EMORY | WINSHIP CANCER INSTITUTE

A Cancer Center Designated by the National Cancer Institute

Radiation Safety/Protection, Shielding and Quality Assurance

Eric Elder, PhD

Why Radiation Protection

Stochastic

- NO threshold doses
- The probability is proportional to dose
- The severity of stochastic effects is independent of dose.
- Example – hereditary effects, cancer induction

Non-Stochastic

- Always has threshold dose
- Above this threshold dose, severity of the damage is proportional to dose
- Example – cataracts, threshold dose of 2 Gy (larger doses if fractionated)

Somatic

- Arising from exposure in individuals lifetime: genetic and teratogenic

Radiation Safety

ALARA – As Low As Reasonably Achievable

make every reasonable effort to maintain exposures to radiation as far below the recommended dose limits in relation to societal needs, values, benefits gained and economic factors

- Time
- Distance
- Shielding

Dose Equivalent

Dose Equivalent (H) = Dose (D) × Quality Factor (Q)

H = Sievert = Sv (1 Sv = 100 rem)

D = Gray = Gy (1 Gy = 100 rad = 100cGy)

Radiation	Quality Factor
X-Rays γ-Rays Electrons	1
Thermal Neutrons	5
Neutrons Heavy Particles	20

Effective Dose Equivalent

Sum of the weighted dose equivalents for irradiated tissues or organs

$$H_E = \sum W_T H_T$$

Where

- H_E is the effective dose equivalent
- W_T is the tissue weighting factor.
- H_T is the mean dose equivalent received by that tissue.

Tissue Weighting Factors, W_T

TABLE 16.2 Recommended Values of the Weighting Factors W_T, for Calculating Effective Dose Equivalent and the Risk Coefficients from which they were Derived

Tissue (T)	*Risk Coefficient*	W_T
Gonads	$40 \times 10^{-4}\ Sv^{-1}$ $(40 \times 10^{-6}\ rem^{-1})$	0.25
Breast	$25 \times 10^{-4}\ Sv^{-1}$ $(25 \times 10^{-6}\ rem^{-1})$	0.15
Red bone marrow	$20 \times 10^{-4}\ Sv^{-1}$ $(20 \times 10^{-6}\ rem^{-1})$	0.12
Lung	$20 \times 10^{-4}\ Sv^{-1}$ $(20 \times 10^{-6}\ rem^{-1})$	0.12
Thyroid	$5 \times 10^{-4}\ Sv^{-1}$ $(5 \times 10^{-6}\ rem^{-1})$	0.03
Bone surface	$5 \times 10^{-4}\ Sv^{-1}$ $(5 \times 10^{-6}\ rem^{-1})$	0.03
Remainder	$50 \times 10^{-4}\ Sv^{-1}$ $(50 \times 10^{-6}\ rem^{-1})$	0.30
Total	$165 \times 10^{-4}\ Sv^{-1}$ $(165 \times 10^{-6}\ rem^{-1})$	1.00

From National Council on Radiation Protection and Measurements. *Recommendations on Limits for Exposure to Ionizing Radiation*. Report No. 91. Bethesda, MD: National Council on Radiation Protection and Measurements; 1987, with permission.
Values are from International Commission on Radiological Protection. *Recommendations of the International Commission on Radiological Protection*. Report No. 26. New York: Pergamon Press; 1977.

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Table 19.1—*Summary of recommendations.*[a,b]

