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Review Article

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A Critical Analysis of the World Health Organization (WHO) Systematic Review 2024 on Radiofrequency Radiation Exposure and Cancer Risks

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Abstract

Radiofrequency (RF) radiation was in 2011 classified as a possible human carcinogen by the International Agency for Research on Cancer (IARC) at the WHO. Currently the WHO undertakes a systematic review of human studies on the cancer risks. In a publication by Karipidis et al (2024), commissioned by the WHO, it was argued that based on all available studies there would be *"moderate certanity evidence"* that mobile phone use *"likely does not increase the risk of glioma, meningioma, acoustic neuroma, pituitary tumours, and salivary gland tumours in adults, or of paediatric brain tumours."* However, the authors have overlooked results showing increased risks for brain tumours in the most exposed groups, the most exposed part of the head, and longest latency time from first exposure to tumour diagnosis. The authors also claimed that there would be *"moderate certainty evidence"* that transmitters and mobile phone base stations do not increase the risk of pediatric leukaemia. These conclusions are based on selective inclusion of very few and low exposure studies. This WHO evaluation is contradicted by scientific results that show increased risks of cancer from exposure to RF-radiation from mobile and cordless phones, transmitters, and base stations. Other scientists have concluded, after reviewing the available evidence, that RF-radiation may increase the risk of cancer. This article analysis the Karipidis et al review and highlights several errors, omissions, and conflicts of interests that may explain the conclusions of no cancer risk. The flawed evaluation of scientific facts should lead to retraction of the article.

Keywords: Mobile phone; Cordless phone; Radiofrequency radiation; WHO; Cancer; Scientific malpractice.

Introduction

In September and October 2024, respectively, two articles were published on radiofrequency electromagnetic (RF-EMF) radiation and cancer risks. The first one was commissioned by the WHO and published by Karipidis et al 2024 [1]. The second study was published by scientists in Korea [2] and the conclusions on brain tumor risk were completely contradictory to the Karipidis group. The Karipidis report [1] concluded that: *For near field RF-EMF exposure to the head from mobile phone use, there was moderate certainty evidence that it likely does not increase the risk of glioma, meningioma, acoustic neuroma, pituitary tumours, and salivary gland tumours in adults, or of paediatric brain tumours*. It was also claimed that there would be *"low certainty evidence"* that cordless phone use may not increase the risk of brain tumours and *"moderate certainty evidence"* that transmitters or base stations do not increase childhood leukaemia risk. In stark contrast, the article by

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Moon et al [2] published shortly after the Karipidis et al. [1] article, concluded that the available studies when analyzed together show that use of mobile phones increase the risk of brain tumours: *"Ipsilateral users [of mobile phone] reported a pooled odds ratio (OR) of 1.40 (95% CI [confidence interval] 1.21-1.62) compared to non-regular users. Users with years of use over 10 years reported a pooled OR of 1.27 (95% CI 1.08-1.48). When 11 studies with an OR with cumulative hours of use over 896 hours were synthesized, the pooled OR was 1.59 (95% CI 1.25-2.02). When stratified by each type of brain tumor, glioma, meningioma, and acoustic neuroma reported the pooled OR of 1.66 (95% CI 1.13-2.44), 1.29 (95% CI 1.08-1.54), and 1.84 (95% CI 0.78-4.37), respectively."*

One contributing cause to the contradictory conclusions based on the same scientific evidence might be that Moon et al [2] did not report any conflicts of interest. In contrast, several of the authors of the Karipidis et al [1] article have conflicts of interest, as outlined below. In a correspondence from ICBE-EMF [3] several flaws in [1] were outlined. These included conclusions based on studies with design flaws, reliance on RF radiation exposure categories that do not reflect current extent of exposure, omission of studies showing increased incidence of brain tumours, relying on studies with short latency, and ignoring standard guidance for pooling results of primary studies (see further discussion below). The correspondence [3] was rebutted by the Karipidis group claiming that: *"Our systematic review provided a comprehensive, evidence-based analysis of the potential link between RF-EMF exposure and cancer, addressing a highly debated issue with scientific rigor and transparency"* [4]. The accuracy of that rebuttal was questioned by ICBE-EMF stating that *"the response by Karipidis et al. [4] to our critique [3] of their systematic review of the research on radiofrequency electromagnetic fields and human cancer studies fails to support their seriously flawed review [1]. Hence, we believe that this review should be retracted. Moreover, this review cannot be used as proof of cell phone safety"* [5]. In the following we make a more thorough review of the many scientific errors by the Karpidis group [1]. There are certainly several pertinent issues to discuss in the review by Karipidis et al [1]. Some of the most flagrant scientific errors in that review will be discussed below. These scientific misconducts are exemplified by e.g.:

- Ignoring the studies with the highest cumulative call time exposure showing increased risks for brain tumours. Karipidis et al [1] seem to have given too much weight on statistically non-significant results of cumulative hours of exposure and on studies with low exposure (see MA1 dataset and Figure 6 in the article) rather than studies showing statistically significant increased ORs in the highest exposed groups. Further, they also claim that there is no increased risk based on a dataset of studies that includes results that do show statistically significant increased risk with cumulative call time exposure from > 896 up to > 1640 hours (MA5 dataset and Figure S2b in Annex 7), see discussion below.

- Exclusion of analyses of laterality (side of the head used during mobile phone calls related to brain tumor localization) which show clear evidence of increased risks of brain tumors for ipsilateral (same side as the brain tumor) use of the mobile phone, including also the cordless phone. Thus, results on the most exposed part of the brain were excluded.

- Inclusion of the Schuz et al study [6] and the Danish Cohort study (7-9) as scientific evidence of no risk. They are cohort studies on mobile phone use and were given relatively important weight. Both cohorts, particularly the Danish cohort, suffer from serious misclassification of exposure and unknown real exposure that render the results invalid as to cancer and other health outcomes from these studies.

- Including only five studies that modelled exposure from transmitters or base stations and only studies on pediatric cancer, thereby excluding several studies showing increased risks for cancer in children and adults near transmitters and base stations. One of the two included base station studies reported increased risk *"of all neoplasms in children with higher-than-median RF exposure to [Mobile phone base stations] MPBS"*. Yet, the authors claimed there would be *"moderate certainty evidence"* of no childhood leukaemia risk [1].

- Risk of Bias (RoB) rating. The studies were classified into three groups based on the potential for bias; low, moderate, or high that appear not to be based on sound scientific evaluation.

- Exclusion of several studies showing increased incidence and trends of brain tumors in several countries that caused bias in the discussion of mobile phone use and time trends of brain tumors.

- Conflicts of interest within the study group were not discussed in depth.

The assessment of results on cumulative exposure to RF radiation

When investigating health risks of environmental or lifestyle factors, it is most relevant to study tumour type, cumulative exposure, especially the highest exposure group, in addition to latency (time from first exposure until diagnosis of the disease). The results should also be discussed in relation to e.g., animal studies and laboratory findings, something that was ignored by the Karipids group. In the case of cancer risks from RF exposure, results of highest exposure groups, i.e., highest cumulative call time, are most important. The studies included in the Karipidis et al [1] main analysis on glioma and cumulative call time are listed in Table 1. At page 29, Figure 6 in Karipidis et al. [1] the results of their analysis

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based on a list of the included studies (MA1) are presented, arguing that *"there was no strong indication against the hypothesis of no summary effect of CCT [cumulative call time] (w=1.74, p=0.42) on glioma risk"*. Only a graph of their result is presented in Figure 6 in [1] and not the results from CCT exposure on which the graph is based. The results presented in Figure 6 seem to only include studies up to about 1 400 hours of cumulative call time exposure while one study included in the MA1 dataset, [10], reported an OR of 2.8 (1.6-4.8) for >2 376 hours cumulative mobile phone use for malignant brain tumors. Thus, the results in Table 6 in [1] do not represent evidence-based science. Further, the three studies in MA1 that had statistically significant results [10-12], all showed increased ORs in the highest cumulative call time group. In addition, the Hardell 2013 [10] study had the highest number of exposed cases (n=137) in that exposure group, see Table 1.

