SECTION 11

Use of Wireless Phones and Evidence for Increased Risk of Brain Tumors

2017 Supplement

Lennart Hardell, MD, PhD, Associate Professor
Department of Oncology, University Hospital, Örebro, Sweden

Michael Carlberg, MSc
Department of Oncology, University Hospital, Örebro, Sweden

Prepared for the BioInitiative Working Group
November 2017

I. INTRODUCTION

The use of wireless digital technology has grown rapidly during the last couple of decades (http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2016.pdf). During use, mobile phones and cordless phones emit radiofrequency (RF) radiation. The brain is the main target for exposure to radiofrequency (RF) radiation during use of handheld wireless phones; both mobile and cordless phones (Cardis et al., 2008, Gandhi et al., 2012). An increased risk for brain tumors has been of concern for a long time. In May 2011 RF radiation in the frequency range 30 kHz–300 GHz was evaluated to be a Group 2B, i.e. a 'possible' human carcinogen, by the International Agency for Research on Cancer (IARC) at the World Health Organization (WHO) (Baan et al., 2011, IARC, 2013). This was based on an increased risk for glioma and acoustic neuroma in human epidemiological studies.

The IARC cancer classification includes all sources of RF radiation. The exposure from mobile phone base stations, Wi-Fi access points, smart phones, laptops and tablets can be long-term, sometimes around the clock, at home, at work place, at school, and in the environment. For children this risk may be accentuated because of a cumulative effect during a long lifetime use (Hedendahl et al., 2015).

No doubt the IARC classification of RF radiation as a Group 2B human carcinogen in 2011 initiated a world-wide spinning machine to misinform about cancer risks and to dismantle the IARC verdict. This reminds of similar methods used by the tobacco industry in the evaluation of passive smoking (Ong and Glantz, 2000). Manufacturing doubt and sowing confusion is a well-known strategy by the industry to defend their products even if they are cancer causing (Michaels, 2008; Walker, 2017).

Thus, in spite of the IARC evaluation little has happened in most countries to reduce exposure to RF fields. On the contrary, with new technology increasing environmental exposure levels are found as in measurements of ambient RF radiation at e.g. Stockholm Central Station and Stockholm Old Town in Sweden (Hardell et al., 2016, 2017). The fifth generation, 5G, for telecommunication will substantially increase exposure to RF-radiation. 5G is planned to be implemented in the near future before potential hazards for human health and the environment have been fully investigated. This should be performed by scientists independent from industry (http://www.stralskyddsstiftelsen.se/wp-content/uploads/2017/09/scientist_5g_appeal_final.pdf).

The exposure guideline used by many agencies was established in 1998 by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and was based only on established short-term thermal (heating) effects from RF radiation neglecting non-thermal biological effects

(ICNIRP 1988). The ICNIRP guidelines were updated in 2009 but still do not cover cancer and other long-term or non-thermal effects (ICNIRP, 2009).

ICNIRP gives the guideline 2 to 10 W/m^2 for RF radiation depending on frequency. This is only based on a short-term immediate thermal effect (ICNIRP 2009). ICNIRP is a private non-governmental organisation (NGO) based in Germany. New expert members can only be elected by members of the organization. Most of the ICNIRP members have ties to the industry that is dependent on the ICNIRP guidelines. The guidelines are of huge economic and strategic importance to the military, telecom/IT and power industry.

In contrast to ICNIRP, the BioInitiative Reports from 2007, updated in 2012 and 2014, has based the evaluation on non-thermal health effects from RF radiation (BioInitiative Working Group 2007, 2012, 2014). The scientific benchmark for possible health risks was defined to be 30 to 60 μW/m^2. Thus, in 2012, the Bioinitiative Working Group proposed a precautionary target level of 3–6 μW/m2, using a safety factor of 10. Using the significantly higher guideline by ICNIRP gives a 'green card' to roll out the wireless digital technology thereby not considering non-thermal health effects from RF radiation.