A. Occupational exposures[c]	
1. Effective dose limits	
a) Annual	50 mSv
b) Cumulative	10 mSv × age
2. Equivalent dose annual limits for tissues and organs	
a) Lens of eye	150 mSv
b) Skin, hands and feet	500 mSv
B. Guidance for emergency occupational exposure[c]	(see Section 14)
C. Public exposures (annual)	
1. Effective dose limit, continuous or frequent exposure[c]	1 mSv
2. Effective dose limit, infrequent exposure[c]	5 mSv
3. Equivalent dose limits for tissues and organs[c]	
a) Lens of eye	15 mSv
b) Skin, hands and feet	50 mSv
4. Remedial action for natural sources:	
a) Effective dose (excluding radon)	>5 mSv
b) Exposure to radon decay products	$>7 \times 10^{-3}$ Jh m^{-3}
D. Education and training exposures (annual)[c]	
1. Effective dose limit	1 mSv
2. Equivalent dose limit for tissues and organs	
a) Lens of eye	15 mSv
b) Skin, hands and feet	50 mSv
E. Embryo-fetus exposures (monthly)	
1. Equivalent dose limit	0.5 mSv
F. Negligible individual dose (annually)[c]	0.01 mSv

[a] Excluding medical expenses.
[b] See Tables 4.2 and 5.1 for recommendations on w_R and w_T, respectively.
[c] Sum of external and internal exposures but excluding doses from natural sources.

Who must wear dosimetry?

Whole Body Badge

Ring Badge

Adults who, in one year, are likely to receive a dose exceeding 10% of an annual occupational dose limit

Minors or pregnant women who, in one year, are likely to receive a dose exceeding 10% of their applicable occupational dose limit of 500 mrem