Their analyses in Figure 6 are based on individual eight small studies within the Interphone study and not the final Interphone study that included 14 participating countries, see Table 6, MA1 dataset [1]. These smaller individual Interphone studies, with low numbers of cases, did not investigate risks in higher exposure groups. In comparison, the highest exposure group in the final Interphone study on glioma [13], based on all individual Interphone studies, was > 1640 cumulative hours of use that gave OR = 1.40, 95 % CI = 1.03–1.89 based on 210 exposed glioma cases, see Table 2 in [13]. Excluding use of hands-free devices yielded OR = 1.82, 95 % CI =1.15-2.89 according to Annex 2 in the Interphone study. In the Hardell et al study on glioma (14) highest exposure group > 1486 hours cumulative use of mobile and cordless phones gave OR = 2.0, 95 % CI = 1.6-2.6 based on 367 exposed cases. Thus, the results were similar as in Interphone [13]. It must be stressed that the Hardell group results included both mobile and cordless phone use in cases aged group 18 – 80 years. Interphone 2010 [13] was based only on mobile phone use in the age group 30-59 years. This difference is important since the highest incidence of astrocytoma WHO grade IV (glioblastoma multiforme) is found in the age group 45–75 years with mean age 61 years and 80% older than 50 years. Thus, excluding the age group 60-80 years in Interphone had major impact on number of cases to be included in the study, as well as the possibility to study longer latency for use of mobile phone. That is of major importance in carcinogenesis. Further, the Karipidis group refers to additional analysis on risks with cumulative call time in Annex 7 (Figure S2.a, and S2.b, based on datasets MA4 and MA5), arguing that those results were *"additional sensitivity analyses on those*

Table 1: Odds ratio (OR) and 95 % confidence interval (CI) in parenthesis for highest cumulative call time in hours (h) for glioma in studies included in Karipdis et. al. MA1 [1]. Numbers of exposed cases are given.

	Cases	Highest exposure (h)	OR (95% CI)
Muscat et al. 2000 [87]	14	>480	0.7 (0.3-1.4)
Inskip et al. 2001 [88]	11	>500	0.5 (0.2–1.3)
Christensen et al. 2005* [89]			
-low grade	12	>467.9	1.18 (0.45 -3.08)
-high grade	15	>467.9	0.52 (0.25- 1.10)
Lonn et al. 2005* [72]	42	≥500	0.6 (0.4-1.0)
Hardell et al. 2006 [68]			
-all malignant			
--analogue	51	>80	4.0 (2.2-7.3)
--digital	119	>64	2.4 (1.6-3.7)
--cordless	90	>243	2.4 (1.5-3.6)
Hepworth et al. 2006* [90]	135	>544	0.94 (0.71 - 1.23)
Schuz et al. 2006* [91]	34	>195	1.01 (0.64 -1.60)
Hours et al. 2007* [92]	24	≥260	1.79 (0.74 4.34)
Klaeboe et al. 2007* [93]	49	≥425	0.7 (0.4–1.3)
Takebayashi et al. 2008* [94]	6	>2 000	1.47 (0.41–5.28)
Hardell et al. 2013 [10]	137	>2 376	2.8 (1.6 - 4.8)
Coureau et al. 2014 [11]	24	≥896	2.89 (1.41 - 5.93)
Yoon et al. 2015 [95]	70	>900	0.64 (0.30 - 1.34)
Momoli et al. 2017* [12]	32	>558	2.0 (1.2 – 3.4)

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with more exposed cases (MA4 and MA5)" that provided *"analogous findings"* to the main analysis (MA1). The results of the analyses, based on MA5 [1] dataset with highest cumulative exposure are displayed in Figure S2b and show a flat curve until about 2500 hours (max cumulative call time in figure). That is obviously incorrect. The largest studies [13, 14] showed statistically significant increased risks for cumulative use ≥1640 and >1486 hours, respectively, see Table 2. In addition statistically significant increased risk for ≥896 hours of cumulative use was published in [11]. These results were obviously excluded from Figure S2.b. in Annex 7. The other results from studies in the MA5 dataset were not statistically significant and two of three studies were based on very few cases, Table 2.

In conclusion, the Karipidis group analysis of glioma risks related to cumulative call time is misleading and incorrect. The data on which the graphs are based are hidden and not presented in a table. The main analysis should have been based on studies with highest cumulative call time (exposure), latency, and ipsilateral use of the phone. The results in the main analysis and those presented in Annex 7 on MA1 and MA5 datasets are not in agreement with the results in the same datasets.

The Danish cohort study on mobile phones and cancer risks (7-9)

The Danish cohort study was included by Karipidis et al [1] and given a classification of *"low risk"* of bias (tier 1; for more details on using tier see below). The Danish cohort study was first published in 2001 [7]. It was updated in 2006 [8] and in 2011 [9]. The results of the latest 2011 version [9] were based on 358 403 mobile phone private subscribers. For all cancer a reduced relative risk (RR) = 0.96, 95 % CI = 0.95 - 0.98 for men, and RR = 1.02, 95 % CI = 0.98 - 1.06 in women was reported for private subscription. For tumors in the central nervous system the risk ratios for individuals with 10-12 years of subscription were RR = 1.08, 95 % CI = 0.93 - 1.25 for men and RR = 1.05, 95 % 0.75 - 1.47 for women. The study has been critically discussed in peer-reviewed articles, e.g., [15, 16]. The design and start of the Danish cohort were made in cooperation between International Epidemiology Institute (IEI), Rockville, MD, USA, and the Danish Cancer Society. Two persons from IEI, John D. Boice Jr. and Joseph K. Laughlin, were coauthors of the two first publications of the cohort [7, 8]. The Danish Cancer Society was represented by Christoffer Johansen and Jørgen H. Olsen, with some additional authors in the second publication [8], among them Joachim Schüz, today Head of the International Agency for Research on Cancer (IARC) Department of Environment and Lifestyle Epidemiology including RF-radiation. The cohort was established by grants from two Danish telecom operation companies (TeleDenmark Mobil and Sonafon), by IEI, and by the Danish Cancer Society [7]. Original funding to the IEI for the IEI grant has never been disclosed. However, funding to IEI from another industry sector (Dow Corning) had previously been paid for research on an issue related to Dow Corning's products [15, 17]. In the Danish cohort study the incidence of brain tumors among the private subscribers was compared with the incidence of the Danish population (control group) by the end of 2007. According to the authors: *"the whole Danish adult population was subdivided into subscribers and non-subscribers of mobile phones and followed up for incidence of cancer and other diseases"* [9].

However, there were severe methodological faults that, taken together, led to erroneous results that are uninformative regarding health risks from mobile phone use [16]:

- Inclusion only of mobile phone private subscribers in Denmark between 1982 and 1995 in the exposure group.
- Exclusion of the most exposed group, consisting of 200 507 corporate users of mobile phones [7]. This group therefore represented a substantial number of users compared to the 358 403 private subscribers included in the 2011 article [9]. The corporate subscribers were treated as unexposed and included in the control group (the rest of the Danish population). It should be noted that the corporate users at the study period on average used mobile phones much more than private subscribers due to considerable higher

Table 2: Odds ratio (OR) and 95 % confidence interval (CI) in parenthesis for highest cumulative call time (CCT) in hours for glioma in studies included in Karipidis MA5 [1]. Number of cases is given.

