05$). Other studies also suggest that a decrease in the level of SOD activity may indicate an increase in the generation of reactive superoxide ions in the biological samples [32]. The decrease in GPx activity might have been due to the excessive production of free radicals. Although GPx is a relatively stable enzyme, it can be inactivated under conditions of severe oxidative stress [33, 34]. In addition to these, the hydrogen superoxide formed during the detoxification process is then illuminated by CAT. Indeed CAT activity is enhanced when H_2O_2 levels are particularly high [35]. Earlier, Rotilio [31] demonstrated that the product of SOD activity (hydrogen superoxide) inhibits the enzyme activity of SOD itself. The possible mechanism defines that EMF exposure leads to generation of ROS [36], which are able to damage many biomolecules, including DNA, enzymes, lipids, and proteins [37]. Under subtoxic conditions, free radicals are also known to play an important role in cellular signal transduction processes [38]. We can hypothesize that a reduction or an increase in antioxidative enzyme activities observed in our study may be related to overproduction of ROS under microwave field exposure.

There is another enzyme, PKC, which may also play a pivotal role in mediating cellular stimuli involved in proliferation, differentiation, apoptosis, and exocytotic release in a number of neuronal and nonneuronal systems. This indicates that any alteration may finally lead to affect the normal growth of the cells. However, in the brain, the hippocampus is probably a preferential site for EMF biointeraction [3]. This is in line with many other reports that a chronic exposure of electromagnetic radiation affects learning and memory functions [39] by affecting hippocampus. Butler et al. [40] reported that cells might be functionally depleted of protein kinase by prolonged exposure to biologically active phorbol esters. They reported that the activity was reduced to 92% as compared to control [40]. An earlier study from our laboratory also suggests that there was a decrease in the activity of PKC in rats exposed to 147-MHz amplitude-modulated at 16 Hz as compared to the control group [22]. It is suggested that protein kinase in the membrane may be a target for microwave radiations, which leads to a variety of altered intracellular events in the cells [41].

Our study on DNA double-strand breaks is in agreement with other scientific reports that have occulted the real picture of mutagenic effects due to EMF radiations. Lai and Singh [18, 42–44] first reported an increases in single- and double-strand DNA breaks in brain cells of rats exposed for 2 h to 2,450-MHz field at 0.6–1.2 W/kg. More recently, this has been confirmed by Paulraj and Behari [16], who reported an increase in single-strand breaks in developing brain cells of rats after 35 days of exposure to 2.45- and 16.5-GHz fields at 1 and 2.01 W/kg. Nikolova et al. [45] reported a low and transient increase in DNA double-strand break in mouse embryonic stem cells after acute exposure to 1.7-GHz field. Aitken et al. [46] reported significant damage to both the mitochondrial genome ($p<0.05$) and the nuclear -globin locus ($p<0.01$) in exposed mice to 900-MHz RFR at a SAR of 0.09 W/kg for 7 days at 12 h per day. A study by Diem et al. [47] reported an effect on exposed human fibroblasts and rat granulosa cells to mobile phone signal (1,800 MHz; SAR 1.2 or 2 W/kg; during 4, 16, and 24 h) and suggested that the exposure may induce DNA single- and double-strand breaks as measured by the comet assay.

Several reports suggested that DNA damage in cells could have an important implication on human health because they are cumulative. Normally, DNA is capable of repairing itself efficiently through a homeostatic mechanism, whereby cells maintain a delicate balance between spontaneous and induced DNA damage. DNA damage accumulates if such a balance is altered. Most cells have considerable ability to repair DNA single-strand breaks; for example, some cells can repair as many as 200,000 breaks in 1 h. However, DNA double-strand breaks, if not properly repaired, are known to lead to cell death or apoptosis. Indeed, we have observed an increase in apoptosis and decrease in sperm count [26, 48, 49] and DNA double-strand break in sperm and brain cells exposed to microwave RFR [17, 27, 42, 44].

The correlation between oxidative damage to cells (DNA strand break, antioxidant enzyme, and PKC level changes) and ROS has been established in the present paper. ROS are free radicals, which may play a role in mechanisms of the biological effects induced by electromagnetic radiation. It is suggested that the outcome of oxidative damage induced by EMFs will therefore depend on various factors, including the oxidative status of the cell, capability of endogenous antioxidation enzymes, and processes to counteract free radical buildup, availability of exogenous antioxidants, iron homeostasis (a balance of iron influx, storage, and use), the parameters of exposure (e.g., intensity and duration of exposure and, possibly, the wave shape), and whether the oxidative damage is cumulative. In aerobic cells, ROS are generated as a by-product of normal mitochondrial activity. If not properly controlled, ROS can cause severe damage to cellular macromolecules, especially DNA and antioxidative enzyme. DNA damage and alteration in enzyme activities are clear indications of tumor promotion.

Conclusion

We conclude that prolonged exposure to 50 GHz field radiation may decrease the level of PKC, cause the DNA double-strand break, and also make the changes in antioxidant enzymes in neurological system of male rats due to free radicals formation. It also confirms that the possible site of action of such radiation is the hippocampus, the region responsible for control of learning and memory in the brain.

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References

1. Stuchley, M. A. (1988). Biological effects of radiofrequency fields. In M. H. Repacholi (Ed.), Non-Ionizing Radiations, Physical characterization, Biological effects and Health Hazard Assessment. *Proceeding for the International Non-Ionizing Radiation Workshop. Melbourne*, pp. 197–217.
2. Kunjilwar, K. K., & Behari, J. (1993). Effect of amplitude-modulated radio frequency radiation on cholinergic system of developing rats. *Brain Research*, *601*, 321–324. doi:10.1016/0006-8993(93)91729-C.
3. Paulraj, R., & Behari, J. (2004). Radiofrequency radiation effect on protein kinase C activity in rats brain. *Mutation Research*, *585*, 127–131. doi:10.1016/S0027-5107(03)00113-1.