II. RESULTS

Since the IARC evaluation in 2011 more studies have been published that support a causal association between RF radiation and brain and head tumors. In the following an updated summary is given of case-control studies on brain and head tumors; glioma, meningioma and acoustic neuroma. The Danish cohort study on 'mobile phone users' (Johansen et al., 2001; Schüz et al., 2006) is not included due to serious methodological shortcomings in the study design, see (Söderqvist et al., 2012). The study by Benson et al. (2013) is of limited value since use of cordless phones were not included, mobile phone use was assessed only at baseline and no information on tumor laterality including ipsilateral *versus* contralateral use were given. In spite of the many shortcomings an increased risk for acoustic neuroma was reported. The study will not be further discussed below.

Glioma

Glioma is the most common malignant brain tumor and represents about 60 % of all central nervous system (CNS) tumors. Most of these are astrocytic tumors divided into low-grade (WHO grades I-II) and high-grade (WHO grades III-IV). The most common glioma type is glioblastoma multiforme (WHO grade IV) with the peak incidence in the age group 45-75 years and median survival less than

one year (Ohgaki and Kleihues 2005). Three research groups have provided results in case-control studies on glioma, Interphone (Interphone, 2010), Coureau et al., (2014) and Hardell and Carlberg (2015). Our study group has published results from case- control studies since the late 1990's on use of wireless phones and brain tumor risk (Hardell et al., 1999), for more discussion, see (Carlberg and Hardell, 2017).

Random effects model was used for meta-analyses of published studies, based on test for heterogeneity in the overall group ("all mobile"). Note that only our group assessed also use of cordless phones. Thus the reference category in our studies included cases and controls with no use of wireless phones in contrast to the other studies investigating only mobile phone use. Including cordless phone use in the 'unexposed' group would bias the risk estimates towards unity.

In Table 1 results for highest cumulative use in hours of mobile phones is given. All studies reported statistically significant increased risk for glioma and the meta-analysis yielded odds ratio (OR) = 1.90, 95 % confidence interval (CI) = 1.31-2.76. For ipsilateral mobile phone use the risk increased further to OR = 2.54, 95 % CI = 1.83-3.52 in the meta-analysis based on 247 exposed cases and 202 exposed controls. Further support for the increased risk of glioma associated with mobile phone use has been obtained in additional analyses of parts of the Interphone study (Cardis et al., 2011; Grell et al., 2016; Momoli et al., 2017).

We analyzed survival of the patients in our studies and found shorter survival in patients with glioblastoma multiforme associated with use of wireless phones compared with patients with no use (Carlberg and Hardell, 2014). Interestingly mutation of the p53 gene involved in disease progression has been reported in glioblastoma multiforme in patients with mobile phone use $\geq$3 hours per day. The mutation was statistically significant correlated with shorter overall survival time (Akhavan-Sigari et al., 2014).

Meningioma

Meningioma is an encapsulated, well-demarked and rarely malignant tumor. It is the most common benign brain tumor that accounts for about 30 % of intracranial neoplasms. It develops from the pia and arachnoid membranes that cover CNS. It is slow growing and gives neurological symptoms by compression of adjacent structures. Most common are headaches and seizures. The incidence is about two times higher in women than in men and meningioma develops mostly among middle aged and older persons (Cea-Soriano et al., 2012). The same research groups as for glioma included also meningioma in their case-control studies with a separate publication on meningioma by Carlberg and

Hardell (2015). Results of the meta-analyses for cumulative exposure in highest exposure category are given in Table 2. In total somewhat, but not statistically significant, increased risk was obtained increasing to OR = 1.49, 95 % CI = 1.08-2.06 for ipsilateral use of mobile phone.

