NIH NATIONAL CANCER INSTITUTE

Cell Phones and Cancer Risk

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Why has there been concern that cell phones may cause cancer?

There are two main reasons why people are concerned that cell (or mobile) phones might have the potential to cause certain types of cancer or other health problems: Cell phones emit radiation (in the form of radiofrequency radiation, or radio waves), and cell phone use is widespread. Even a small increase in cancer risk from cell phones would be of concern given how many people use them.

Brain and central nervous system cancers have been of particular concern because hand-held phones are used close to the head and because ionizing radiation—a higher energy form of radiation than what cell phones emit—has been found to cause some brain cancers. Many different kinds of studies have been carried out to try to investigate whether cell phone use is dangerous to human health.

However, the evidence to date suggests that cell phone use does not cause brain or other kinds of cancer in humans.

Is the radiation from cell phones harmful?

Cell phones emit radiation in the radiofrequency region of the electromagnetic spectrum. Second-, third-, and fourth-generation cell phones (2G, 3G, 4G) emit radiofrequency in the frequency range of 0.7–2.7 GHz. Fifth-generation (5G) cell phones are anticipated to use the frequency spectrum up to 80 GHz.

These frequencies all fall in the nonionizing range of the spectrum, which is low frequency and low energy. The energy is too low to damage DNA. By contrast, ionizing radiation, which includes x-rays, radon, and cosmic rays, is high frequency and high energy. Energy from ionizing radiation can damage DNA. DNA damage can cause changes to genes that may increase the risk of cancer.

The NCI fact sheet Electromagnetic Fields and Cancer lists sources of radiofrequency radiation. More information about ionizing radiation can be found on the Radiation page.

The human body does absorb energy from devices that emit radiofrequency radiation. The only consistently recognized biological effect of radiofrequency radiation absorption in humans that the general public might encounter is heating to the area of the body where a cell phone is held (e.g., the ear and head). However, that heating is not sufficient to measurably increase core body temperature. There are no other clearly established dangerous health effects on the human body from radiofrequency radiation.

Has the incidence of brain and central nervous system cancers changed during the time cell phone use increased?

No. Investigators have studied whether the incidence of brain or other central nervous system cancers (that is, the number of new cases of these cancers diagnosed each year) has changed during the time that cell phone use increased dramatically. These studies found:

- stable incidence rates for adult gliomas in the United States (1), Nordic countries (2) and Australia (3) during the past several decades
- stable incidence rates for pediatric brain tumors in the United States during 1993–2013 (4)
- stable incidence rates for acoustic neuroma (5), which are nonmalignant tumors, and meningioma (6), which are usually nonmalignant, among US adults since 2009

In addition, studies using cancer incidence data have tested different scenarios (simulations) determining whether the incidence trends are in line with various levels of risk as reported in studies of cell phone use and brain tumors between 1979 and 2008 (7, 8). These simulations showed that many risk changes reported in case–control studies were not consistent with incidence data, implying that biases and errors in the study may have distorted the findings.

Because these studies examine cancer incidence trends over time in populations rather than comparing risk in people who do and don't use cell phones, their ability to observe potential small differences in risk among heavy users or susceptible populations is limited. Observational/epidemiologic studies—including case–control and cohort studies (described below)—

are designed to measure individual exposure to cell phone radiation and ascertain specific health outcomes.

How is radiofrequency radiation exposure measured in studies of groups of people?

Epidemiologic studies use information from several sources, including questionnaires and data from cell phone service providers, to estimate radiofrequency radiation exposure in groups of people. Direct measurements are not yet possible outside of a laboratory setting. Estimates from studies reported to date take into account the following:

- How regularly study participants use cell phones (the number of calls per week or month)
- The age and the year when study participants first used a cell phone and the age and the year of last use (allows calculation of the duration of use and time since the start of use)
- The average number of cell phone calls per day, week, or month (frequency)
- The average length of a typical cell phone call
- The total hours of lifetime use, calculated from the length of typical call times, the frequency of use, and the duration of use

What has research shown about the link between cell phone use and cancer risk?

Researchers have carried out several types of population studies to investigate the possibility of a relationship between cell phone use and the risk of tumors, both malignant (cancerous) and nonmalignant (not cancer). Epidemiologic studies (also called observational studies) are research studies in which investigators observe groups of individuals (populations) and collect information about them but do not try to change anything about the groups.