4. Harvey, C., & French, P. W. (2000). Effects on protein kinase C and gene expression in a human mast cell line, HMC-1, following microwave exposure. *Cell Biology International, 23*, 739–748. doi:10.1006/cbir.1999.0436.
5. Nishizuka, Y. (1986). Studies and perspectives of protein kinase C. *Science, 233*, 305–312. doi:10.1126/science.3014651.
6. Ohkusu, K., Isobe, K., Hidaka, H., & Nakashima, I. (1986). Elucidation of the protein kinase C-dependent apoptosis pathway in distinct of T lymphocytes in MRL-*lpr/lpr* mice. *European Journal of Immunology, 25*, 3180–3186. doi:10.1002/eji.1830251129.
7. Suzuki, T. (1994). Protein kinase involved in the expression of long-term potentiation. *The International Journal of Biochemistry, 26*, 735–744. doi:10.1016/0020-711X(94)90102-3.
8. Castagna, M., Takai, Y., Kaibuchi, K., Sano, K., Kikkawa, U., & Nishizuka, Y. (1982). Direct activation of calcium-activated, phospholipid-dependent protein kinase by tumorpromoting phorbol esters. *The Journal of Biological Chemistry, 78*, 47–51.
9. Hunter, T., Ling, N., & Cooper, J. A. (1984). Protein kinase C phosphorylation of the EGF receptor at a threonine residue close to the cytoplasmic face of the plasma membrane. *Nature, 311*, 480–483. doi:10.1038/311480a0.
10. Niedel, J. E., Kuhn, L. J., & Vandenbark, G. R. (1983). Phorbol diester receptor copurifies with protein kinase C. *Proceedings of the National Academy of Sciences of the United States of America, 80*, 36–40. doi:10.1073/pnas.80.1.36.
11. Mahfouz, R., Sharma, R., Lackner, J., Aziz, A., & Agarwal, A. (2008). Evaluation of chemiluminescence and flow cytometry as tools in assessing production of hydrogen peroxide and superoxide anion in human spermatozoa. *Fertility and Sterility*, in press. doi:10.1016/j.fertnstert.2008.05.087.
12. Behari, J., Kunjilwar, K. K., & Pyne, S. (1998). Interaction of low level modulated RF radiation with Na+–K+–ATPase. *Bioelectrochemistry and Bioenergetics, 47*, 247–252. doi:10.1016/S0302-4598(98)00195-0.
13. Paulraj, R., Behari, J., & Rao, A. R. (1999). Effect of 112 MHz amplitude modulated radiation on calcium ion efflux and ODC activity in chronically exposed rat brain. *Indian Journal of Biochemistry & Biophysics, 36*, 337–340.
14. Paulraj, R., & Behari, J. (2002). The effect of low level continuous 2.45 GHz wave on brain enzymes of developing rat brain. *Electromagnetic Biology and Medicine, 21*, 231–241. doi:10.1081/JBC-120015993.
15. Sarkar, S., Ali, S., & Behari, J. (1994). Effect of low power microwave on the mouse genome: a direct DNA analysis. *Mutation Research, 320*, 141–147. doi:10.1016/0165-1218(94)90066-3.
16. Paulraj, R., & Behari, J. (2006). Single strand DNA breaks in rat brain cells exposed to microwave radiation. *Mutation Research, 596*, 76–80. doi:10.1016/j.mrfmmm.2005.12.006.
17. Behari, J., & Kesari, K. K. (2006). Effects of microwave radiations on reproductive system of male rats. *Embryo Talk, 1*, 81–85.
18. Lai, H., & Singh, N. P. (1996). Double strand breaks in rats brain cells after acute exposure to radio frequency electromagnetic radiation. *International Journal of Radiation Biology, 69*, 513–521. doi:10.1080/095530096145814.
19. Singh, N. P., & Lai, H. (1998). 60-Hz magnetic field exposure induces DNA crosslinks in rat brain cells. *Mutation Research, 400*, 313–320. doi:10.1016/S0027-5107(98)00017-7.
20. Altman, S. A., Zastawny, T. H., Randers-Eichhorn, L., Cacciuttolo, M. A., Akman, S. A., & Dizdaroglu, M. (1995). Formation of DNAprotein cross-links in cultured mammalian cells upon treatment with iron ions. *Free Radical Biology & Medicine, 19*, 897–902. doi:10.1016/0891-5849(95)00095-F.
21. Lloyd, D. R., Phillips, D. W., & Carmichael, P. L. (1997). Generation of putative intrastrand cross-links and strand breaks by transition metal ion-mediated oxygen radiacl ttack. *Chemical Research in Toxicology, 10*, 393–400. doi:10.1021/tx960158q.
22. Ivancsits, S., Diem, E., Pilger, A., Rudiger, H. W., & Jahn, O. (2002). Induction of DNA strand breaks by intermittent exposure to extremely-low-frequency electromagnetic fields in human diploid fibroblasts. *Mutation Research, 519*, 1–13.
23. Ivancsits, S., Diem, E., Jahn, O., & Rudiger, H. W. (2003a). Intermittent extremely low frequency electromagnetic fields cause DNA damage in a dose-dependent way. *International Archives of Occupational and Environmental Health, 76*, 431–436. doi:10.1007/s00420-003-0446-5.
24. Ivancsits, S., Diem, E., Jahn, O., & Rudiger, H. W. (2003b). Age-related effects on induction of DNA strand breaks by intermittent exposure to electromagnetic fields. *Mechanism of Ageing and Development, 124*, 847–850.
25. Suzuki, T. (1994). Protein kinase involved in the expression of long-term potentiation. *The International Journal of Biochemistry, 26*, 735–744.