Acoustic neuroma

Acoustic neuroma, also called vestibular schwannoma, is a benign tumor located on the eight cranial nerve from the inner ear to the brain. It is usually encapsulated and grows in relation to the auditory and vestibular portions of the nerve. It grows slowly and due to the narrow anatomical space may give compression of vital brain stem structures. First symptoms of acoustic neuroma are usually tinnitus and hearing problems. Results for use of mobile phones in Interphone (2011) and Hardell et al., (2013) are given in Table 3. Statistically significant increased risk was found for cumulative ipsilateral use $\geq$ 1,640 h yielding OR = 2.71, 95 % CI = 1.72-4.28.

The study by Moon et al. (2014) was not included in the meta-analysis since data on cumulative mobile phone use with numbers of cases and controls were not given. Support of an increased risk was seen in the case-case part of the study (Moon et al., 2014), as also reported by Sato et al., (2011) in their case-case analysis. Pettersson (2014) made a case-control study on acoustic neuroma in Sweden not overlapping our study (Pettersson et al., 2014). An increased risk for highest category of cumulative use of both mobile phone ($\geq$ 680 h OR = 1.46, 95 % CI = 0.98-2.17) and cordless phone ($\geq$900 hours OR = 1.67, 95 % CI = 1.13-2.49) was found. We did not include that study in our meta-analysis due to the many scientific shortcomings in the study, e.g. laterality analysis was not made for cordless phone and the numbers in the laterality analysis for mobile phone are not consistent in text and tables and obviously not correct, and the 'unexposed' reference category included subjects using either mobile or cordless phone (Hardell and Carlberg 2014).

The Danish part of Interphone study reported mean tumor volume 1.66 cm^3 among regular mobile phone users and 1.39 cm^3 for non-users (p = 0.03) (Christensen et al., 2004). We analyzed percentage change in tumor volume per year of latency and 100 h of cumulative use (Hardell et al., 2013). For all types of wireless phones the percentage of tumor volume increased, statistically significant for analogue mobile phones. Moon et al., (2014) reported statistically significant larger mean tumor volume for heavy users (11.32 $\pm$ 15.43 cm^3) compared with light users (4.88 $\pm$ 5.60 cm^3) based on daily amount of mobile phone use (p = 0.026). Similar results were found for cumulative hours of use. Taken together these results support tumor promotion by RF radiation.

III. CONCLUSIONS

Based on case-control studies there is a consistent finding of increased risk for glioma and acoustic neuroma associated with use of mobile phones. Similar results are found for cordless phones in the Hardell group studies. The findings are less consistent for meningioma although somewhat increased risk was seen in the meta-analysis of ipsilateral mobile phone use. A longer follow-up time is necessary for this type of slow growing tumor.

The results on glioma and acoustic neuroma are supported by results from animal studies showing co-carcinogenic and tumor promoting effects from RF radiation (Tillman et al., 2010; Lerchl et al., 2015). Recent results from the National Toxicology Program (NTP) study showed genotoxicity of RF radiation in rats and mice exposed to RF radiation (Smith-Roe et al., 2017). That result supports previous findings of DNA strand breaks in rat brain cells exposed to RF radiation (Lai and Singh, 1997).

Interestingly extremely low-frequency electromagnetic field (ELF-EMF) promotes a more malignant phenotype in neuroblastoma cells (Falone et al., 2017). ELF-EMF induced a proliferative and survival advantage by activating key redox-responsive antioxidative and detoxification cytoprotective pathways associated with a more aggressive behaviour of neuroblastoma cells. These results support epidemiological findings of late stage glioma carcinogenesis (promotion) from occupational ELF-EMF exposure (Turner et al., 2016; Carlberg et al., 2017).

Of importance are also results in the NTP study with increased incidence of tumors of the similar types, glioma and malignant schwannoma, as in humans (Wyde et al., 2016). Acoustic neuroma (vestibular schwannoma) is a similar type of tumor as malignant schwannoma although benign.

One mechanism in carcinogenesis could be oxidative stress with productions of reactive oxygen species (ROS) as summarised by Yakymenko et al., (2016). This could be an indirect mechanism for the increased brain and head tumor risk (Megha et al., 2015) since ROS may result in DNA damage.

