Radiation Protection Considerations for Occupational Health Professionals Following a Radiological Event

REAC/TS

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REAC/TS

- The Radiation Emergency Assistance Center/Training Site (REAC/TS) is a DOE emergency response asset located at Methodist Medical Center in Oak Ridge, TN
- REAC/TS is a Collaborating Center with WHO and the IAEA
- REAC/TS staff are on call to respond to radiation accidents anywhere in the world 24/7

MISSION STATEMENT

REAC/TS

The Radiation Emergency Assistance Center/Training Site (REAC/TS) provides DOE/SO with medical advice, specialized training, and the unique capability of on-site assistance for the treatment of all types of radiation exposure accidents. REAC/TS maintains a 24-hour response center to provide direct support, including deployable equipment and personnel trained and experienced in the treatment of radiation exposure, to assist Federal, State, Tribal and local organizations, and Emergency Response Assets of Accident Response Group, Nuclear Emergency Search Team, and Federal Radiological Management Assessment Center. REAC/TS also manages the national use of DTPA and Prussian Blue, and provides occupational medical assistance to DOE EH. Continuous operation since June 1976.

REAC/TS Staff

Al Wiley, M.D., Ph.D	Director
Doran Christensen, D.O.	Assoc. Director
Pat Lowry, M.D.	Physician
W. M. Hart, R.N., M.S.	Nurse/EMT-P
R. Beauchamp, R.N.	Nurse/EMT-P
S. L. Sugarman, M.S.	HP Team Leader
Becky Kitchin, A.S.	HP Tech.

Emergency Medical & Health Physics Response Capabilities

- 24-Hour Emergency Response/Consultation
- 24-Hour Surgical/Decontamination Capabilities
- Consultant Medical/Health Physics Team, including Physician, Registered Nurse, Paramedic, Health Physicist, and Radiobiologist
- Coordination of DTPA and Prussian Blue Therapy in the United States
- Interlaboratory Collaboration

Assistance with cytogenetic dosimetry and whole body counting is also provided.

Radiation Can Cause

Nausea, Vomiting	1/2 - 48 Hours
Lymphocyte Depletion	Hours to Days
Immunosuppression	7-30 Days
Granulocytosis	1-7 Days
Thrombocytopenia	15-30 Days
Granulocytopenia	15-30 Days
Death from shock	6-48 Hours