Any individual entering a high or very high radiation area

Signage for Radiation Area

- Controlled area: >2mR/hr at 30cm

- Radiation Area >5mR/hr at 30 cm

- High Radiation Area >100 mR/hr at 30 cm

- Very High Radiation Area >500 rads/hr at 1 meter

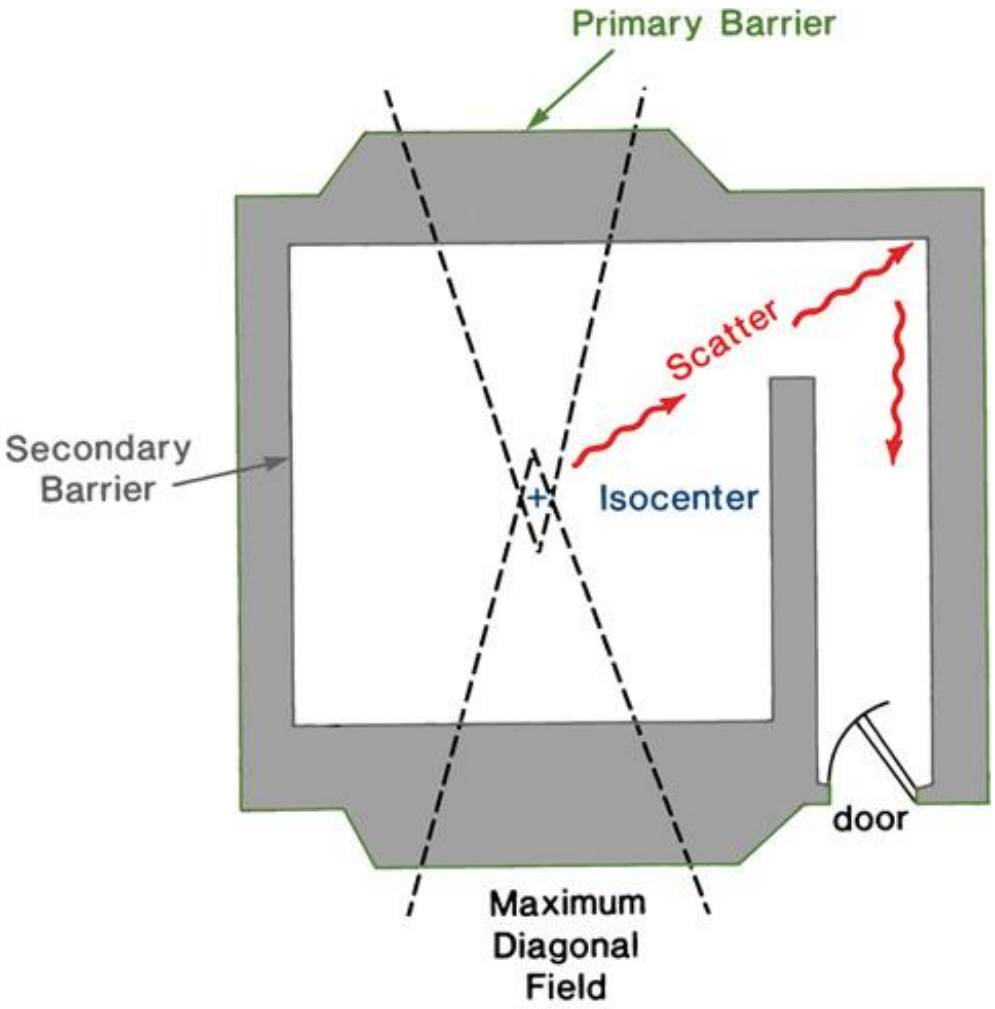
Transportation Labels

Package Labeling Criteria

Warning Label	Max. Rad. Level at Package Surface (mR/hr)	Max. Rad. Level at 1 m (TI)
RADIOACTIVE WHITE I	0.5	None
RADIOACTIVE YELLOW II	50	0 to ≤ 1
RADIOACTIVE YELLOW III	200	0 to ≤ 10