	Cases	Highest CCT	OR, 95 % CI
Muscat et al. 2000 [87]	14	>480	0.7 (0.3-1.4)
Inskip et al. 2001 [88]	11	>500	0.5 (0.2–1.3)
Interphone 2010 [13]	210	≥1640	1.40 (1.03–1.89)
-Appendix 2*	160	≥1640	1.82 (1.15 - 2.89)
Coureau et al. 2014 [11]	24	≥896	2.89 (1.41 - 5.93)
Hardell, Carlberg 2015 [14]**	367	>1486	2.0 (1.6 - 2.6)
Yoon et al. 2015 [95]	70	>900	0.64 (0.30 - 1.34)

*No hands-free
**Wireless phone

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prices for mobile phone use [15, 16]. For comparison, data from the Swedish Telecommunication Agency (PTS) show that in 2001, 2002 and 2003 corporate subscribers used a mobile phone on average between 187 and 198 minutes per month while a private subscriber used the mobile phone on average between 39 and 41 minutes per month, see page 69 in [18]. Similar results would be expected in the Danish population. Two of the Danish cohort authors [19] wrote in 2007: By *"using data on subscriptions for a cellular telephone provided by network operators… subjects are misclassified when they regularly use a cellular telephone subscribed in someone else's or in a company name or when they subscribe for a cellular telephone which they use only occasionally"*. Further, Schuz and Johansen were part of another publication in 2007 stating that: *"until the late 1990's mobile phone use was mainly restricted to people in the age range most likely to use the phones for business purposes"*. These statements seem to have had no impact on the design and conclusions of their study [20].

- Users with mobile phone subscription after 1995 were not included in the exposed group and were thus treated as unexposed in the reference group: *"individuals with a subscription in 1996 or later were classified as non-users"* [9]. The number of cell phone users more than doubled between1995 and 1997. By the end of 1997, around 44% of the Danish population had a subscription [21]. Among the individuals who started using mobile phones after 1995 many could have been exposed up to 11 years but were included in the unexposed group. Mobile phone subscriptions among the Danish population increased from 10% in 1995 to 95% in 2004. All these subscribers were included in the control group and were treated as unexposed by the authors of the Danish cohort [22].
- Actual exposure data was unknown and no analysis by laterality (the side where the phone is hold in relation to the localization of the brain tumor) was performed. No analyses of low use *versus* high use of the mobile phone were performed.
- All use of cordless (DECT) phones was disregarded although they were also exposed to the same kind of RF radiation as from mobile phone use. The Hardell group has shown that also use of cordless phones is associated with increased risk for glioma and acoustic neuroma tumors [14, 23].
- Statistic from Danish Cancer Registry contradicts the results of the Danish Cohort study [8]. When studying the incidence rates of tumors in the brain and central nervous system from 1995 to 2023 a clear increasing incidence trend is observed both among men and women starting in 2004 and a steeper increase starting in 2014 [24-26].

Although these data are available for everybody interested in brain tumor incidence trends, no study has this far compared the Danish cancer registry data with the outcome of the Danish cohort, which is the most relevant data to compare the cohort with. Thus, the conclusion by Frei et al is not correct: *'Also, population level ecological studies of central nervous system tumours and incidence rates for glioma after the introduction of mobile phones rule out mobile phones as a strong independent risk factor.'* [9]. That statement was obtained by giving reference to time trends in the Nordic Countries, instead of Denmark that would have been the most relevant comparison [27, 28]. These trends are biased downwards by the Swedish Cancer Register with deficient registration of brain tumor cases clearly shown by comparison with the hospital register data [29, 30]. The scientific correct comparison would have been between the Danish cohort results and the Danish Cancer Registry data that are not in agreement of no risk. Professor Michael Kundi of the Medical University of Vienna expressed his opinion that the Danish cohort study is *"the most severely biased study among all studies published so far"* [21]. The study [7-9] was regarded by IARC in the 2011 evaluation to be uninformative regarding cancer risks due to *"considerable misclassification in exposure assessment"* and *"it lacked information on level of mobile phone used and there were several sources of potential misclassification of exposure"* [31, 32].

The IARC evaluation in 2011 included Martin Röösli, co-author of Karipidis et al 2024 [1]. He did not state any contradictory view at the time of the IARC evaluation (see also conflicts of interest below).

The Danish cohort study is subject to serious misclassification of exposure, and the consequences of that should be well known to every person trained in epidemiology: *"in situations in which subjects are assigned to the wrong exposure categories with the same probabilities regardless of whether they develop the disease or not (nondifferential misclassification of exposure). The result will always be dilution, and the effect estimate will be pulled towards its null value"* [33]. Consequently, it was concluded in a review [15] that: *"After reviewing the four publications on the Danish cohort study, one might rightly wonder whether this cohort was initially set up to show no increased risk."*

In view of all the serious errors in the Danish cohort, this study should be considered to have a high risk of bias, not a *"low risk of bias"* as stated by Karipidis et al [1]. The conclusions by IARC in 2011 are still valid [31, 32].

The Schüz et al 2022 Cohort study [6]

Also, this study suffers from poor exposure assessment and potentially serious exposure misclassification [6]. It was based on 1.3 million women born in 1935-1950 who were

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recruited to the cohort during 1996-2001 within a breast screening program. Very few questions on mobile phone use were asked in 2001 and again in 2011, that gave no meaningful data for analyzing risks related to mobile phone use. All participants were linked to the National Health Services (NHS) databases on deaths and cancer registrations. The incidence of cancer among the women in the cohort who had reported ever using a mobile phone in 2001 was compared to the incidence among the women in the cohort who had reported never use. It was an update from a previous publication in 2013 [34]. The authors concluded: *"Taking use in 2011 as baseline, there were no statistically significant associations with talking for at least 20 minutes per week or with at least 10 years use."* The exposure variables in the Schuz et al study [6] were not detailed: *In median year 2001, women were asked, "About how often do you use a cellular telephone ['mobile phone' in the original British English questionnaire]?"* and given 3 options to respond:—*"never," "less than once a day," "every day"*—and *"For how long have you used one (in years)?"* Women who reported in 2001 that they used a cellular telephone less than once a day or every day were classified as ever-users. In median year 2011, women were asked, *"How long have you used a cellular telephone (in years)?"* and *"How much do you talk on a cellular telephone (in minutes per week)?"* Women who reported in 2011 that they talked on a cellular telephone for at least 1 minute per week were classified as ever-users. Responses to the 2001 questionnaire were used as baseline for most analyses, providing mean follow-up time of 14.2 years for cancer incidence. Responses to the 2011 questionnaire were used as baseline in some analyses, providing mean follow-up time of 6.2 years.