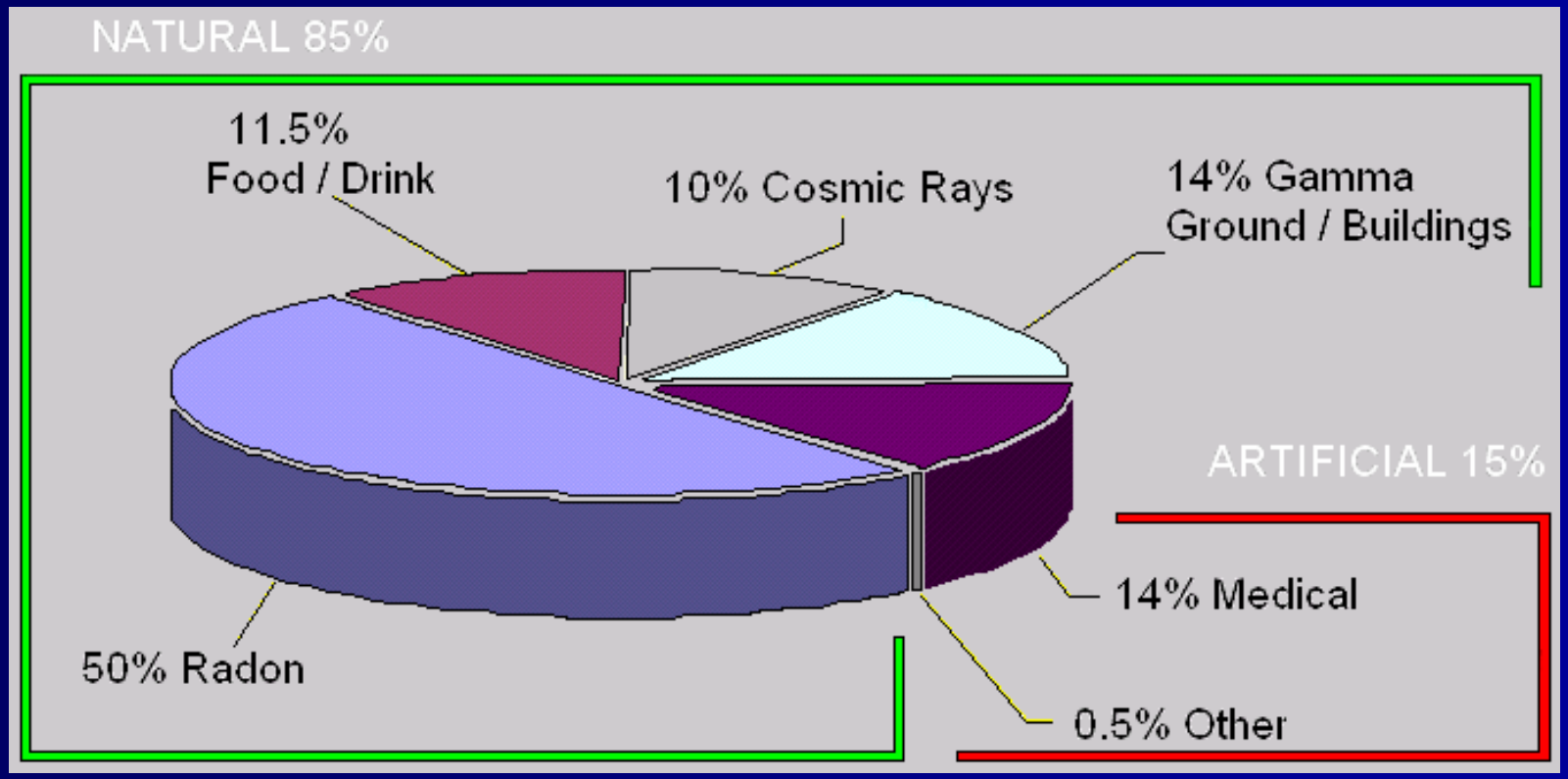
Radiation Does Not Cause

- Immediate death
- Immediate burns, wounds

Irradiation or contamination alone are not a medical emergency, or threat to responders, other persons or facilities, therefore –

Deal with life and limb threatening_conditions first – then deal with radiological conditions!

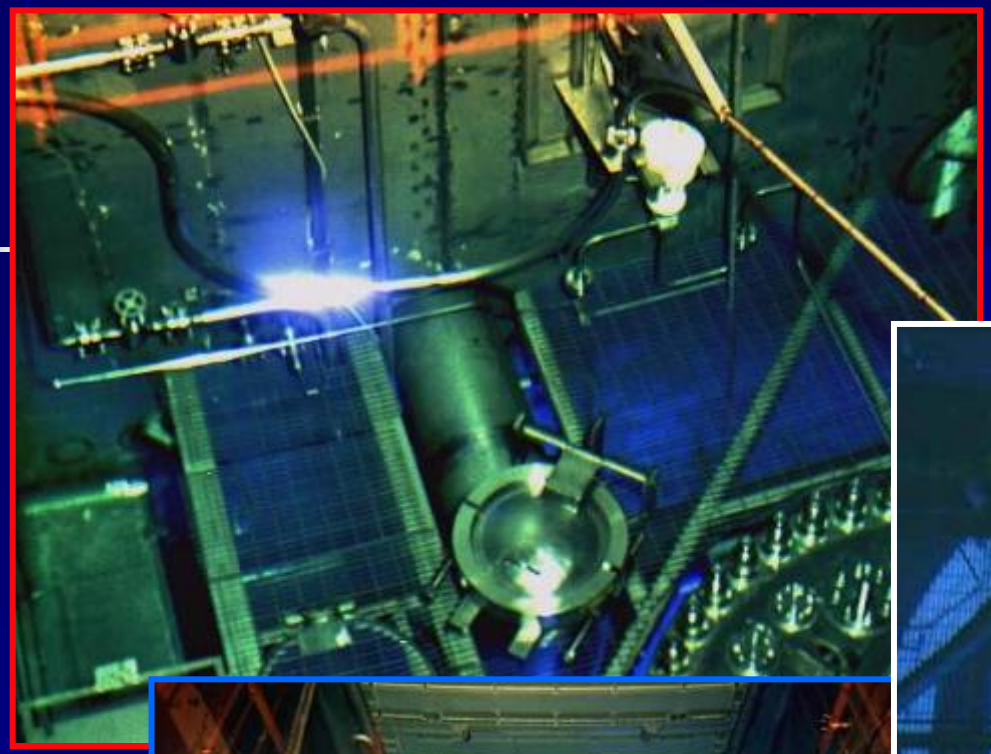
Background Radiation Sources ~360 mrem per year

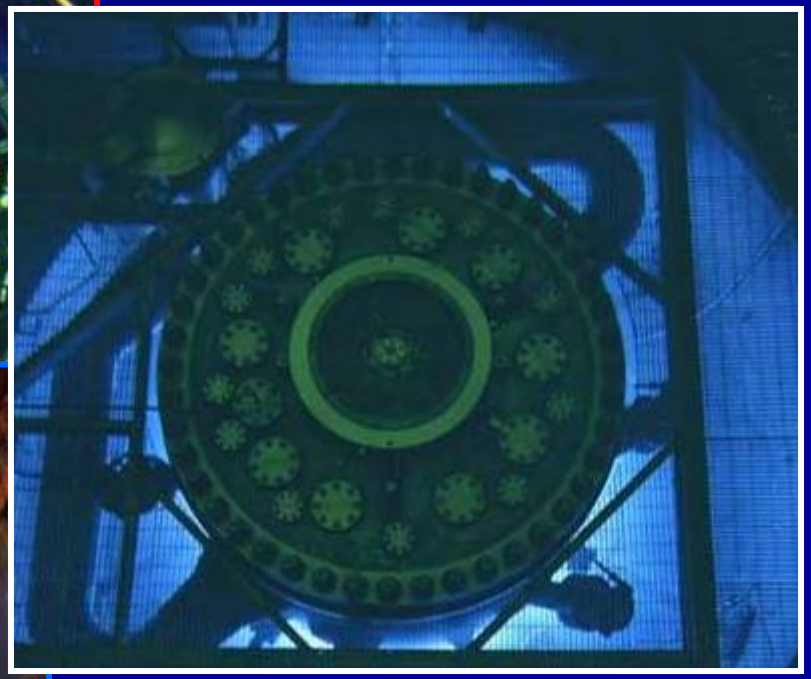


Typical Radiation Exposures

Source	Annual Dose
Natural background and manmade radiation (incl. radon)	360 mrem
Diagnostic chest x-ray	10 mrem
Flight from LA to Paris	4.8 mrem
Barium study	800 mrem
Smoking 1.5 packs per day	16 rem
Heart catheterization	45 rad
Mild Acute Radiation Sickness*	200 rad
LD50 for Irradiation*	400 rad

