EPIDEMIOLOGIC STUDIES OF NON-IONIZING RADIATION

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Non-Ionizing Radiation
Outline of Presentation

I. Scope and terminology

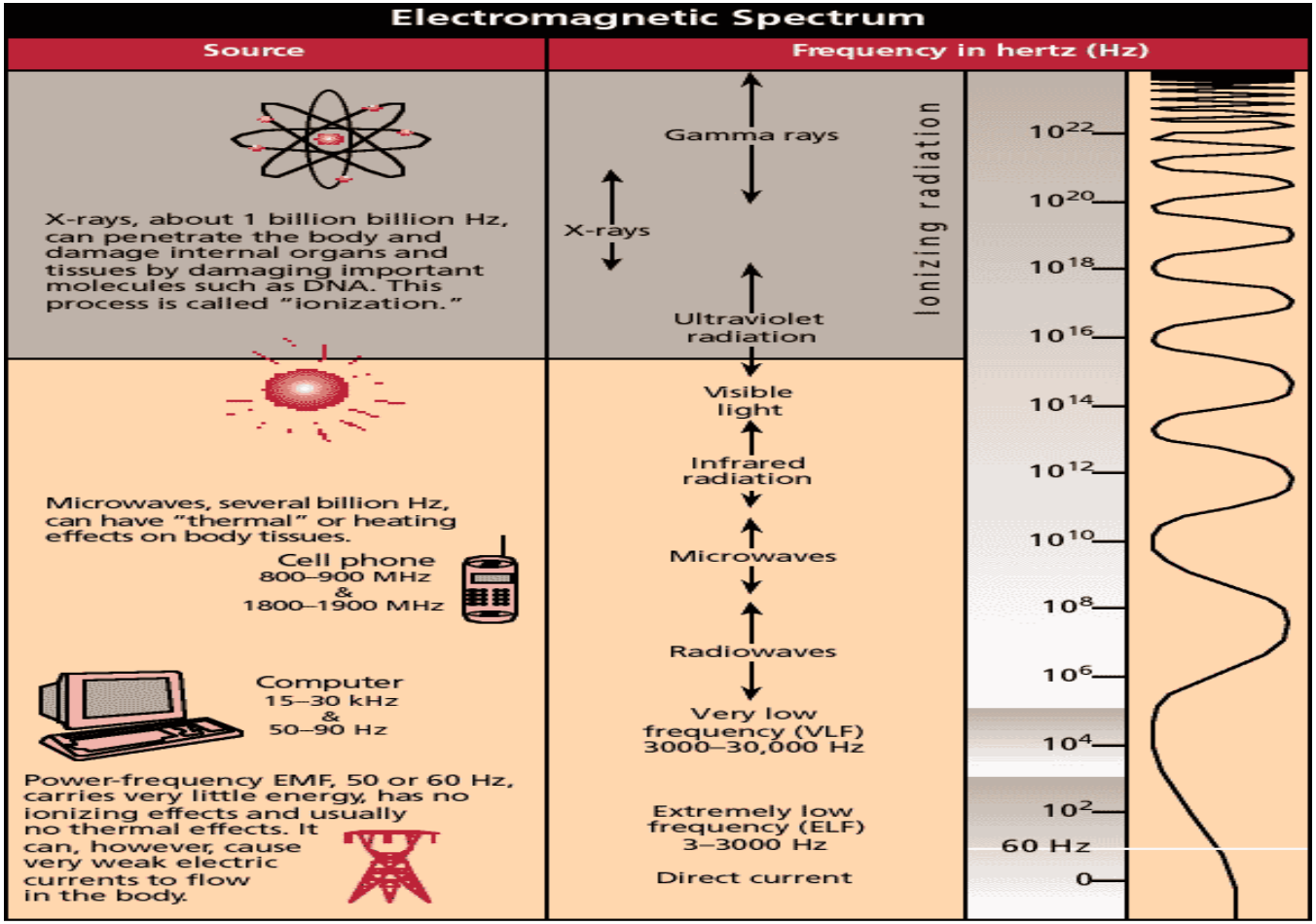
II. Measurement and methodologic issues

III. Extremely low frequency (power frequency) exposures and cancer risks

   a. Types of measurements
   b. Guide to analyzing/reporting results
   c. Childhood cancer
   d. Adult cancer

IV. Radiofrequency and microwave exposures and cancer risks

Electromagnetic Spectrum



Terminology - 1

Electromagnetic spectrum

- **frequency expressed in cycles per second (e.g. Hertz)**
- **1 cycle = 1 wavelength**
- **as frequency ⇧, wavelength ⇩**