Adjusted RRs forever (1+ minute/week) vs never cellular telephone use were for glioblastoma RR =1.14, 95% CI = 0.90 - 1.44. In the 10+ years of use RR increased to 1.22, 95 % CI 0.95-1.57. It should be noted that 1 minute per week for 10 years (2001-2011) corresponds approximately to cumulative use of only 8.7 hours. Women born between 1935 and 1950 are not a representative choice of a typical high user of a mobile phone. Further, the study was clearly not designed to detect cancer risks with intense mobile phone use. Using a mobile phone daily in 2001 was reported by 66 362 women in the cohort of 842 518 women, thus only 8%. The authors admit that the *"cohort consists only of women of middle to older ages, who generally have lower cellular telephone use than younger women or men"* [6]. Consequently, the cohort gives no or very little information about cancer risks from normal to heavy use of mobile phones. The highest exposure category for glioma including glioblastoma in the Schuz et al [6] analysis was using a mobile phone for at least 20 minutes per week, thus a very low highest exposure group compared to normal use today. The mean follow-up period was only 6.2 years corresponding to cumulative use of at least 107 hours. This may be compared with the results for glioma in Interphone [13] yielding OR = 1.40, 95 % CI = 1.03-1.89 for cumulative mobile phone use ≥1640 hours, Table 2. In the Hardell group studies [14] the highest cumulative exposure group > 1486 h gave OR = 2.0, 95 % CI = 1.6-2.6 (including also use of cordless phones) for glioma, see Table 2. No statistically significant increased OR was reported for meningioma, see Table 3 [35]. Coureau et al [11] reported OR = 2.89, 95 % CI = 1.41-5.93 for cumulative use ≥ 896 hours. Ipsilateral mobile phone use yielded even higher ORs. In a similar analysis increased risk was also reported for acoustic neuroma [23]. Meta-analysis for ipsilateral use yielded OR=2.71, 95 % CI = 1.72-4.28 for acoustic neuroma [36]. In contrast, Schuz et al [6] gave no results for longer latency period, higher cumulative use than over 20 minutes per week, and not for ipsilateral mobile phone use.

According to the previously discussed Benson et al. [34] article of the same cohort it was stated *"The main limitation of the study is that mobile phone use was reported at baseline and may have changed subsequently. Almost all women who reported daily use of mobile phones at baseline were still using a mobile phone at least once a week when asked again 8.8 years later. However, some women who reported not using a mobile phone at baseline began use subsequently; and this might dilute our estimates of relative risk towards the null"* The study is uninformative as to cancer risks from a normal usage of mobile phones among most people today. It *"suffers from poor exposure assessment which likely contributed to exposure misclassification. …the analysis sample included few participants with heavier cell phone use, the group with the greatest brain tumor risk"* [37].

Laterality of mobile phone use in relation to tumour localization

For worst case scenarios based on the highest exposed area of the head, the preferred side used for the wireless phone is important to assess in relation to brain tumour risks. However, this method was disregarded by Karipidis et al [1] with the following argument: *"The preferred side of the head for mobile phone use is an important exposure determinant but, when assessed retrospectively through self-report, is affected by substantial misclassification and recall bias…… indicated by concurrent observations of increased risk for ipsilateral mobile phone use and protective effect for contralateral use; i.e. in certain studies with no overall association, there was an increased risk with ipsilateral use which was compensated by a decreased risk with contralateral use, indicating a bias [38]. Due to such a poor validity, self-reported laterality of mobile phone use is not included among the exposure metrics and contrasts examined in SR-A (Table 1)."* That conception is not based on scientific facts and is contradicted by the results in the Hardell group studies, the Interphone study and the Coureau

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study, as shown in the following. Numbers of exposed cases and controls are given, OR and 95 % CI, see Table 3 [14, 23, 35]. These results do not show as suggested by Karipidis et al [1] *"increased risk for ipsilateral mobile phone use and protective effect for contralateral use"*. Karipidis et al refer to [38], written even before the evaluation by IARC in 2011 [31, 32], and the publications on relevant case-control studies [11] and Hardell et al [10, 14, 35]. Furthermore, the conclusion by Karipidis [1] is contradicted by Schuz [38,39] who admits that in the largest published part of the Interphone study by that time *"an observed increased OR for ipsilateral use was not compensated by a similarily decreased OR for contralateral use (ORs of 1.39 versus 0.98, Table I), especially as this was found among the cases with the longest time since first use… this is what one would expect under the assumption of a causal effect"*.

The Hardell et al [10, 14, 23, 35] studies showed that assessment of exposure was valid and that recall bias for preferred side of the head for use of the wireless phone (mobile phone or cordless phone) could not explain the results, see Table 3. It is important to note that these results were ignored, not mentioned, or discussed by Karipidis et al [1]. Similar results were found for salivary gland tumours, i.e., no indication of recall bias, data not in table [40, 41]. In the Interphone study [13] statistically significant increased OR for glioma was reported for ipsilateral use for cumulative mobile phone use ≥1640 h, see Table 3. Also, an increased risk for contralateral use was found, thus not in agreement with *"protective effect for contralateral use"* as claimed by the Karipidis group. For acoustic neuroma there was a constant pattern of highest risk for ipsilateral mobile phone use that cannot be explained by recall bias [42]. Coureau et al [11] found lower OR for glioma for contralateral use of the mobile phone compared with ipsilateral use, however not statistically significant, see Table 3. For meningioma OR > 1.0 was found both for ipsilateral and contralateral mobile phone use ≥ 896 h, highest for ipsilateral use although not statistically significant in contrast to the statistically significant increased OR for all exposure.

The study by Pettersson et al [43] on acoustic neuroma did not give evidence of recall bias in the assessment of mobile phone use, Table 3. Interestingly, increased risk was found for cumulative use of the mobile phone ≥680 h yielding OR = 1.46, 95 % CI 0.98-2.17. Both ipsilateral and contralateral use of the mobile phone gave increased risk. Hearing problems on the affected side is one of the first signs of an acoustic neuroma. Therefore, the subject may shift use of the wireless phone to the contralateral side. Consequently, use of the wireless phone should be carefully assessed over the years. Similar results were reported for use of cordless phone in the highest category of cumulative use ≥900 h yielding OR = 1.67, 95 % CI = 1.13-2.49, [43] although no results were given separately for ipsilateral and contralateral use, see Table 3.

Table 3: Odds ratio and 95 % confidence interval in parenthesis in epidemiological studies on use of the wireless phone in relation to tumor localization. Ipsilateral use = same side as the tumor site, contralateral use = opposite side to the tumor. Numbers of exposed cases and controls are given.

STUDY	Total	Ipsilateral	Contralateral
Hardell et al., 2013 [23]			
-Acoustic neuroma, total			
--mobile phone	200/2148	123/920	73/729
	1.6	1.8	1.5
	(1.2-2.2)	(1.3-2.6)	(0.98-2.2)
--cordless phone	156/1724	101/766	52/565
	1.5	1.8	1.2
	(1.1-2.1)	(1.2-2.6)	(0.7-1.8)
Carlberg, Hardell, 2015 [35]			
Meningioma, total			
--mobile phone	956/2148	459/920	342/729
	1.0	1.2	1.0
	(0.9-1.2)	(0.9-1.5)	(0.8-1.3)
--cordless phone	817/1724	378/766	290/565
	1.1	1.1	1.0
	(0.9-1.3)	(0.9-1.4)	(0.8-1.3)
Hardell, Carlberg, 2015 [14]			
Glioma, total			