*acu





Source
Source

Human Sensitivity to Radiation

Highly Radiosensitive

Embryo

Fetus

Child

Adult

Least Radiosensitive

Biological Effects are Determined by:

- Total dose
- Dose rate
- Volume of tissue or body part irradiated
- Type of radiation
- Pre-existing conditions, trauma, illness, burns
- Individual susceptibility factors

Irradiation

- With an Irradiation there is no radioactive material transferred.
- An irradiated patient is NOT radioactive and cannot transfer contamination or radiation to a health care provider.

What is Contamination?

- Contamination is simply the presence of radioactive material where it is not wanted
- Persons may be contaminated either externally, internally, or both
- Exposure does not necessarily imply contamination

Health Physics Challenges

- Establishing radiological controls
- Interaction with responders and medical personnel
- Dose estimation
- Interaction with management and investigators
- Public information
- Patient interaction

Establishing Radiological Controls

- Characterize the situation
  - Process knowledge
  - Get a good history
  - Direct measurements
  - Doesn’t take long if pre-planned
- Determine appropriate controls, if any
  - Ingress & egress routes, stay time
  - Shielding
  - Monitoring

Radiological Situations

- SL-1: readings at entrance to reactor room > 500 R/hr
- Chernobyl: no periodic decon to remove ash, smoke particles, fallout from skin & clothing increased doses
- Goiania: dose rates up to 10 rad/hr from the ruptured source
- Yanango: contact dose rate with source 310 rad/min

What Takes Priority?

- Always seems to be a concern...
- In general, safety of on-scene responders takes precedence
- Medical care of victims always takes precedence over decontamination
- If an accident involves a nuclear weapon, security issues may take precedence

Interaction with Responders & Medical Care Providers

- Education and training issues
- Risk communication
- Radiological triage
- Care of contaminated patient
- Prognosis and therapy
- Contamination control & clean-up
- Waste disposal

Training / Risk Communication

- Do this well in advance of the accident
- Irradiation (exposure) vs. contamination
- Risk acceptance is a very personal decision
- Emphasize applicable exposure and contamination control techniques
- Nuclear medicine personnel are great allies

Communication

- HP's potentially involved with accident victim management may not be familiar with basic medical terminology (http://www.pharma-lexicon.com)
- Conversely, medical personnel may not speak "Health Physics-ese"

Medical Procedures

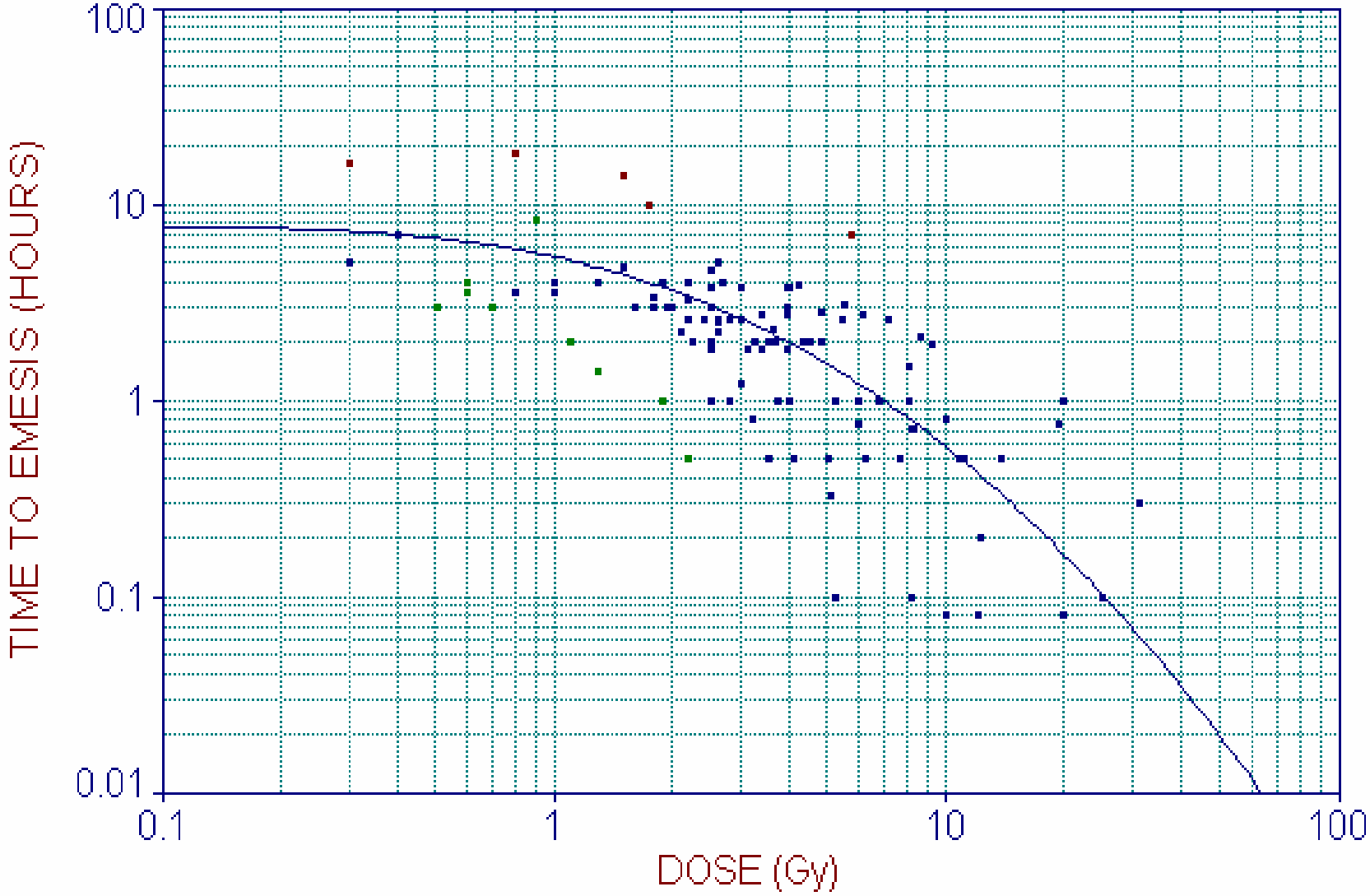
- If you're going to be in the ER, know how it operates
- Sharpen up your people skills
- Remember that in the ER, you are an advisor, but not in charge
- Get used to blood, gore and death