"TRANSPORT INDEX" - TI is the Radiation Level at 1 meter

Linac Vault Shielding



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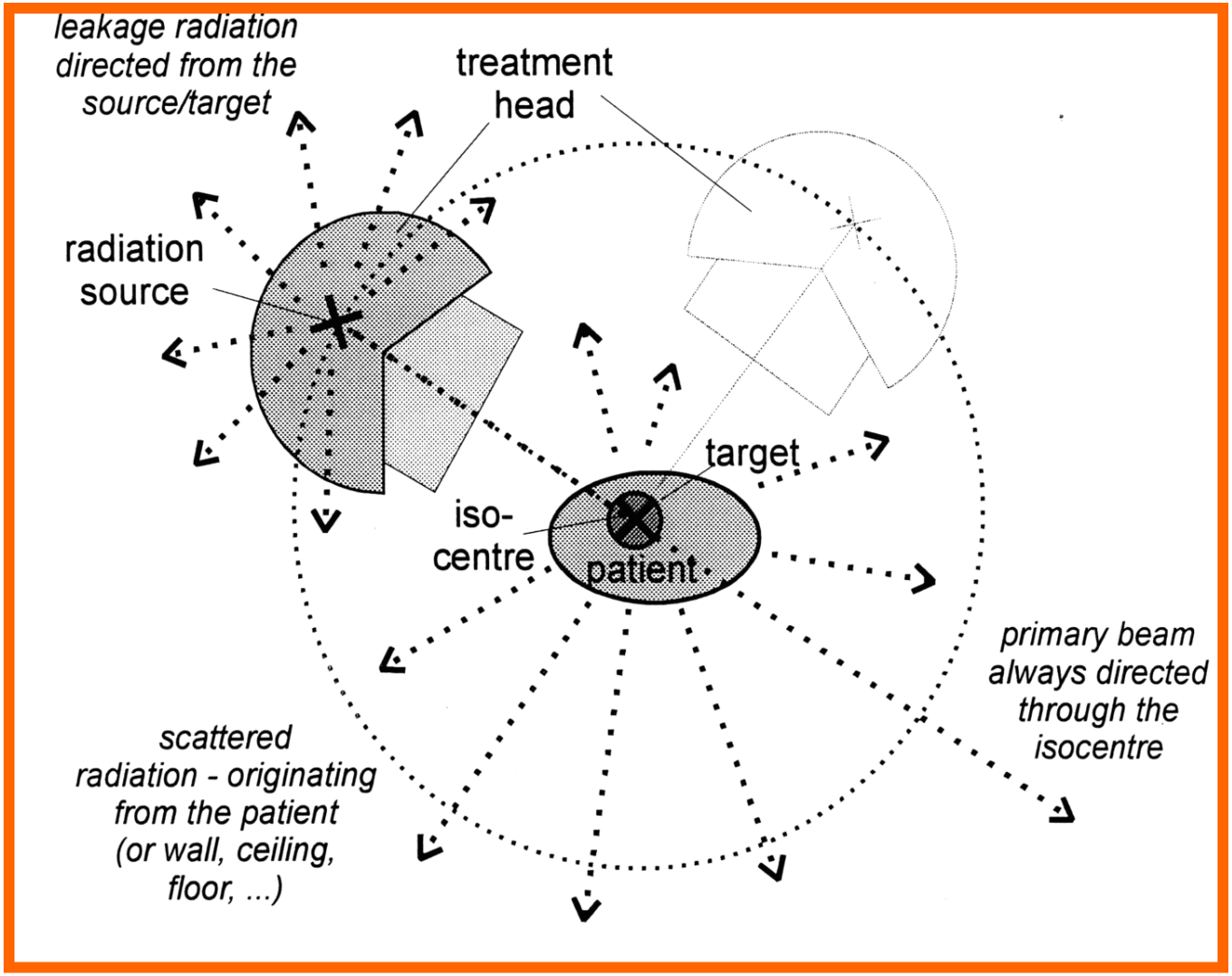
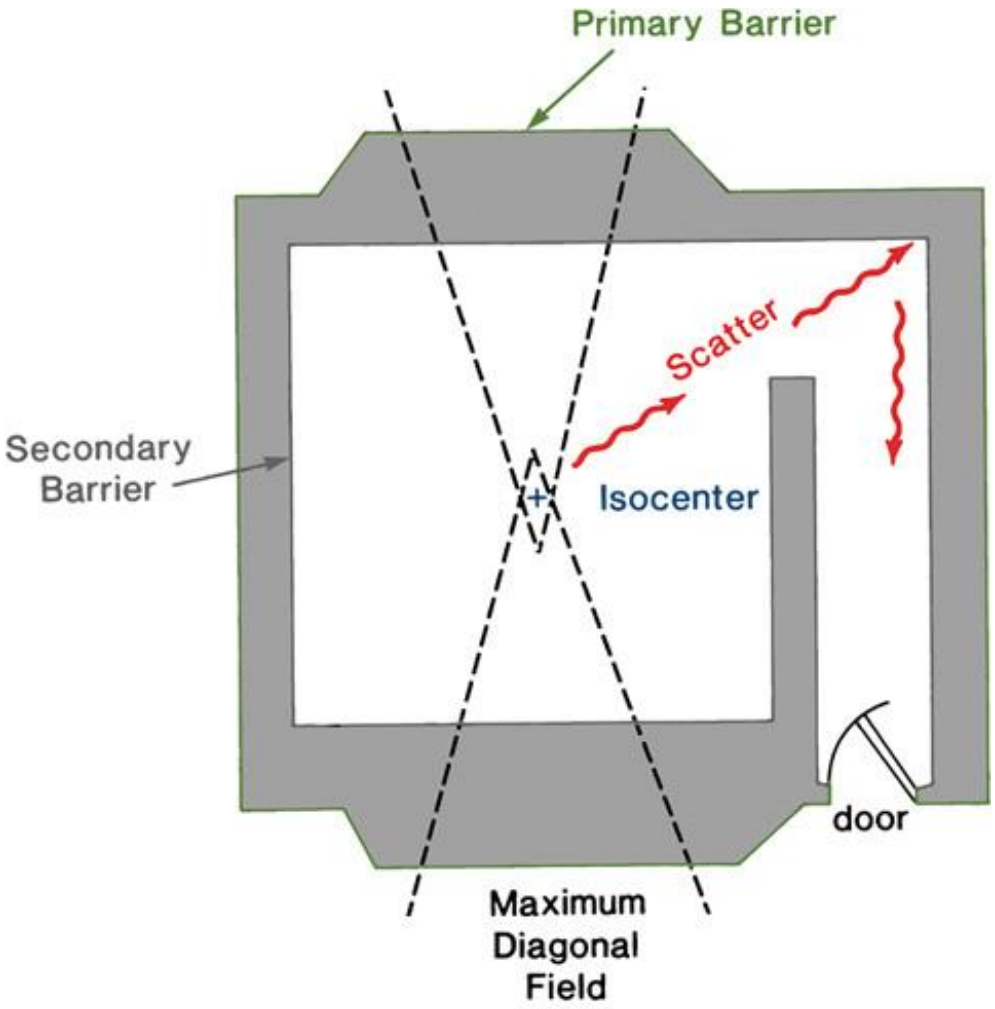
Primary, Secondary, Leakage