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--mobile phone	952/2148	592/920	316/729
	1.3	1.8	1.1
	(1.1-1.6)	(1.4-2.2)	(0.8-1.4)
--cordless phone	752/1724	461/766	259/565
	1.4	1.7	1.2
	(1.1-1.7)	(1.3-2.1)	(0.9-1.6)
Interphone, 2010 [13]			
-Glioma ≥ 1640 h			
--mobile phone	210/154	100/62	39/31
	1.40	1.96	1.25
	(1.03-1.89)	(1.22-3.16)	(0.64-2.42)
-Meningioma ≥ 1640 h			
--mobile phone	130/107	46/35	28/28
	1.15	1.45	0.62
	(0.81-1.62)	(0.81-1.62)	(0.31-1.25)
Interphone, 2011 [42]			
- Acoustic neuroma ≥ 1640 h			
--mobile phone, latency ≥ 1 year	77/107	47/46	16/26
	1.30	2.33	0.72
	(0.87-1.94)	(1.23-4.40)	(0.34-1.53)
--mobile phone, latency ≥ 5 year	36/31	27/22	6/5
	2.86	3.53	1.69
	(1.55-5.28)	(1.59-7.82)	(0.43-6.69)
Coureau et al 2014 [11]			
-Glioma,			
90th perc. ≥896 h			
--mobile phone	231/446	167/325	144/278
	2.89	2.11	0.66
	(1.41-5.93)	(0.73-6.08)	(0.23-1.89)
-Meningioma,			
90th perc. ≥896 h	185/361	140/276	144/280
	2.57	2.29	1.18
	(1.02-6.44)	(0.58-8.97)	(0.34-4.12)
Pettersson et al., 2014 [43]			
-Acoustic neuroma			
--mobile phone	89/110	38/43	33/39
≥680 h	1.46	1.20	1.26
	(0.98-2.17)	(0.69-2.08)	(0.70-2.25)
--cordless phone	84/97	Not reported	Not reported
≥900 h	1.67		
	(1.13-2.49)		
Yoon et al., 2015 [95]			
-Glioma			
--mobile phone	70/96	22/19	14/19
>900 h	0.64	1.77	0.63
	(0.30-1.34)	(0.32-1.84)	(0.24-1.65)

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In conclusion the Hardell group studies showed no evidence of recall bias in the analyses of laterality of wireless phone (mobile phone and cordless phone) use and tumor localization for acoustic neuroma, meningioma, and glioma. Overall detailed analysis of the published results [36, 44] clearly makes the claim of *"substantial misclassification and recall bias"* scientifically invalid. Thus, these laterality results should have been included by Karipidis et al [1]. The exclusion of this topic distorts the overall evaluation, and casts doubt on the scientific integrity and credibility of Karipidis et al [1].

Pediatric brain tumors and mobile phone use

Karipidis et al [1] included three studies on children and mobile phone use on which they based their conclusion that there *"were no indications of an increased risk"* and that there is *"moderate certainty evidence"* that mobile phone use *"likely does not increase the risk of glioma, meningioma, acoustic neuroma, pituitary tumours, and salivary gland tumours in adults, or of paediatric brain tumours."* One of the three studies included is the so called Cefalo study [45]. It was coauthored by Martin Röösli who is both coauthor of the Karipidis article and member of ICNIRP. The Cefalo study showed non-significantly increased risk for brain tumours in most of the analyses in the study. For regular use the reported result was OR = 1.36, 95 % CI =0.92 – 2.02. However, for children with the longest time since first subscription, > 2.8 years, the reported risk was OR = 2.15, 95 % CI = 1.07 - 4.29 based on operator recorded use. A second study, the Mobi-Kids study [46] reported no increased risks for brain tumours among children and adolescents using mobile phones. In fact, most ORs in the study were <1.0, and several of them statistically significant. Such results are biologically implausible and indicate that the study has methodological problems [47].

One potential problem is that the control group consisted of hospitalized children with appendicitis instead of population-based controls. Appendicitis has been suggested to be associated with RF-radiation [48]. Further brain tumors in the center of the head were excluded [47]. The third study is a small pilot study [49]. Based on 49 cases and 78 controls in the age between 15 and 24, the OR for speaking on a mobile phone more than only 20 times was 0.9, 95 % CI = 0.9 - 2.3. The study included different neuroepithelial tumours and 27 were astrocytoma. The response rate was only 52 % for cases and 32 % for controls. Evidently this small study's result gives no information on risks related to normal use or intense use of mobile phones, which today can amount to several hours a day for children and teenagers. The Karipidis et al [1] conclusion that there would be moderate certainty of no increased risk for pediatric brain tumours is not supported by the few studies included in the analysis.

Transmitters and Base Stations

Only five studies were included in the Karipidis group analysis regarding risk of childhood leukaemia related to exposure to RF-radiation from broadcast transmitters (Radio/TV), or base stations [50-54] The authors included only studies based on modelled estimates of RF radiation at the address of the children's homes and excluded all studies based on distance to a transmitter or base station. Studies on adult cancers were not considered. Balmori [55] concluded that ten of 13 studies on base stations and cancer risks reported increased risks of cancers near mobile phone base stations. In a presentation in Stockholm in 2016, one of the authors of the Karipidis et al. article [1], Martin Röösli, concluded that until the year 2003, studies showed increased risks for childhood leukaemia near transmitters in *"all but one risk estimates"*

(https://www.youtube.com/watch?v=IKFf5zzlGqM – at 1 h. 25:15 minutes).

Modelled estimates are no less susceptible than studies based on distance to misclassification of exposure as they omit other sources of RF-radiation and other established risk factors for childhood leukaemia such as proximity to EMFs from powerlines [56]. Furthermore, modelled exposure, like distance, does not take into consideration wall materials or placement of children's bedroom in the house or apartment which may significantly impact real exposure levels. In spite of these very few studies with potential for misclassification of exposure, and omitting studies showing increased cancer risks, the authors concluded that *"For whole-body far-field RF-EMF exposure from fixed-site transmitters (broadcasting antennas or base stations), there was moderate certainty evidence that it likely does not increase childhood leukaemia risk and low certainty evidence that it may not increase the risk of paediatric brain tumours"* [1]. According to Figure 20 at page 38 in the Karipidis et al article [1] the modelled highest exposure categories for broadcast transmitters and base stations in the five studies included are far below the ICNIRP limits of 4.5 to 10 W/m^2 or 45-61 V/m. The modelled highest exposure category in one of the two base station studies is only ≥ 0.016997 mW/m^2 [51], and the distance to the base stations in this highest exposure group was up to 612 m. The highest exposure groups in the transmitter studies are also relatively low, for instance in the Hauri et al study [50], the highest exposure group is ≥ 0.21 V/m, see Table 4. The modelled exposure levels in all of the five included studies are well below the exposure levels frequently measured in people's homes and in towns after the 4G and 5G rollout [57-59].

Base stations

One of the two base station studies, [52] reported that a higher than median annual power density exposure was *"significantly associated with an increased [adjusted odds*

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Table 4: Highest exposure group in studies on transmitters and base stations

Transmitters	Highest exposure group
Merzenich et al 2008 [53]	≥0.7 V/m
Ha et al 2007 [54]	≥0.917 V/m
Hauri et al 2014 [50]	≥0.21 V/m
Base stations	
Elliott et al 2010 [51]	≥0.016997 mW/m^2 (distance 0-612 m)
Li et al 2012 [52]	≥392.86 W-years/km^2

ratio] AOR for all neoplasms (1.13; 1.01 to 1.28)", and a borderline statistically significant increased risk of childhood leukaemia (AOR=1.23; 95 % CI=0.99 – 1.52). Li et al. [52] concluded that *"This study noted a significantly increased risk of all neoplasms in children with higher-than-median RF exposure to [Mobile Phone Base stations] MPBS"*. However, these results were not reported in the Karipidis analysis [1] that included the following results: AOR = 0.85 (95 % CI = 0.68 – 1.07) for medium exposure category and AOR = 0.82 (95 % CI = 0.59 – 1.13) for highest exposure category. The other study included in the Karipidis analysis [1] of childhood cancers and exposure to RF-radiation from base stations, the Elliott et al 2010 study [51] was based on all registered cases of cancer in children aged 0-4 in Great Britain in 1999-2001. The national mobile phone operators provided data for the period 1 January 1996 to 31 December 2001. Long term health effects were not studied; the follow-up time was very short (up to 4 years). Information on other sources of radiofrequency exposure, such as-cordless phone base stations, maternal use of mobile/DECT phones, or radio and television transmitters, were not considered. Most relevant is that the results do not reflect current much higher exposure to RF radiation from base stations after the 4G and 5G-rollout [58, 59]. Due to the many shortcomings, the Elliot study [51] is uninformative as to cancer risks in children exposed to RF-radiation from base stations at levels encountered in many homes today, which may well exceed the highest exposure group in the investigation. An objective evaluation of assessment of the risk, in contrast to Karipidis et al [1], should mention that the levels are extremely low even in the highest exposure category compared to levels measured today after the 5G roll-out.