Radiological Triage

- Contaminated or not?
- Magnitude of exposure/dose
  - Time and severity of vomiting
    - 5% incidence of vomiting at approximately 50 rad, 90% at 350 rad
  - Na-24 activation (70 cpm = 1 rad)
  - Decrease in peripheral lymphocyte count
- Irradiation alone is never a medical emergency
  - If patient is dying, need to find cause

TIME TO EMESIS POST-ACCIDENT

REAC/TS RADIATION ACCIDENT REGISTRY 1945-2001



Care of the Contaminated Patient

- Goal is delivery of prompt and appropriate medical care to the victim(s) of a radiological accident while minimizing the potential for the contamination of the healthcare team, their equipment, and the facility.

- Medical needs have priority over contamination control concerns

Secondary Focus

- Preventing the inadvertent spread of any existing contamination.
- Facilitating a simplified clean-up effort.
- Return of the hospital Radiation Emergency Area back to regular use in a timely manner.

Patient Care Team

- Ideal team (per patient):
  - 1 physician, or more as needed
  - 1-2 nurses, or more as needed
  - 1 HP
  - 1 recorder
- Real team (per patient):
  - Whoever is available

Response Team Preparation

- Universal precautions...with a twist
- Attire: Scrubs, surgical gown (paper coveralls?), mask, head coverings, gloves, shoe covers
- Tape all clothing seams and cuffs
- Splash protection for eyes
- Double gloving procedures
- Issue dosimetry (TLD, OSLD, & self-reading)
- Lead aprons are not recommended

Contamination Control Techniques

- Set up area large enough to facilitate the reception, triage, and medical management of the anticipated number of victims
- Restrict access to the RCA
- Monitor anything or anyone leaving the controlled area
- Establish a buffer zone or secondary control line for added security

RCA Preparation

- If floor is not impervious to liquids, an absorbent cover should be emplaced
- The cover must not create additional safety hazards!
- Butcher paper has the advantage of making spilled liquids visible

Patient Arrival

- Medical assessment/treatment takes priority
- Initial patient survey is to establish if patient is contaminated or not
- Exact levels of contamination are unimportant—determine only if high or low
- Hold ambulance and attendants for survey unless needed to return to scene

Patient Management Sequence

- History (time to emesis, etc.)
- Physical assessment
- Intervention
- Assessment of contamination
  - Survey
  - Collect samples
- Prevent/treat internal contamination
- Decontamination

Sample Collection

- Nose
- Mouth
- Wounds
- Also: baseline urine, then 24-hour samples of urine and feces
- CBC w/ differential

Contamination Control Techniques

- Change medical instruments, outer gloves, patient drapes, wound dressings, etc. frequently
- Collect contaminated or soiled waste, clothing, linens, drapes, etc. in large, plastic-lined, properly-labeled containers
- Use water-absorbent sponges to capture liquids while protecting larger areas with waterproof materials

Decontamination

- Consider:
  - Medical needs of patient
  - Seriousness and extent of contamination
  - Chemical nature of contaminant
  - Presence of wounds
- Usual decontamination order:
  - Wounds
  - Body orifices
  - Intact skin

Decontamination: Wounds

1. Save dressing for analysis
2. Drape
3. Cleanse using usual wound cleansing procedures and wound cleansing agents
4. “Blot” to dry
5. Remove drapes and survey
6. Repeat as necessary
7. Dress wounds with waterproof cover before proceeding to cleanse other areas

Decontamination Procedures

Body Orifices

- Use slightly moistened swabs or irrigation
- A Morgan lens,nasal cannula, or other means may be used to irrigate the eyes
- Control run-off

Decontamination: Intact Skin

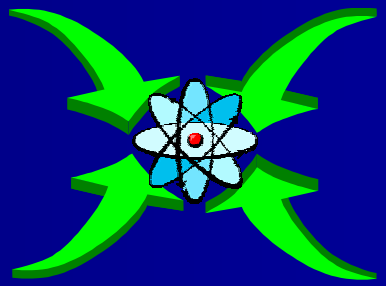
1. Wash with water.
2. Use the mechanical action of flushing and/or friction of cloth, sponge or soft brush.
3. Begin with the least aggressive techniques and the mildest agents.
4. For showering, begin with the head and proceed to the feet.

