Selection of our scientific peer reviewed international articles on EHS published since 2015

- Carpenter DO, Belpomme D. Idiopathic environmental intolerance. Rev Environ Health. 2015 Dec 1;30(4):207.

- 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 Dec 1;30(4):251-71.

- Irigaray P, Caccamo D, Belpomme D. **Oxidative stress in electrohypersensitivity self-reporting patients: Results of a prospective in vivo investigation with comprehensive molecular analysis.** Int J Mol Med. 2018 Oct;42(4):1885-1898.

- 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 Mar 11;21(6):1915.

- Belpomme D, Carlo GL, Irigaray P, Carpenter DO, Hardell L, Kundi M, Belyaev I, Havas M, Adlkofer F, Heuser G, Miller AB, Caccamo D, De Luca C, von Klitzing L, Pall ML, Bandara P, Stein Y, Sage C, Soffritti M, Davis D, Moskowitz JM, Mortazavi SMJ, Herbert MR, Moshammer H, Ledoigt G, Turner R, Tweedale A, Muñoz-Calero P, Udasin I, Koppel T, Burgio E, Vorst AV. **The Critical Importance of Molecular Biomarkers and Imaging in the Study of Electrohypersensitivity. A Scientific Consensus International Report.** Int J Mol Sci. 2021 Jul 7;22(14):7321.

- Belpomme D, Irigaray P. **Why electrohypersensitivity and related symptoms are caused by non-ionizing man-made electromagnetic fields: an overview and medical assessment.** Env. Res. 2022 Sep;212(Pt A):113374.

- Belpomme D, Irigaray P. Electro-hypersensitivity as a Worldwide, Man-made Electromagnetic Pathology: A Review of the Medical Evidence. In Electromagnetic Fields of Wireless Communications: Biological and Health Effects, Panagopoulos Ed. 2023, pp 297-367.

- Belpomme D. Irigaray P. Electrohypersensitivity and multiple chemical sensitivity as parts of a unique combined neurologic environmental syndrome: a medical re-assessment based on clinical and biological analysis. 2023, submitted for publication

Study presentation

We present here the results we obtained from the analysis of a large cohort of 2,018 electrohypersensitivity (EHS) and/or multiple chemical sensitivity (MCS) consecutive evaluable cases

and extend and confirm our previous findings (2015) showing that both EHS and MCS are associated in 25% of the cases and shared identified symptoms and biological changes in the framework of a common neurologic syndrome.

Belpomme D. Irigaray P. **Electrohypersensitivity and multiple chemical sensitivity as parts of a unique combined neurologic environmental syndrome: a medical re-assessment based on clinical and biological analysis. 2023, submitted to publication.**

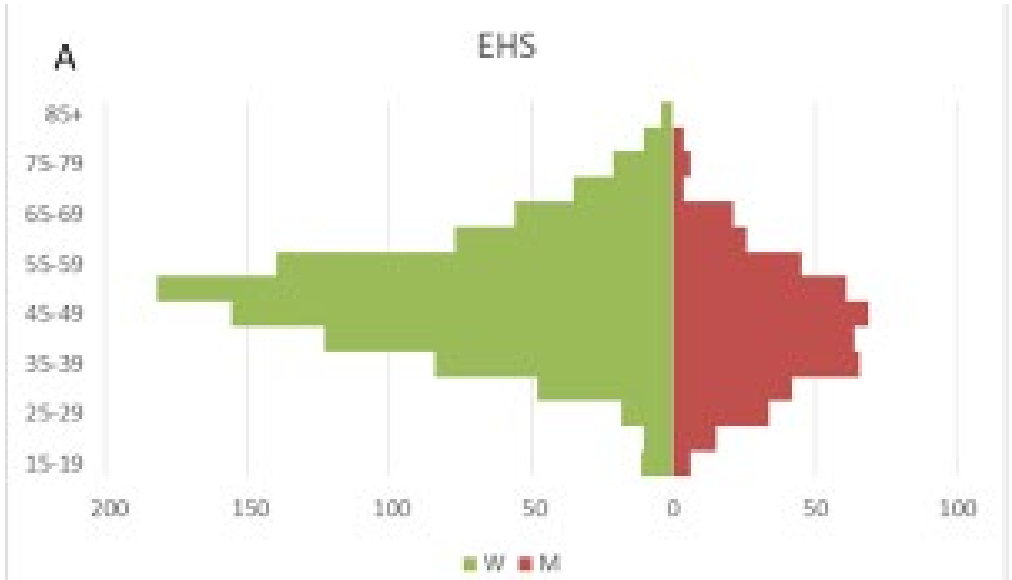
Inclusion criteria

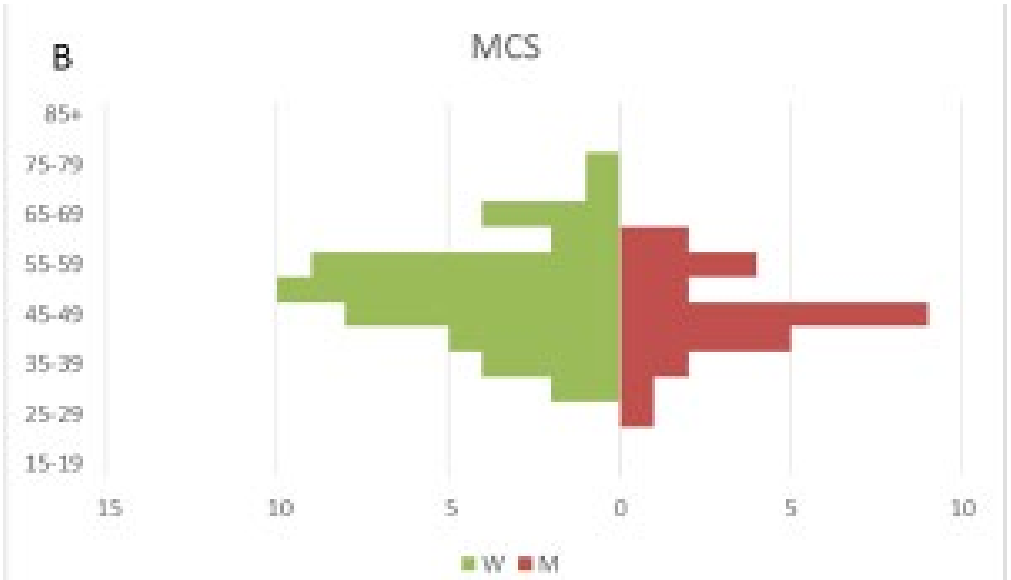
For MCS inclusion criteria were those recommended by the 1999 Atlanta consensus meeting and for EHS patients those proposed by WHO (2006) similar to the MCS criteria adapted to EHS. They were:

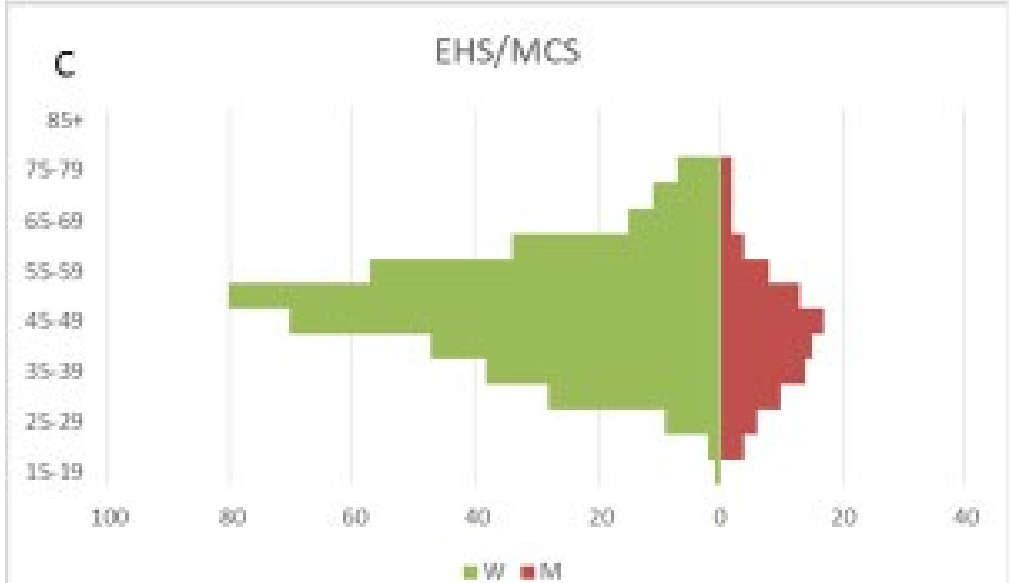
- **chronic evolution**
- **reproducibility of symptom occurrence under low intensity level of presumed EMF source**
- **regression or disappearance of symptoms when incitants are removed**
- **absence of known pathology accounting for the observed clinical symptoms**
- **no preexisting coexisting pathology such as atherosclerosis, diabetes, neurodegenerative or psychiatric diseases**.

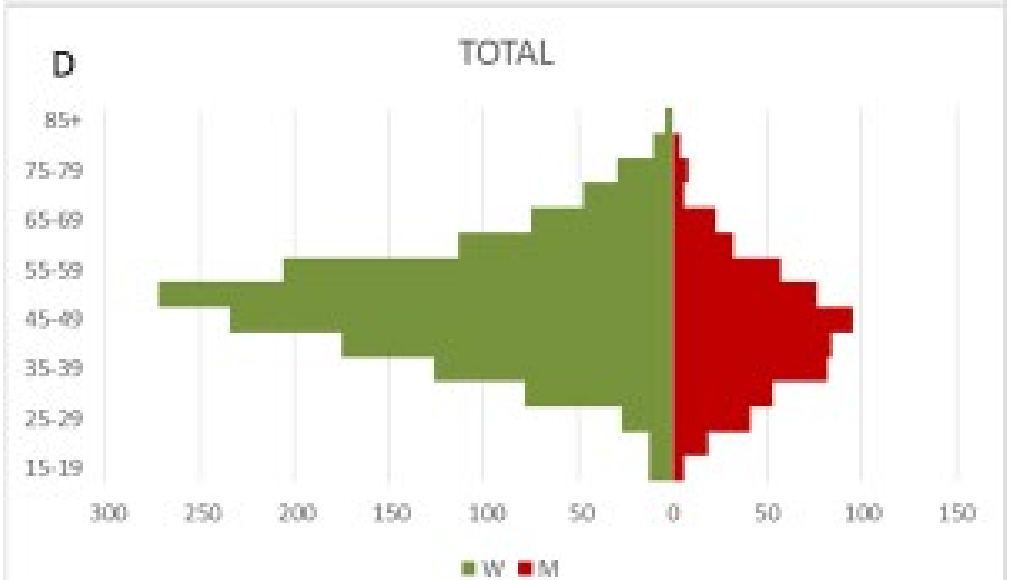
We emphasize that our inclusion criteria were not only based on the subjective claims by the patients, but on a careful clinical analysis of the medical anamnesis, a systematic face-to-face questioning, and a physical examination of all included patients.

Distribution of the different investigated group in the 2,018 cases









Demographic data based on the 2018 serially individualized cases

Demographic Data	EHS	MCS	p*	EHS/MCS	p**
Number of cases (%)	1428 (70.8 %)	85 (4.2 %)	-	505 (25%)	-
Age (mean ± SD)	48.86+/-12.74	49.15+/-9.71	0.84	48.57+/-11.38	**0.67**
Age (median (range))	49	48	-	49	-
Sex ratio (women/men)	972/456 (68%)	50/35 (58.8%)	0.07	406/99 (80.4%)	<0.0001

We used the chi-squared test

*Comparing the MCS group of patients to that of EHS
**Comparing the EHS/MCS group of patients to that of EHS

Belpomme D. Irigaray P. **Electrohypersensitivity and multiple chemical sensitivity as parts of a unique combined neurologic environmental syndrome: a medical re-assessment based on clinical and biological analysis.** 2023, submitted to publication

Frequency of EHS, MCS and EHS/MCS patients

Type of disorder	2015 analysis	2023 analysis
	Evaluable cases (%)	Evaluable cases (%)
EHS	521/727 (71.7 %)	1428/2018 (70.8 %)
MCS	52/727 (7.1 %)	85/2018 (4.2 %)
EHS/MCS	154/727 (21.2 %)	505/2018 (25 %)

- 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 Dec 1;30(4):251-71.
- Belpomme D. Irigaray P. **Electrohypersensitivity and multiple chemical sensitivity as parts of a unique combined neurologic environmental syndrome: a medical re-assessment based on clinical and biological analysis.** 2023, submitted to publication.