Metcalfe et al

Linac Vault Shielding



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Compton Scatter

General Form

$$h\nu' = \frac{h\nu}{1 + \left(\frac{h\nu}{m_0 c^2}\right)(1 - \cos\varphi)}$$

Photon Scatter Angle $\varphi = 90°$

$$h\nu' = \frac{h\nu}{1 + \left(\frac{h\nu}{0.511}\right)(1 - 0)} = \frac{h\nu}{1 + \left(\frac{h\nu}{0.511}\right)} = 0.511 MeV$$

Photon Scatter Angle $\varphi = 180°$

$$h\nu' = \frac{h\nu}{1 + \left(\frac{h\nu}{0.511}\right)(1 - (-1))} = \frac{h\nu}{\left(\frac{h\nu}{0.511}\right)2} = \frac{0.511 MeV}{2} = 0.256 MeV$$

Shielding Definitions

- **Workload (W)** – Weekly dose output at isocenter
  - Estimated by (number of patients treated/day) x (dose @ isocenter per patient) x 5
- **Use Factor (U)** – Fraction of the operating time during which the linac beam is directed at a particular primary barrier.
- **Occupancy Factor (T)** – Fraction of operating time during which the area of interest is occupied by an individual (between 0 and 1).
- **Distance (d)** – Distance in meters from the radiation source to the area to be protected (inverse square law assumed).

Suggested Use Factors

Location	Use Factor
Floor	1
Walls	1/4
Ceiling	1/4 – 1/2, depending on equipment and techniques

Suggested Occupancy Factors

Location	Occupancy Factor (T)
Full occupancy areas (areas occupied full time by an individual), e.g. administrative or clerical offices; treatment planning areas, treatment control rooms, nurse stations, receptionist areas, attended waiting rooms, occupied space in nearby building	1
Adjacent treatment room, patient examination room adjacent to shielded vault	1/2
Corridors, employee lounges, staff rest rooms	1/5
Treatment Vault Doors	1/8
Public Toilets, unattended vending rooms, storage areas, outdoor areas with seating, unattended waiting rooms, patient holding areas, attics, janitor's closets	1/20
Outdoor areas with only transient pedestrian or vehicular traffic, unattended parking lots, vehicular drop off areas (unattended), stairways, unattended elevators	1/40

P, Maximum Permissible Dose Equivalents

- Controlled Areas
  - 0.1 mSv/wk
  - 5 mSv/y
- Uncontrolled Areas
  - 0.02 mSv/wk
  - 1 mSv/y

Barrier Thickness Equations

Primary

$$B_P = \frac{Pd^2}{WUT}$$

Secondary – Scatter

$$B_s = \frac{Pd^2 d'^2}{WUT} \times \frac{400}{aF}$$

Secondary – Leakage

$$B_L = \frac{Pd^2}{WUT} \times \frac{1}{0.001}$$

Neutrons

$$^{63}_{29}\mathrm{Cu} + g \rightarrow {}^{62}_{29}\mathrm{Cu} + {}^{1}_{0}\mathrm{n}$$

- Neutron contamination increases rapidly with energy from 10 to 20 MV
- Concrete barriers designed for x-ray shielding are sufficient for photoneutrons.
- Door must be protected against neutrons

Doors

- Megavoltage units require a maze and may actually not require a door at all if the maze is long enough and well designed – in this case one must ensure no one enters the room during or before treatment

- A door-less maze requires warning signs and motion detectors which can determine if someone enters the room unauthorized and disable beam delivery

Quality Assurance

- TG40 – Linac, Cobalt, Simulator, Brachy, etc.