Decontamination: Intact Skin

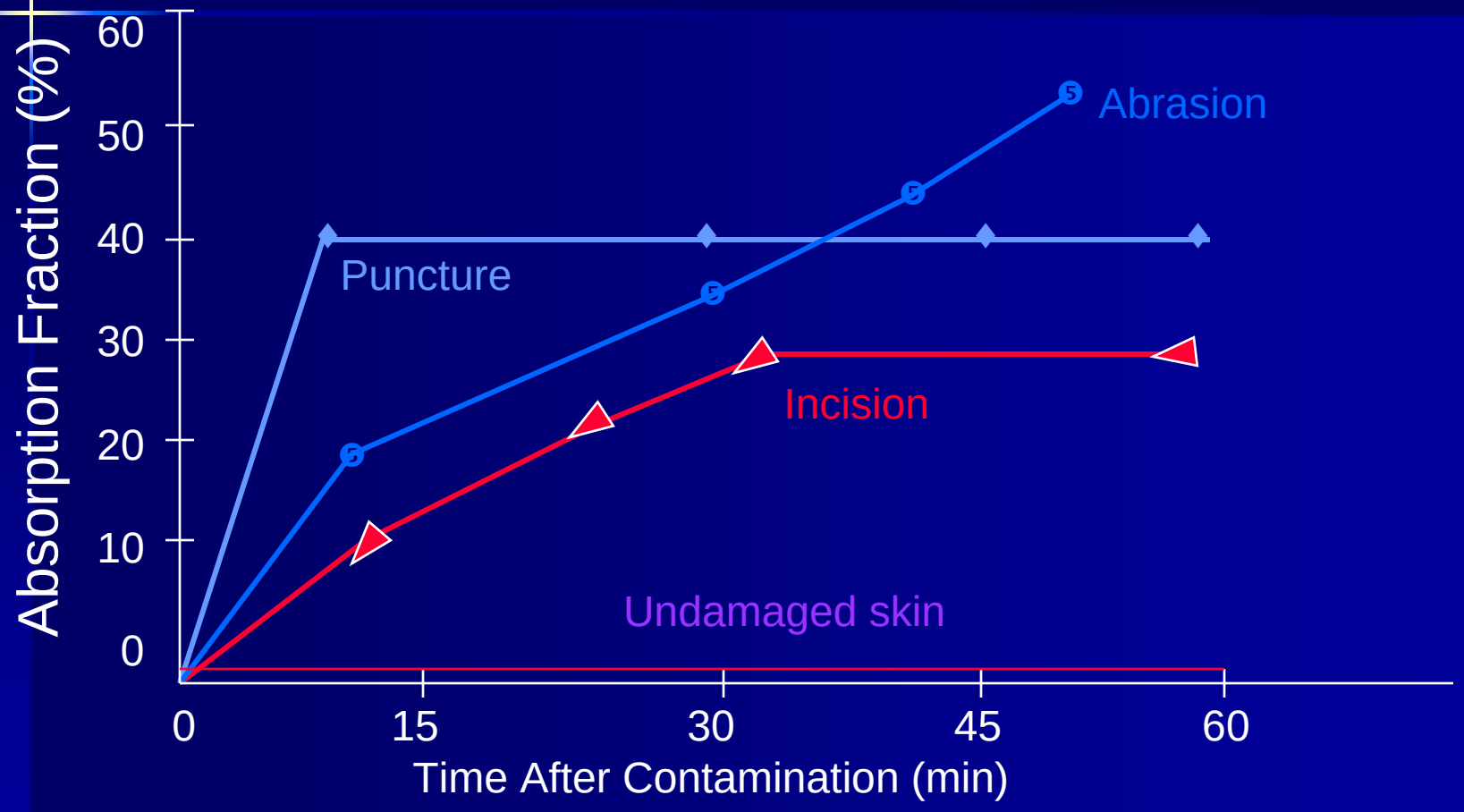
5. Keep materials out of eyes, nose, mouth and wounds. Use waterproof draping to limit spread.

6. Avoid causing mechanical, chemical or thermal damage to skin.

- Helpful Hints:
  - Drape clean areas
  - Wipe toward center
  - Blot to dry
  - Privacy for patient
  - Remember GRAVITY



Whole-body Absorption Fractions of $^{58}CoCl_2$ through mechanically wounded and damaged skin

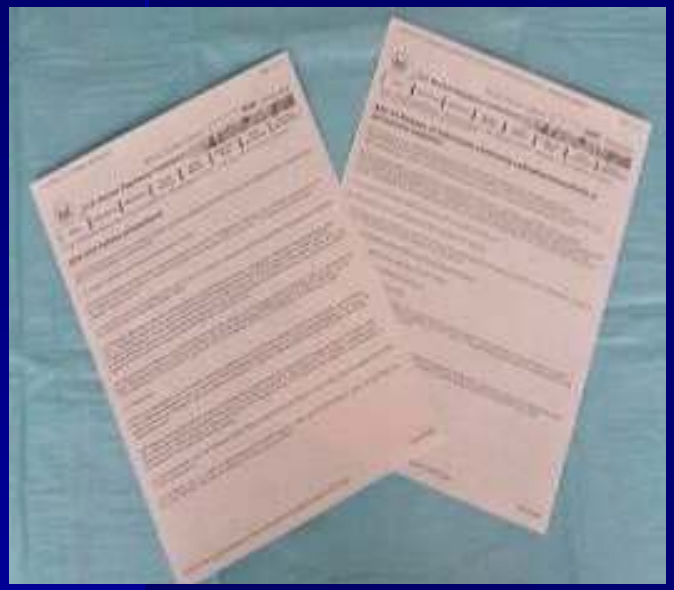


Adapted from kusama, T., et al, "Absorption of radionuclides through wounded skin." Health Physics, Vol. 51, July 1986.