By now carcinogenicity has been shown in human epidemiological studies replicated in animal studies. Laboratory studies on RF radiation have shown increased ROS production that can cause DNA strand breaks. In 2013, we published the conclusion that RF radiation should be regarded as a human carcinogen Group 1 according to IARC definition, based on scientific evidence (Hardell and Carlberg, 2013) further supported in our up-dated article (Carlberg and Hardell, 2017)

Clearly also based on the IARC preamble to the monographs, RF radiation should be classified as

Group 1: The agent is *carcinogenic* to humans:

> *"This category is used when there is sufficient evidence of carcinogenicity in humans. Exceptionally, an agent may be placed in this category when evidence of carcinogenicity in humans is less than sufficient but there is sufficient evidence of carcinogenicity in experimental animals and strong evidence in exposed humans that the agent acts through a relevant mechanism of carcinogenicity."*
>
> (*http://monographs.iarc.fr/ENG/Preamble/currentb6evalrationale0706.php)*

IV. REFERENCES

Akhavan-Sigari R, Baf MM, Ariabod V, Rohde V, Rahighi S. 2014. Connection between cell phone use, p53 gene expression in different zones of glioblastoma multiforme and survival prognoses, Rare Tumors 6:5350.

Baan R, Grosse Y, Lauby-Secretan B, El Ghissassi F, Bouvard V, Benbrahim-Tallaa L, et al. 2011. Carcinogenicity of radiofrequency electromagnetic fields. Lancet Oncol. 12:624–626.

Benson VS, Pirie K, Schüz J, Reeves GK, Beral V, Green J; 2013. Million Women Study Collaborators. Mobile phone use and risk of brain neoplasms and other cancers: prospective study. Int J Epidemiol. 42:792-802.

BioInitiative Working Group. BioInitiative Report: A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF). Sage C and Carpenter DO (eds.). Bioinitiative, 2007. Available online: http://www.bioinitiative.org/table-of-contents/ (accessed on 11 October, 2017).

BioInitiative Working Group. BioInitiative 2012. A Rationale for a Biologically-based Exposure Standard for Electromagnetic Fields (ELF and RF). Sage C and Carpenter DO (eds.). Bioinitiative, 2012. Available online: http://www.bioinitiative.org/table-of-contents/ (accessed on 11 October, 2017).

BioInitiative Working Group. BioInitiative 2014 Supplement. A Rationale for a Biologically-based Exposure Standard for Electromagnetic Fields (ELF and RF). Sage C and Carpenter DO (eds.). Bioinitiative, 2012. Available online: http://www.bioinitiative.org/table-of-contents/. (accessed on 9 November, 2017).

Cardis E, Deltour I, Mann S, Moissonnier M, Taki M, Varsier N, et al. 2008. Distribution of RF energy emitted by mobile phones in anatomical structures of the brain. Phys Med Biol. 53:2771-2783.

Cardis E, Armstrong BK, Bowman JD, Giles GG, Hours M, Krewski D, et al. 2011. Risk of brain tumours in relation to estimated RF dose from mobile phones: results from five Interphone countries. Occup Environ Med. 68:631-640.

Carlberg M, Hardell L. 2014. Decreased survival of glioma patients with astrocytoma grade IV (glioblastoma multiforme) associated with long-term use of mobile and cordless phones. Int J Environ Res Public Health 11:10790-10805.

Carlberg M, Hardell L. 2015. Pooled analysis of Swedish case-control studies during 1997-2003 and 2007-2009 on meningioma risk associated with the use of mobile and cordless phones. Oncol Rep. 33:3093-3098.

Carlberg M, Hardell L. 2017. Evaluation of mobile phone and cordless phone use and glioma risk using the Bradford Hill viewpoints from 1965 on association or causation. Biomed Res Int. 9218486.

