

Martha Linet, M.D., M.P.H.
Senior Investigator, DCEG

**Radiofrequency (mobile
telephones) Exposures and
Health Risks: Findings and
Controversies**



Radiation Epidemiology & Dosimetry Course

National Cancer Institute

www.dceg.cancer.gov/RadEpiCourse

Radiofrequency (RF) Exposures & Health: Topics

- RF exposures - general
 - > Sources, terminology, measurements, energy levels, biological effects
 - > Occupational & environmental
- RF exposures – mobile phones
 - > Background
 - > Epidemiologic studies: cancer
 - > Experimental studies
 - > IARC designation
 - > Controversies
 - > Ongoing research
 - > Regulation
 - > Protective measures



RF Exposure Sources, Terminology, Measurements, Energy Levels, and Biologic Effects

Sources of Radiofrequency Exposure

■ Mobile telephones

- > 6.9 billion subscriptions globally
- > use is increasing, particularly in low- and middle-income countries
- > in some regions, most reliable or only phones available



■ Base stations

- > a transceiver providing connection between mobile phones & wider telephone network



State to nix cell towers on schools, hospitals

Perfalia Marpakow / iStock

Mumbai: Taking a cue from the widespread concern about mobile towers installed on school and hospital buildings, the Maharashtra government is all set to amend the Development Control (DC) Rules in this regard. Of the 1,600 mobile towers in Mumbai, nearly 600 (or 38%) are atop schools and hospitals. The remaining are on private or commercial buildings.



Mobile towers in Mumbai 1,600
On schools and hospitals 500
6 metres proposed distance from schools and hospitals

"Since fears have been expressed about the radiation from mobile towers, we are ready to remove them from school and hospital buildings," a senior official said TOI on Monday. "Once the DC

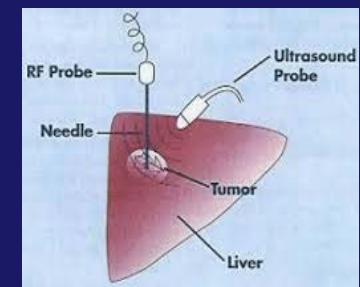
rules are amended, it will be mandatory for the operators to remove the towers within six months."

As per the proposed amendment, the operator will have to submit a certificate stating that the radiation is within the permissible level and not undertaking that the existing tower will be removed within six months. "Now Delhi has already imposed stringent restrictions on mobile towers. We have proposed that they should be at

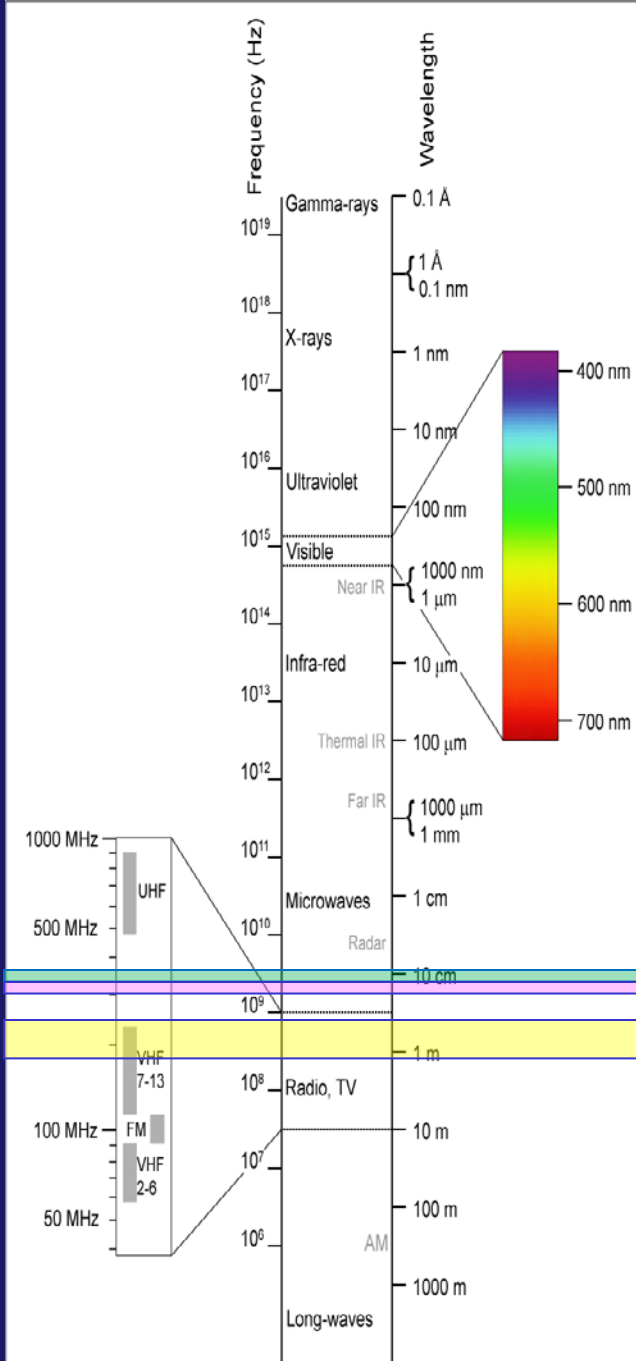
least six metres away from a school or hospital and that the radar should not face the school or hospital," the official said. The proposed measures will be implemented by the concerned civic corporation.