Clinical symptoms in EHS self-reporting patients in comparison with those in normal controls

Clinical Symptoms	EHS ratio (%) n=1428	Normal Controls (%) n=100	p **
Headache	90%	13	<0.0001
Neck stifness*	32%	0	<0.0001
Dysesthesia	84%	0	<0.0001
Skin lesions	16%	0	<0.0001
Tremors/vibrations*	20%	0	<0.0001
Myalgia*	46%	6	<0.0001
Trismus/muscular contraction*	8%	0	<0.0001
Arthralgia*	32%	19	0.008
Ear heat/otalgia*	63%	0	<0.0001
Tinnitus	64%	5	<0.0001
Hyperacusis	35%	6	<0.0001
Photohobia*	260/783	0	<0.0001
Occular troubles	33%	0	<0.0001
Paralytic ictus*	10%	0	<0.0001
Dizziness	69%	0	<0.0001
Balance disorder	34%	0	<0.0001

Clinical Symptoms	EHS ratio (%) n=1428	Normal Controls (%) n=100	p **
Concentration/attention deficiency	78%	0	<0.0001
Loss of immediate memory	76%	6	<0.0001
Confusion*	6%	0	<0.0001
Sleep disturbance	75%	6	<0.0001
Fatigue	84%	10	<0.0001
Depression tendency	57%	0	<0.0001
Suicidal ideation	16%	0	<0.0001
Anxiety/panic	26%	0	<0.0001
Emotional behavior	13%	11	**0.56**
Irritability	23%	6	<0.0001
Nausea/abdominal pain*	18%	0	<0.0001
Cardiovascular abnormalities	46%	0	<0.0001
Chest tightness*	12%	2	<0.0001
Asthma-like crisis*	6%	0	<0.0001
ENT (ear, nose, and throat) troubles*	12%	4	<0.0001
Impaired thermoregulation	13%	0	0.02

Belpomme D. Irigaray P. Electrohypersensitivity and multiple chemical sensitivity as parts of a unique combined neurologic environmental syndrome: a medical re-assessment based on clinical and biological analysis. 2023, submitted to publication.

Clinical symptoms in EHS self-reporting patients in comparison with those in MCS patients

Clinical Symptoms	EHS ratio (%)	MCS ratio (%) n=85	p ***
Headache	90%	89%	**0.86**
Neck stifness*	32%	31%	**0.92**
Dysesthesia	84%	71%	0.001
Skin lesions	16%	18%	**0.68**
Tremors/vibrations*	20%	10%	**0.07**
Myalgia*	46%	43%	**0.69**
Trismus/muscular contraction*	8%	2%	**0.12**
Arthralgia*	32%	27%	**0.51**
Ear heat/otalgia*	63%	43%	0.004
Tinnitus	64%	40%	<0.0001
Hyperacusis	35%	31%	**0.41**
Photohobia*	33%	27%	**0.92**
Occular troubles	33%	45%	**0.03**
Paralytic ictus*	10%	14%	**0.39**
Dizziness	69%	51%	0.0004
Balance disorder	34%	35%	**0.80**

Clinical Symptoms	EHS ratio (%)	MCS ratio (%) n=85	p ***
Concentration/attention deficiency	78%	65%	0.004
Loss of immediate memory	76%	67%	**0.06**
Confusion*	6%	4%	**0.54**
Sleep disturbance	75%	51%	<0.0001
Fatigue	84%	80%	**0.49**
Depression tendency	57%	30%	<0.0001
Suicidal ideation	16%	11%	**0.18**
Anxiety/panic	26%	36%	**0.03**
Emotional behavior	13%	15%	**0.55**
Irritability	23%	18%	**0.25**
Nausea/abdominal pain*	18%	16%	**0.67**
Cardiovascular abnormalities	46%	42%	**0.51**
Chest tightness*	12%	56%	<0.0001
Asthma-like crisis*	6%	43%	<0.0001
ENT (ear, nose, and throat) troubles*	12%	86%	<0.0001
Impaired thermoregulation	13%	6%	**0.05**

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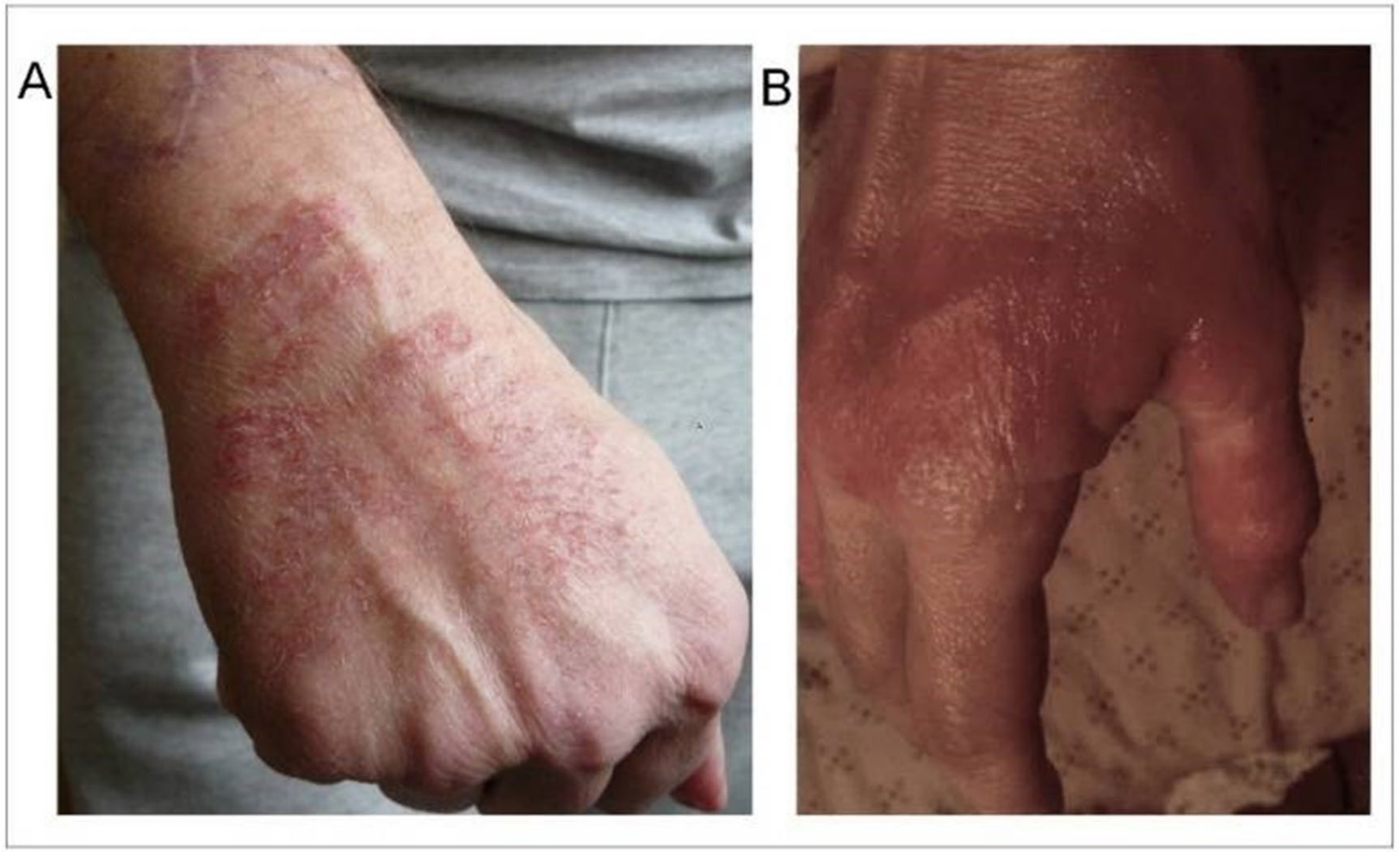
Clinical symptoms in EHS self-reporting patients in comparison with those in EHS/MCS patients