Carlberg M, Koppel T, Ahonen M, Hardell L. 2017. Case-control study on occupational exposure to extremely low-frequency electromagnetic fields and glioma risk. Am J Ind Med. 60:494-503.

Cea-Soriano L, Wallander MA, García Rodríguez LA. 2012. Epidemiology of meningioma in the United Kingdom. Neuroepidemiology 39:27-34.

Christensen HC, Schüz J, Kosteljanetz M, Poulsen HS, Thomsen J, Johansen C. 2004. Cellular telephone use and risk of acoustic neuroma. Am J Epidemiol. 159:277-283.

Coureau G, Bouvier G, Lebailly P, Fabbro-Peray P, Gruber A, Leffondre K, et al. 2014. Mobile phone use and brain tumours in the CERENAT case-control study. Occup Environ Med. 71:514-522.

Falone S, Santini S Jr, Cordone V, Cesare P, Bonfigli A, Grannonico M, et al. 2017. Power frequency magnetic field promotes a more malignant phenotype in neuroblastoma cells via redox-related mechanisms. Sci Rep. 7:11470. doi: 10.1038/s41598-017-11869-8.

Gandhi OP, Morgan LL, de Salles AA, Han YY, Herberman RF, Davis DL. 2012. Exposure limits: the underestimation of absorbed cell phone radiation, especially in children. Electromagn Biol Med. 31:34-51.

Grell K, Frederiksen K, Schüz J, Cardis E, Armstrong B, Siemiatycki J, et al. 2016. The intracranial distribution of gliomas in relation to exposure from mobile phones: Analyses from the INTERPHONE study. Am J Epidemiol. 184:818-828.

Hardell L, Carlberg M. 2013. Using the Hill viewpoints from 1965 for evaluating strengths of evidence of the risk for brain tumors associated with use of mobile and cordless phones. Rev Environ Health. 28:97-106.

Hardell L, Carlberg M. 2014. Long-term mobile phone use and acoustic neuroma. Epidemiology 25:778.

Hardell L, Carlberg M. 2015. Mobile phone and cordless phone use and the risk for glioma – Analysis of pooled case-control studies in Sweden, 1997-2003 and 2007-2009. Pathophysiology 22:1-13.

Hardell L, Näsman Å, Påhlson A, Hallquist A, Hansson Mild K. 1999. Use of cellular telephones and the risk for brain tumours: A case-control study. Int J Oncol. 15:113-116.

Hardell L, Carlberg M, Söderqvist F, Hansson Mild K. 2013. Pooled analysis of case-control studies on acoustic neuroma diagnosed 1997-2003 and 2007-2009 and use of mobile and cordless phones. Int J Oncol. 43:1036-1044.

Hardell L, Koppel T, Carlberg M, Ahonen M, Hedendahl L. 2016. Radiofrequency radiation at Stockholm Central Railway Station in Sweden and some medical aspects on public exposure to RF fields. Int J Oncol. 49:1315-1324.

Hardell L, Carlberg M, Koppel T, Hedendahl L. 2017. High radiofrequency radiation at Stockholm Old Town: An exposimeter study including the Royal Castle, Supreme Court, three major squares and the Swedish Parliament. Mol Clin Oncol. 6:462-476.

Hedendahl L, Carlberg M, Hardell L. 2015. Electromagnetic hypersensitivity - an increasing challenge to the medical profession. Rev Environ Health 30:209-215.

IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 102. 2013.Non-Ionizing Radiation, Part 2: Radiofrequency Electromagnetic Fields. Lyon, France: International Agency for Research on Cancer. Available from: http://monographs.iarc.fr/ENG/Monographs/vol102/mono102.pdf (accessed on 11 October, 2017).

International Commission on Non-Ionizing Radiation Protection. 1998. Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health Phys. 74:494-522.

International Commission on Non-Ionizing Radiation Protection. 2009. ICNIRP statement on the "Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz)". Health Phys. 97:257-258.