■ Other sources of exposure

- > radar (air traffic, weather, speed control, military)
- > medical treatment devices



Electromagnetic Spectrum



Universal mobile telecommunications system (1900-2200 Mhz)

Digital phones (1800-1900 MHz)

Early analog phones (450 & 900 Mhz)

Terminology

- Mobile phones: low-powered radiofrequency transmitters
 - > frequencies: 450 – 2700 megahertz (MHz)
 - > peak powers: 0.1 – 2 watts
 - > handset transmit power only when turned on
 - > exposure falls off rapidly with \uparrow distance
- Radar systems: object detection system bouncing radio waves off objects to assess range, altitude, direction or speed
 - > frequencies: 300 MHz and 15 Gigahertz (GHz)
 - > intensity: power density in watts/m² ranging from milliwatts or microwatts to 1000 W/m²
- Absorption of RF in tissues measured in Specific Absorption Rate (SAR)

Energy Levels and Biological Effects

- Energy levels

- > low, orders of magnitude less than x-rays
- > doesn't break molecular bonds

- Biological effects

- > known: thermal
- > activation proteins & genes?
- > brain glucose metabolism?
- > cancer?
- > diseases and disorders other than cancer?

Occupational and Environmental RF Exposures and Cancer

Occupational & Environmental RF Exposures and Cancer Risks

- Occupational RF exposures
 - 195,775 Motorola workers: no brain cancer excess
 - 49,581 U.S. Navy exposed to high-intensity radar: no brain tumor excess, but ↑ non-lymphocytic leukemia in high-exposure group
- Residential sources
 - inconsistent evidence, mostly null, for increased cancer in residents near base stations