Transmitters

Only three studies were included by Karipidis et al [1], and all reported no increased risks of total childhood cancers. The Ha et al article [54] reported increased leukaemia risk for children living within 2 km from a transmitter. Previous studies showing increased risks for childhood cancers in the vicinity of Radio/TV transmitters were omitted from the analysis. One such previous study omitted by Karipidis et al was published in 1996 [60]. This study reported increased risks for children 0-14 years living within 4 km from transmitters with RR = 1.58, 95% CI =1.07-2.34 for leukaemia and RR =1.55, 95% CI = 1.00-2.41 for childhood lymphatic leukaemia. For all ages, the RR for total leukaemia incidence was 1.24, 95% CI = 1.09-1.40. Further, the study found increased incidence of mortality from all leukemia. The conclusion on base stations and transmitters by Karipidis et al. [1] is misleading and unscientific. There is no evidence to support the conclusion that there would be moderate certainty of no increased risk of childhood leukaemia at levels that may arise in many people's home today who live close to base stations and/or transmitters. Further there is no evidence to support that there would be no cancer risks for children exposed to base stations at levels allowed by the ICNIRP limits, see discussion in [16, 36], that are recommended and supported by several of the authors of the Karipidis paper.

Rates/incidence of BrainTumors

Karpidis et al [1] concluded that the increased risks observed in several case-control studies on mobile phone use and brain tumours are *"incompatible with the actual incidence rates of glioma/brain cancer observed in several countries and over long periods"*. The authors refer to three simulation studies showing that risk estimates over 1.5 would be *"definitiely implausible [61-63]. Based on these findings, we carried out the planned sensitivity meta-analyses of glioma risk in relation to long-term mobile phone use (10+ years) excluding studies reporting implausible effect sizes."* To exclude studies with *"implausible results"* is not scientifically acceptable. It may merely reflect a biased predetermined opinion of no risk that would have a major impact on the scientific evaluation. Thus, excluding results that seem to conflict with the authors' forgone opinion makes the credibility of Karipidis et al [1] less valid.

Furthermore, the conclusions are not based on review of all literature on brain tumor incidence. Philips et al [64] reported: *"a sustained and highly statistically significant ASR (age–standardized incidence rates) rise in glioblastoma multiforme (GBM) across all ages. The ASR for GBM more than doubled from 2.4 to 5.0, with annual case numbers rising from 983 to 2531."* This study was excluded in the review by Karipidis et al [1]. Promotion of low-grade tumour to high grade form RF radiation may be one cause in addition to initiation of glioblastoma multiforme. Some support is obtained in the case-control study on glioma by Hardell, Carlberg [14]. Increased OR was seen with short latency < 10 years, and after some decline, again increasing OR with latency >15 years, see Fig 1 in the publication. Interestingly, also Interphone [13] published increased OR with short latency, 2-9 years, but highest in the 10+ latency group, see Appendix 2 in the article. This indicates both promotion (short latency) and initiation (long latency) of cancer associated with exposure to RF radiation, an item not discussed by Karipidis et al [1].

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Other studies excluded by Karipidis et al [1] were Swedish data [65, 66]. Both studies provided evidence of increasing rates of brain tumours. The Swedish National Inpatient Register (IPR) and Causes of Death Register (CDR) were used to study the rates of brain tumours comparing with the Cancer Register incidence data for the period 1998–2013 using joinpoint regression analysis [65]. *"In the IPR we found a joinpoint in 2007 with Annual Percentage Change (APC) +4.25%, 95% CI +1.98, +6.57% during 2007–2013 for tumours of unknown type in the brain or CNS. In the CDR joinpoint regression found one joinpoint in 2008 with APC during 2008–2013 +22.60%, 95% CI +9.68, +37.03%. These tumour diagnoses would be based on clinical examination, mainly CT and/or MRI, but without histopathology or cytology. No statistically significant increasing incidence was found in the Swedish Cancer Register during these years. We postulate that a large part of brain tumours of unknown type are never reported to the Cancer Register."* Interestingly, data showed increasing number of patients per 100 000 inhabitants with D43 (tumour of unknown type in the brain), in the article with some lag time from increasing number of out-going mobile phone minutes in millions during 1999-2013, see Fig 2, in [65].

Further analysis was made for the time 1998-2015 using the Swedish National Inpatient register and the Swedish Cancer Register [66]. *"Average Annual Percentage Change (AAPC) per 100,000 increased with +2.06%, 95% confidence interval (CI) +1.27, +2.86% in both genders combined. A join point was found in 2007 with Annual Percentage Change (APC) 1998-2007 of +0.16%, 95% CI -0.94, +1.28%, and 2007-2015 of +4.24%, 95% CI +2.87, +5.63%. Highest AAPC was found in the age group 20-39 years. In the Swedish Cancer Register the age standardized incidence rate per 100,000 increased for brain tumors, ICD-code 193.0, during 1998-2015 with AAPC in men +0.49%, 95% CI +0.05, +0.94%, and in women +0.33%, 95% CI -0.29, +0.45%.*

This is shown in Fig 3 (men), and Fig 4 (women), in [66]. Both figures show increasing rates of tumours of unknown type (D43) in the brain or CNS, in men during 2007-2015 and in women during 2008-2015. Both results were statistically significant (age–standardized incidence rates). The Danish Cancer registry data clearly show that tumours in the brain and central nervous system have increased between 2004 and 2023 [24-26], for discussion and graph see (https://radiationprotection.se/cancer/increasing-incidence-of-cns-tumours-in-denmark/).

This is also illustrated in NORDCAN (https://nordcan.iarc.fr/en/factsheets).

These incidence data are incompatible with the results of the Danish cohort [9]. On the contrary the results may reflect the increased risks observed in case-control studies on use of wireless phones. In addition the French public health agency, Santé public France, reported in 2018 an increase in glioma incidence in France between 1990 and 2018, from 883 cases in 1990 to 3,481 new cases in 2018 (https://phonegatealert.org/en/press-release-brain-cancers-4-times-more-new-cases-of-glioblastoma-in-2018-according-to-public-health-france/).

Bias and Weight Assessment

Karipidis et al [1] used something they called *"tiering"* for assessment of bias in the studies. It seems to be a somewhat odd and arbitrary method that is not well defined and is hard to evaluate. The article gives the following definition: *"Summary risk of bias (study tiering). Tier-1 comprised studies with definitely or probably low risk of bias for all key-items and most of other items; tier-3 included studies with definitely or probably high risk of bias for all key-items and most of other items; and studies not meeting the above criteria were classified as tier-2".* The Danish cohort study [7-9], with its serious misclassification of exposures, as well as the Schuz et al [6] cohort article, were rated tier-1, in contrast to the Hardell case-control studies [14, 23, 35] that were rated tier-2. Contrary to the two cohort studies, these case-control studies gave individual exposure data, such as type of used mobile phone, cumulative mobile and cordless phone use, laterality (ipsilateral/contralateral use in relation to side of head for the tumour), and latency that all are of importance in epidemiological studies. Another example is that a small pilot study [49] was given the same tier as the Hardell group's large epidemiological studies, tier 2, see Table 7 in [1]. This further strengthens that there is scientific bias within the Karipidis group of authors. The evaluation by Karipidis et al [1] is scientifically not defensible, i.e., there are large differences between the Hardell group studies [10, 14, 23, 35] and Feltbower et al [49] regarding epidemiological accuracy.