26. Sakuma, N., Komatsubara, Y., Takeda, H., Hirose, H., Sekijima, M., Nojima, T., & Miyakoshi, J. (2006). DNA strand breaks are not induced in human cells exposed to 2.1425 GHz band CW and W-CDMA modulated radiofrequency fields allocated to mobile radio base stations. *Bioelectromagnetics, 27*, 51–57. doi:10.1002/bem.20179.
27. Vijayalaxmi, , & Obe, G. (2004). Controversial cytogenetic observations in mammalian somatic cells exposed to radiofrequency radiation. *Radiation Research, 162*, 481–496.
28. Lowry, O. H., Resebrough, N. J., Farr, A. L., & Randall, R. J. (1951). Protein measurement with folin-phenol reagent. *The Journal of Biological Chemistry, 193*, 265–275.
29. Singh, N. (2003). In R. Blumenthal (Ed.), *Apoptosis by DNA diffusion assay, methods in molecular medicine (chemosensitivity)*. Totowas: Humana.
30. Tice, R. R., Agurell, E., Anderson, D., Burlinson, B., Hartmann, A., Kobayashi, H., et al. (2000). Single cell gel/comet assay; guidelines for in vitro and in vivo genetic toxicology testing. *Environmental and Molecular Mutagenesis, 35*, 206–221. doi:10.1002/(SICI)1098-2280(2000)35:3<206::AID-EM8>3.0.CO;2-J.
31. Rotilio, G. (1972). Effect of hydrogen peroxide on dismutase and catalase activity in rat liver. *Biochemichistry, 11*, 2187–2189.
32. Alvarez, J. G., Touchstone, C. J., Blasco, L., & Storey, B. T. (1987). Spontaneous lipid peroxidation and production of hydrogen peroxide and superoxide in human spermatozoa. SOD as major enzyme protectant against oxygen toxicity. *Journal of Andrology, 8*, 33–89.
33. Condell, R. A., & Tappel, A. L. (1993). Evidence for suitability of glutathione peroxidase as a protective enzyme: studies of oxidative damage, restoration and proteolysis. *Archives of Biochemistry and Biophysics, 223*, 407. doi:10.1016/0003-9861(83)90604-5.
34. Reiter, R. J. (1997). Melatonin aspects of exposure to low frequency electric and magnetic fields. *Advances in electromagnetic fields in living systems* (vol. 2, (pp. 1–27)). New York: Plenum.
35. Jones, D. P., Eklow, L., Thor, H., & Orrenius, S. (1981). Metabolism of hydrogen peroxide in isolated hepatocytes: relative contributions of catalase and glutathione peroxidase in decomposition of endogenously generated H_2O_2 Arch. *Biochemistry & Biophysics, 210*, 505–516. doi:10.1016/0003-9861(81)90215-0.
36. Chen, G., Upham, B. L., & Sun, W. (2000). Effect of electromagnetic field exposure on chemically induced differentiation of friend erythroleukemia cells. *Environmental Health Perspectives, 108*, 967–972. doi:10.2307/3435056.
37. Brydon, L., Petit, L., Delagrange, P., Strosberg, A. D., & Jockers, R. (2000). Functional expression of MT2 (Mel 1b) melatonin receptors in human PAZ6 adipocytes. *Endocrinology, 142*, 4264–4271. doi:10.1210/en.142.10.4264.
38. Suzuki, Y. J., Forman, H. J., & Sevanian, A. (1997). Oxidants as stimulators of signal transduction. *Free Radical Biology & Medicine, 22*, 269–285. doi:10.1016/S0891-5849(96)00275-4.
39. Rodnight, R., Grower, H., Martinez-Millan, L., & DeSouza, D. (1982). Molecular aspects of neural transmission, learning and memory. In R. Caputto, & C. Ajmone-Marsan (Eds.), *IBRO, vol. 10* (p. 125). New York: Raven.
40. Butler, A. P., Mar, P. K., McDonald, F. F., & Ramsay, R. L. (1991). Involvement of protein kinase C in the regulation of ornithine decarboxylase mRNA by phorbol esters in rat hepatoma cells. *Experimental Cell Research, 194*, 56–61. doi:10.1016/0014-4827(91)90129-I.
41. Byus, C. V., Kartun, K., Pieper, S. E., & Adey, W. R. (1988). Increased ornithine decarboxylase activity in cultured cells exposed to low energy modulated microwave fields and phorbol ester tumor promoters. *Cancer Research, 48*, 4222–4226.
42. Lai, H., & Singh, N. P. (1995). Acute low-intensity microwave exposure increases DNA single-strand breaks in rat brain cells. *Bioelectromagnetics, 16*, 207–210. doi:10.1002/bem.2250160309.
43. Lai, H., & Singh, N. P. (2005). Interaction of microwaves and a temporally incoherent magnetic field on single and double DNA strand breaks in rat brain cells. *Electromagnetic Biology and Medicine, 24*, 23–29. doi:10.1081/JBC-200055046.
44. Lai, H., & Singh, N. P. (1997a). Acute exposure to a 60-Hz magnetic field increases DNA strand breaks in rat brain cells. *Bioelectromagnetics, 18*, 156–165. doi:10.1002/(SICI)1521-186X(1997)18:2<156::AID-BEM8>3.0.CO;2-1.
45. Nikolova, T., Czyz, J., Rolletschek, A., Blyszczuk, P., Fuchs, J., Jovtchev, G., et al. (2005). Electromagnetic fields affect transcript levels of apoptosis-related genes in embryonic stem cell-derived neural progenitor cells. *ASEB J, 19*(12), 1686–1688.
46. Aitken, R. J., Bennetts, L. E., & Sawyer, D. (2005). Impact of radio frequency electromagnetic radiation on DNA integrity in the male germline. *International Journal of Andrology, 28*, 171–179. doi:10.1111/j.1365-2605.2005.00531.x.

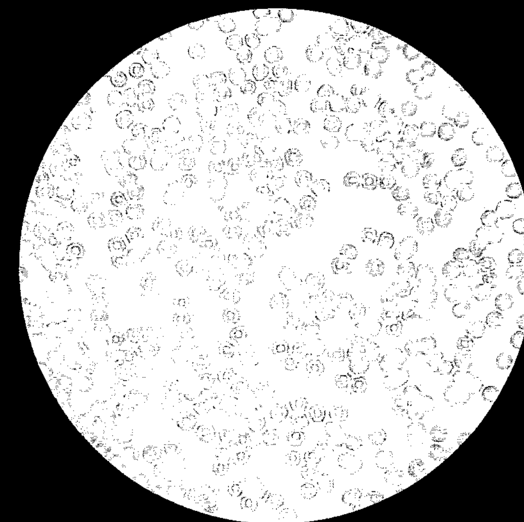
47. Diem, E., Schwarz, C., Adlkofer, F., Jahn, O., & Rudiger, H. (200). Non-thermal DNA breakage by mobile-phone radiation. (1800). MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro. *Mutation Research*, *583*(2), 178–183.
48. Agarwal, A., Deepinder, F., & Sharma, R. K. (2007). Effect of cell phone usage on semen analysis in men attending infertility clinic: An observational study. *Fertility and Sterility* doi:10.1016/j.fertnstert.2007.01.166.
49. Agarwal, A., Deepinder, F., Sharma, R. K., Ranga, G., & Li, J. (2008). Effect of cell phone usage on semen analysis in men attending infertility clinic: an observational study. *Fertility and Sterility*, *89*(1), 124–128. doi:10.1016/j.fertnstert.2007.01.166.

