# Observations on Uncertainties in Dosimetry


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# Outline

- Terminology
- Omissions
- ISO terminology
- The customers
  - of dosimetry science
  - of radiation epidemiology
- Dosimetry, dosinference, and doswaggery

# Terminology

- Used as synonyms today:
  - a trial
  - a set of doses
  - a replication
  - a realization
  - an imputation (in the sense of “multiple implementation”)
  - a dose vector
- Used as synonyms today:
  - classical error
  - measurement error
- Used as synonyms today:
  - Berkson error
  - grouping error
  - averaging error

# Terminology

- Used as synonyms today:
  - observed dose
  - measured dose
  - estimated dose
  - assessed dose
  - reconstructed dose
  - imputed dose

# Terminology

- Used as synonyms today:
  - shared error
  - type B error
- Used as synonyms today:
  - unshared error
  - type A error

# Not Addressed Today

- Covariance among sources of uncertainty (either shared or unshared)
- Intra-individual autocorrelation over time of annual doses
- Use of left-censored data
- Cultural differences among scientists in different countries
- ISO Guide to the Expression of Uncertainty in Measurement terminology
  - observables and measurands
  - error, uncertainty and blunder
  - Type A uncertainty evaluation, Type B uncertainty evaluation

International Organization for Standardization (ISO). 2008. Uncertainty of Measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM: 1995). Guide 98-3 (2008), ISO, Geneva, Switzerland.

# ISO Terminology: Type A and Type B Measurement Uncertainty

- Uncertainty that is evaluated by the statistical analysis of series of observations is called a "**Type A**" uncertainty evaluation.
- Uncertainty that is evaluated by means *other* than the statistical analysis of a series of observations is called a "**Type B**" uncertainty evaluation.

ISO. 2008. *Uncertainty of Measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM: 1995).* Guide 98-3 (2008), International Organization for Standardization, Geneva, Switzerland.

# Uncertainty and Variability

- Uncertainty
  - stems from lack of knowledge, so it can be characterized and managed but not eliminated
  - can be reduced by the use of more or better data
- Variability
  - is an inherent characteristic of a population, inasmuch as people vary substantially in their exposures and their susceptibility to potentially harmful effects of the exposures
  - cannot be reduced, but it can be better characterized with improved information

-- National Research Council. 2008. *Science and Decisions: Advancing Risk Assessment.* http://www.nap.edu/catalog.php?record_id=12209, National Academies Press, Washington, DC

# Terms: Error, Uncertainty, Variability

- “The difference between error and uncertainty should always be borne in mind.”
- “For example, the result of a measurement after correction can unknowably be very close to the unknown value of the measurand, and thus have negligible error, even though it may have a large uncertainty.”
- *Error bars?* No! *Uncertainty bars* is what we should say
- Variability is the range of values for different individuals in a population
  - e.g., height, weight, metabolism

# Who Are the "Customers" of Dose Reconstruction Scientists?

- Biostatisticians and epidemiologists will use our numbers, but they are not the only customers for many of us
- Other researchers
  - Tissue Repository (Mayak, US Transuranium & Uranium Registries)
  - Electron paramagnetic resonance (EPR) dosimetrists
  - Fluorescence in-situ hybridization (FISH) dosimetrists
- Scientific review groups will review our methods and results
- Editorial boards of scientific journals will scrutinize our work
- Our funding agencies
- [Lawyers, workers, relatives of workers…]

# What Do the “Customers” Need?

- Biostatisticians need
  - Best point estimates of doses for exploratory analyses
    - For each individual
    - For each year (annual, not cumulative, doses)
    - To each tissue or organ
    - For each kind of radiation
  - Many replications of dose for uncertainty analysis with correct handling of
    - shared and unshared uncertainty
    - Berkson (grouping) and classical (measurement) uncertainty
- Tissue repository needs individual tissue doses until death with quantitative expression of uncertainty
- EPR needs dose to individual’s teeth until time of extraction
- FISH needs dose to individual’s bone marrow until time of sample

# Who Are the Customers of Radiation Epidemiology, and What Do They Need?

- Customers: Radiation risk managers: ICRP, NCRP, UNSCEAR, Standards Organizations, Governments, Regulators, Public Health Organizations
- Gone are the days of hypothesis generation, and “person-years at risk” is not useful
- Need quantitative risk assessment to manage radiation risks
- Need risk-per-unit-dose with credible confidence limits for
  - deterministic effects (e.g., cataract), stochastic effects (e.g., cancer, heritable ill-health)
  - for different tissues and organs
  - controlled for confounders and effect modifiers
  - as a function of age, sex, and other susceptibility groups
  - as a function of linear energy transfer (LET), dose rate & fractionation

# Dosimetry, Dosinference, and Doswaggery

Radiation Protection Dosimetry
Vol. 98, No. 4, pp. 363-366 (2002)
Nuclear Technology Publishing

## Guest Editorial

### Dosimetry, Dosinference and Doswaggery

For ionising radiation, absorbed dose is defined as the energy imparted per unit mass of an infinitesimal volume. While straightforward to define, absorbed dose is somewhat more difficult to measure or infer. There is growing attention to the uncertainty in values of absorbed dose and its derivative quantities such as equivalent dose and effective dose. The process of arriving at a value of dose to record is variously called measuring a dose, computing a dose, calculating a dose, assessing a dose, evaluating a dose, estimating a dose, reconstructing a dose, inferring a dose, or doing dosimetry. All values for the quantity dose are based on some amount of inference, but the effect of the inference on uncertainty may range from trivial to enormous. The more inferential steps required to arrive at a dose value, the greater the uncertainty associated with the result. It is suggested here that the word dosimetry is being stretched too far when it is applied to inferential processes whose total uncertainty is little affected by measurement uncertainty, but is dominated by uncertainty in models, their parameters, and imputed data that have little or no basis in measurement.

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# Word Choice Based on Uncertainty

| Term | Typical Dominant Uncertainty | | | | Ratio of 97.5%ile to 2.5%ile of Inferred Dose |
|---|---|---|---|---|---|
| | Measure-ments | Models | Model Parameters | Imputed Data | |
| **Dosimetry** | ✓✓ | ✓ | ~ | ~ | 1.01 to 2 |
| **Dosinference** | ✓ | ✓✓ | ✓✓ | ~ | 2 to 20 |
| **Doswaggery** | ~ | ✓ | ✓ | ✓✓ | >20 |

**✓ denotes important; ✓✓ denotes very important; ~ relatively trivial**

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# Calling a Spade a Spade…

- maybe it's time to choose different words when the dose in question is measured, inferred, or essentially assumed
- *dosimetry* when measurement uncertainty predominates
- *dosinference* when model parameter uncertainty predominates
- *doswaggery* when assumption or imputed value uncertainty predominates

# Conclusions

- Agreement is needed on terminology
  - distinguishing between error and uncertainty is critical
  - suggest using ISO GUM terminology
- More work is needed on
  - Covariance among sources of uncertainty (either shared or unshared)
  - Intra-individual autocorrelation over time of annual doses
  - Use of left-censored data
- Epidemiologists, biostatisticians must learn basic dosimetry
  - time-course of irradiation (dose rate, dose fractionation)
  - non-uniform or partial body irradiation
  - differences in linear energy transfer (LET) of different kinds of radiation
  - dose reconstruction based on individual v. environmental measurements
- Some so-called "doses" are neither measured ("dosimetry") nor inferred from measurements ("dosinference"): these are "doswaggery" results