Two main types of epidemiologic studies—cohort studies and case–control studies—have been used to examine associations between cell phone use and cancer risk. In a case–control study, cell phone use is compared between people who have tumors and people who don't. In a cohort study, a large group of people who do not have cancer at the beginning of the study is followed over time and tumor development in people who did and didn't use cell phones is compared. Cohort studies are limited by the fact that they may only be able to look at cell phone subscribers, who are not necessarily the cell phone users.

The tumors that have been investigated in epidemiologic studies include malignant brain tumors, such as gliomas, as well as nonmalignant tumors, such as acoustic neuroma (tumors in the cells of the nerve responsible for hearing that are also known as vestibular schwannomas), meningiomas (usually nonmalignant tumors in the membranes that cover and protect the brain and spinal cord), parotid gland tumors (tumors in the salivary glands), skin cancer, and thyroid gland tumors.

Four large epidemiologic studies have examined the possible association between cell phone use and cancer: Interphone, a case–control study, and three cohort studies, the Danish Study, the Million Women Study, and the Cohort Study on Mobile Phones and Health (COSMOS). The findings of these studies are mixed, but overall, they do not show an association between cell phone use and cancer (9–23).

Interphone Case–Control Study

How the study was done: This is the largest case–control study of cell phone use and the risk of head and neck tumors. It was conducted by a consortium of researchers from 13 countries. The data came from questionnaires that were completed by study participants in Europe, Israel, Canada, Australia, New Zealand, and Japan.

What the study showed: Most published analyses from this study have shown no increases overall in brain or other central nervous system cancers (glioma and meningioma) related to higher amounts of cell phone use. One analysis showed a statistically significant, although small, increase in the risk of glioma among study participants who spent the most total time on cell phone calls. However, for a variety of reasons the researchers considered this finding inconclusive (11–13).

An analysis of data from all 13 countries reported a statistically significant association between intracranial distribution of tumors within the brain and self-reported location of the phone (14). However, the authors of this study noted that it is not possible to draw firm conclusions about cause and effect based on their findings.

An analysis of data from five Northern European countries showed an increased risk of acoustic neuroma in those who had used a cell phone for 10 or more years (15).

In subsequent analyses of Interphone data, investigators investigated whether tumors were more likely to form in areas of the brain with the highest exposure. One analysis showed no relationship between tumor location and level of radiation (16). However, another found evidence that glioma and, to a lesser extent, meningioma were more likely to develop where exposure was highest (17).

Danish Cohort Study

How the study was done: This cohort study linked billing information from more than 358,000 cell phone subscribers with brain tumor incidence data from the Danish Cancer Registry.

What the study showed: No association was observed between cell phone use and the incidence of glioma, meningioma, or acoustic neuroma, even among people who had been cell phone subscribers for 13 or more years (18–20).

Million Women Cohort Study

How the study was done: This prospective cohort study conducted in the United Kingdom used data obtained from questionnaires that were completed by study participants.

What the study showed: Self-reported cell phone use was not associated with an increased risk of glioma, meningioma, or non-central nervous system tumors. Although the original published findings

reported an association with an increased risk of acoustic neuroma (21), it was not observed with additional years of follow-up of the cohort (22).

Cohort Study of Mobile Phones and Health (COSMOS)

How the study was done: This large prospective cohort study conducted in Denmark, Finland, Sweden, the Netherlands, and the United Kingdom used data on health, lifestyle, and current and past cell phone use obtained from a questionnaire completed by participants when they joined the study. That information was supplemented with cancer occurrence data obtained from linkage to national cancer registries and cell phone records obtained from mobile network operators.

What the study showed: Among 264,574 participants with a median follow-up of just over 7 years, the cumulative amount of mobile phone call-time was not associated with the risk of developing glioma, meningioma, or acoustic neuroma (23). No associations with cancer risk were seen in the heaviest mobile phone users or among among those with the longest history of mobile phone use (15 or more years).