COMPREHENSIVE QA FOR RADIATION ONCOLOGY

- TG142–Linac

Task Group 142 report: Quality assurance of medical accelerators[a)]

- TG66 – CT Simulator

Quality assurance for computed-tomography simulators and the computed-tomography-simulation process: Report of the AAPM Radiation Therapy Committee Task Group No. 66

QA – AAPM TG40

- Comprehensive QA Program
  - QA Committee
  - Policies and Procedures Manual
  - Comprehensive Team
  - Quality Audit
  - Resources (personnel, tools, time)
  - Continuous Quality Improvement

QA – AAPM TG40

THERAPY EQUIPMENT

- A. General
- B. Test Frequency
- C. Guidelines for Tolerance Values
- D. QA of Cobalt-60 Units
- E. QA of Medical Electron Accelerators
  - QA of Newer Innovations on Medical Accelerators
- F. QA of Simulators
- G. QA of CT Scanners
- H. QA of Measurement Equipment
- I. Documentation and Records of QA

QA – AAPM TG40 Brachytherapy

- 1. Description of Sources
- 2. Calibration of Sources
  - a. Specification of Source Strength
  - b. Traceability of Source Calibration
  - c. Recommendations
- 3. Brachytherapy Source Calibrators
  - a. Commissioning a Calibrator
  - b. Redundancy
- 4. Brachytherapy Applicators
- 5. Source Inventories
  - a. Long Half-life Sources
  - b. Short Half-life Sources
  - c. In-use Inventory

TG-142 – Daily

TABLE I. Daily.

Procedure	Machine-type tolerance		
	Non-IMRT	IMRT	SRS/SBRT
Dosimetry			
X-ray output constancy (all energies) Electron output constancy (weekly, except for machines with unique e-monitoring requiring daily)		3%	
Mechanical			
Laser localization	2 mm	1.5 mm	1 mm
Distance indicator (ODI) @ iso	2 mm	2 mm	2 mm
Collimator size indicator	2 mm	2 mm	1 mm
Safety			
Door interlock (beam off)		Functional	
Door closing safety		Functional	
Audiovisual monitor(s)		Functional	
Stereotactic interlocks (lockout)	NA	NA	Functional
Radiation area monitor (if used)		Functional	
Beam on indicator		Functional	

TG-142 – Monthly

TABLE II. Monthly.

Procedure	Machine-type tolerance		
	Non-IMRT	IMRT	SRS/SBRT
Dosimetry			
X-ray output constancy Electron output constancy Backup monitor chamber constancy		2%	
Typical dose rate[a] output constancy	NA	2% (@ IMRT dose rate)	2% (@ stereo dose rate, MU)
Photon beam profile constancy		1%	
Electron beam profile constancy		1%	
Electron beam energy constancy		2%/2 mm	
Mechanical			
Light/radiation field coincidence[b]		2 mm or 1% on a side	
Light/radiation field coincidence[b] (asymmetric)		1 mm or 1% on a side	
Distance check device for lasers compared with front pointer		1mm	
Gantry/collimator angle indicators (@ cardinal angles) (digital only)		1.0°	
Accessory trays (i.e., port film graticle tray)		2 mm	
Jaw position indicators (symmetric)[c]		2 mm	
Jaw position indicators (asymmetric)[d]		1 mm	
Cross-hair centering (walkout)		1 mm	
Treatment couch position indicators[e]	2 mm/1°	2 mm/1°	1 mm/0.5°
Wedge placement accuracy		2 mm	
Compensator placement accuracy[f]		1 mm	
Latching of wedges, blocking tray[g]		Functional	
Localizing lasers	±2 mm	±1 mm	< ± 1 mm
Safety			
Laser guard-interlock test		Functional	
Respiratory gating			
Beam output constancy		2%	
Phase, amplitude beam control		Functional	
In-room respiratory monitoring system		Functional	
Gating interlock		Functional	