Karipidis et al [1] added the Danish cohort study [7-9] and the Schuz cohort study [6] in the assessment of overall risk for glioma, see (Fig 2-5), meningioma (Fig 7, 8), and acoustic neuroma (Fig 10,11) in the publication and gave the two cohorts overall an important weight. This distorted risk estimates towards unity and made the results erroneous and unreliable, see also [15, 16, 31, 32]. In conclusion, due to the serious methodological shortcomings, the Danish cohort study results in particular [7-9], but also the Schuz cohort study [6], cannot be used as scientific evidence of no association between use of mobile phones and brain tumors as made by Karipidis et al [1].

Risk of Bias (RoB) assessment

For evaluation of RoB the Office of Health Assessment and Translation (OHAT) tool was used. There seems to be no justification or discussion of how that tool was used in practice. The studies were classified into three so called tiers (ranking) based on potential for bias: low, moderate, or high.

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The rating for each study was made by one or two persons from the Karipidis author group. Results of their assessment may be found in Table 7 and Annex 6 in Karipidis et al [1].

The evaluated questions were: Confounding, Selection, Healthy Worker Effect, Attrition/Missing Data, Exposure Characterization, Outcome Assessment, Selective Reporting, Statistical methods. For each question risk of bias (RoB) was evaluated: Definitely Low, Probably Low, Probably High, Probably High NR (NR not defined in Table), Definitely High (red 'flag') Total Mobile phone: 80 studies were evaluated. In total 42 red flags were given for one or several questions above. Of these, 35 were given to the Hardell group studies, that is 83.3 % assigned to the 17 Hardell group studies. The remaining seven red flags, 16.7 %, were given to studies among the 63 other studies. These facts indicate clear bias in the Karipidis group. Total cordless phone: 21 studies were evaluated. In total 32 red flags were assigned to cordless phone studies and all of these, 100 % were given to the 14 Hardell group studies. For the other 7 studies no red flags were given. Another clear example of the biased evaluation by Karipidis et al [1]. The skewed and biased RoB rating by Karipidis et al may be exemplified by the evaluation of the Danish cohort study [8, 9]. Frei et al. [9] was rated Definitely Low (++), dark green, for bias concerning selection, outcome, selective reporting and statistical methods. For attrition, exposure and confounding it was rated light green

As we have described above there were many limitations of the Danish cohort study such as exclusion of the most exposed group, consisting of 200 507 corporate users of mobile phones and all users starting using mobile phones after 1995. It is incorrect as stated by Karipidis et al [1] that *'all users'* were included. Further there is no information about actual use, i.e., exposure. None of these flagrant biased and methodological errors in the Danish cohort is highlighted or even mentioned by the assessors Karipidis and da Silva or Baaken and Loney. An objective assessment would give this study red flag for severe bias regarding selection, outcome, exposure, confounding and selective reporting. Another flagrant example is the biased evaluation of cordless phone use in the study by Aydin et al [45] that investigated brain tumour risks from mobile and cordless phone use among children and adolescents aged 7 to 19 years. As we have discussed elsewhere [16] only the three first years of cordless phone use were assessed. There is no scientific explanation to why only the first three years were studied and the following years were excluded, especially since the use of cordless phones is known to be increasing with age in the studied population. In Annex 6 [1] attrition/missing data are rated dark green *'Definitely Low (++)'*, a most peculiar evaluation taking that for most subjects the highest lifetime use was disregarded. An objective evaluation would give this study red flag for missing exposure data. This study should also have been given red flag for selective reporting since the authors [45] did not clarify that results for cordless phones were only based on the first three years of use in the result section. Instead, the authors gave the impression that the results were based on highest exposure category: *"use of cordless phones was not related to brain tumor risk (for the group with the highest amount of cordless phone use [>70 hours], OR = 1.18, 95% CI = 0.65 to 2.14; Table 6)"*. Among the authors of the Aydin study [45] is Martin Röösli, also author of the Karipidis study, and Joachim Schuz, also coauthor of the Danish Cohort study [8, 9] and first author of the Schuz 2022 cohort study [6]. These are just a few examples of the misinterpretation and distortion of scientific facts in the RoB assessment. The authors have neglected rebuttals published after peer-review in scientific journals, as described above, on the different low quality studies. In this context a remarkable statement was made by Karpidis et al [1] on the Hardell group studies at page 45 *(5.3. Limitations in the review process): "Relevant information was missing in several articles by one particular research team [40, 67-70]. The missing data consisted of key-study features, such as number of exposed cases and controls, details on the control selection procedures, response rates among controls (overall, and by reason) and other important pieces of information. Although we made two subsequent attempts to obtain additional information for these studies, we were not provided with the requested data."*

In fact, this statement by Karpidis et al [1] is not correct. The authors were advised to read the different publications since all information such as on *"number of exposed cases and controls, details on the control selection procedures, response rates among controls"* are published in the different articles. It is unclear why Karipidis et al [1] did not read and assess that information. Karipidis et al [1] claimed at page 45 that *"other important pieces of information"* were missing. This may refer to Annex 6 with the statement that *"The authors change the statistical approach, breaking the individual matching and use the whole control group"*. However, this is based on standard epidemiological principles if adjustment is made, as in our studies, for the matching variables in the statistical analyses. Another statement was that *"Participation rate for cases based on non-standard calculations and no details given for controls."* This seems to be another *ad hoc* statement. In fact, each study gave detailed information on participation of the cases in Materials and Methods, including in Tables. Also, for controls participation rates were published. Furthermore, the rules according to the Ethical Committee were followed (all studies approved by the Ethical Committee). Thus, the study persons could abstain from participation without motivation. It was possible for a person to terminate any further involvement at any time without any comment. Details on number of participating controls were given in each study. These ethical principles seem to be unfamiliar to the Karipidis group of authors.

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These data questioned in [1] can easily be found in our different publications. The facts were submitted to Karipidis et al, (1) but they neglected the information which enhances the overall impression of a biased risk assessment. Further, in the same paragraph Karipdis et al [1] stated: *"We also asked for the number of cases exposed to cordless phones not reported in two articles from the Swedish Interphone study [71, 72], but the raw data were no longer available since it has been almost twenty years after their publication."* The Hardell group studies were also published twenty years or more before the Karpidis et al review [1]. This is another example of the different scientific standards applied to the Hardell group studies compared with other studies, notably those that did not report an increased risk for brain tumors according to the evaluation by the Karipidis group. It may be added that most studies, except the Hardell group, did not assess use of cordless phones which may lead to an underestimation of the real risks since cordless phones were an important source for exposure to RF radiation during the study period. It is noteworthy regarding the Danish cohort [9] that the Karipidis group seems not have asked the authors for data regarding use of mobile phones among the corporate subscribers and the private subscribers starting using mobile phones after 1995. These data are crucial to assess the impact of the misclassification of exposure due to the exclusion of these groups. Yet another example of the study group's biased assessment of RoB is the Elliott et al. [51] study on pediatric cancer and base stations. This study was given overall *"tier 1"* thus highest ranking and (++) *"definitely low"* risk of bias for outcome and statistical methods and (+) *"probably low"* risk of bias for confounding, missing data, selection, missing data and selective reporting. As explained above this study has many design problems and the outcome is non-informative due to high risk of exposure misclassification, missing data (real exposure) and very low highest exposure group (only $\geq$0.017 mW/m^2) based on accommodation during pregnancy and short follow-up of only four years. An objective evaluation would have concluded that this study is uninformative regarding the risk of childhood cancers near mobile phone base stations.