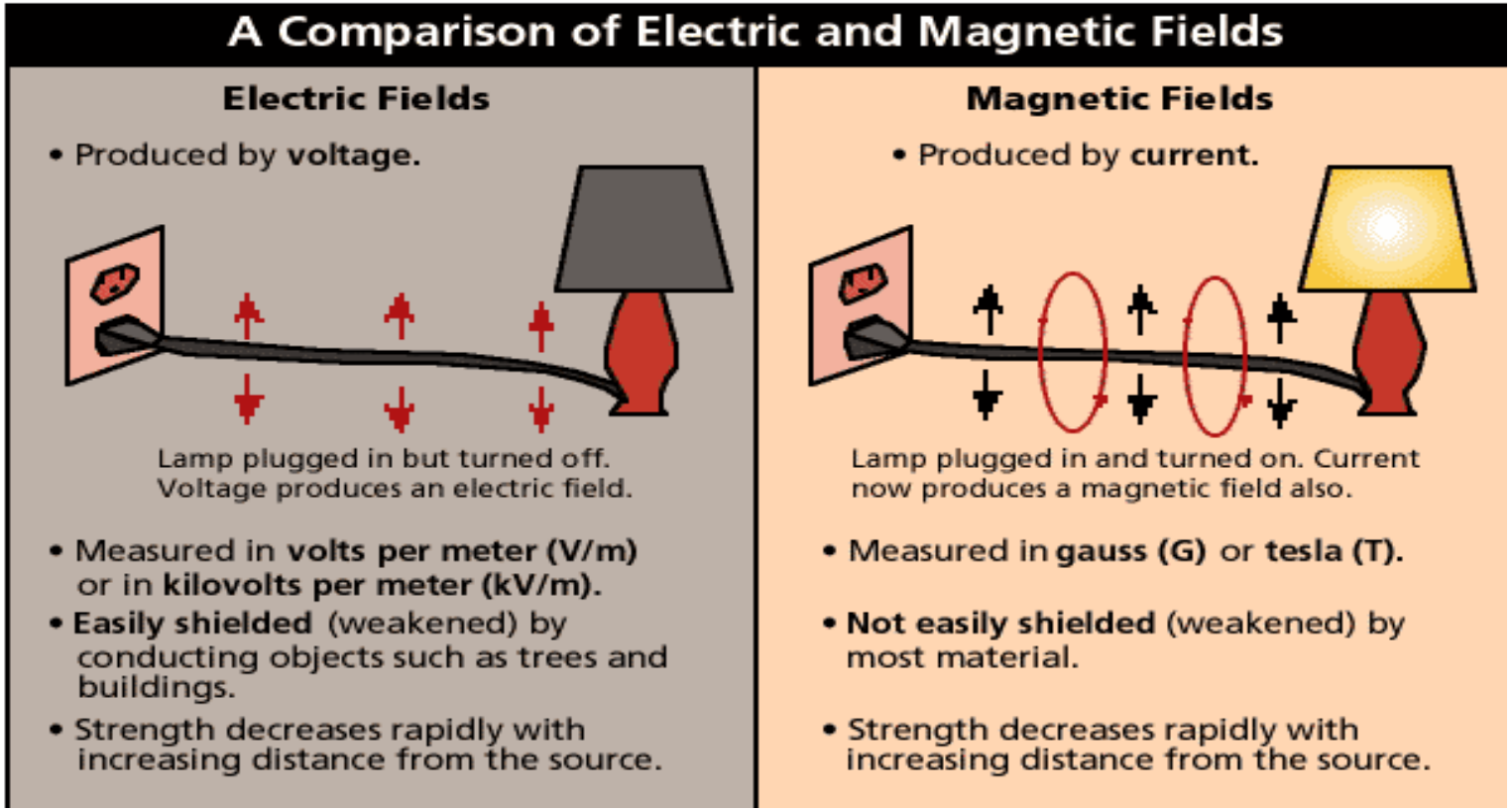
Electric fields

- **measured in volts per meter**
- **easily shielded**

Magnetic fields

- **measured in gauss (G) or tesla (T)**
- **not easily shielded**

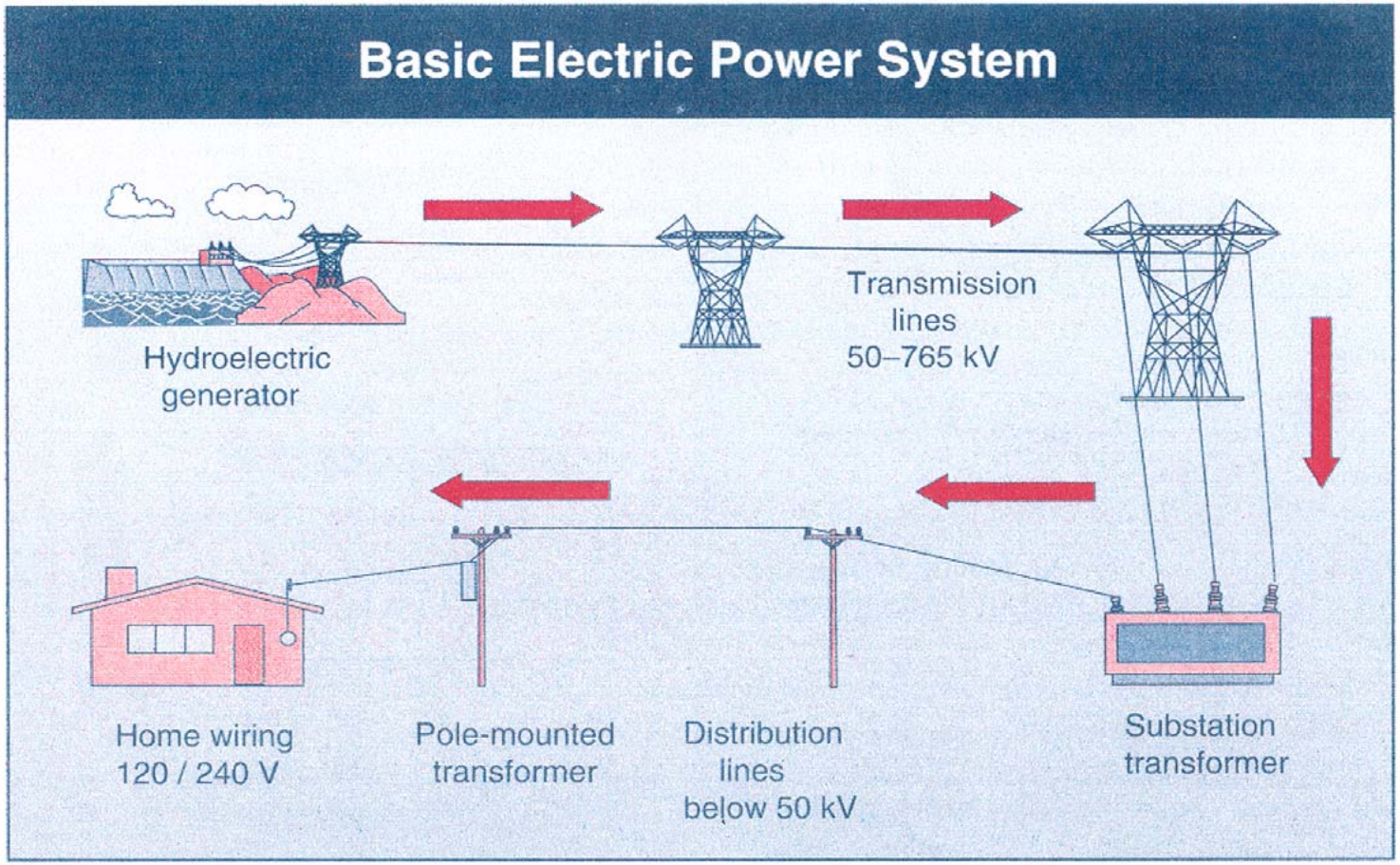
Comparison of Electric Vs. Magnetic Fields



Terminology - 2

- **Voltage = potential to do work**
- **Current = movement of electric charge**
  - **AC = electric power ‘alternates’ at 60 Hz (50 Hz) inducing weak currents in humans and other conductors**
  - **DC = ‘direct current’ flows from batteries to appliance (doesn’t induce currents)**
- **Power = product of volts and currents**
- **Conductor = material/object that carries current**
- **Load = the electric power needed by homes and businesses**