Clinical Symptoms	EHS ratio (%)	EHS/MCS ratio (%) n=505	p ***
Headache	90%	90%	**0.95**
Neck stifness*	32%	33%	**0.79**
Dysesthesia	84%	74%	<0.0001
Skin lesions	16%	45%	<0.0001
Tremors/vibrations*	20%	20%	**0.95**
Myalgia*	46%	50%	**0.21**
Trismus/muscular contraction*	8%	16%	0.0004
Arthralgia*	32%	27%	**0.11**
Ear heat/otalgia*	63%	54%	0.0013
Tinnitus	64%	62%	**0.42**
Hyperacusis	35%	55%	<0.0001
Photohobia*	33%	30%	**0.41**
Occular troubles	33%	44%	<0.0001
Paralytic ictus*	10%	15%	0.02
Dizziness	69%	60%	0.0002
Balance disorder	34%	23%	<0.0001

Clinical Symptoms	EHS ratio (%)	EHS/MCS ratio (%) n=505	p ***
Concentration/attention deficiency	78%	84%	0.002
Loss of immediate memory	76%	78%	**0.35**
Confusion*	6%	15%	<0.0001
Sleep disturbance	75%	81%	0.006
Fatigue	84%	88%	**0.04**
Depression tendency	57%	47%	<0.0001
Suicidal ideation	16%	18%	**0.30**
Anxiety/panic	26%	30%	**0.08**
Emotional behavior	13%	15%	**0.30**
Irritability	23%	25%	**0.37**
Nausea/abdominal pain*	18%	33%	<0.0001
Cardiovascular abnormalities	46%	50%	**0.11**
Chest tightness*	12%	56%	<0.0001
Asthma-like crisis*	6%	43%	<0.0001
ENT (ear, nose, and throat) troubles*	12%	30%	<0.0001
Impaired thermoregulation	13%	5%	<0.0001

Belpomme D. Irigaray P. **Electrohypersensitivity and multiple chemical sensitivity as parts of a unique combined neurologic environmental syndrome: a medical re-assessment based on clinical and biological analysis.** 2023, submitted to publication.

Cutaneous lesions in the face, forearms, or hands in 16% and 45% of the cases in EHS and EHS/MCS patients, respectively.



Examples of skin lesions observed on the hand of an EHS patient (A) and of an EHS/MCS patient (B). (Photographs of subjects registered in the database). Picture A shows a right hand with several skin lesions in red. Picture B shows a right hand with a large skin lesion in red.

Common biomarkers use for EHS and/or MCS diagnosis

Biomarkers		**interpretation**
Vitamin D2-D3	↘	Metabolic disorders (?)
Histamine	↗	Inflammation (mast cells) Brain hypoperfusion BBB disruption/opening
IgE	↗	Humoral allergy (?)
Protein S100B	↗	Brain hypoperfusion BBB disruption/opening
NTT	↗	Nitrosative-Oxidative stress BBB disruption/opening
Hsp27 and/or Hsp70	↗	Cellular stress
Anti-myelin P0 protein autoantibodies	↗	Autoimmune response
Hydroxymelatonin sulfate (6-OHMS)	↘	Decrease in synthesis/increase of consumption