Patient Release from RCA

- Perform a final survey before the patient is transferred from the area (head to toe, front and back)
- Use a technique that minimizes the potential for contamination spread
- Be sure all participants are familiar with transfer procedures

Patient Release (cont.)



- Key Issues:
  - Consultation of RSO
  - Method of discharge
  - Discharge instructions
- Perform a final survey before the patient is transferred from the area (head to toe,

  front and back).
- Use a clean team transfer technique.
- Be sure all procedures are documented.

HP Lab Tasks

- Identify the contaminant(s)
- Identity is typically more important than quantification (medical therapies for intakes of radionuclides are element-specific)

Additional HP Tasks

- Periodic checking of SRDs
- Assist staff with exiting RCA
- If only 1 or 2 HPs available, exit first to establish monitoring of team as they exit
- Supervise & monitor decontamination efforts

Cleanup and Recovery

- Control access to RCA
- Remove and dispose of all waste (ownership)
- Survey all portable items and remove if clean
- Remove floor covering if used
- Survey all remaining surfaces
- Decontaminate as necessary
- Release area for normal use
- Prepare to talk to managers, lawyers, reporters, etc.

Dose Estimation Methods

- Physical dosimetry
  - Issued dosimeters
  - Opportunistic dosimeters
- Biological dosimetry
  - Lymphocyte kinetics
  - Tissue ESR or activation
- Physical/mathematical reconstruction

General Rules for Dose Estimation

- Be a pessimist
- Consider the maximum CREDIBLE accident
- Develop contingency plans
- Medical management assuming an over-estimate of dose is less consequential than medical management assuming an under-estimate

Absorbed Dose vs. Equivalent and Effective Dose

- Equivalent dose is usually not a useful concept in radiation accident management
- Radiation weighting factors (quality factors, RBEs) are specific for both end point and reference radiation
- Published values that estimate stochastic risk from low-dose, low dose-rate irradiation are irrelevant to critical care
- Applies for both external and internal dose (tissue weighting factors also based on stochastic risk)

Dose Assessment Needs

- Deep dose to victim, especially to blood-forming organs, GI tract and lungs
- Internal dose to victim if intake occurred
- Local (shallow, or skin) and lens doses
- Doses to responders and care providers
- Doses to members of the public