Basic Electric Power System



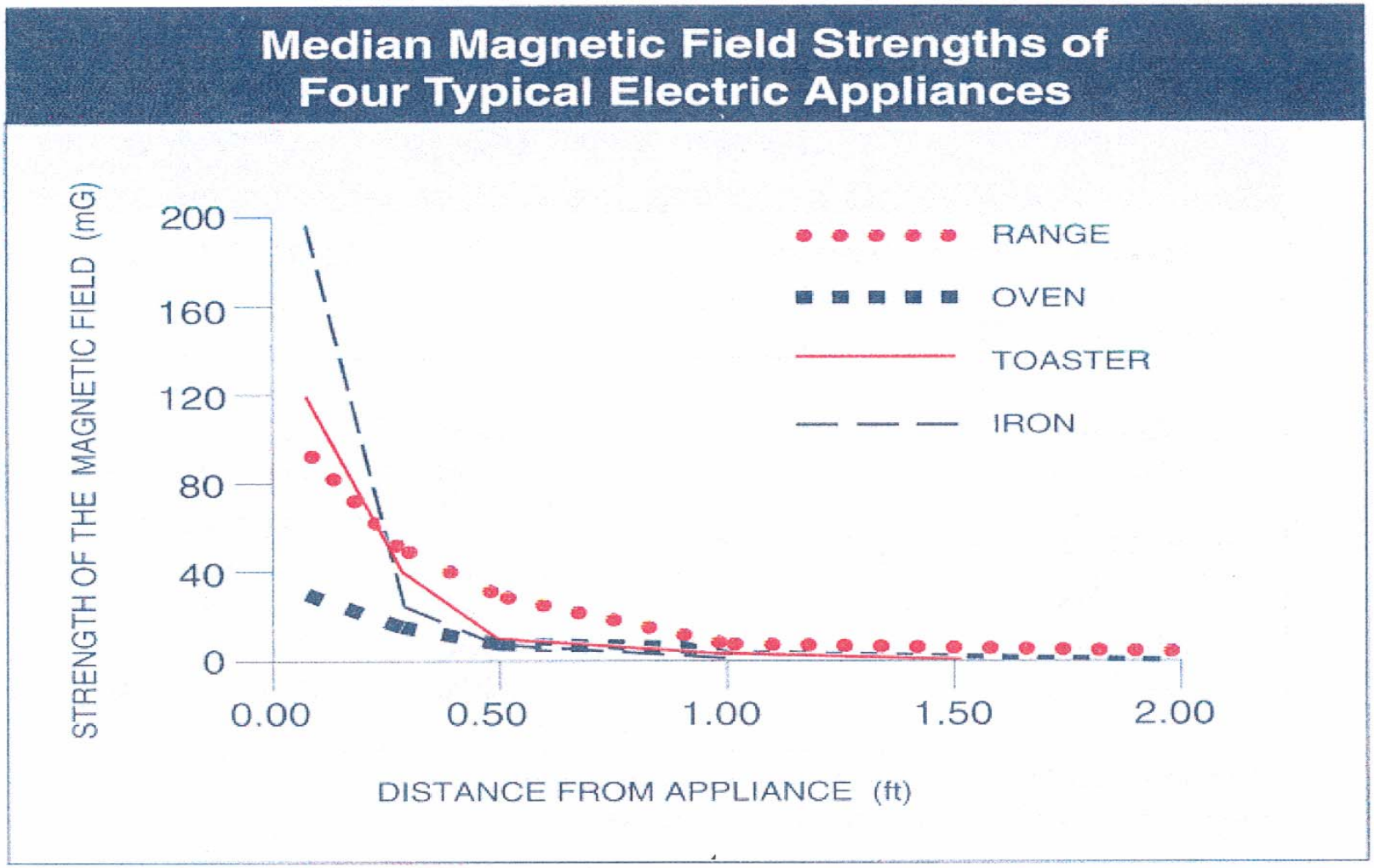
MEASUREMENT AND METHODOLOGIC ISSUES

Measurement Issues - 1

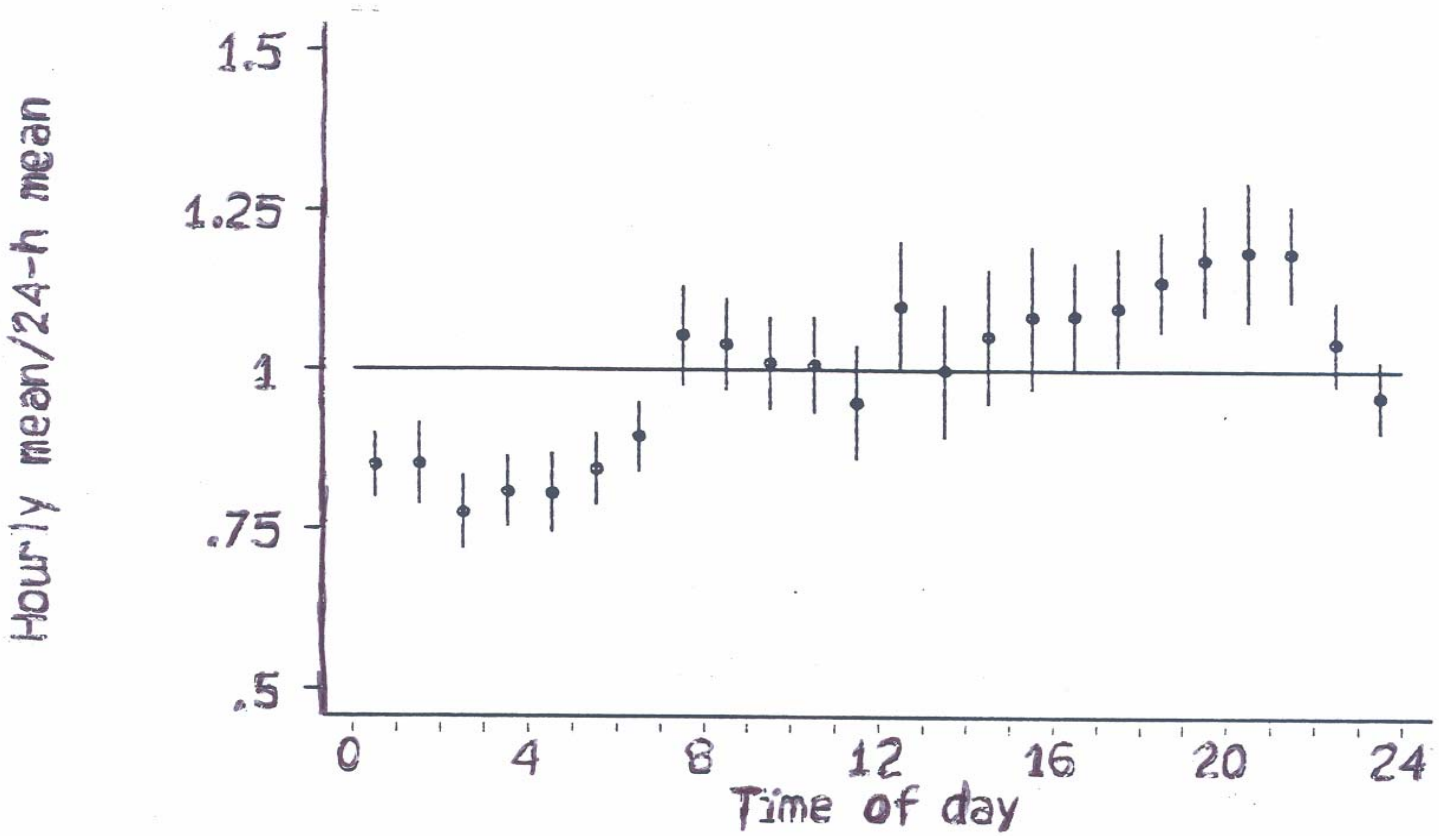
- **Relevant metric?**
  - **time-weighted average**
  - **other measures of central tendency**
  - **threshold**
  - **peak**
  - **rate-of-change**
- **Distance from source**
  - **rapid decline with increasing distance**
- **Incomplete characterization of exposure sources**
- **Time-related variation**