Other Epidemiologic Studies

In addition to these four large studies, other, smaller epidemiologic studies have looked for associations between cell phone use and individual cancers in both adults and children. These include:

- Two NCI-sponsored case–control studies, each conducted in multiple US academic medical centers or hospitals between 1994 and 1998 that used data from questionnaires (24) or computer-assisted personal interviews (25). Neither study showed a relationship between cell phone use and the risk of glioma, meningioma, or acoustic neuroma in adults.
- The CERENAT study, another case–control study conducted in multiple areas in France from 2004 to 2006 using data collected in face-to-face interviews using standardized questionnaires (26). This study found no association for either gliomas or meningiomas when comparing adults who were regular cell phone users with non-users. However, the heaviest users had significantly increased risks of both gliomas and meningiomas.
- A pooled analysis of two case–control studies conducted in Sweden that reported statistically significant trends of increasing brain cancer risk for the total amount of cell phone use and the years of use among people who began using cell phones before age 20 (27).
- Another case–control study in Sweden, part of the Interphone pooled studies, did not find an increased risk of brain cancer among long-term cell phone users between the ages of 20 and 69 (28).
- The CEFALO study, an international case–control study of children diagnosed with brain cancer between ages 7 and 19, found no relationship between their cell phone use and risk for brain cancer (29).
- The MOBI-Kids study, a large international case–control study of young people ages 10 to 24 years diagnosed with brain tumors, found no evidence of an association between wireless phone use and the risk of brain tumors (30).
- A population-based case–control study conducted in Connecticut found no association between cell phone use and the risk of thyroid cancer (31).

What are the findings from studies of the human body?

Researchers have carried out several kinds of studies to investigate possible effects of cell phone use on the human body. In 2011, two small studies were published that examined brain glucose metabolism in people after they had used cell phones. The results were inconsistent. One study showed increased glucose metabolism in the region of the brain close to the antenna compared with tissues on the opposite side of the brain (32); the other study (33) found reduced glucose metabolism on the side of the brain where the phone was used.

The authors of these studies noted that the results were preliminary and that possible health outcomes from changes in glucose metabolism in humans were unknown. Such inconsistent findings are not uncommon in experimental studies of the physiological effects of radiofrequency electromagnetic radiation in people (11). Some factors that can contribute to inconsistencies across such studies include assumptions used to estimate doses, failure to consider temperature effects, and investigators not being blinded to exposure status.

Another study investigated blood flow in the brain of people exposed to radiofrequency radiation from cell phones and found no evidence of an effect on blood flow in the brain (34).

What are the findings from experiments in laboratory animals?

Early studies involving laboratory animals showed no evidence that radiofrequency radiation increased cancer risk or enhanced the cancer-causing effects of known chemical carcinogens (35–38).

Because of inconsistent findings from epidemiologic studies in humans and the lack of clear data from previous experimental studies in animals, in 1999 the Food and Drug Administration (FDA) nominated radiofrequency radiation exposure associated with cell phone exposures for study in animal models by the US National Toxicology Program (NTP). NTP is an interagency program that coordinates toxicology research and testing across the US Department of Health and Human Services and is headquartered at the National Institute of Environmental Health Sciences, part of NIH.

The NTP studied radiofrequency radiation (2G and 3G frequencies) in rats and mice (39, 40). This large project was conducted in highly specialized labs. The rodents experienced whole-body exposures of 3, 6, or 9 watts per kilogram of body weight for 5 or 7 days per week for 18 hours per day in cycles of 10 minutes on, 10 minutes off. A research overview of the rodent studies, with links to the peer-review summary, is available on the NTP website. The primary outcomes observed were a small number of cancers of Schwann cells in the heart and non-cancerous changes (hyperplasia) in the same tissues for male rats, but not female rats, nor in mice overall.

These experimental findings raise new questions because cancers in the heart are extremely rare in humans. Schwann cells of the heart in rodents are similar to the kind of cells in humans that give rise to acoustic neuromas (also known as vestibular schwannomas), which some studies have suggested are increased in people who reported the heaviest use of cell phones. The NTP plans to continue to study radiofrequency exposure in animal models to provide insights into the biological changes that might explain the outcomes observed in their study.