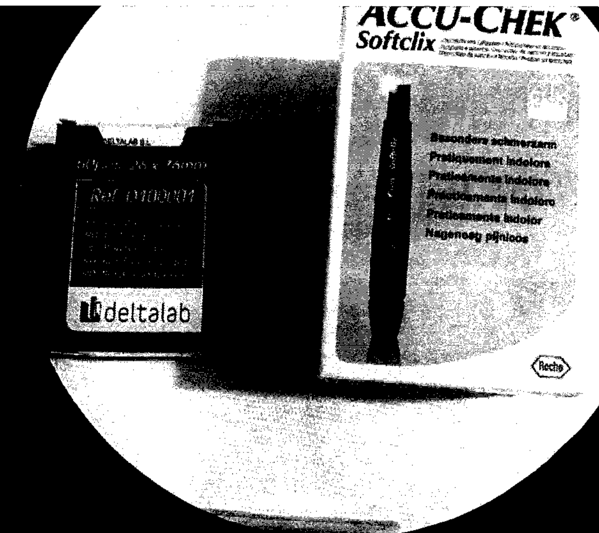
Estudio Observacional de Campo de Muestras de Sangre Expuestas a Radiación de Microondas (MOO)

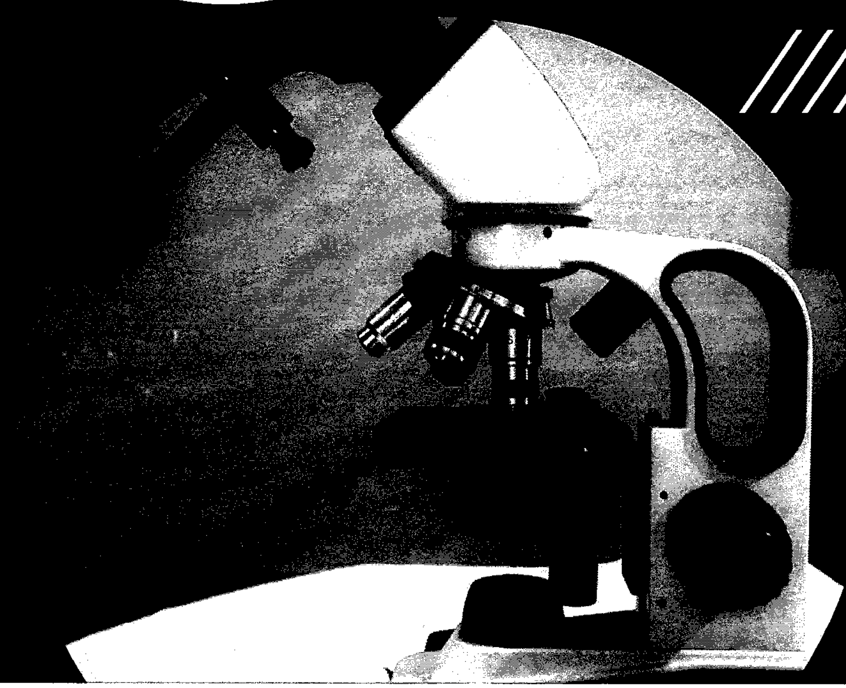
Autores: Campos, Viviana ; Alfaro, Carlos D

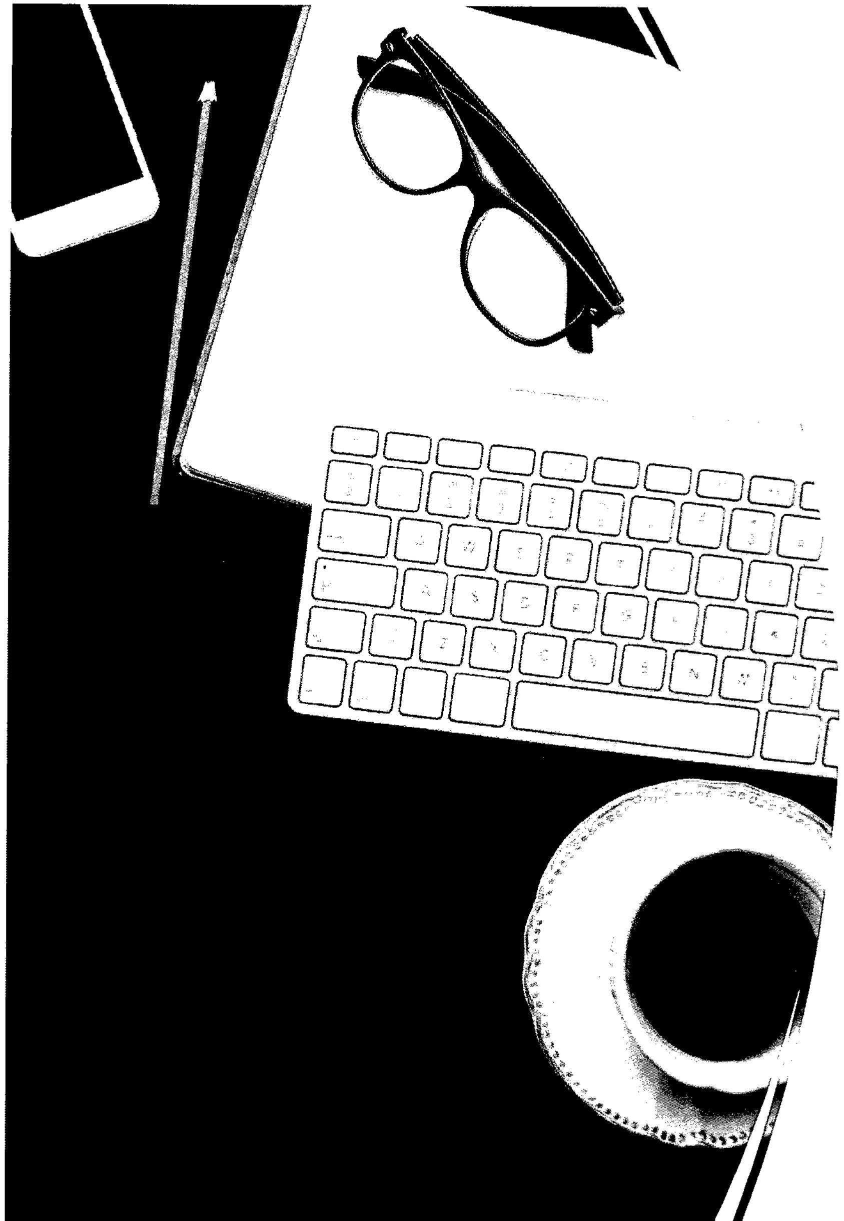
Agradecimiento :Witt, Marcela

Motivación: Integrantes de MOTESA.