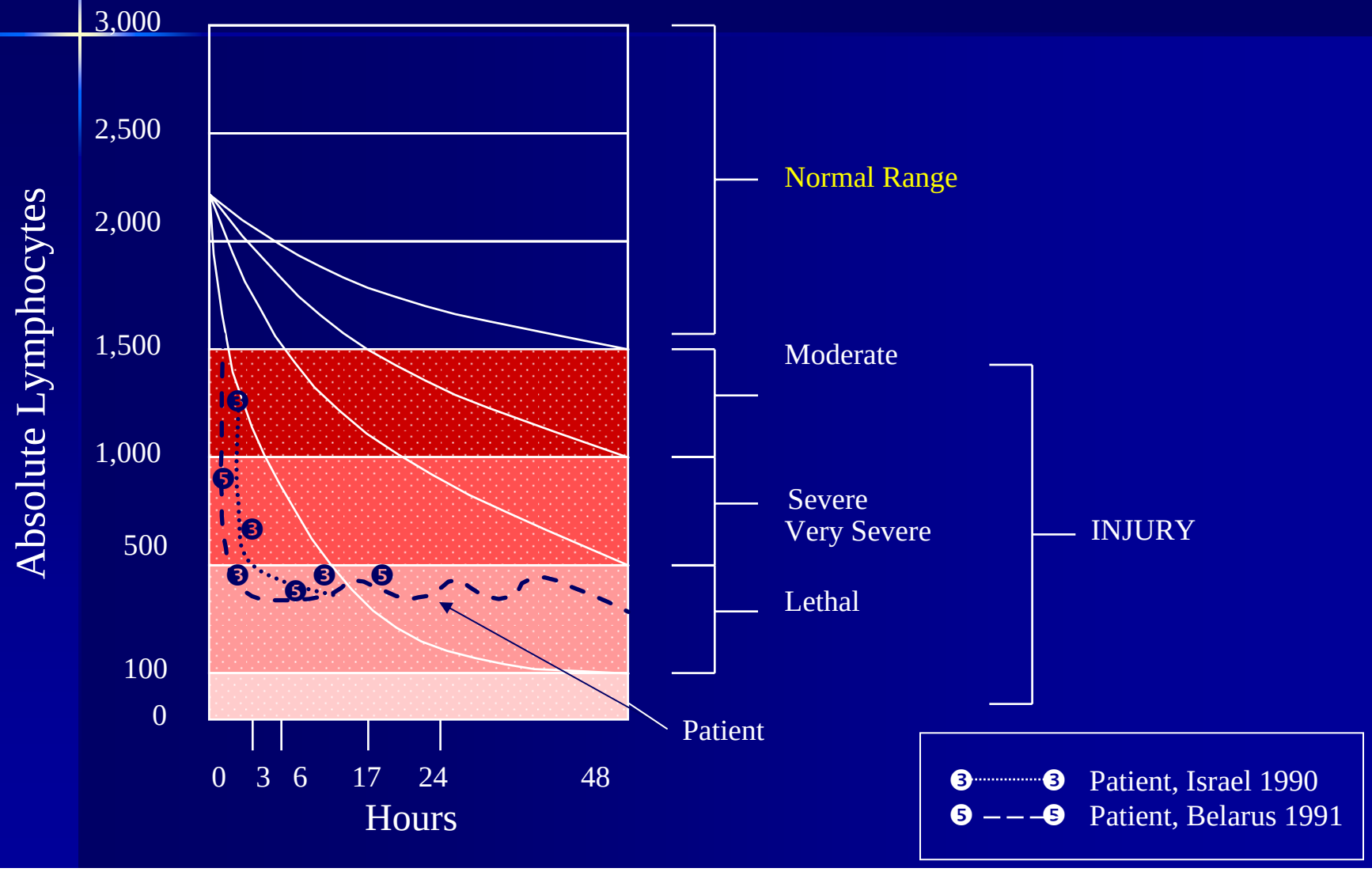
Problems with Dosimeters

- Only issued to radiation workers
- Usually not worn at time of accident
- Single point measurement—does not reflect a non-uniform radiation field
- May not be calibrated for actual exposure conditions

Biological Dosimetry

- Peripheral lymphocyte count
- Chromosome aberration analysis
  - Rings and dicentrics
  - PCC
- ESR in tooth enamel or bone samples
- Neutron activation: P-32 in hair and Na-24 in blood/whole body may be analyzed
  - Na-24 in body used for triage with survey meter

Comparison of Patient Lymphocyte Counts with Values Predicted by Andrews' Model



Opportunistic Neutron Dosimeters

- Available for neutron exposure, e.g., a criticality accident, via activation analysis
- Any metal object on the person of the victim can be used: rings, keys, coins, etc.
- Plastic eyeglass lenses may be used as “track” dosimeters
- Neutron energy spectrum must be known to interpret dose

Physical Reconstruction

- A physical phantom and dosimeters (e.g., TLD chips) are exposed to a radiation field simulating that of the accident
- Interpretation requires knowledge of:
  - Exposure time
  - Geometry
  - Characteristics of radiation field (energy, attenuation, scattering, etc.)
- Usually only relatively simple situations can be simulated, e.g., the radiography source in a pocket.

Mathematical Reconstruction

- Monte Carlo methods are used to simulate exposure (MCNP, EGS4, etc.)
- Again, exposure situation and characteristics of field must be known
- Results may be normalized to a known dose or the dose required to produce an observed biological effect
- Sophistication is limited by computer speed and memory
- Set-up and debugging can be laborious

Monte Carlo Calculations

- The Monte Carlo method follows millions of particles (betas, photons, neutrons) from their points of origin to their points of absorption or escape
- Mean free paths and interaction cross sections are used with a random number generator to generate interactions, scattering angles, and energy deposited
- Energy deposited by each particle in every volume element of the target is tallied.

Wound Dosimetry

- A common radiation accident involves a contaminated wound
- Wound monitoring equipment is used to estimate the activity in the wound, and perhaps its depth
- Surgical excision is an option if function is not threatened
- Local dosimetry models are unsophisticated
- Few systemic dosimetry models exist for intakes via wounds

What about Internal Dose?

- Doses to internal organs are not directly measured, but calculated
- Numerous models have been developed for occupational and medical internal dosimetry, but may not be applicable to the accident situation
- Radionuclide(s) must be known
- Published dose coefficients (Sv/Bq intake) and intake limits are for committed effective dose, which may or may not be relevant
- Absorbed dose rates need to be computed from first principles

Internal Deposition

- Annual Limit on Intake (ALI)
  - The amount if a radionuclide that, if taken into the body, will result in a regulatory limit being met.
- The ALI can be used to determine the magnitude of a contaminating event.
- ALI and DAC tables can be found in Federal Guidance Report #11 (EPA)

Bioassay Methods

- In-vitro
  - Excreta samples are routinely collected in medical settings
  - Laboratory capability should be pre-arranged
  - Fecal analysis may be most sensitive for inhaled activity
- In-vivo
  - Rapid method for detection of photon emitters
  - Generally cannot distinguish internal/external contamination
  - May be precluded by patient's medical condition

Bioassay Interpretation

- Accident situation may make collection and interpretation of data difficult
  - Smoke inhalation may affect lung clearance
  - Multiple intake pathways may occur
  - High activity creates dead-time problems for whole-body counting (Goiania)
  - Continued intake from embedded, contaminated glass fragments (Hanford)

Impact of Therapy

- Therapy will affect radionuclide biokinetics
  - e.g., DTPA will increase the urinary excretion rate of soluble plutonium compounds by as much as a factor of fifty, with an exponential decay of effectiveness
- The health physicist must compute “saved dose” from planned therapy so the physician can make an informed decision if toxicity is possible
  - e.g., renal damage from too-rapid uranium excretion

Internal Dose Follow-up

- Internal doses may be received for extended periods after the accident
- Estimates of internal doses are more likely to change with time than are estimates of external doses
- Biological consequences of internal dose may not be readily observable