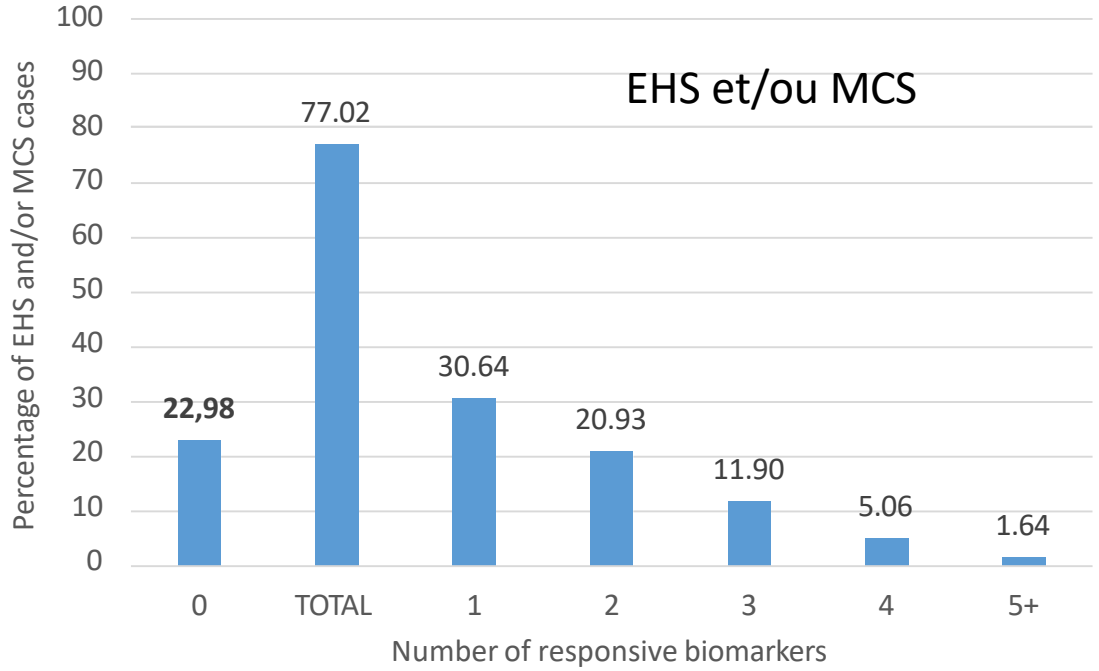
BBB = Blood Brain Barrier

Biomarkers detection

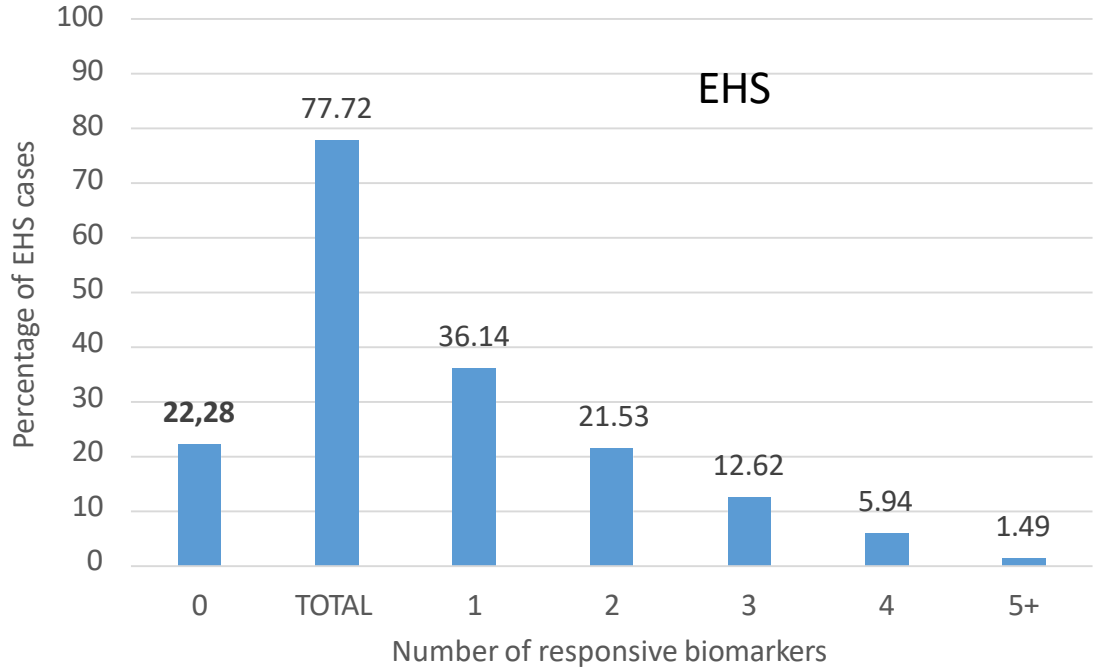
Percentages and numbers of EHS and/or MCS patients (total number=672) according to the number of biomarkers detected (included biomarkers: histamine, 6-OHMS, HSP, autoantibodies to myelin P0, S100B and NTT) in the overall population studied (A), in the EHS group (B), in the MCS group (C) and in the EHS/MCS group (D).

14 to 24% of cases with no markers detection.

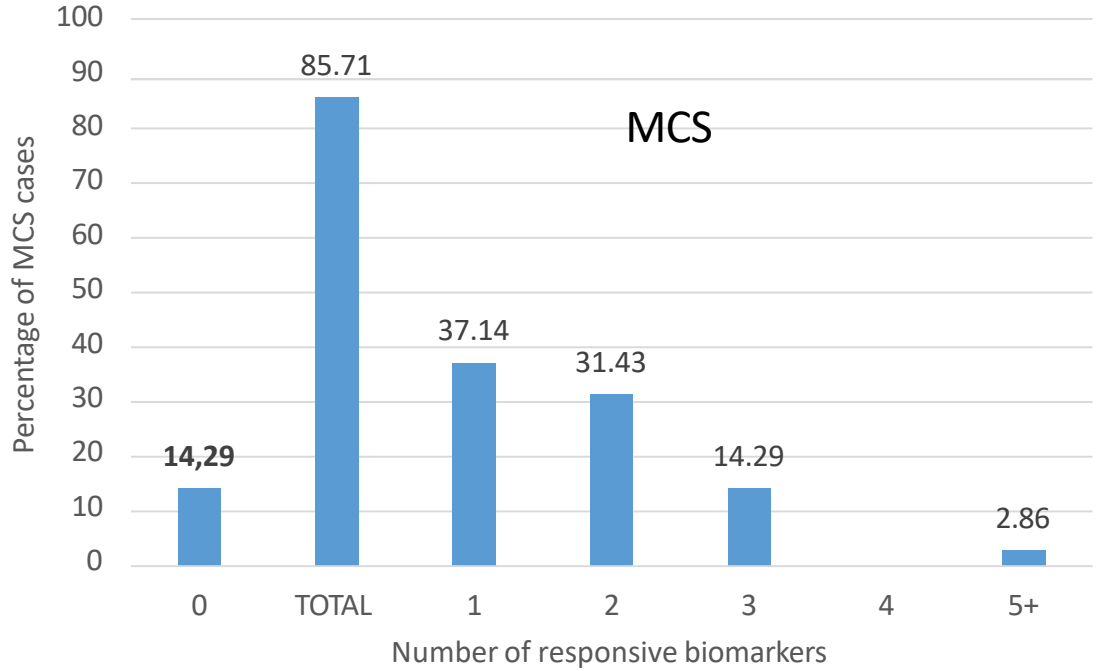
A


EHS et/ou MCS
Percentage of EHS and/or MCS cases
100
90
80
70
60
50
40
30
20
10
0
22,98
77.02
30.64
20.93
11.90
5.06
1.64
0
TOTAL
1
2
3
4
5+
Number of responsive biomarkers

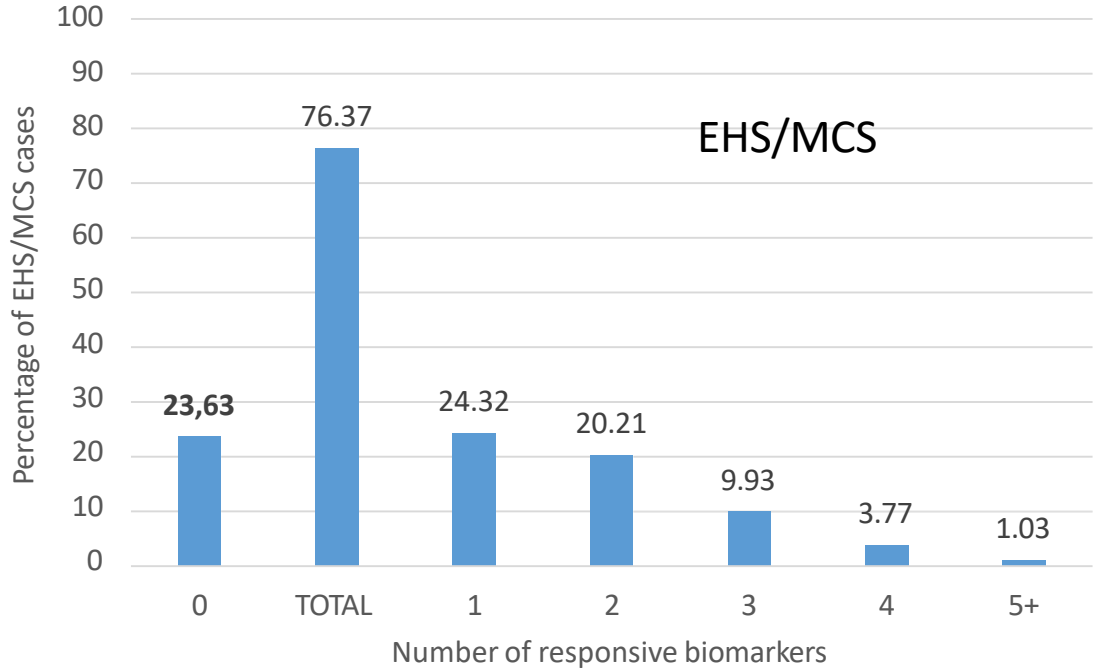
B


EHS
Percentage of EHS cases
100
90
80
70
60
50
40
30
20
10
0
22,28
77.72
36.14
21.53
12.62
5.94
1.49
0
TOTAL
1
2
3
4
5+
Number of responsive biomarkers