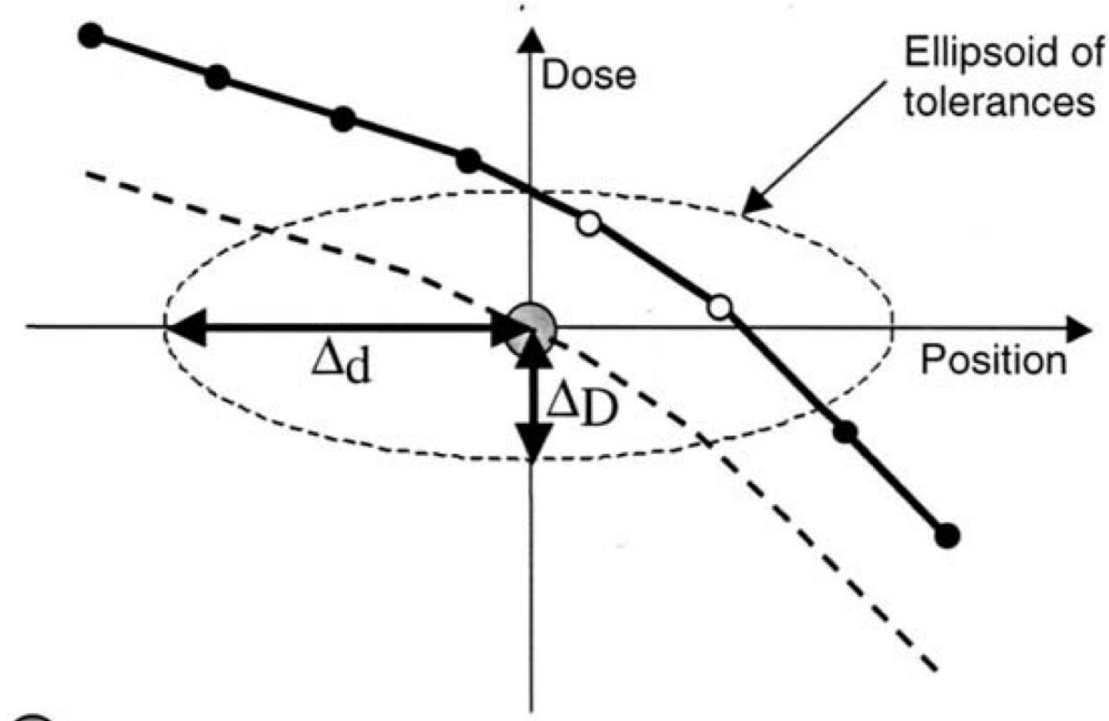
[a]Dose monitoring as a function of dose rate.
[b]Light/radiation field coincidence need only be checked monthly if light field is used for clinical setups.
[c]Tolerance is summation of total for each width or length.
[d]Asymmetric jaws should be checked at settings of 0.0 and 10.0.
[e]Lateral, longitudinal, and rotational.
[f]Compensator based IMRT (solid compensators) require a quantitative value for tray position (wedge or blocking tray slot) set at a maximum deviation of 1.0 mm from the center of the compensator tray mount and the cross hairs.
[g]Check at collimator/gantry angle combination that places the latch toward the floor.

TG-142 – Annual

TABLE III. Annual.