Resumen: *Se observó un claro efecto rouleaux al manipular por 10 o 15 min. un móvil.*

- **Introducción:**
- **Se tiene conocimiento sobre los efectos de electrosensibilidad (ES) en las personas debido a la exposición a radiaciones de radiofrecuencia de microondas (300 MHz-300 GHz), provenientes de: la radio, la televisión, las PC, los teléfonos móviles y sus antenas, teléfonos inalámbricos, routers inalámbricos (WiFi), vigila bebés inalámbricos, juegos inalámbricos, etc.**
- **En base a este conocimiento se decidió, realizar observaciones "in situ", sobre muestras obtenidas de los propios autores y de personas que colaboraron para las distintas observaciones.**

- **Procedimiento**
- **En pruebas piloto realizadas por los autores se comprobó que el manejo de celulares conectados a datos móviles por 10 o 15 minutos producía el efecto “fenómeno rouleaux” muy grande por lo cual se realizaron distintos ensayos como se detallan a continuación:**

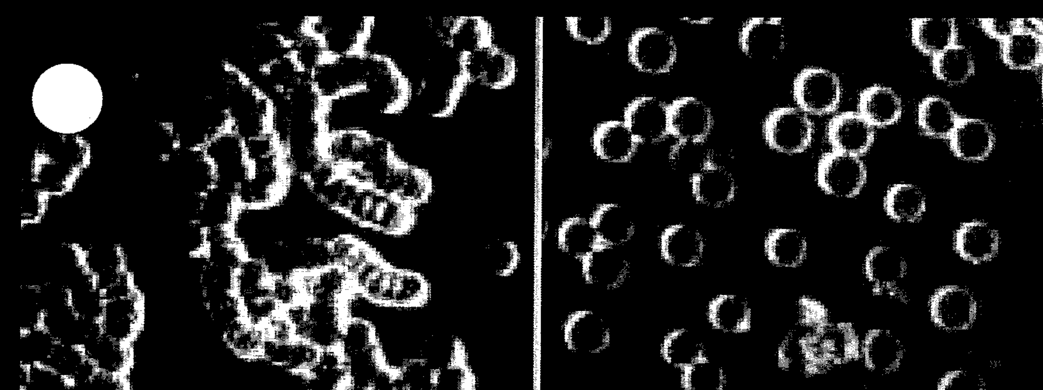
Efecto Rouleaux

- **El electrosmog afecta a la sangre**

- La sangre sana está formada por eritrocitos (glóbulos rojos), que son redondos y flotan libremente en el plasma. Una muestra de sangre viva, consistente en una gota de sangre de un pinchazo en el dedo, puede observarse al microscopio. Cambios en el tamaño, la forma y la aglomeración de estos eritrocitos pueden indicar un deterioro de la salud.

- Si los eritrocitos están pegados entre sí y se asemejan a una pila de monedas. Esto se conoce como formación rouleaux e indica que la sangre no está sana.

- Con la formación de rouleaux, la superficie de los glóbulos rojos se reduce significativamente, y la liberación de nutrientes y la eliminación de productos de desecho. Los síntomas pueden incluir dolores de cabeza, dificultad para concentrarse, mareos, náuseas, problemas cardiacos y de tensión arterial, así como sensación de frío, entumecimiento u hormigueo en las extremidades (manos y pies)..



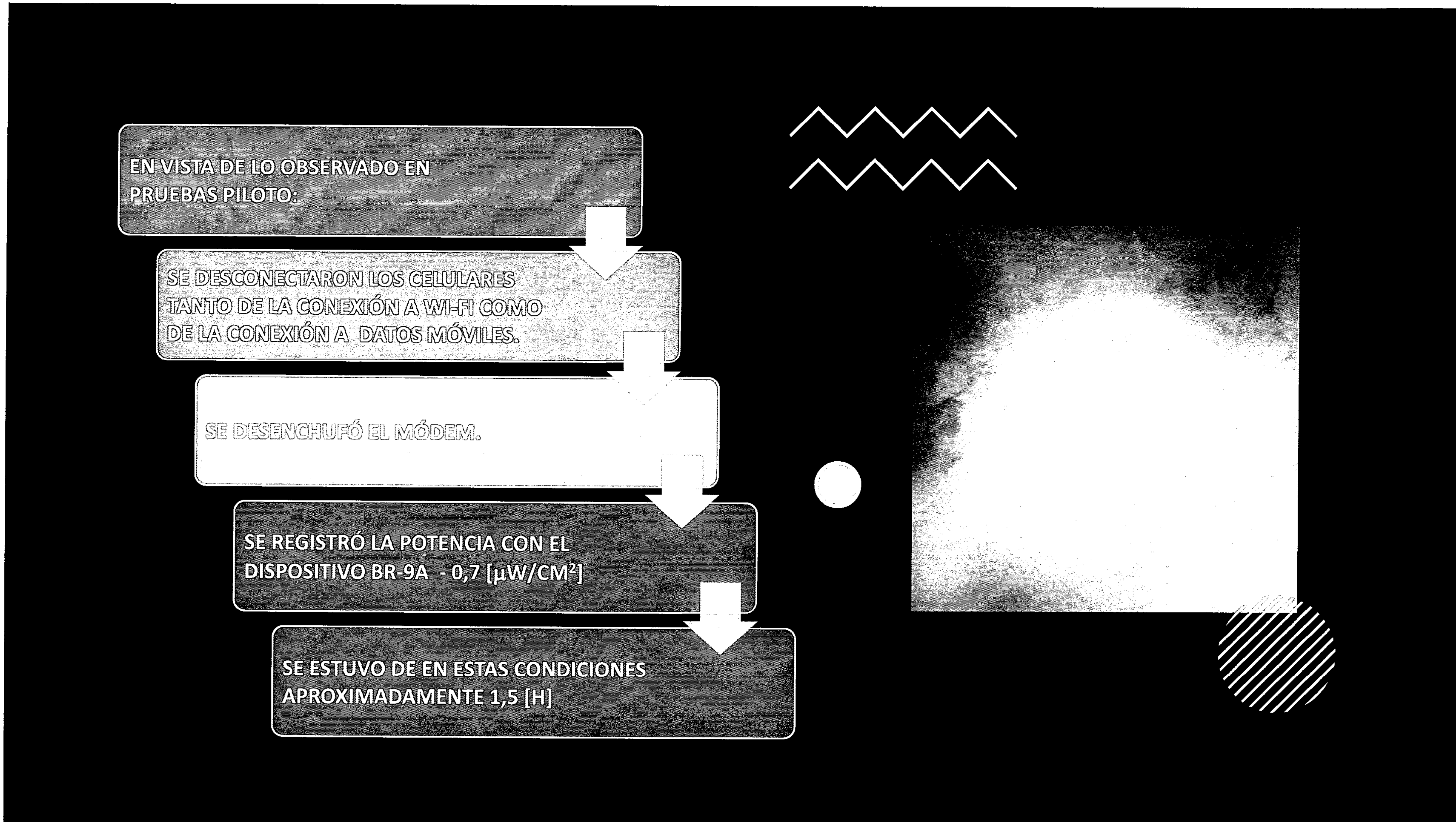
Dispositivo de medición BR-9A

- Indica que la radiación emitida por el móvil es mayor cuando está conectado sólo a datos móviles que cuando lo está sólo al WI-FI