Measurement Issues - 2

- **Relevant induction period?**
- **Retrospective nature of exposure assessment**
- **Difficulties of combining exposures from different sources into a single metric**
- **Reproducibility**
  - **over time**
  - **among data collectors**
- **Validity**


Median Magnetic Field Strengths of
Four Typical Electric Appliances
STRENGTH OF THE MAGNETIC FIELD (mG)
200
160
120
80
40
0
0.00
0.50
1.00
1.50
2.00
DISTANCE FROM APPLIANCE (ft)
RANGE
OVEN
TOASTER
IRON

Diurnal Patterns in 24-hour Measurements in Homes



Methodological Issues

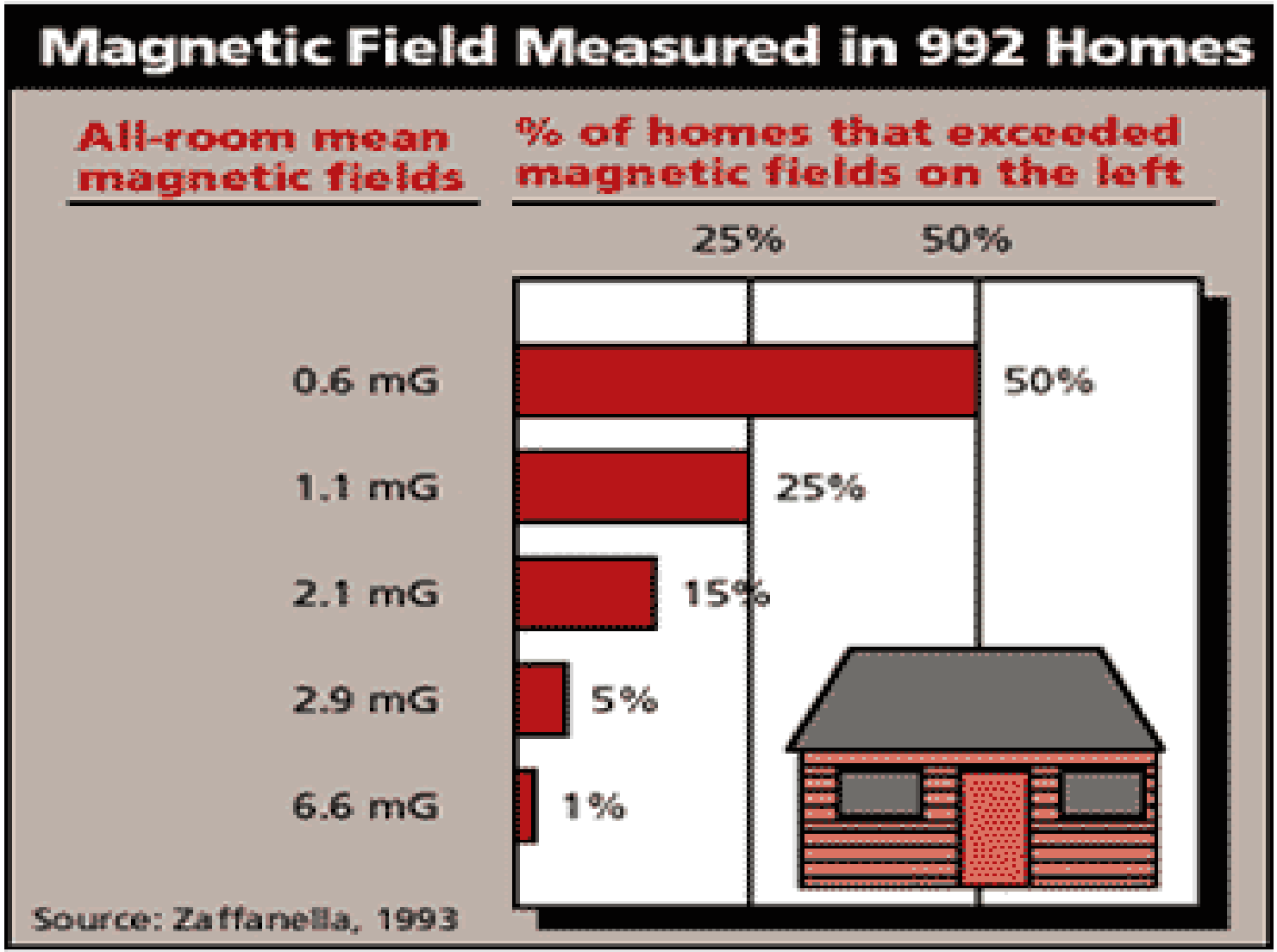
- Selection bias
- Confounding
- Measurement error
- Reporting bias
- Small increases or decreases in risk
- Meta-analysis and pooled analysis

EPIDEMIOLOGICAL STUDIES OF EXTREMELY LOW FREQUENCY (ELF) MAGNETIC FIELD (MF) EXPOSURES

Any established adverse health effects of extremely low frequency electric or magnetic field exposures?