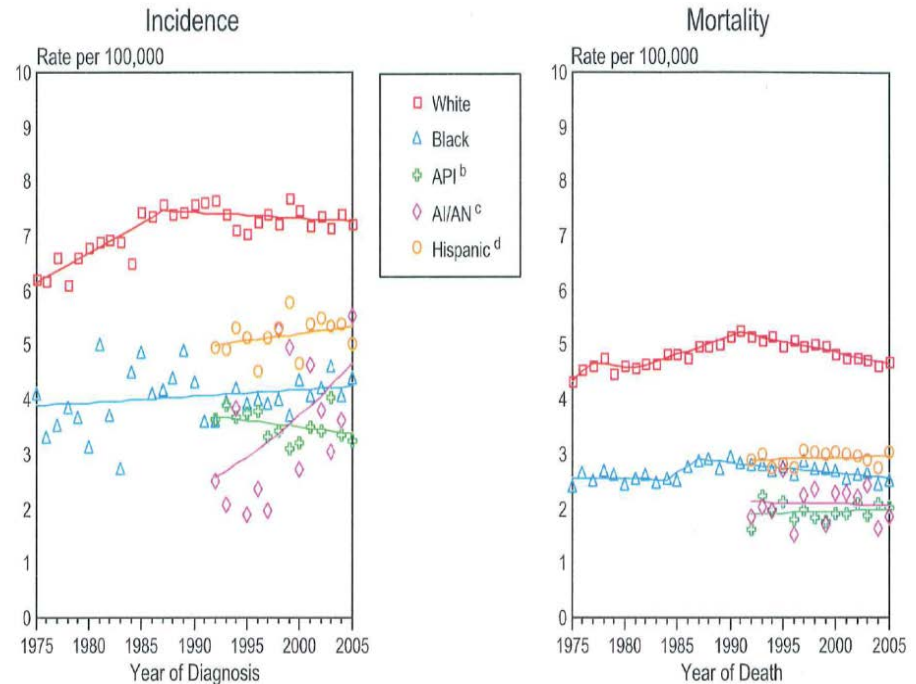
Mobile Phones and Cancer

Background, Epidemiologic Studies,
Experimental Studies, IARC Designation

Background

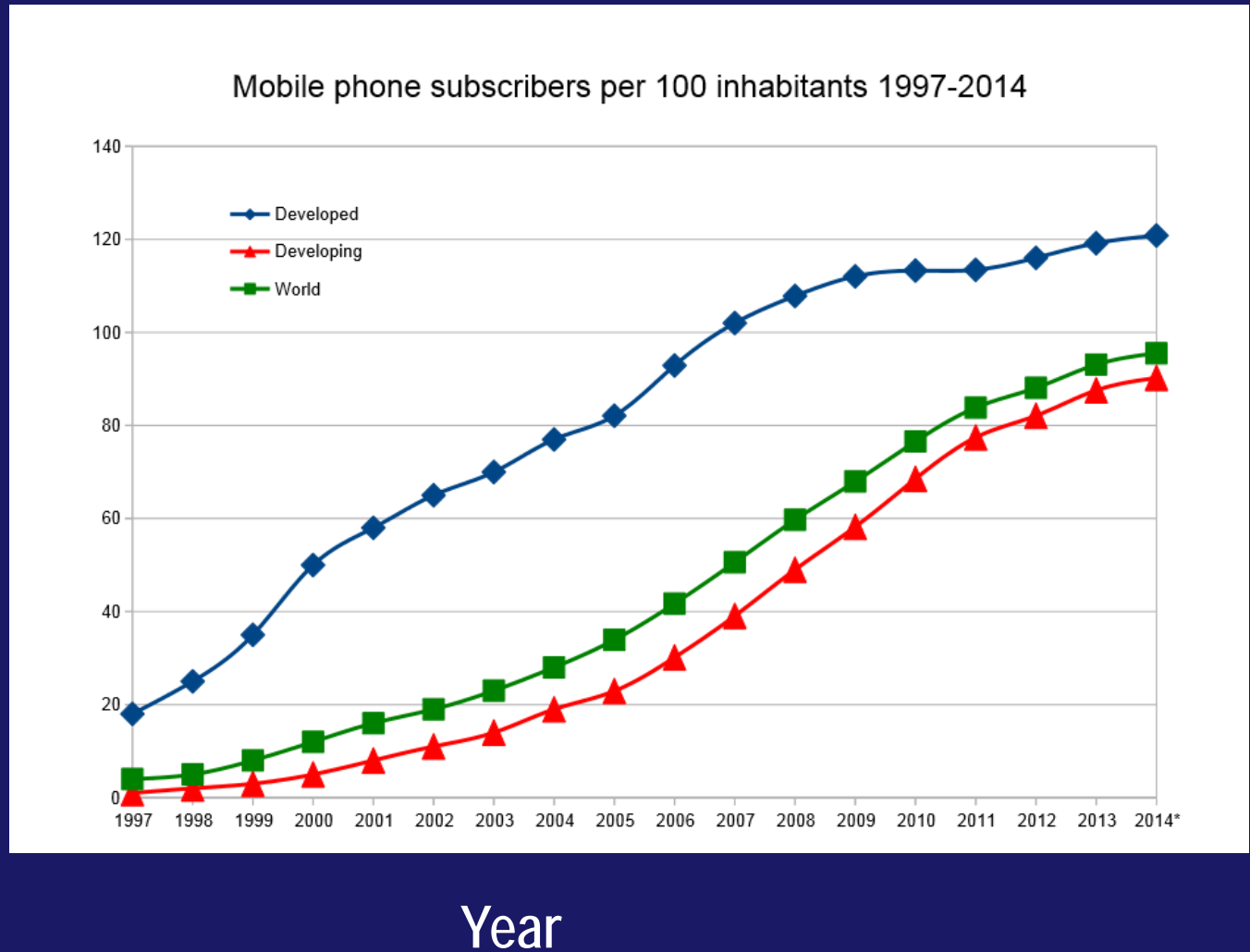
- Radiation & cancer: long-standing concern
- Non-ionizing radiation: passionate & polarized views
- Rising incidence of adult brain tumors
- Rapid increase in U.S. of cell phone use in 1990s

SEER Incidence and US Death Rates^a
Brain and Other Nervous System Cancer, Both Sexes
Joinpoint Analyses for Whites and Blacks from 1975-2005
and for Asian/Pacific Islanders, American Indians/Alaska Natives and Hispanics from 1992-2005



Mobile Phone Subscribers per 100 Persons Worldwide*

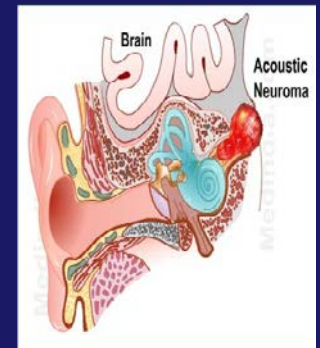
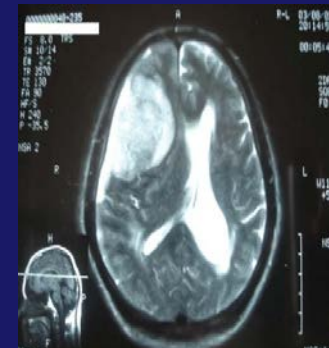
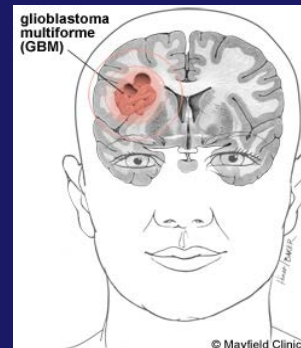
Number of
subscribers
per 100
persons