-

Procedimiento

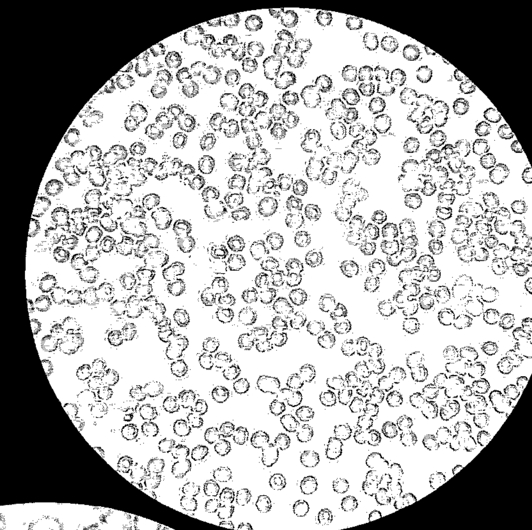
- **En pruebas piloto realizadas por los autores se comprobó que el manejo de celulares conectados a datos móviles por 10 o 15 minutos producía el efecto “fenómeno rouleaux” muy grande por lo cual se realizaron distintos ensayos como se detallan a continuación:**
- **Se utilizaron 3 celulares distintos para las pruebas de irradiación: 1 para filmar y los otros 2 para realizar y recepcionar las llamadas utilizando datos móviles con las que se irradia la muestra, estos móviles se colocan a muy corta distancia de la muestra (aproximadamente 4 cm) y a la altura donde se encuentra colocada en la platina del microscopio.**



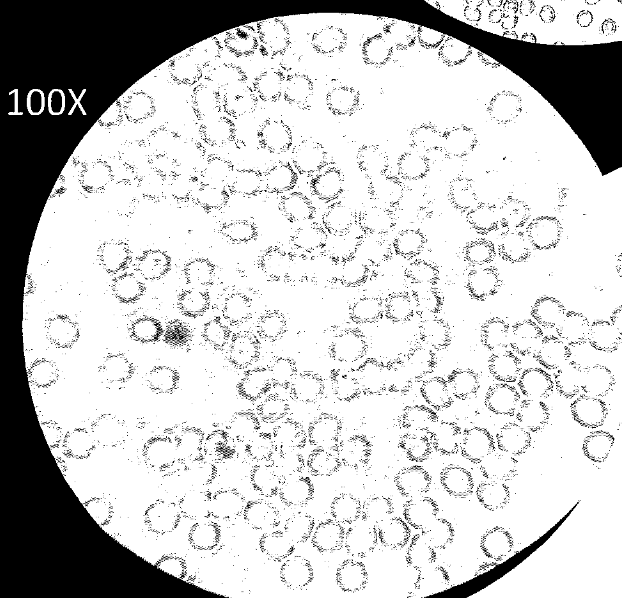
EN VISTA DE LO OBSERVADO EN PRUEBAS PILOTO:
SE DESCONECTARON LOS CELULARES TANTO DE LA CONEXIÓN A WI-FI COMO DE LA CONEXIÓN A DATOS MÓVILES.
SE DESENCHUFÓ EL MÓDEM.
SE REGISTRÓ LA POTENCIA CON EL DISPOSITIVO BR-9A - 0,7 [μW/CM²]
SE ESTUVO DE EN ESTAS CONDICIONES APROXIMADAMENTE 1,5 [H]