Another animal study, in which rats were exposed 7 days per week for 19 hours per day to radiofrequency radiation at 0.001, 0.03, and 0.1 watts per kilogram of body weight was reported by investigators at the Italian Ramazzini Institute (41). Among the rats with the highest exposure levels, the researchers noted an increase in heart schwannomas in male rats and nonmalignant Schwann cell growth in the heart in male and female rats. However, key details necessary for interpretation of the results were missing: exposure methods, other standard operating procedures, and nutritional/feeding aspects. The gaps in the report from the study raise questions that have not been resolved.

ICNIRP (an independent nonprofit organization that provides scientific advice and guidance on the health and environmental effects of nonionizing radiation) critically evaluated both studies. It concluded that both followed good laboratory practice, including using more animals than earlier research and exposing the animals to radiofrequency radiation throughout their lifetimes. However, it also identified what it considered major weaknesses in how the studies were conducted and statistically analyzed and concluded that these limitations prevent drawing conclusions about the ability of radiofrequency exposures to cause cancer (42).

Why are the findings from different studies of cell phone use and cancer risk inconsistent?

A few studies have shown some evidence of statistical association of cell phone use and brain tumor risks in humans, but most studies have found no association. Reasons for these discrepancies include the following:

- **Recall bias**, which can occur when data about prior habits and exposures are collected from study participants using questionnaires administered after diagnosis of a disease in some of the participants. Study participants who have brain tumors, for example, may remember their cell phone use differently from individuals without brain tumors.
- **Inaccurate reporting**, which can happen when people say that something has happened more often or less often than it actually did. For example, people may not remember how much they used cell phones in a given time period.
- **Morbidity and mortality** among study participants who have brain cancer. Gliomas are particularly difficult to study because of their high death rate and the short survival of people who develop these tumors. Patients who survive initial treatment are often impaired, which may affect their responses to questions.
- **Participation bias**, which can happen when people who are diagnosed with brain tumors are more likely than healthy people (known as controls) to enroll in a research study.
- **Changing technology.** Older studies evaluated radiofrequency radiation exposure from analog cell phones. Today, cell phones use digital technology, which operates at a different frequency and a lower power level than analog phones, and cellular technology continues to change (43).
- **Exposure assessment limitations.** Different studies measure exposure differently, which makes it difficult to compare the results of different studies (44). Investigations of sources and levels of exposure, particularly in children, are ongoing (45).

- **Insufficient follow-up of highly exposed populations.** It may take a very long time to develop symptoms after exposure to radiofrequency radiation, and current studies may not yet have followed participants long enough.
- **Inadequate statistical power and methods** to detect very small risks or risks that affect small subgroups of people specifically
- **Chance** as an explanation of apparent effects may not have been considered.

What are other possible health effects from cell phone use?

The most consistent health risk associated with cell phone use is distracted driving and vehicle accidents (46, 47). Several other potential health effects have been reported with cell phone use. Neurologic effects are of particular concern in young persons. However, studies of memory, learning, and cognitive function have generally produced inconsistent results (48–51).

What have expert organizations said about the cancer risk from cell phone use?

In 2011, the International Agency for Research on Cancer (IARC), a component of the World Health Organization, appointed an expert working group to review all available evidence on the use of cell phones. The working group classified cell phone use as "possibly carcinogenic to humans," based on limited evidence from human studies, limited evidence from studies of radiofrequency radiation and cancer in rodents, and inconsistent evidence from mechanistic studies (11).

The working group indicated that, although the human studies were susceptible to bias, the findings could not be dismissed as reflecting bias alone, and that a causal interpretation could not be excluded. The working group noted that any interpretation of the evidence should also consider that the observed associations could reflect chance, bias, or confounding variables rather than an underlying causal effect. In addition, the working group stated that the investigation of brain cancer risk associated with cell phone use poses complex research challenges.

The American Cancer Society's cell phones page states "It is not clear at this time that RF (radiofrequency) waves from cell phones cause dangerous health effects in people, but studies now being done should give a clearer picture of the possible health effects in the future."

The National Institute of Environmental Health Sciences (NIEHS) states that the weight of the current scientific evidence has not conclusively linked cell phone use with any adverse health problems, but more research is needed.