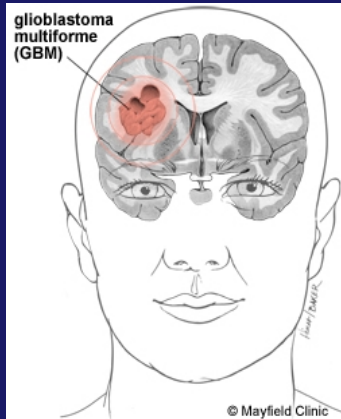


*International Telecommunication Union, specialized UN agency

Early Epidemiological Studies

- 1993: anecdotal TV report
 - U.S. Congressional hearings
 - trade industry (CTIA) commits \$25 million
- 1994: 4 studies launched
 - NCI case-control study
 - Am Health Foundation case-control study
 - Örebro University case-control study
 - Danish cohort study
- Cancers studied
 - gliomas
 - meningiomas
 - acoustic neuromas
 - other head & neck



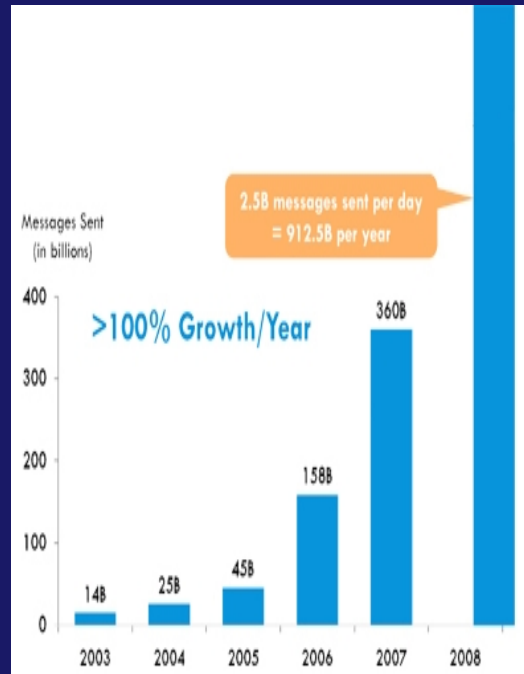


Summary: Early Studies of Gliomas*

- No association:
 - minutes per day/hours per month of use
 - duration in years of use (> 5 yrs – high category)
 - cumulative lifetime use (>100 hrs – high category)
- No evidence of excess malignancies on side of head where cell phones typically held in 3 of 4 studies

* Inskip PD et al. *N Engl J Med* 2001
Muscat JE et al. *JAMA* 2000
Hardell L et al. *Eur J Cancer* 2001
Johansen C et al. *J Natl Cancer Inst* 2001

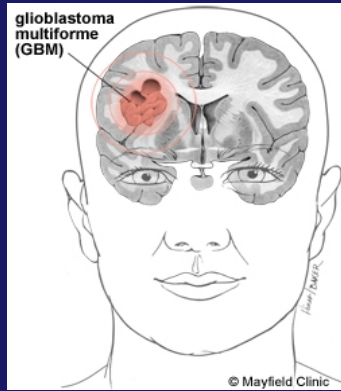
Challenges in Assessing Cancer Risks Associated with Cell Phone Use



Interphone Case-Control Study of Brain & Other Tumors: Study Design

- Denmark
 - Finland
 - Norway
 - Sweden
 - United Kingdom
 - Germany
 - France
 - Italy
 - Israel
 - New Zealand
 - Australia
 - Japan
 - Canada
- > 13 countries – study led by International Agency for Research on Cancer (IARC)
 - > Countries where mobile phones used earlier than in U.S.A.
 - > Brain tumor & other neoplasms diagnosed during 2000-2004

Interphone Study- Results*



- Glioma and meningioma
 - overall modest reduction in risk
 - no dose-response
 - modest ↓: duration, cumulative numbers, and years since first use
 - ↑ tumor on same side as cell phone held, regardless of length or level of use
- Glioma
 - modest ↑: highest cumulative call time



*Interphone Study Group. *Int J Epidemiol* (2010)

Danish Cohort Study: Design and Results*

- 358,403 subscribers
- Followed up 1990-2007
- Individuals with longest mobile phone use ≥ 13 years

Brain Tumor Type	Males		Females	
	IRR	95%CI	IRR	95%CI
Glioma	1.04	0.85-1.26	1.04	0.56-1.95
Meningioma	0.90	0.57-1.42	0.93	0.46-1.87

- No brain tumor increases overall or in 13+ year subscribers

*Frei P et al. *BMJ*, 2011

Series of Case-Control Studies by Hardell et al*

- Pooled two case-control studies
- 1,498 glioma cases (89% participating); 3,530 controls (87%)
- Cases diagnosed 1997-2003 and 2007-2009

	OR	95% CI
Latency >1yr (945,2148)	1.3	1.1- 1.6
Latency >15-20 yrs (211,476)	1.6	1.1-2.2
Latency >20-25 yrs (50/81)	2.1	1.3 - 3.2
Latency >25 yrs (29/33)	3.0	1.7 - 5.2