C


MCS
Percentage of MCS cases
100
90
80
70
60
50
40
30
20
10
0
14,29
85.71
37.14
31.43
14.29
2.86
0
TOTAL
1
2
3
4
5+
Number of responsive biomarkers

D


EHS/MCS
Percentage of EHS/MCS cases
100
90
80
70
60
50
40
30
20
10
0
23,63
76.37
24.32
20.21
9.93
3.77
1.03
0
TOTAL
1
2
3
4
5+
Number of responsive biomarkers

Sensitivity, specificity and reproducibility of biochemical test

- **Specificity:** The tests are not specific since they are associated with low-grade inflammation, nitroso-oxidative stress, Blood brain barrier disruption/opening, etc. which are as well found in other chronic pathological disorders.
- **Sensitivity:** The tests were negative in 14-24% of the cases.
- **Reproducibility:** The tests were reproducible in the same laboratory, but performed in a unique laboratory in Paris. We are waiting for similar studies performed in other laboratories.

Cerebral imaging for the diagnosis and pathophysiological understanding of electrohypersensitivity

- Transcranial doppler ultrasonic (TDU) technique
- Ultrasonic cerebral tomosphygmography (UCTS) technique
- Functional cerebral magnetic resonance imaging (fMRI) technique
- Positron emission tomography (PET) technique
- Single photon emission computed tomography (SPECT) technique

Belpomme D, Carlo GL, Irigaray P, Carpenter DO, Hardell L, Kundi M, Belyaev I, Havas M, Adlkofer F, Heuser G, Miller AB, Caccamo D, De Luca C, von Klitzing L, Pall ML, Bandara P, Stein Y, Sage C, Soffritti M, Davis D, Moskowitz JM, Mortazavi SMJ, Herbert MR, Moshammer H, Ledoigt G, Turner R, Tweedale A, Muñoz-Calero P, Udasin I, Koppel T, Burgio E, Vorst AV. The Critical Importance of Molecular Biomarkers and Imaging in the Study of Electrohypersensitivity. A Scientific Consensus International Report. Int J Mol Sci. 2021 Jul 7;22(14):7321

Irigaray P, Heuser G, Heuser SA, Belpomme D. 2023. Cerebral imaging for the diagnosis and pathophysiological understanding of electrohypersensitivity. Submitted for publication.

Transcranial Doppler Ultrasound (TDU)

By using TDU in EHS patients we showed a **decrease in the mean Pulsatility Index**, in one or both middle cerebral artery (MCA), i.e. for one artery in near 18% and 20% of the cases for the right and left artery respectively, and for both arteries in near 10% of the cases.

Moreover, for the EHS/MCS group of patients, there was a decrease in the mean Pulsatility Index for one artery in near 17% of the cases, and for both arteries in 7% of the cases.

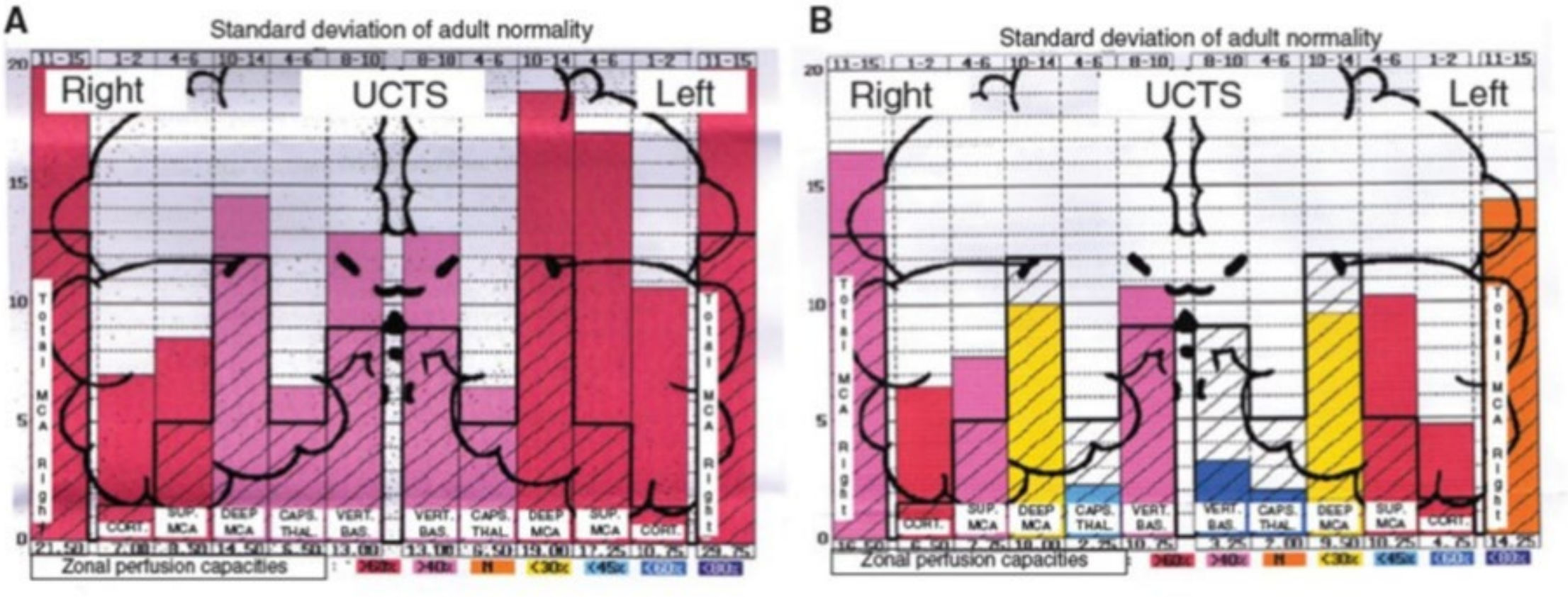
In addition, regarding resistance in the Brain Blood Flow (BBF) we found that, in EHS patients, **BBF resistance was increased** in one artery in near 57% of the cases, and in both arteries in 42% of the cases, while in EHS/MCS patients, BBF resistance was increased in one artery in near 54% of the cases and in both arteries in 42% of the cases.

