RADIATION DOSE RECONSTRUCTION: PRINCIPLES AND PRACTICES

An NCRP Report

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Just a partial discussion today…

- Purposes of Dose Reconstruction
- Basic Elements / Foundation Issues
- Methodologic Issues
- Handling of Uncertainty for Epidemiological Inputs

Dose Reconstruction Defined

- Retrospective assessment of dose to *identified* or *representative* individuals or populations *by any means*

Dose Reconstruction Purpose

- Dose reconstruction can be done for a variety of purposes
  - Compensation for occupational disease (NIOSH / EEOICPA)
  - Management of radiation emergencies (1976 Hanford americium accident)
  - Information for the public (NCI Fallout Study)
  - Epidemiological use (LSS, NTS, HTDS, Mayak)

Basic Elements/Foundation Issues

- Definition of exposure scenarios/exposed groups
- Identification of exposure pathways
- Development and implementation of dose reconstruction methods
- Evaluation of uncertainties
- Presentation/interpretation of results
- * Data and information
- * QA/QC

Basic Elements – Exposure Scenarios

- Assumptions about conditions of exposure
  - Conceptual representation of a situation of concern
  - Description of individuals/populations
    - Characteristics
    - Activities
    - Time spent
- Descriptions of the sources of radiation exposure

Basic Elements – Exposure Pathways

- Pathways of internal and external exposure
  - Simple – medical x-rays
  - Complex – environmental release, transport, deposition, transfer, uptake

Basic Elements – Dose Estimation Methods (1)

- Dosimetric quantity to be evaluated
  - Generally, absorbed dose to specific organs and tissues
    - Radiation protection quantities are often NOT appropriate!
  - Frequently, time dependent
  - Separation of low and high LET – no “quality factor” or “radiation weighting factor”
  - Separation of internal and external dose

Basic Elements – Dose Estimation Methods (2)

- Model Use
  - Dosimeter reading conversions
  - Calculation of energy spectra
  - Physical mock-ups
  - Medical symptoms
- Complexity of modeling should be commensurate with purpose and type, quality, and availability of data
- Validation is useful

Methodological Issues

- All computations use “models”
  - Some are relatively simple – converting a meter reading in uR/hr to an organ dose in Gy
  - Some are complex – converting an atmospheric release into an air concentration, deposition, and uptake by a cow into a concentration in milk consumed by a person

Dose Reconstruction Techniques

- Direct radiation measurements
  - Film badges, TLD
- Indirect radiation measurements or estimates
  - Environmental concentrations
  - Biodosimetry
  - Opportunistic dosimeters

Dose Reconstruction Techniques - Biodosimetry

- Cytogenetic analyses (chromosome aberrations)
  - FISH and others
- Genetic/molecular markers (Somatic mutations)
  - Glycophorin A
  - T-Cell antigen receptor (HPRT gene inactivation)
  - Micronucleus assay
- Electron Paramagnetic Resonance
  - Irradiation of hydroxyapatite (tooth enamel) produces stable paramagnetic radicals; linear dose/response 0.1 to 200 Gy

Dose Reconstruction Techniques – Opportunistic Dosimeters

- Luminescence – natural TLD, OSL
  - Quartz crystals in bricks
  - Ceramics like glass (electrical insulators), pottery, false teeth
- Neutron activation
  - Radioactive
  - Accelerator mass spectroscopy – isotopic ratios
    - Cl-36, Ni-63, Eu-152
- Track Etch
  - Glass, ceramic, plastic

Basic Elements – Estimation of Uncertainty

- ALL dose estimates are uncertain
  - Lack of complete knowledge of exposure scenario
  - Variability in relevant measurements
  - Lack of knowledge of relevant processes
- Uncertainty can be *random* or *systematic*
  - Statistical fluctuations
  - Bias (e.g., calibration, desire for "conservatism")
- Essential purpose is to provide a credible range within which there is a high degree of confidence the "true" dose lies (We'll come back to this!)

Handling of Uncertainties

- All estimates should address uncertainty
  - If worst-case assumptions indicate small doses, detailed uncertainty analyses may be unnecessary
  - In compensation programs, if reasonable upper-bound assumptions result in doses above a threshold, detailed uncertainty analyses may be unnecessary
  - But in epidemiological applications, best estimates are needed, thus a realistic description of uncertainty is required

Use of Dose Uncertainty in Epidemiology is Rapidly Changing

- In the mid-1990s, dose/effect estimates did not use dose uncertainties
- Today, the use of dose distributions is the state of the art, via maximum-likelihood estimation
- The biostatisticians know about Berkson errors, and have asked that they be identified – but don't yet know what to do with them

Basic Elements – Presenting Results

- During the work:
  - Peer reviews (SRG for JCCRER)
  - Interested parties
    - At Mayak, the combined JCCRER projects have over 200 peer-reviewed open-literature publications
- Describing conclusions
  - Interpret by discussing in the context of the objectives
  - Usually, journal articles are NOT the endpoint; epidemiology, legal uses, etc.

Basic Elements - Data

- Describe characteristics, locations, activities of people
- Describe sources of radiation
- Identify pathways of exposure
- Can be a major challenge if dealing with tens of thousands of people
- Human subjects – privacy is important
- Can be especially important in time-sensitive dose reconstructions – accidents
- Data validity is often not obvious

Basic Elements – QA/QC

- Approaches may vary for research, legal, or accident situations
- Documentation of sources, assumptions
- Computer code verification
- Standard operating procedures

Summary

- Basic Elements of Dose Reconstruction
  - Definition of exposure scenarios/exposed groups
  - Identification of exposure pathways
  - Development and implementation of dose reconstruction methods
  - Evaluation of uncertainties
  - Presentation/interpretation of results
  - * Data and information
  - * QA/QC

Summary

- No two dose reconstructions are alike
  - But they have many common features
- Use all of the data you have available
- Estimate uncertainties