- Highest risk for glioma in temporal lobe
- Higher risk for first use age <20 than older age

*Hardell L and Carlberg M. *Pathophysiology* , 2015

CERENAT Multi-center Case-Control Study in France*

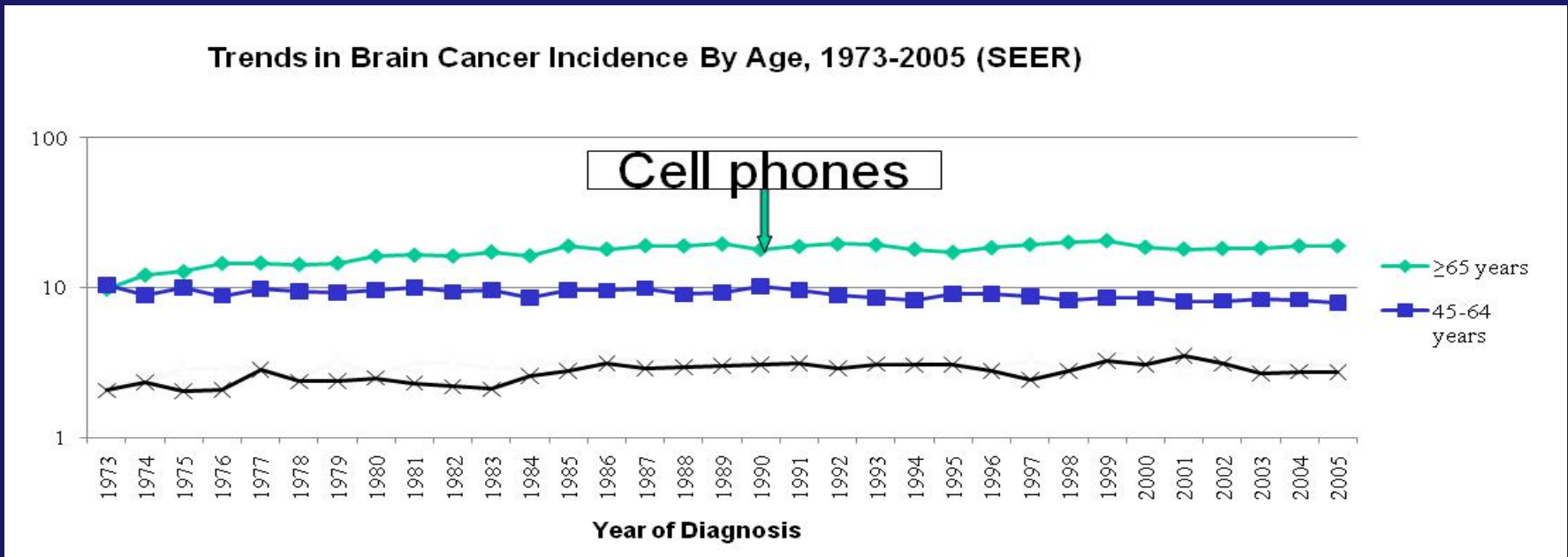
- 4 centers in France
- 254 gliomas, 194 meningiomas (73% participating); 1,192 controls (45%)
- Cases diagnosed 2004-2006

Weighted Value	Glioma		Meningioma	
	OR	95% CI	OR	95% CI
Duration (≥ 836 hrs)	2.8	1.3- 6.2	1.7	0.7-4.4
Cum. No. ($\geq 14,700$)	2.1	1.0-4.3	1.3	0.4-3.9