Conflicts of interest

Several of the authors in the Karipidis group have conflicts of interests in terms of ties to ICNIRP or other bias. ICNIRP is the organization that has recommended the exposure limits that most countries in the world have adopted. The telecommunications industry has adapted their technology to the ICNIRP limits. Several investigations [73, 74] have concluded that there are ties between the telecommunications industry, the ICNIRP and the WHO, the latter commissioning the Karipidis et al [1] report. Being a member of ICNIRP is a conflict of interest due to the importance of the ICNIRP limits for the telecommunication's industry and should always be reported. According to the Ethical Council at the Karolinska Institute, Stockholm, Sweden [75] in a verdict on Anders Ahlbom at Karolinska Institute Stockholm, the membership in ICNIRP is a potential conflict of interest. He was an ICNIRP member during 1996 – 2008 (12 years). If a cancer risk with mobile phone technology would be recognized below the ICNIRP limits, the consequences for the industry would be substantial in economic terms. Further, the ICNIRP limits are also of importance for the industry's implementation of new technology such as 5G. Lower limits than ICNIRP's would make the 5G roll out *"difficult or impossible"* according to one of the major infrastructure providers [76].

Below is a list of authors with conflicts of interests:

Ken Karipidis, first author, is member of ICNIRP (today vice chair), since 2015 (https://www.icnirp.org).

Dan Baaken, second author, is scientific secretary of ICNIRP since July 2024. (https://www.icnirp.org/en/activities/news/news-article/scientific-secretariat-2024-2028.html)

Tom Loney has performed research and provided advisory services to the defense, industrial and healthcare sectors. The defense industry has interests in the outcome of a cancer risk evaluation of RF radiation, thus a potential conflict of interest (https://www.mbru.ac.ae/a-z-directory/tom-loney/).

Martin Röösli is a member of ICNIRP since 2016 (https://www.icnirp.org). In addition, he has received funding for research from a Swiss foundation funded by the telecommunications industry (https://www.emf.ethz.ch/en/) that serves as an intermediate between telecom industry and researchers [77].

Susanna Lagorio has collaborated with scientists with known conflicts of interests in terms of funding from industry and membership in ICNIRP (https://microwavenews.com/news-center/repacholi-half-who-emf-project-funding-came-industry).

On behalf of Radio Vatican she has testified regarding cancer risks from the RF-radiation (https://spectrum.ieee.org/vatican-radio-still-making-waves)

Maria Feycthing developed the RoB tool for the Karipidis review. She has been a long-term ICNIRP member during 2000-2020 (https://www.icnirp.org). She has also received funding from the telecommunication industry for research [73].

Discussion

The conclusions by Karipidis et al [1] are unfounded and misleading regarding the scientific evidence of no cancer risks from mobile phone use and exposure to other sources of RF radiation, e.g., base stations. The conclusions are contradicted by other reviews [36, 77-80] and are likely a

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result of bias within the author group, where several persons, including the first author, have clear conflicts of interests. In the critical review by Frank et al [3] it was concluded that: *we find that few, if any, of the RF-EMF exposure/ tumor associations examined by Karipidis et al. [1] have been the subject of sufficiently replicated, high-quality primary studies, of adequate power and follow-up time, to warrant any legitimate scientific certainty about the absence of causation, especially when accounting for the animal studies of RF-EMF carcinogenicity [81-83]. The overall GRADE recommendations in this paper appear to reflect biases of the authors. In contrast to the authors' rating of the evidence for RF-EMF exposures NOT causing these tumors as being of "moderate certainty," we contend there is no scientific justification for concluding there is any certainty that RF-EMF exposures do not cause cancer."* Indeed, the Karipidis group of authors incorrectly draw conclusions of no increased risks on cumulative call time exposure ignoring the largest studies with significantly increased ORs in the highest exposed groups. In addition, they give high weight to two large cohorts with results that show no increased risks for cancer from mobile phone use that, due to their design, are uninformative regarding cancer risks from mobile phone use. On the other hand, the Karipidis group gives more reliable studies low weight and ignore results showing clear increased risks for brain tumours in the highest exposed categories.

Further, the Karipidis group makes the unscientific conclusion that there would be some grade of *"certainty"* of no risks of childhood cancers from exposure to mobile phone use, transmitters and base stations based on very few studies with low exposure and conflicting results. Ken Karipidis, the first author, and two other authors are members of or secretary of ICNIRP. ICNIRP has been identified as an organization with ties to the industry, promoting standards that are beneficial to the industry [73]. According to 267 EMF scientists (EMFscientist.org) and according to ICBE-EMF [36], an international commission of scientists, ICNIRP's limits are insufficient to protect the public against harmful effects from radiofrequency radiation. The ICNIRP limits are only based on acute thermal effects, observed within an hour of exposure to very high intensities of RF radiation, excluding diseases not caused by heating (non-thermal effects), and long-term exposure effects, i.e., cancer. A result showing increased cancer risks would make the ICNIRP limits invalid for human health protection. The Karipidis et al [1] article is part of a review of this issue commissioned by the WHO. The WHO is known to collaborate with ICNIRP, promoting the ICNIRP limits and opinion that there are no cancer risks from RF-radiation emitted from mobile phones and mobile phone base stations [84]. The collaboration has been very close since the start of the WHO EMF project in 1996 resulting in the WHO conducting a project promoting the ICNIRP guidelines worldwide. WHO has received funding from telecommunications industry for the EMF Project during many years [84]. These examples above illustrate that the outcome of the current WHO review may have already been pre-determined solely based on the selected ICNIRP related group members, Karipidis, Baaken and Röösli. Obviously this applies also to Feychting. Evaluations of health risks from RF radiation should be performed by scientists without ties to ICNIRP or industry, in view of the huge economic interests (telecom and military) that have vested interests in such evaluations. Such ties may compromise objective and sound scientific code of conduct, a fact that is documented in several reports on the impact of industry funding of scientific studies [85]. Ties to industry are a potential bias that may influence the scope, design and performance of research [77-80]. Industry sponsored research is more likely to present a result favourable to the industry [78]. A similar observation was made by James Lin, former ICNIRP member during 2004-2016, in a recent publication: *"What may not be as apparent for the WHO-EMF systematic reviews is the lack of diversity of views. A large number of ICNIRP commissioners and committee members are listed as authors for the WHO-EMF systematic reviews; some also served as lead authors. These concerns advance issues of reviewer independence and potential for conflicts of interest."* [86].

Conclusion

The Karipidis group's conclusions on no cancer risks from use of mobile and cordless phones, or exposure to RF radiation from transmitters and base stations, are based on several errors in their interpretation of scientific results, omission of facts contradicting the conclusions and inherent conflicts of interest. Further, most of the results on which the authors base their conclusions are based on very low exposure levels not representative for the public's exposure today and the authors have excluded or ignored results based on highest exposure categories. The conclusions by the authors of various grades of *"certainty"* that RF-EMF exposures do not cause cancer are unscientific and unjustified in view of the available scientific evidence. Evaluations of health risks from RF radiation should be performed by scientists without ties to ICNIRP or industry. Industrial direct or indirect ties may compromise objective and sound scientific evaluation. The serious scientific malpractice by Karipidis et al [1] with fatally flawed evaluation of radiofrequency radiation and cancer risks, as outlined in this review, should lead to retraction of the article.

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Availability of Data and Materials

The information generated and analysed during the current study is available from the corresponding author on reasonable request.

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Author's contributions

LH and MN contributed to the conception, design and writing of the manuscript. Both authors read and approved the final manuscript.

Ethics Approval and Consent to Participate

Not applicable

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Competing interests

The authors declare that they have no competing interests.

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