Types of Measurements

- **Residential measurements**
  - **direct measures**
    - **“spot” (30-second) measurements**
    - **24-hr measurements**
  - **proxy measures**
    - **wire codes (power line distance, thickness, configuration)**
    - **historical estimated exposures (transmission line distance & load)**
    - **distance of residence from transmission lines**
- **Personal monitoring**
  - **residential, school, job**
  - **job title proxy measure**


Magnetic Field Measured in 992 Homes
All-room mean magnetic fields
% of homes that exceeded magnetic fields on the left
25%
50%
0.6 mG
50%
1.1 mG
25%
2.1 mG
15%
2.9 mG
5%
6.6 mG
1%
Source: Zaffanella, 1993

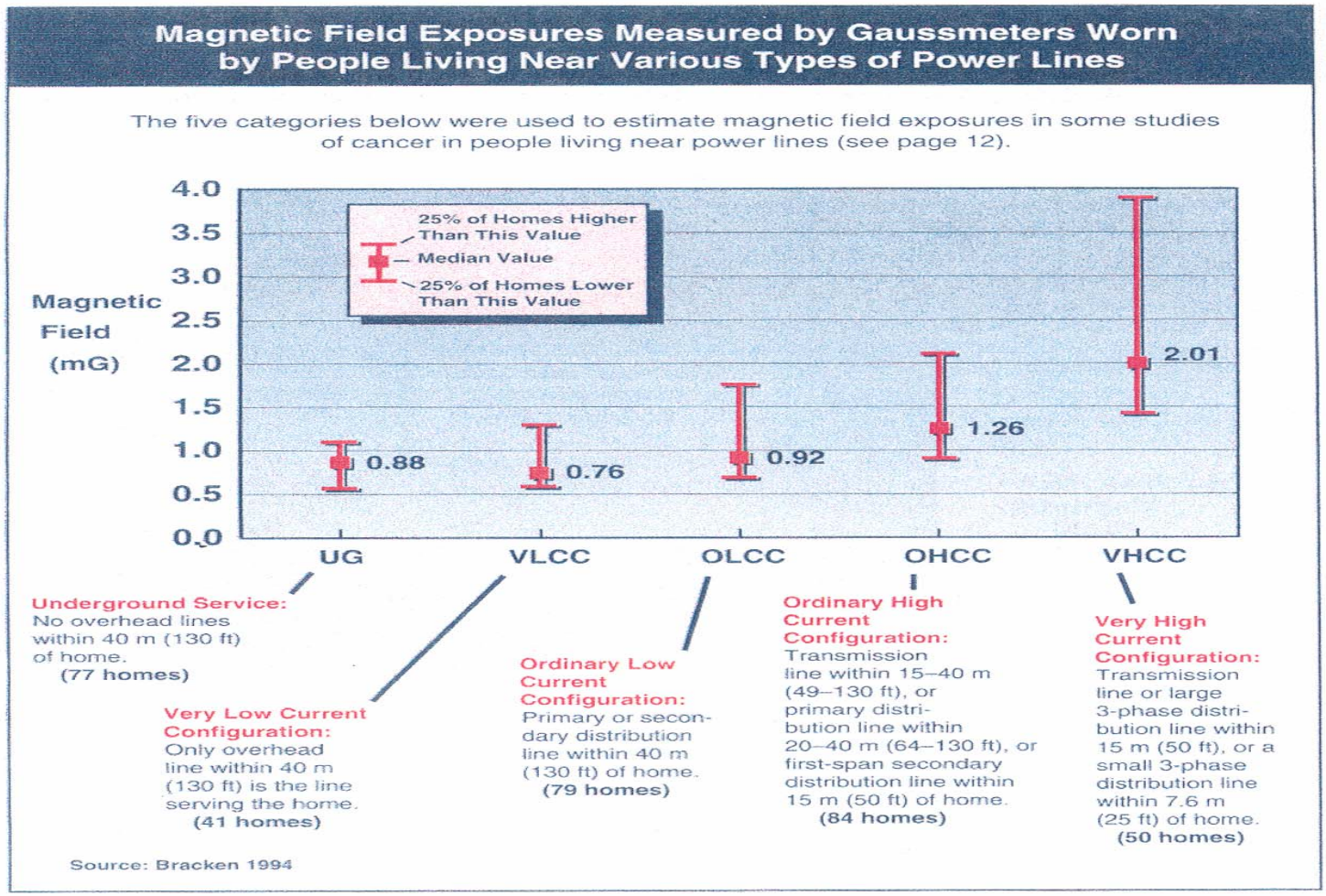
Guide to Analyzing/Reporting Results - 1

- **Direct residential measurements and historical estimated magnetic field levels**
  - **reported in milligauss (mG) or in microtesla (μT): 1 mG = 0.1 μT**
  - **most epidemiological studies report results using categorical measures**
  - **'high' level has gradually changed from >0.2 μT to >0.3 μT to >0.4 μT**
  - **residential magnetic field levels generally somewhat higher in North America than Europe**
  - **within North America, average field levels increase with increasing latitude**