- Increased risk for gliomas among heaviest users

*Coureau G et al. *Occup Environ Med*, 2014

Incidence Trends in Central Nervous System Tumors



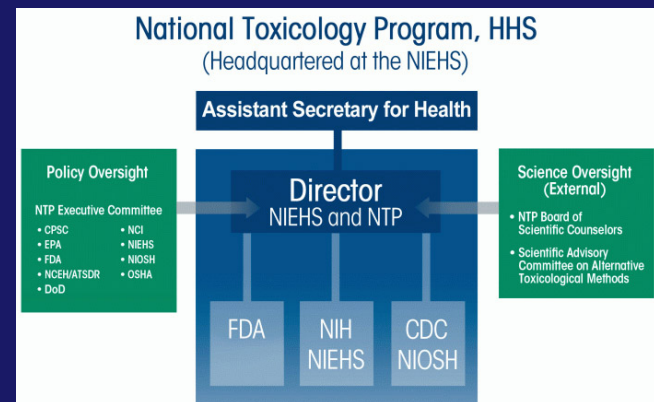
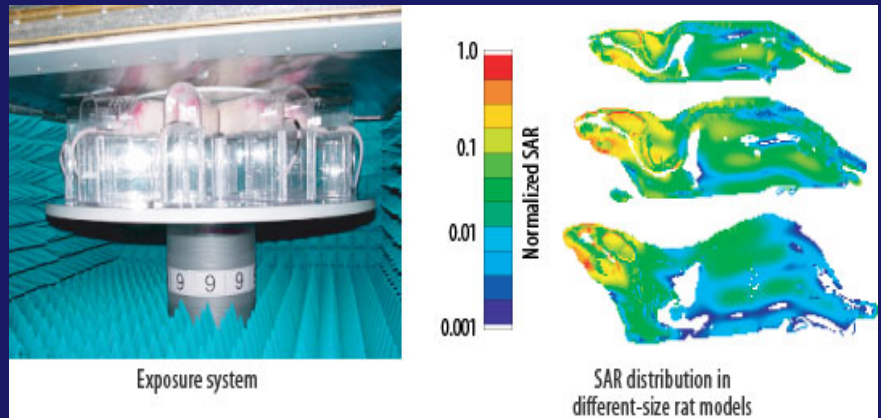
- Inskip et al (2010); Incidence of brain cancer downward or flat, 1992-2006
- Deltour et al (2009): No change in glioma or meningioma in Nordic countries, 1998-2003
- Nelson et al (2006): acoustic neuroma rose 3-fold during 1980-1997, then declined 30% during 1997-2000 due most likely to ↑reporting & diagnosis

Other Health Concerns about Mobile Phone Exposures

Other cancers	Many neurological disorders
Development <i>in utero</i>	Impaired fertility
Cognitive function	Reaction time
Attention	Motor function
Memory	Distraction
Perception	Hyperactivity
Learning capacity	Inability to focus on long-term tasks
Emotions	Fatigue
Poor sleep	Social skills
DNA Mutations	Autism?

Experimental Studies

- Early studies: inconsistent
- National Toxicology Program (NIEHS, NIH)
 - > mimic human exposure but high intensity
 - > 900 and 1900 MHz and CDMA & GSM modulations
 - > specially designed labs (validated by the National Institute of Standards and Technology)
 - > final results in 2015 or 2016



Conclusions of IARC and Other Cancer Organizations

- International Agency for Research on Cancer (2011)
(IARC) – part of the World Health Organization
 - “possibly carcinogenic to humans”
 - based on limited evidence from human studies: 2 studies were primary basis of conclusion (Interphone Study Group, *Int J Epidemiol* 2010; Hardell et al, *Int J Oncol* 2011)
- American Cancer Society
 - most studies have not found associations but studies have had important limitations
 - more epidemiological studies needed with high-quality methods, particularly in children and adolescents

Mobile Phones and Cancer

Methodologic Limitations, Controversies and Gaps in
Understanding, Current Research,
Regulation, Protective Measures

Methodologic Limitations

- Lack of substantial numbers with long duration of use
- Limits of questionnaires
 - impaired/ill cases
 - recall bias
 - recall errors
 - differential participation of cases vs. controls, heavier vs lighter users
- Technologic changes
 - analog → digital
 - changing frequencies
- Rapid growth & changes in usage

Heavy Use 1994-98 U.S.:

- 4% used > 5 yrs duration
- 3% used > 500 hrs lifetime
- 3% first used before 1990

Heavy Use 2000-2004 Interphone

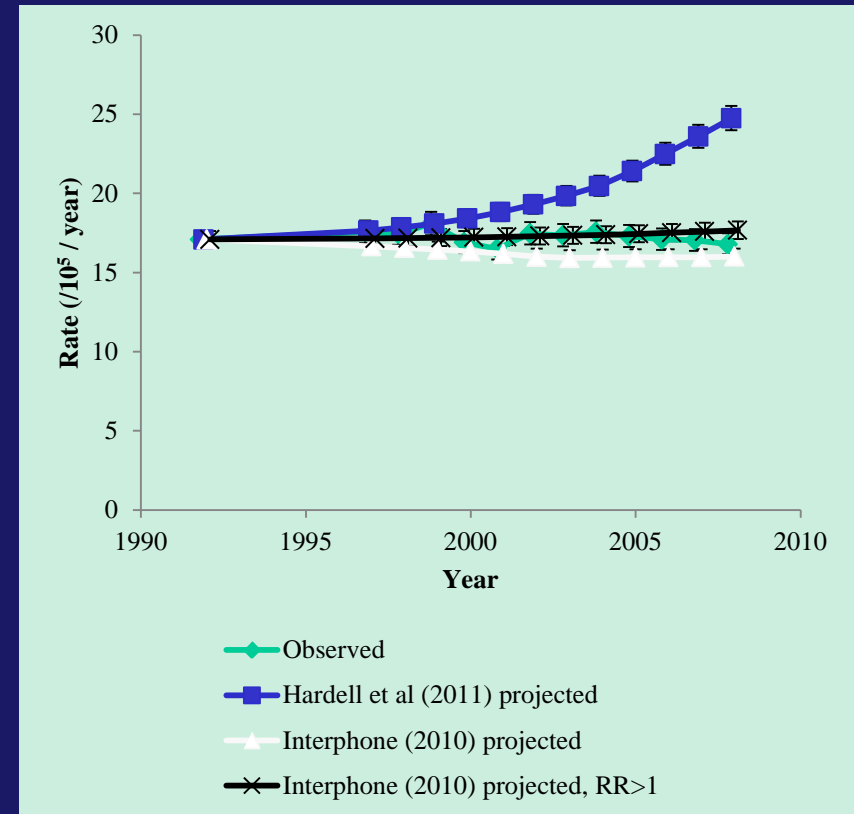
- 31% used > 5 yrs duration
- 12% used > 758 hrs lifetime