A Few Dosimetry Rules

- Eventually the patient will tell you what the dose was (N. Wald, M.D.)
- Dose estimates should inform, but not determine medical decisions
- No one is built like Reference Man nor follows the ICRP models
- “Primum non nocere” also applies to health physics

Interactions with Management

- Keep management informed of situation, but...
- Complete information will take a long time to obtain
- Dose estimates (especially internal) will change with time
- Hindsight is always 20/20
- Establish the emergency response plan, then follow it

More Interactions with Management

- HP advice/input will be needed for:
  - Re-entry and recovery
  - Site clean-up
  - Actual/predicted releases to environment
  - Root cause analysis
  - Corrective actions
  - Lessons learned

Interactions with Investigators

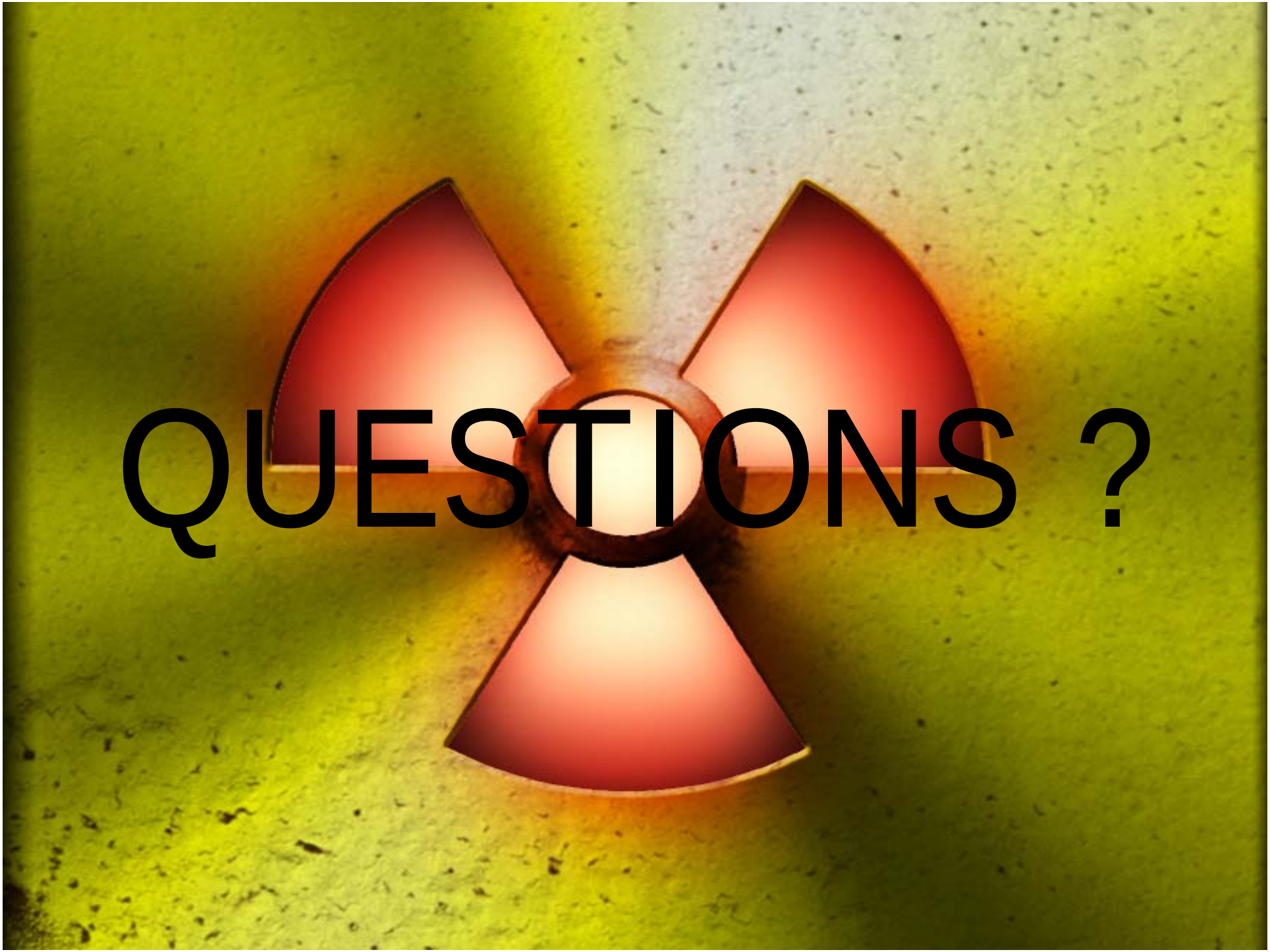
- As time permits, make copious notes (use a tape recorder?)
- Remember to preserve evidence (e.g., chain of custody on samples)
- Following approved procedures is usually defensible
- As soon as possible, write out your notes into a comprehensive (and comprehensible) document
- Keep your story straight, i.e., tell it like it happened

Public Information Issues

- Best to let trained public relations experts handle the situation
- You may be asked to provide sound bites to cover footage
- Emphasize effectiveness of emergency procedures and prior training
- K. I. S. S.

Conclusions

- Health physics management of a severe radiation accident is not for the faint of heart
- Get used to medical terminology and hospital procedures
- Stick to your area of expertise
- Call REAC/TS at 1-865-576-3131


QUESTIONS ?