The US Food and Drug Administration (FDA) notes that studies reporting biological changes associated with radiofrequency radiation have failed to be replicated and that the majority of human epidemiologic studies have failed to show a relationship between exposure to radiofrequency radiation from cell phones and health problems. FDA, which originally nominated this exposure for review by the NTP in 1999, issued a statement on the draft NTP reports released in February 2018, saying "based on this current information, we believe the current safety limits for cell phones are

acceptable for protecting the public health." FDA and the Federal Communications Commission (FCC) share responsibility for regulating cell phone technologies.

The US Centers for Disease Control and Prevention (CDC) states that no scientific evidence definitively answers whether cell phone use causes cancer.

The Federal Communications Commission (FCC) concludes that currently no scientific evidence establishes a definite link between wireless device use and cancer or other illnesses.

In 2015, the European Commission Scientific Committee on Emerging and Newly Identified Health Risks concluded that, overall, the epidemiologic studies on cell phone radiofrequency electromagnetic radiation exposure do not show an increased risk of brain tumors or of other cancers of the head and neck region (9). The committee also stated that epidemiologic studies do not indicate increased risk for other malignant diseases, including childhood cancer (9).

Has radiofrequency radiation from cell phone use been associated with cancer risk in children?

There are theoretical considerations as to why the potential health effects of cell phone use should be investigated separately in children. Their nervous systems are still developing and, therefore, more vulnerable to factors that may cause cancer. Their heads are smaller than those of adults and consequently have a greater proportional exposure to radiation emitted by cell phones. And, children have the potential of accumulating more years of cell phone exposure than adults.

Thus far, the data from studies of children with cancer do not suggest that children are at increased risk of developing cancer from cell phone use. The first published analysis came from a large case–control study called CEFALO, which was conducted in Europe. The study included 352 children who were diagnosed with brain tumors between 2004 and 2008 at the ages of 7 to 19 years. They were matched by age, sex, and geographical region with 646 young people randomly selected from population registries. Researchers did not find an association between cell phone use and brain tumor risk by amount of use or by the location of the tumor (29).

The largest case–control study among children, a 14-country study known as MOBI-Kids, included 899 young people ages 10 to 24 years who were diagnosed with brain tumors between 2010 and 2015. They were matched by sex, age, and region with 1,910 young people who were undergoing surgery for appendicitis. Researchers found no evidence of an association between wireless phone use and brain tumors in young people (30).

Which US federal agencies have a role in evaluating the effects of or regulating cell phones?

The National Institutes of Health (NIH), including the National Cancer Institute (NCI), conducts research on cell phone use and the risks of cancer and other diseases.

FDA and FCC share regulatory responsibilities for cell phones. FDA is responsible for testing and evaluating electronic product radiation and providing information for the public about the radiofrequency energy emitted by cell phones. FCC sets limits on the emissions of radiofrequency energy by cell phones and similar wireless products.

Where can I find more information about radiofrequency radiation from my cell phone?

The dose of the energy that people absorb from any source of radiation is estimated using a measure called the specific absorption rate (SAR), which is expressed in watts per kilogram of body weight (52). The SAR decreases very quickly as the distance to the exposure source increases. For cell phone users who hold their phones next to their head during voice calls, the highest exposure is to the brain, acoustic nerve, salivary gland, and thyroid.

The FCC provides information about the SAR of cell phones produced and marketed within the previous 1 to 2 years. Consumers can access this information using the phone's FCC ID number, which is usually located on the case of the phone, and the FCC's ID search form. SARs for older phones can be found by checking the phone settings or by contacting the manufacturer.

What can cell phone users do to reduce their exposure to radiofrequency radiation?

FDA has suggested some steps that concerned cell phone users can take to reduce their exposure to radiofrequency radiation:

- Reduce the amount of time spent using your cell phone.
- Use speaker mode, head phones, or ear buds to place more distance between your head and the cell phone.
- Avoid making calls when the signal is weak as this causes cell phones to boost RF transmission power.
- Consider texting rather than talking, but don't text while you are driving.

Use of wired or wireless headsets reduces the amount of radiofrequency radiation exposure to the head because the phone is not placed against the head (53). Exposures decline dramatically when cell phones are used hands-free. For example, wireless (Bluetooth) devices (such as headphones and earbuds) use short-range signals that typically transmit radiofrequency waves at power levels 10–400 times lower than cell phones (54).