Also the **mean BBF velocity was below normal** in near 66.89-69%, and **above normal** in 10-20 % of the cases, depending on the group considered (EHS or EHS/MCS).

This suggests that, in EHS and/or MCS patients, BBF may be abnormal in one or both MCA.

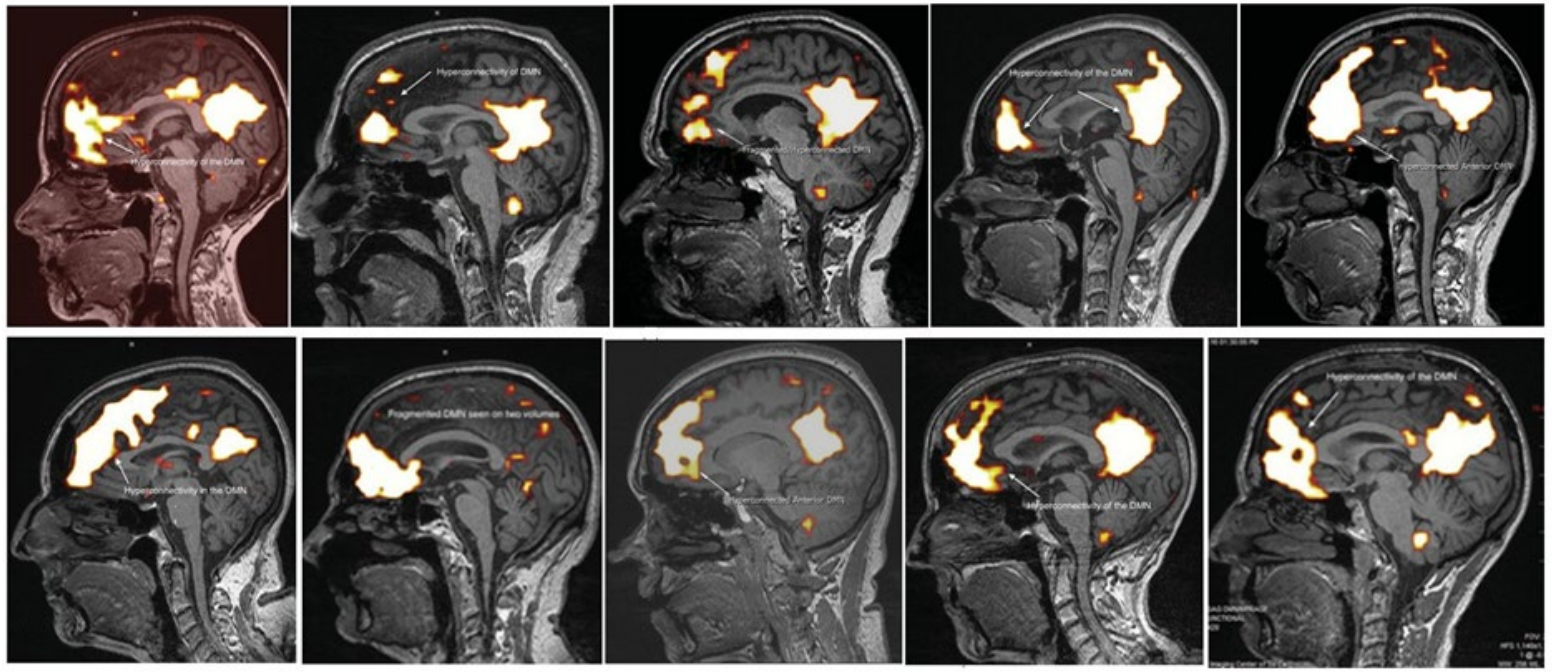
Irigaray P, Heuser G, Heuser SA, Belpomme D. 2023. Cerebral imaging for the diagnosis and pathophysiological understanding of electrohypersensitivity. Submitted for publication.

Cerebral pulsometric detection using Ultrasonic cerebral Tomosphygmography (UCTS)



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 Mar 11;21(6):1915

Abnormal functional MRI brain scan in 10 analyzed patients suffering of EHS after long-term exposure to EMFs



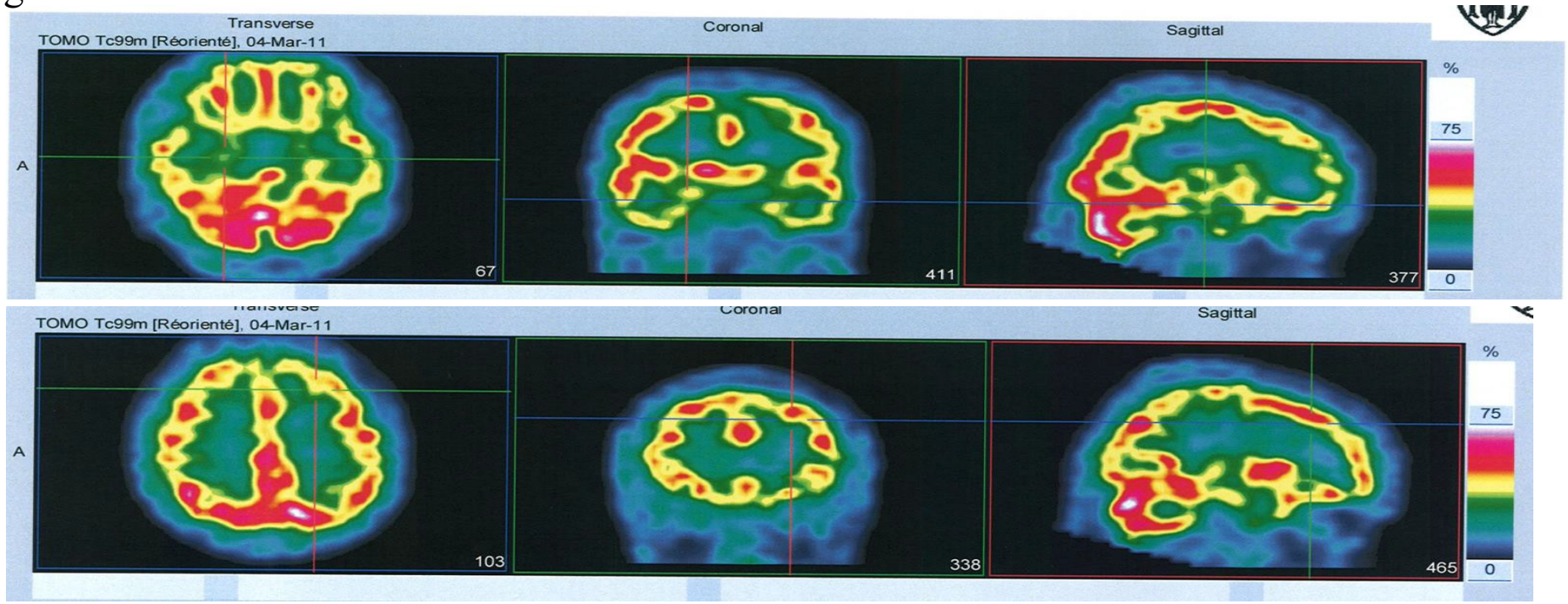
Regional BBF changes were mainly reported in the frontal lobes as an abnormal default mode network (DNM). These changes were associated with a decrease in cerebral BBF and metabolic processes in the two hyperconnected components.