Interphone Study Group. 2010. Brain tumour risk in relation to mobile telephone use: results of the INTERPHONE international case-control study. Int J Epidemiol. 39:675-694.

Interphone Study Group. 2011. Acoustic neuroma risk in relation to mobile telephone use: results of the INTERPHONE international case-control study. Cancer Epidemiol. 35:453-464.

Johansen C, Boice J Jr, McLaughlin J, Olsen J. 2001. Cellular telephones and cancer – a nationwide cohort study in Denmark. J Natl Cancer Inst. 93:203–207.

Lai H, Singh NP. 1997. Melatonin and a spin-trap compound block radiofrequency electromagnetic radiation-induced DNA strand breaks in rat brain cells. Bioelectromagnetics. 18:446-454.

Lerchl A, Klose M, Grote K, Wilhelm AF, Spathmann O, Fiedler T, et al. 2015. Tumor promotion by exposure to radiofrequency electromagnetic fields below exposure limits for humans. Biochem Biophys Res Commun. 459:585-590.

Megha K, Deshmukh PS, Banerjee BD, Tripathi AK, Ahmed R, Abegaonkar MP. 2015. Low intensity microwave radiation induced oxidative stress, inflammatory response and DNA damage in rat brain. Neurotoxicology 51:158-165.

Michaels D. 2008. Doubt is Their Product. How Industry's Assault on Science Threatens Your Health. Oxford University Press, New York.

Momoli F, Siemiatycki J, McBride ML, Parent ME, Richardson L, Bedard D, et al. 2017. Probabilistic multiple-bias modeling applied to the Canadian data from the INTERPHONE study of mobile phone use and risk of glioma, meningioma, acoustic neuroma, and parotid gland tumors. Am J Epidemiol. 186:885-893.

Moon IS, Kim BG, Kim J, Lee JD, Lee WS. 2014. Association between vestibular schwannomas and mobile phone use. Tumour Biol. 35:581-587.

Ohgaki H, Kleihues P. 2005. Population-based studies on incidence, survival rates, and genetic alterations in astocytic and oligodendroglial gliomas. J Neuropath Exp Neurol. 64:479-489.

Ong EK, Glantz SA. 2000. Tobacco industry efforts subverting International Agency for Research on Cancer's second-hand smoke study. Lancet 355:1253-1259.

Pettersson D, Mathiesen T, Prochazka M, Bergenheim T, Florentzson R, Harder H, et al. 2014. Long-term mobile phone use and acoustic neuroma risk. Epidemiology 25:233-241.

Sato Y, Akiba S, Kubo O, Yamaguchi N. 2011. A case-case study of mobile phone use and acoustic neuroma risk in Japan. Bioelectromagnetics 32:85-93.

Schüz J, Jacobsen R, Olsen JH, Boice JD Jr, McLaughlin JK, et al. 2006. Cellular telephone use and cancer risk: update of a nationwide Danish cohort. J Natl Cancer Inst. 98:1707 – 1713.

Smith-Roe SL, Wyde ME, Stout MD, Winters JW, Hobbs CA, Shepard KG, et al. 2017. Evaluation of the genotoxicity of cell phone radiofrequency radiation in male and female rats and mice following subchronic exposure. Environmental Mutagenesis and Genomics Society, Annual Meeting, Raleigh, North Carolina, USA September 9-13, 2017.

Söderqvist F, Carlberg M, Hardell L. 2012. Review of four publications on the Danish cohort study on mobile phone subscribers and risk of brain tumors. Rev Env Health 27:51-58.

Tillmann T, Ernst H, Streckert J, Zhou, Y, Taugner F, Hansen V, et al. 2010. Indication of cocarcinogenic potential of chronic UMTS-modulated radiofrequency exposure in an ethylnitrosourea mouse model. Int J Radiat Biol. 86:529-541.