Controversies and Gaps in Understanding

Issue	Mobile phones pose no risks	Mobile phones pose major risks	Gaps in understanding
Interpretation of epidemiologic studies	<ul style="list-style-type: none"> -Majority of studies find no risk increase -Decreased risk for key outcomes in IARC study -Evidence of several types of bias: Interphone -Major contrast in results for two Swedish studies" Hardell et al vs Feychting et al 	<ul style="list-style-type: none"> -Ubiquitous exposure whose safety is unknown -2 key studies used as basis for IARC conclusion show brain tumor risk increase 	<ul style="list-style-type: none"> -RF exposure metric unknown -Biologically relevant surrogate measure unclear -Long-term effects still unclear -Risks for exposures of young children/ adolescents not yet available -Awaiting results of well-conducted, big animal studies
Radiation protection & regulation	No need to employ regulation	Report & regulate exposures; limit use in children	

Consistency of incidence trends with two studies forming basis of IARC conclusion: Interphone (2010) & Hardell et al (2011)

- Deltour et al (2012): Two case-control studies forming basis of IARC conclusion incompatible with absence of glioma trend in middle-aged Nordic countries.
- Little et al (2012): Hardell et al (2011) not consistent, but Interphone (2010) could be consistent with U.S. trends



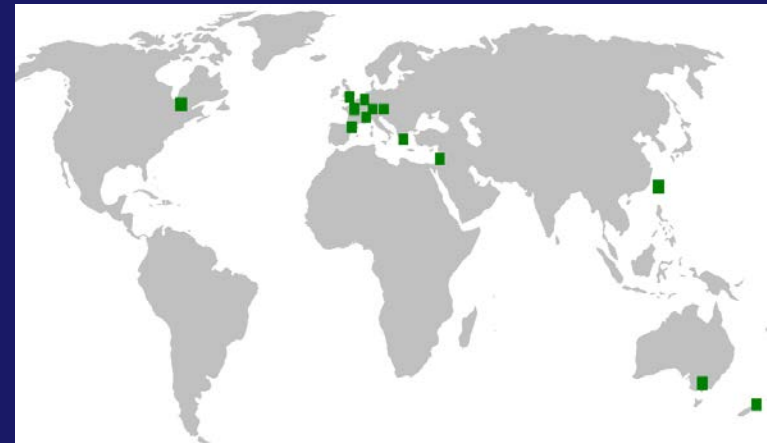
*Little MP et al. BMJ 2012

Gap: Childhood Exposures & Cancer

- **Greater susceptibility of developing nervous systems**
- **Greater penetration of RF relative to head size**
- **Longer lifetime of exposure than adults**
- **Only one published epidemiologic studies of childhood exposure (pediatric brain tumor risk)**
- **Mobi-kids (ongoing) targets exposures in children, adolescents and young adults**

Study Design

- **Case-control study**
 - **Cases (targeting ~ 2000) diagnosed 2010-2013**
 - benign and malignant brain tumours
 - ages 10-24
 - rapid ascertainment
 - **Controls**
 - 2 per case
 - hospital-based, to minimize selection bias
 - individually matched on age, sex and region