1) Muestra Testigo

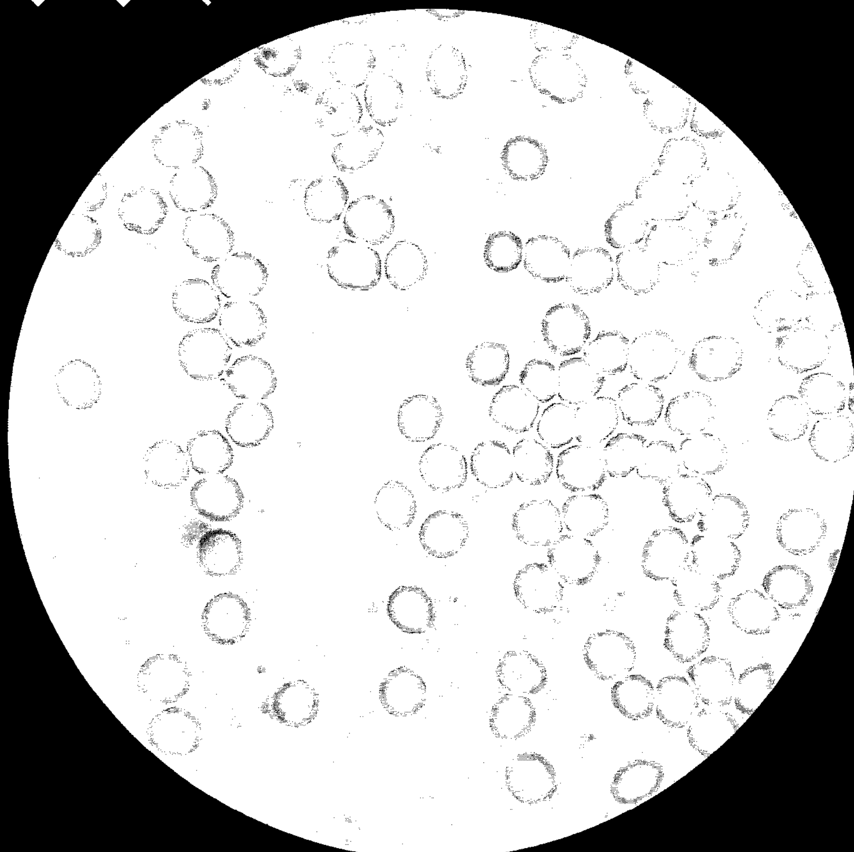
40X



100X



Muestra testigo luego de aprox. 5 [min] en el portaobjetos



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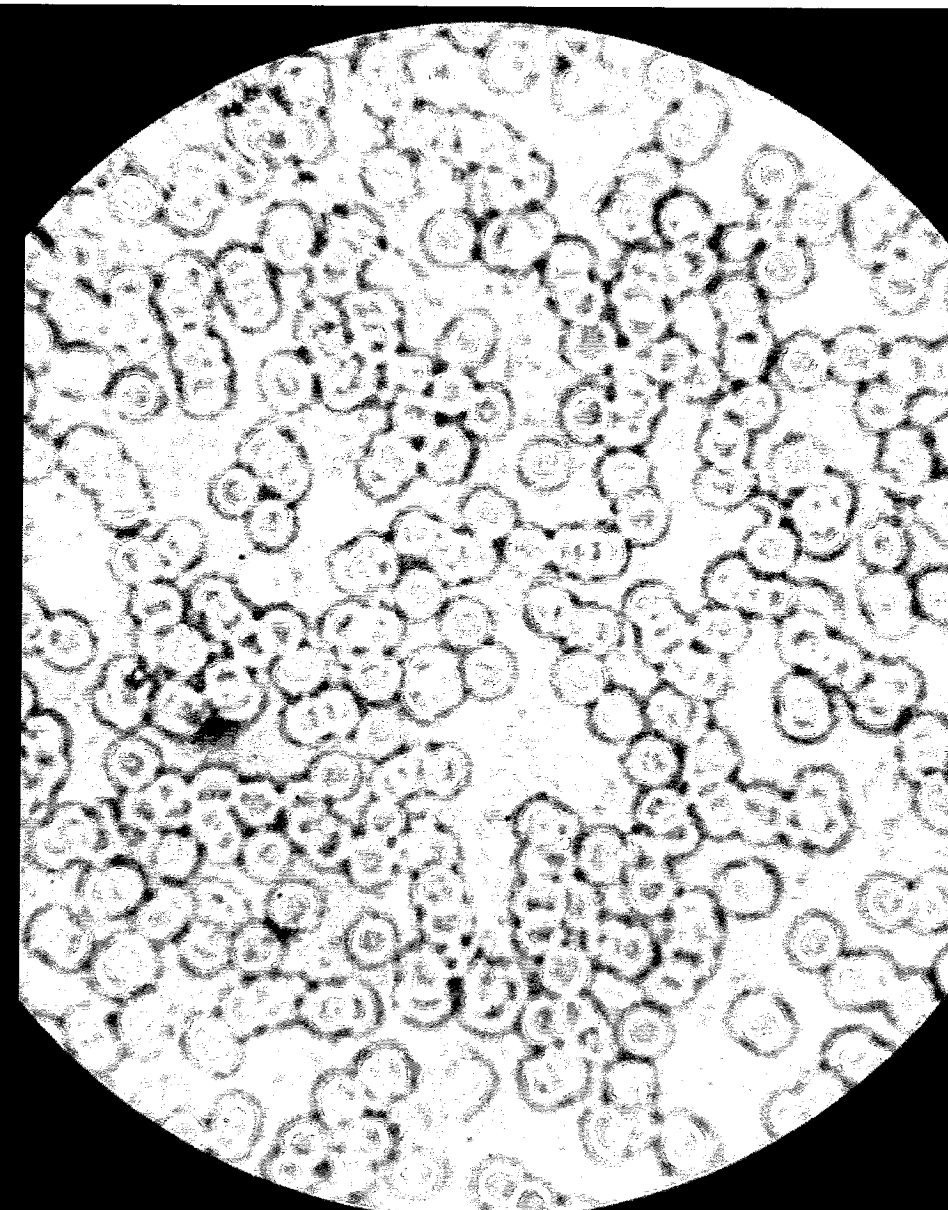
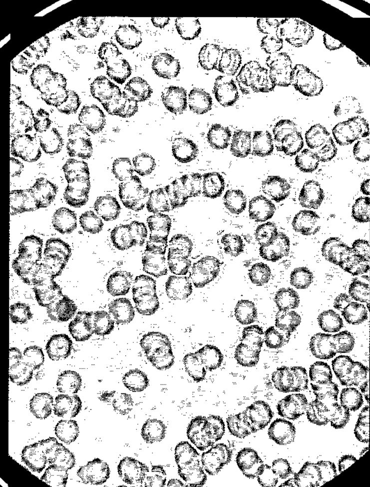
Muestra para irradiar

•





Irradiando la muestra con llamadas de celular, utilizando datos móviles, el dispositivo BR-9A indica valores entre 15 y 19 [μW/cm²].

- También se observa el efecto de la radiación sobre el lente objetivo:

- Luego de Irradiar con datos móviles aproximadamente 10 [min] se comienza a notar el efecto rouleaux.

Finalmente, luego de manipular el celular conectado sólo con datos móviles para poder hacer las observaciones anteriores, se observaron dos muestras, una obtenida del dedo de la mano y otra del dedo del pie.

- Del dedo de la mano (cabe señalar que se notaba adormecimiento en las manos):
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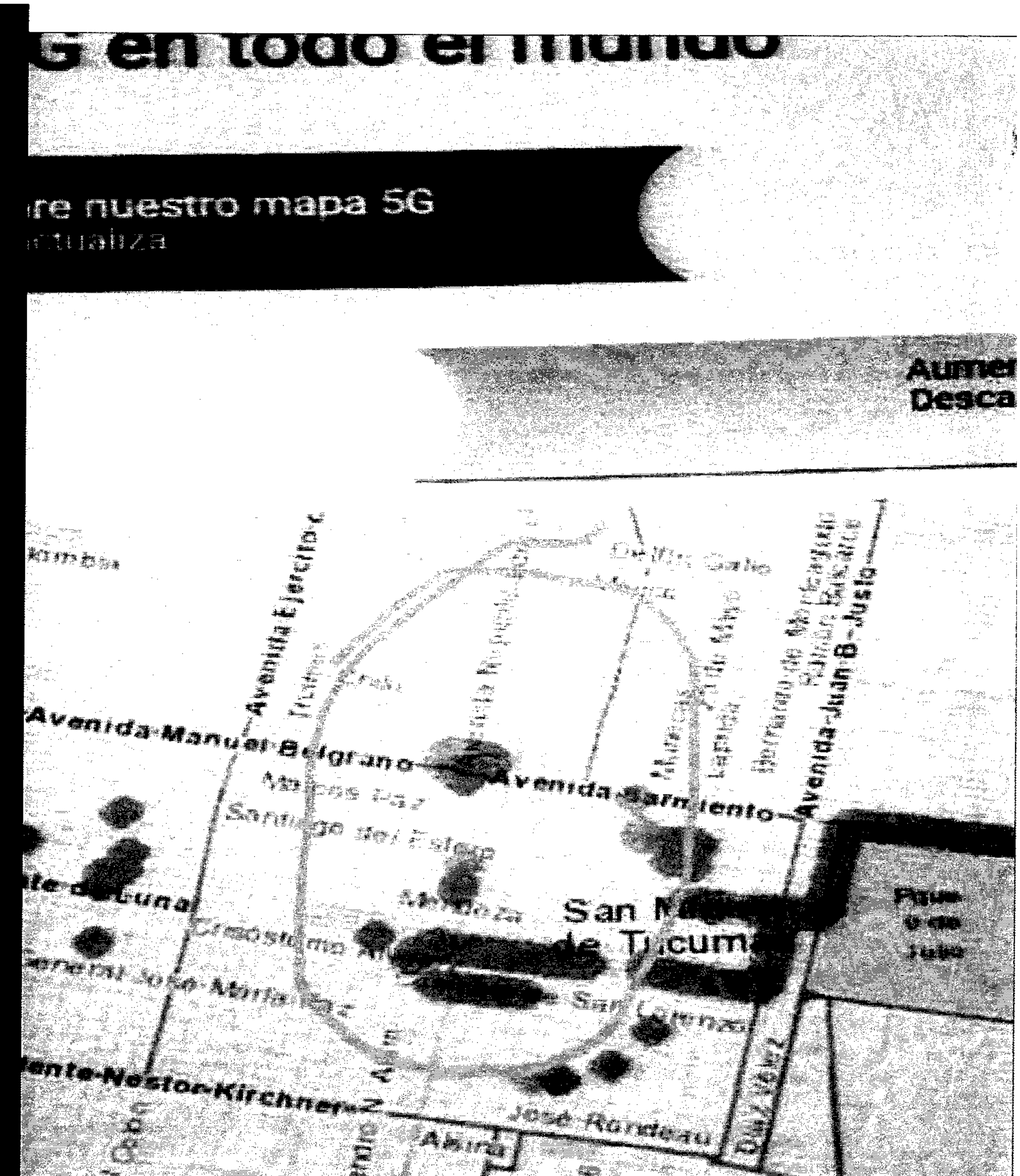
- Del dedo del pie :
-