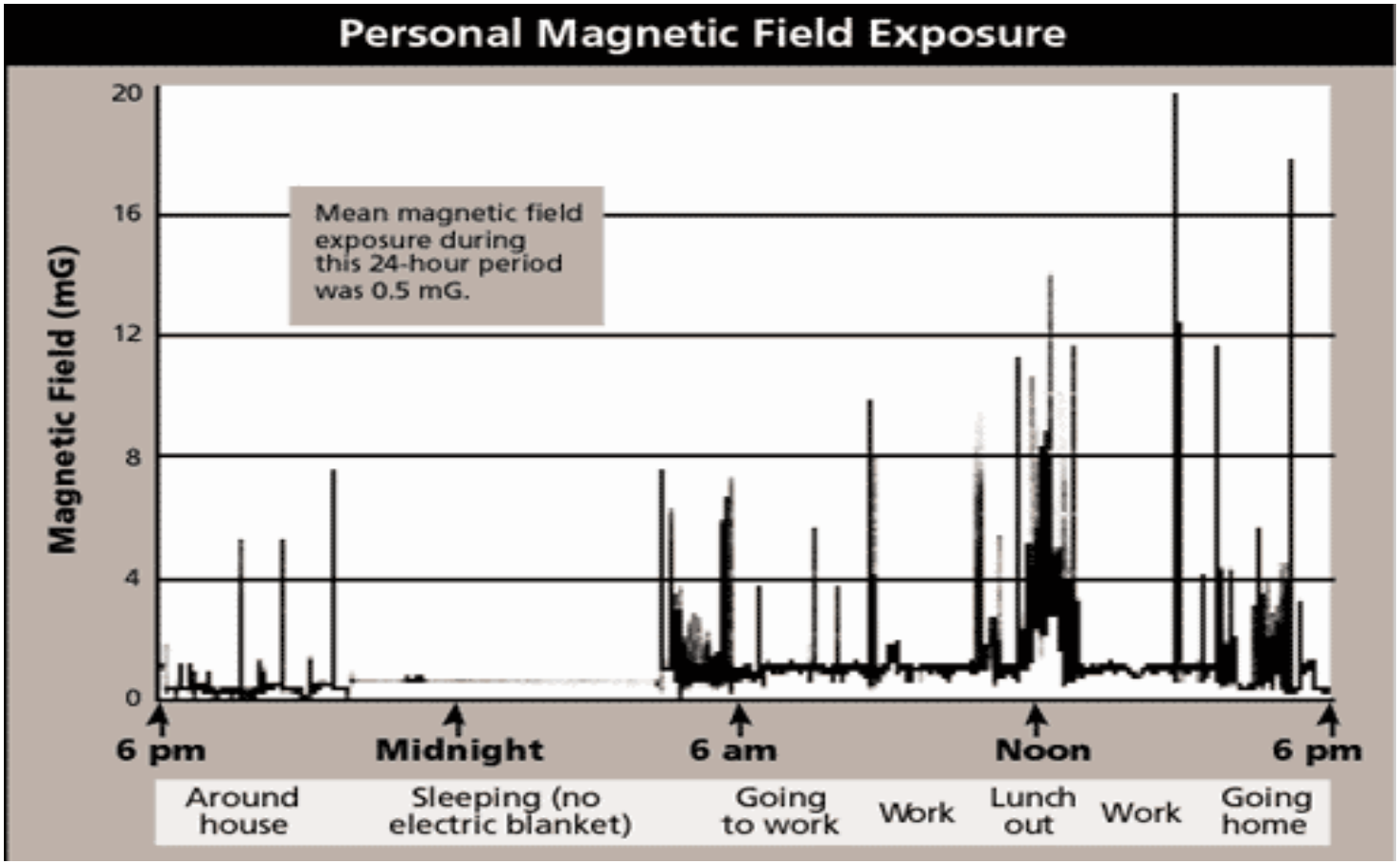
Guide to Analyzing/Reporting Results - 2

- **Wire codes**
  - **Wertheimer-Leeper**
    - **initially 2 categories (HCC vs LCC)**
    - **since 1988, 5 categories (VHCC, OHCC, OLCC, OLCC, UG)**
  - **Kaune-Savitz**
    - **a simplified Wertheimer-Leeper classification**
    - **3 categories (HWC, MWC, LWC)**

Magnetic Field Exposure Levels Associated with Wire Code Categories



Example of 24-hour Magnetic Field Pattern in Home



Childhood Cancer Residential Studies: Historical Summary

- **1979 - Wertheimer-Leeper**
- **16 subsequent studies**
  - **9 several types of cancer**
  - **6 leukemia only**
  - **2 brain only**
- **size of studies increased over time**
- **sophistication of exposure assessment improved**
- **types of measurement varied but included overlap**

Childhood Cancer Residential Studies: Results - 1

- **By type of cancer**

<u>Early Studies (1979,1988)</u>

- **↑ leukemia, brain, lymphoma RR=1.9-3.3) 2 Denver (N cases = 30-155)**

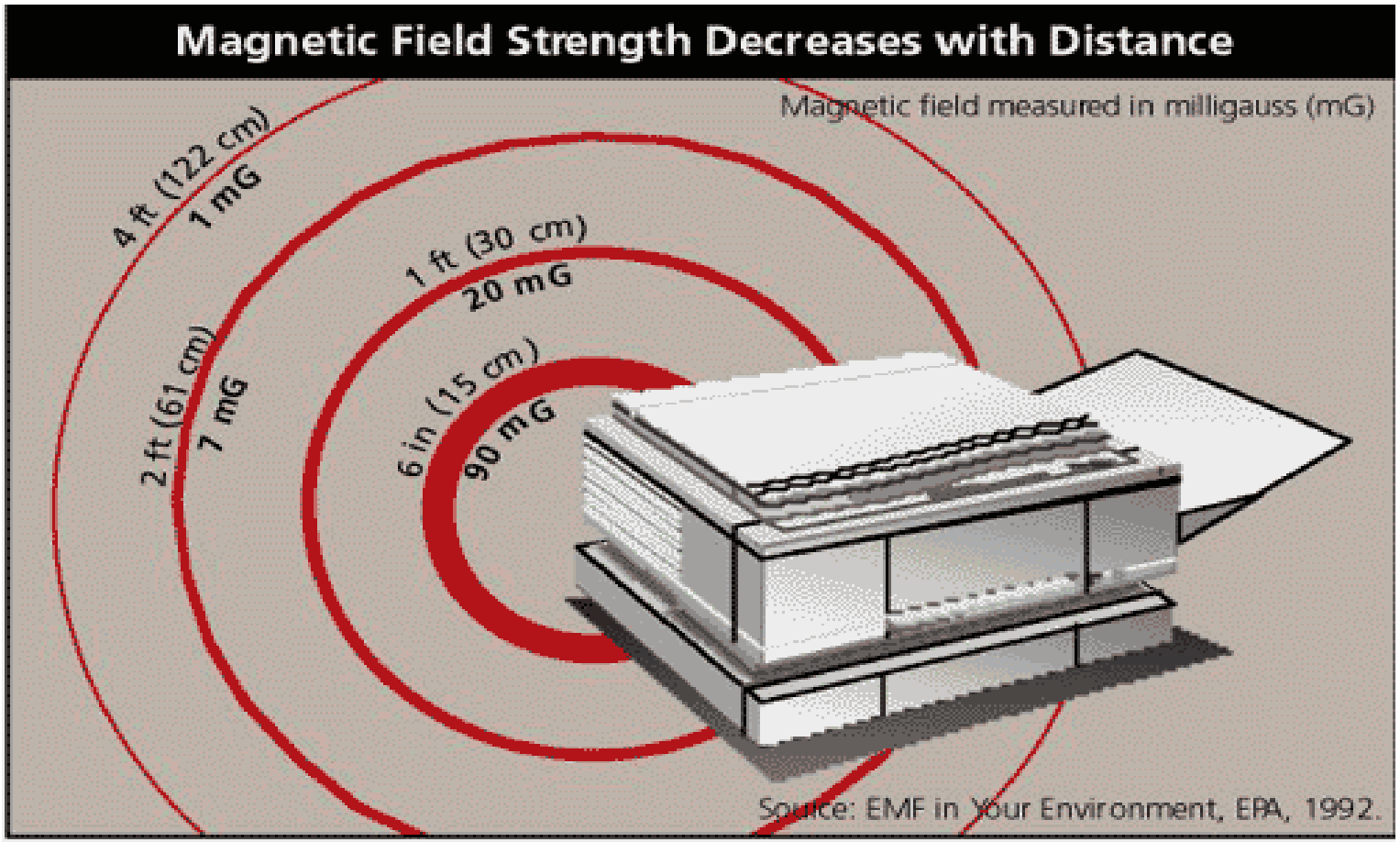
<u>More Recent Studies (1996-99)</u>

- **↑ leukemia only (RR=1.5) in some (not all) studies (N cases = 120-1,094)**

Childhood Cancer Residential Studies: Results - 2

- **By type of measurement**
  - **initial focus on wire codes (1979, 1988) or spot measurements (1988) in 2 Denver studies**
  - **Scandinavian studies described historical estimated levels (Sweden, Denmark, Finland - 1993, Norway - 1997) from registry data**
  - **focus shifted to direct measurements in Los Angeles (1991), German (1997), US-NCI (1997), Canadian (1999), UK (1999) studies**