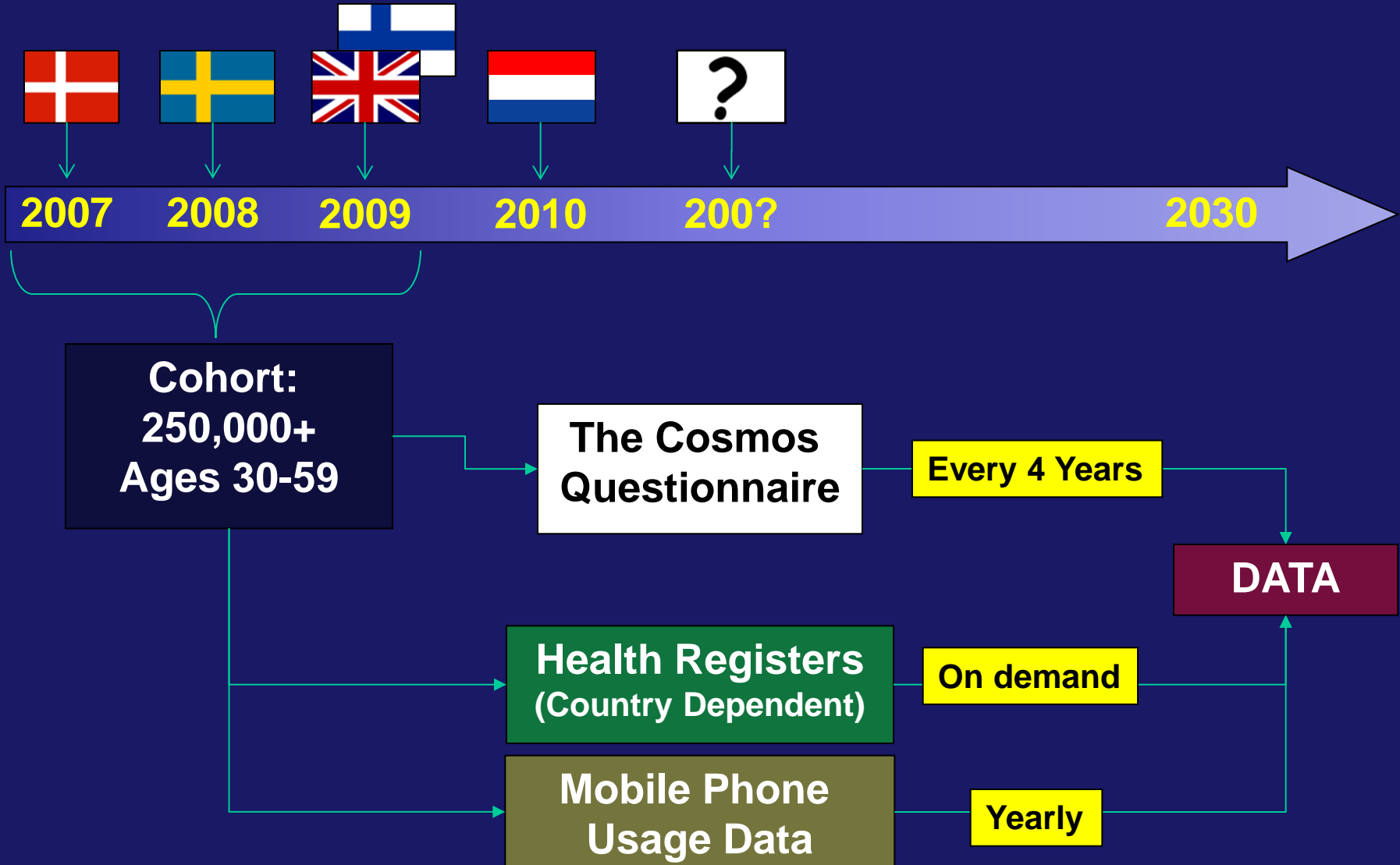


Gap: Prospective Studies with Detailed Data

- Only one prospective study: limited information on individual's phone use and confounders
- Biases of case-control studies: recall and selection
- COSMOS: a prospective, multi-country epidemiologic study addressing shortcomings of case-control studies and earlier prospective study



Study Design



Regulatory Efforts – United States

- **U.S. Food and Drug Administration (FDA) regulates devices: manufacturer must provide SAR exposure**
- **U.S. Federal Communications Commission re-examining exposure limits and policies for all regulated sources of RF**
- **38 states ban use by novice drivers, 20 prohibit use by school bus drivers; 46 ban text messaging by drivers**
- **U.S. Federal Motor Carrier Safety Administration restricts use by drivers of commercial motor vehicles**
- **Radiofrequency Interagency Work Group**

Regulatory Efforts – International

- **Many countries regulate use by drivers**
- **U.K. recommends children should only use mobile phones for essential purposes and keep calls short**
- **International workgroup meets regularly to discuss health effects, recent biological research, standards development, & safety of wireless telecommunications**

Reducing RF Exposures from Cell Phones*

- Cell phones: shorter calls
use landlines: longer calls
- Hands-free devices
- More consistent SAR labeling



Consumer Reports, Jan 2011

*U.S. Food and Drug Administration (2015). www.fda.gov/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/HomeBusinessandEntertainment/CellPhones/default.htm

U.S. Federal Communications Commission (2015). www.fcc.gov/cgb/cellular.html

Summary

- RF occupational exposures: few studies, no excess of brain tumors
- RF exposures from base stations: small number of studies, inconsistent evidence, mostly null
- Mobile phone use
 - > case-control studies: early were null, Interphone reduced risk for most metrics but increased risk for highest category of cumulative call time, 2 Swedish studies inconsistent, French study ↑ risk
 - > Danish cohort study: null
 - > Methodologic limitations of published studies

Summary

- Research gaps
 - > children's & adolescent exposures: Mobi-kids
 - > prospective studies: COSMOS
- Regulatory
 - > exposure: phones and sources
 - > drivers
- Reduce individual exposures

Questions and Answers

U.S. Department of Health and Human Services
National Institutes of Health | National Cancer Institute

www.dceg.cancer.gov/RadEpiCourse

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