Turner MC, Benke G, Bowman JD, Figuerola J, Fleming S, Hours M, Kincl L, Krewski D, McLean D, Parent ME, et al. 2014. Occupational exposure to extremely low-frequency magnetic fields and brain tumor risks in the INTEROCC study. Cancer Epidemiol Biomarkers Prev. 23:1863-1872.

Walker MJ. 2017. Corporate Ties that Bind. An Examination of Corporate Manipulation and Vested Interest in Public Health. Skyhorse Publishing, New York.

Wyde M, Cesta M, Blystone C, Elmore S, Foster P, Hooth M, et al. 2016. Report of Partial Findings from the National Toxicology Program Carcinogenesis Studies of Cell Phone Radiofrequency Radiation in Hsd: Sprague Dawley® SD rats (Whole Body Exposures). Draft 5-19-2016. US National Toxicology Program (NTP), 2016. DOI: http://dx.doi.org/10.1101/055699. Available online: http://biorxiv.org/content/biorxiv/early/2016/05/26/055699.full.pdf (accessed on 11 October, 2017).

Yakymenko I, Tsybulin O, Sidorik E, Henshel D, Kyrylenko O, Kyrylenko S. 2016. Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation. Electromagn Biol Med. 35:186-202.

Table 1. Numbers of exposed cases (Ca) and controls (Co) and odds ratio (OR) with 95 % confidence interval (CI) for glioma in case-control studies in the highest category of cumulative use in hours for mobile phone use.

	All			**Ipsilateral**		
	Ca/Co	OR	95 % CI	Ca/Co	OR	95 % CI
Interphone 2010						
Cumulative use ≥1,640 h	210/154	1.40	1.03 – 1.89	100/62	1.96	1.22 – 3.16
Coureau et al 2014						
Cumulative use ≥896 h	24/22	2.89	1.41 – 5.93	9/7	2.11	0.73 – 6.08
Hardell, Carlberg 2015						
Cumulative use ≥1,640 h	211/301	2.13	1.61 – 2.82	138/133	3.11	2.18 – 4.44
Meta-analysis						
Cumulative use ≥1,640 h*	445/477	1.90	1.31 – 2.76	247/202	2.54	1.83 – 3.52

**≥896 h used for Coureau et al.*

Table 2. Numbers of exposed cases (Ca) and controls (Co) and odds ratio (OR) with 95 % confidence interval (CI) for meningioma in case-control studies in the highest category of cumulative use in hours for mobile phone use.

	All			**Ipsilateral**		
	Ca/Co	OR	95 % CI	Ca/Co	OR	95 % CI
Interphone 2010						
Cumulative use ≥1,640 h	130/107	1.15	0.81 – 1.62	46/35	1.45	0.80 – 2.61
Coureau et al 2014						
Cumulative use ≥896 h	13/9	2.57	1.02 – 6.44	6/4	2.29	0.58 – 8.97
Carlberg et al 2013						
Cumulative use ≥1,640 h	141/301	1.24	0.93 – 1.66	67/133	1.46	0.98 – 2.17
Meta-analysis						
Cumulative use ≥1,640 h*	284/417	1.27	0.98 – 1.66	119/172	1.49	1.08 – 2.06

**≥896 h used for Coureau et al.*

Table 3. Numbers of exposed cases (Ca) and controls (Co) and odds ratio (OR) with 95 % confidence interval (CI) for acoustic neuroma in case-control studies in the highest category of cumulative use in hours for mobile phone use..

	All			**Ipsilateral**		
	Ca/Co	OR	95 % CI	Ca/Co	OR	95 % CI
Interphone 2010						
Cumulative use ≥1,640 h	77/107	1.32	0.88 – 1.97	47/46	2.33	1.23 – 4.40
Hardell et al 2013						
Cumulative use ≥1,640 h	27/301	2.40	1.39 – 4.16	19/133	3.18	1.65 – 6.12
Meta-analysis						
Cumulative use ≥1,640 h	104/408	1.73	0.96 – 3.09	66/179	2.71	1.72 – 4.28