Magnetic Field Levels in Homes in Relation to Distance from Power Lines



Childhood Cancer Residential Studies: Results - 3

- **By metric or time of day**
  - **most studies reported only time-weighted average**
  - **German study reported median and night-time risks (latter confirmed in NCI study)**
  - **NCI study explored alternative metrics (but measures of central tendency showed highest risks)**

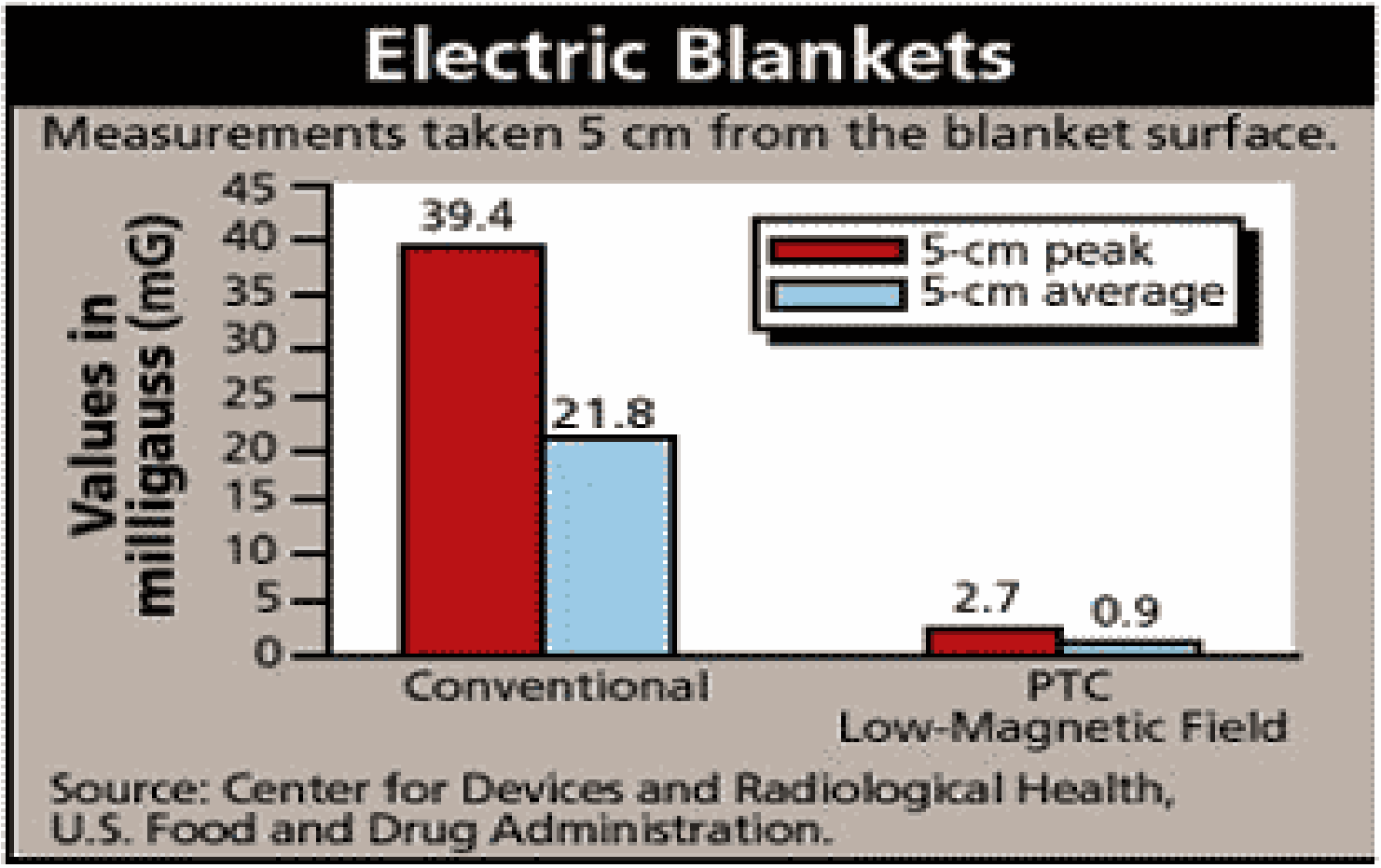
Childhood Cancer Residential Studies: Results - 4

- **By threshold level**
  - **focus on VHCC in all but initial studies**
  - **focus shifted from >0.2 μT to >0.3 μT and finally >0.4 μT in more recent studies**
  - **2 pooled analyses of childhood leukemia:**

Childhood Cancer Appliance Studies: Results

- **5 studies: all interviewed mothers to assess prenatal and postnatal exposure information**
  - **leukemia (4 studies)**
    - **⇧ risks for:**
      – prenatal electric blankets (2)
      – postnatal electric blankets (3)
      – hair dryers (2)
      – television watching (2)
    - **no consistent dose-response**
    - **TV linked with duration, not distance**
    - **measurement study showed MF exposures were not greater than ambient levels at typical distances**
  - **brain (3 studies)**
    - **little consistency among results**

Magnetic Field Differences Between Old Vs. New Electrical Blankets



Adult Cancer Residential Studies: Results - 1

- **4 leukemia studies**
  - **all focused on exposures from transmission lines**
  - **only 1 each collected information on other sources of residential exposure or occupational exposure**
  - **no increase in risk for 3; one showed small increase in risk for MF levels >0.1 μT in year before diagnosis; no consistency by subtype**

Adult Cancer Residential Studies: Results - 2

- **4 brain tumor studies**
  - **all focused on exposures from transmission lines**
  - **none collected information on other sources of residential exposure, one collected data on occupational exposure**
  - **no evidence of an association**