Heuser G, Heuser SA. 2017. **Functional brain MRI in patients complaining of electrohypersensitivity after long term exposure to electromagnetic fields.** Rev Environ Health 32:291–299.

Irigaray P, Heuser G, Heuser SA, Belpomme D. 2023. **Cerebral imaging for the diagnosis and pathophysiological understanding of electrohypersensitivity.** Submitted for publication.

Single photon emission computed tomography (SPECT)

We used high-resolution 99m TC-HMPAO (technetium 99m-hexamethylpropyleneamine oxime) for qualitative analysis of brain perfusion imaging.



HMPAO study in a 54-year-old male (EHS). Note decreased perfusion (yellow-green) and asymmetrical presentation.

Irigaray P, Heuser G, Heuser SA, Belpomme D. 2023. Cerebral imaging for the diagnosis and pathophysiological understanding of electrohypersensitivity. Submitted for publication.

Why EHS and related symptoms are caused by non-ionizing anthropogenic EMFs (1)

1. EHS is associated with MCS in 25% of cases
2. Both may be associated with somatic abnormalities such as low-grade inflamation, nitroso-oxidative stress, blood brain barrier disruption/opening and brain neurotransmitters changes, all changes which have been shown in laboratory animals to be caused by anthropogenic EMFs.
3. EHS occurrence has appeared subsequently to artificial electromagnetic pollution which is associated with a seemingly progressive increasing prevalence since the use of wireless communication (WC) technologies.
4. EHS is a worldwide plague with pandemic extension as is the case for the EMF emitting technologies.
5. There are many independant provocation studies showing that EMF can biologically damage the organism and are noxious agents in healthy people, while due to the incorrect methodology in EHS suffering patients there is a limited number of provocation studies showing pathophysiological changes and symptoms induction.
6. Several main EHS-associated symptoms such as sleep disturbance, depressive tendency and suicide risk have been shown in independant epidemiological studies to result from a dose dependent EMF exposure implying that excessive EMF exposure can cause these characteristic EHS-associated symptoms.

Belpomme D, Irigaray P. Why electrohypersensitivity and related symptoms are caused by non-ionizing man-made electromagnetic fields: an overview and medical assessment. Env. Res. 2022 Sep;212(Pt A):113374.

Why EHS and related symptoms are caused by non-ionizing anthropogenic EMFs (2)

7. Most EHS patients present in their past medical history excessive exposure to WC technologies.
8. Many independant in vitro and in vivo studies demonstrate that anthropogenic EMFs can interact with endogenous physiological electric fields which control cellular biological funcions in normal organisms. This is particularly the case for human brain, heart and muscles, a finding confirming the multi-target causing role of anthropogenic EMF-exposure.
9. At the difference of natural EMF anthropogenic EMF are polarized and coherent. This key difference in biophysics may explain why anthropogenic EMF are harmful and toxic on biomolecules and tissues.
10. At molecular levels non or microthermal low intensity/long duration EMF exposure can act directly on DNA, not only by inducing DNA strand breaks or chomosome fragmentations but also by inducing chromatin modifications resulting in both genetic and epigenetic damage.

All these different findings clearly argue for a causal role of EMF in inducing EHS directly or indirectly via ROS and/or RNS. However in a limited number of cases (10%) MCS may precede the occurrence of EHS implying the hypothesis that chemicals may be also be involved.

Belpomme D, Irigaray P. Why electrohypersensitivity and related symptoms are caused by non-ionizing man-made electromagnetic fields: an overview and medical assessment. Env. Res. 2022 Sep;212(Pt A):113374.

Why the psychogenic or psychosomatic theories for EHS causality should be abandonned

1. Psychogenic or psychosomatic symptoms do not mean causality.
2. Objective physiopathological changes including nitroso-oxidative stress détection in EHS patients.
3. EMF exposure induces similar clinical symptoms in humans and pathophysiological changes in laboratory animals.
4. In addition to EMF exposure these findings do not exclude an associated nocebo effect in some patients.

Belpomme D, Irigaray P. **Why electrohypersensitivity and related symptoms are caused by non-ionizing man-made electromagnetic fields: an overview and medical assessment**. Env. Res. 2022 Sep;212(Pt A):113374.

Some confusion in the scientific literature

- We should distinguish EHS from **Idiopathic Environmenal Intolerance attributed to ElectroMagnetic Fields** (IEI-EMF), both having been acknowledged by WHO.
- EHS should be defined as an **EMF threshold loss** in the brain of patients while IEI-EMF is a general term that does not include necessarily this EMF threshold loss, thus EHS.
- We should distinguish the environmental causes that trigger pathophysiological changes and clinical symptoms after EHS has occured (it pathogenesis) from the cause of EHS itself, its etiology.

Hypothetical biophysical mechanisms specifically involved in EHS

1. Neurons are more vulnerable to EMF-induced apoptosis than other cells of the organism.
2. Electromagnetic receptors individualized in bacteria, animals and humans include **magnetosomes**, made of ferrous magnetite (grigite) and maghemite cristals, which can sense not only natural EMF, but also anthropogenic EMF.
3. These receptors are biogenic receptors. The alteration or destruction of a protective adaptative neurologic system by excessive EMF exposure may explain the recovery of the remnant primordial sensing effects, thus the occurrence of EHS.
4. Other theories have been proposed such as the voltage-gated ion channel (VGICs) mechanism in cell membranes which is considered as possible target for polarized and coherent (man-made) EMFs, but these theories does not fit specifically on the **EMF threshold loss** in the brain, which is characteristic of EHS.

Hypothetical model for a common pathophysiological mechanism accounting for the effects of anthropogenic EMFs and environmental chemicals on the brain in EHS and/or MCS patients.