Muestra de sangre de persona expuesta a radiación antenas 4G y 5G

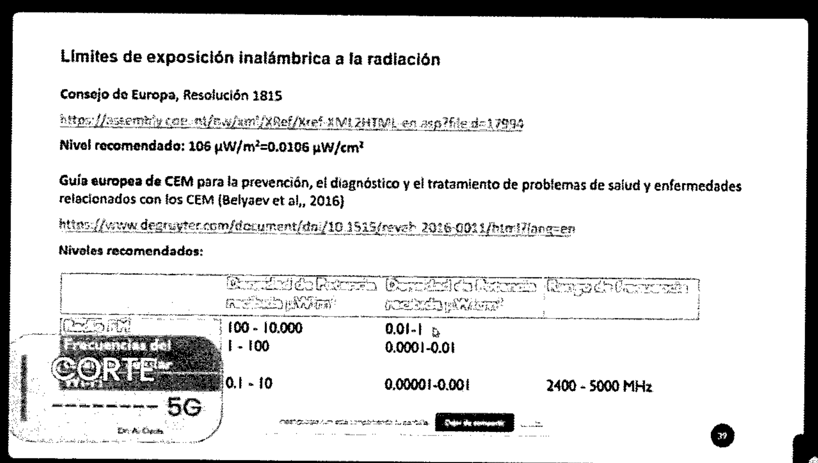
-
- Link mapa 5G
-



- **Referencias**

- Charlas del Dr Touzet
- Charlas del Dr Ozols
- Entrevistas del Canal de MOTESA
- Radiation from wireless technology affects the blood, the heart, and the autonomic nervous system. Magda Havas. https://doi:10.1515/reveh-2013-0004
- Effects of mobile phone radiofrequency on the structure and function of the normal human hemoglobin. (Científicos Irán). doi:10.1016/j.ijbiomac.2009.01.001
- Mobile phone calls, genetic susceptibility, and new-onset hypertension: results from 212 046 UK Biobank participants. https://doi.org/10.1093/ehjdh/ztad024

Límites de Exposición -



Límites de exposición inalámbrica a la radiación

Consejo de Europa, Resolución 1815

https://assembly.coe.int/nw/xml/XRef/Xref-XML2HTML-en.asp?fileid=17994

Nivel recomendado: 106 µW/m²=0.0106 µW/cm²

Guía europea de CEM para la prevención, el diagnóstico y el tratamiento de problemas de salud y enfermedades relacionados con los CEM (Belyaev et al,, 2016)

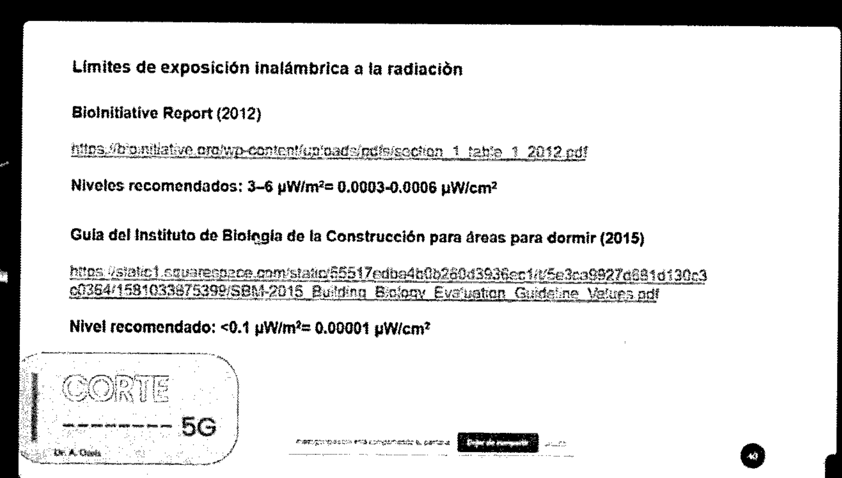
https://www.degruyter.com/document/doi/10.1515/reveh-2016-0011/html?lang=en

Niveles recomendados:

	[illegible]	[illegible]	[illegible]
[illegible]	100 - 10.000	0.01-1	
Frecuencias del [illegible]	1 - 100	0.0001-0.01	
[illegible]	0.1 - 10	0.00001-0.001	2400 - 5000 MHz

Capturas de pantalla video Dr Ozols

Link video Dr Ozols



Límites de exposición inalámbrica a la radiación

BioInitiative Report (2012)

https://bioinitiative.org/wp-content/uploads/pdfs/section_1_table_1_2012.pdf

Niveles recomendados: 3–6 µW/m²= 0.0003-0.0006 µW/cm²

Guía del Instituto de Biología de la Construcción para áreas para dormir (2015)

https://static1.squarespace.com/static/55517edba4b0b260d3936ec1/t/5e3ca9927d881d130c3c0364/1581033875399/SBM-2015_Building_Biology_Evaluation_Guideline_Values.pdf

Nivel recomendado: <0.1 µW/m²= 0.00001 µW/cm²