Adult Cancer Residential Studies: Results - 3

- **female breast cancer studies: 5 case-control, 4 cohort**
  - **3 collected in-home measurements, 4 wire codes, and 5 distance from transmission lines**
  - **none collected information on other sources of residential exposure or occupational exposure**
  - **no increase in risk for 8; initial study showed increase in subgroups only**

Adult Cancer Occupational Studies: Results-1

- **Voluminous literature focusing on job title only**

<u>Leukemia</u>

- **overall, risk modestly increased (RR meta-analysis = 1.2) among persons in electrical occupations**
- **similar risks for jobs with higher and lower exposures**
- **highest risk for CLL (RR=1.4) (N=38 studies)**

<u>Brain Cancer</u>

- **electrical workers had modest risk increase (RR meta-analysis = 1.2)**
- **higher risks in electrical engineers (RR=1.7), and for gliomas (RR=1.4) (N=29 studies)**

Adult Cancer Occupational Studies: Results-2

- **Measurement studies**

  <u>Leukemia</u>

  - **5/10 studies showed no association**
  - **5/10 reported increased risks (RR=1.5–2.5), with ⇧ AML in 2, ⇧ CLL in 2**

  <u>Brain Cancer</u>

  - **5/10 studies showed no association**
  - **5/10 reported small increases in risk (RR=1.3-3.1); few included subtype information**

Adult Cancer Occupational Studies: Results-3

- **Male breast cancer**
  - **2 reports (Lancet, letters to editor 1990, 1991)**
  - **5 case-control studies: 2 reported significantly increased risks (OR=1.8, 2.2)**
  - **14 cohort studies, several with limited power: 2 reported significantly increased risks (RR=2.1, 4.9)**

Adult Cancer Occupational Studies: Results-4

- **Female breast cancer**
  - **research more limited than for brain tumors or leukemia because electrical occupations rare among women**
  - **6 case-control studies: 2 reported significantly increased risks including (PMA=1.38; OR=1.14 for white women, OR=1.34 for black women)**
  - **10 cohort studies: 1 reported significantly increased risk (RR=1.14)**

Occupational Studies: Cancer in Offspring

- **Childhood cancer in relation to parental occupational exposure**
  - **case-control studies: a few have reported increased risk of specific childhood cancers and parental employment in ‘electrical’ occupations, but methods and findings have not been consistent**
  - **cohort studies ??**

ELF EXPOSURES: OTHER OUTCOMES

- **Outcomes other than cancer**
  - **neurodegenerative diseases**
    - **amyotrophic lateral sclerosis**
    - **Alzheimer's disease**
  - **suicide and depression**
  - **reproductive disorders**
    - **spontaneous abortion**
    - **low birth weight**
    - **congenital malformations**
  - **cardiac effects**
    - **heart rate**
    - **CVD mortality**

ELF EXPOSURES: EXPERIMENTAL DATA

- **Experimental evidence**
  - **Voluminous literature, no replication of positive studies (Portier and Wolfe (eds) NIH Publ No. 98-3981, Research Triangle Park, NC, NIEHS, 1998**
  - **Large, well-controlled studies all negative (Boorman GA et al. 1997, 1999, 2000a, b; McCormick et al. 1999)**

EPIDEMIOLOGICAL STUDIES OF RADIOFREQUENCY (RF) EXPOSURES

Any established adverse health effects of radio-frequency electromagnetic field exposures?

Whole or partial body heating

TYPES OF MEASUREMENTS

- **Specific energy absorption rate (SAR)**
  - **the rate at which energy is absorbed by unit mass of tissue (unit = watt per kilogram)**
  - **exposure guidelines established to prevent whole or partial body heating**
    - **for whole body, exposure guidelines restrict exposures averaged over whole body mass (0.4 watts per Kg, time-averaged over 15 minutes)**
    - **for head, exposure guidelines restrict exposures averaged over small mass of tissue in head (0.1 watt per 10 g, time-averaged over 6 minutes)**

Cellular Telephones

Adult Brain Tumors, Other Cancers, and Cellular Telephones: Historical Aspects

- **1984 – handheld cellular telephones introduced, followed by improvements in technology: analog (800 MHz), then early digital (900 MHz), then later digital (1800 GHz)**
- **1993-96 four case-control studies initiated**
- **1998 – WHO launched multi-country case-control study coordinated by IARC**
- **1999 – Swedish brain tumor study reported ipsilateral use of cell phones increased risk for brain tumors of temporal/occipital region**
- **2001 – 3 other studies reported no association**

Limitations of 4 Studies

- **Limited latency**
- **Few long-term, heavy users**
- **No validation for case-control studies**
- **Technology changes over time (little information collected)**
- **Limited information on details of use for cohort study**
- **Limited power to assess glioma subtype-specific risks**
- **No exposure level information**

Other Radiofrequency Exposures

Other RF Exposures: Cancer Studies - 1

- **Occupational studies (no quantitative data)**
  - **aircraft industry (Barron and Baraff, 1958)**
  - **U.S. Moscow embassy employees (Lilienfeld et al, 1978)**
  - **U.S. Navy (Robinette et al, 1980)**
  - **Polish military (Szmigielski et al, 1988, 1996)**
  - **Amateur radio operators (Milham, 1988)**
  - **Canadian/French utility workers (Armstrong et al 1994)**
  - **U.S. Air Force (Grayson, 1996)**
  - **Motorola workers (Morgan et al 2000)**

Other RF Exposures: Cancer Studies - 2

- **Residential studies (populations living near radio or TV transmitters; all lack quantitative exposure assessment)**
  - **children (Selvin et al, 1992)**
  - **adults (Hocking et al 1996; Dolk et al 1997a, b)**

Other RF Exposures: Outcomes Other Than Cancer

- **Reproductive outcomes (poor exposure assessment)**
  - **inconsistent findings among female plastic welders and physiotherapists using diathermy equipment**
  - **no excess of Down syndrome among offspring of male radar workers**

Other RF Exposures: Experimental Data

- **Experimental evidence**
  - **numerous studies show thermal effects, with damage to sensitive tissues (eye, testis), and other physiological effects with temperature increases of 1-2°C**
  - **microwave exposures below threshold for thermal effects show no carcinogenicity**
  - **2 conflicting studies of lymphoma in transgenic mice**

RF Exposures: The Future?

- **Interphone studies of cellular telephones and risk of head and neck tumors: publications in 2005**
- **NCI-SEER multicenter study of non-Hodgkin lymphoma assessed risks associated with cellular telephones: publication in 2005**
- **IARC Monograph on radiofrequency exposures: to appear in 2006**

RF Exposures: The Future?

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