Procedure	Machine-type tolerance		
	Non-IMRT	IMRT	SRS/SBRT
Dosimetry			
X-ray flatness change from baseline		1%	
X-ray symmetry change from baseline		±1%	
Electron flatness change from baseline		1%	
Electron symmetry change from baseline		±1%	
SRS arc rotation mode (range: 0.5–10 MU/deg)	NA	NA	Monitor units set vs delivered: 1.0 MU or 2% (whichever is greater) Gantry arc set vs delivered: 1.0° or 2% (whichever is greater)
X-ray/electron output calibration (TG-51)		±1% (absolute)	
Spot check of field size dependent output factors for x ray (two or more FSs)		2% for field size $<4\times4$ cm^2, 1% $\geq4\times4$ cm^2	
Output factors for electron applicators (spot check of one applicator/energy)		±2% from baseline	
X-ray beam quality (PDD_{10} or TMR_{10}^{20})		±1% from baseline	
Electron beam quality (R_{50})		±1 mm	
Physical wedge transmission factor constancy		±2%	
X-ray monitor unit linearity (output constancy)	±2% ≥5 MU	±5% (2–4 MU), ±2% ≥5 MU	±5% (2–4 MU), ±2% ≥5 MU
Electron monitor unit linearity (output constancy)		±2% ≥5 MU	
X-ray output constancy vs dose rate		±2% from baseline	
X-ray output constancy vs gantry angle		±1% from baseline	
Electron output constancy vs gantry angle		±1% from baseline	
Electron and x-ray off-axis factor constancy vs gantry angle		±1% from baseline	
Arc mode (expected MU, degrees)		±1% from baseline	
TBI/TSET mode		Functional	
PDD or TMR and OAF constancy		1% (TBI) or 1 mm PDD shift (TSET) from baseline	
TBI/TSET output calibration		2% from baseline	
TBI/TSET accessories		2% from baseline	
Mechanical			
Collimator rotation isocenter		±1 mm from baseline	
Gantry rotation isocenter		±1 mm from baseline	
Couch rotation isocenter		±1 mm from baseline	
Electron applicator interlocks		Functional	
Coincidence of radiation and mechanical isocenter	±2 mm from baseline	±2 mm from baseline	±1 mm from baseline
Table top sag		2 mm from baseline	
Table angle		1°	
Table travel maximum range movement in all directions		±2 mm	
Stereotactic accessories, lockouts, etc.	NA	NA	Functional
Safety			
Follow manufacturer's test procedures		Functional	
Respiratory gating			
Beam energy constancy		2%	
Temporal accuracy of phase/amplitude gate on		100 ms of expected	
Calibration of surrogate for respiratory phase/amplitude		100 ms of expected	
Interlock testing		Functional	

Gamma Analysis



$$\Gamma_{\mathrm{r}}(\boldsymbol{r}_{\mathrm{c}}, D_{\mathrm{c}}) \equiv \sqrt{\frac{\Delta r^2}{\Delta d_{\mathrm{M}}^2} + \frac{\Delta D^2}{\Delta D_{\mathrm{M}}^2}} \leq 1$$

T. Depuydt et al. / Radiotherapy and Oncology 62 (2002) 309–319

ACR-ASTRO Practice Guidelines

1. Plan and/or approve the immobilization/ repositioning system in consultation with other members of the team.
2. Define the goals and requirements of the treatment plan.
3. Delineate tumor and specify and approve target volumes, preferably using the methodology in the International Commission on Radiation and Measurements (ICRU) Report 50 and 62 [10- 11].
4. Contour organs at risk ("critical normal structures") not clearly discernible on treatment planning images, as clinically appropriate.
5. Review and approve all critical structures contoured.

ACR-ASTRO Practice Guidelines

6. Prescribe the appropriate target dose and limitations on critical normal structures, as clinically appropriate.
7. Perform the final evaluation and approve the 3D treatment plan for implementation. The plan must be signed, or otherwise authenticated, and dated by the physician.
8. Review all implementation and verification images (simulation and/or portal images), and initial, or otherwise authenticate, and date them.
9. Participate in peer review of contours, prescription, 3D treatment plans, and verification images in conjunction with other members of the team.

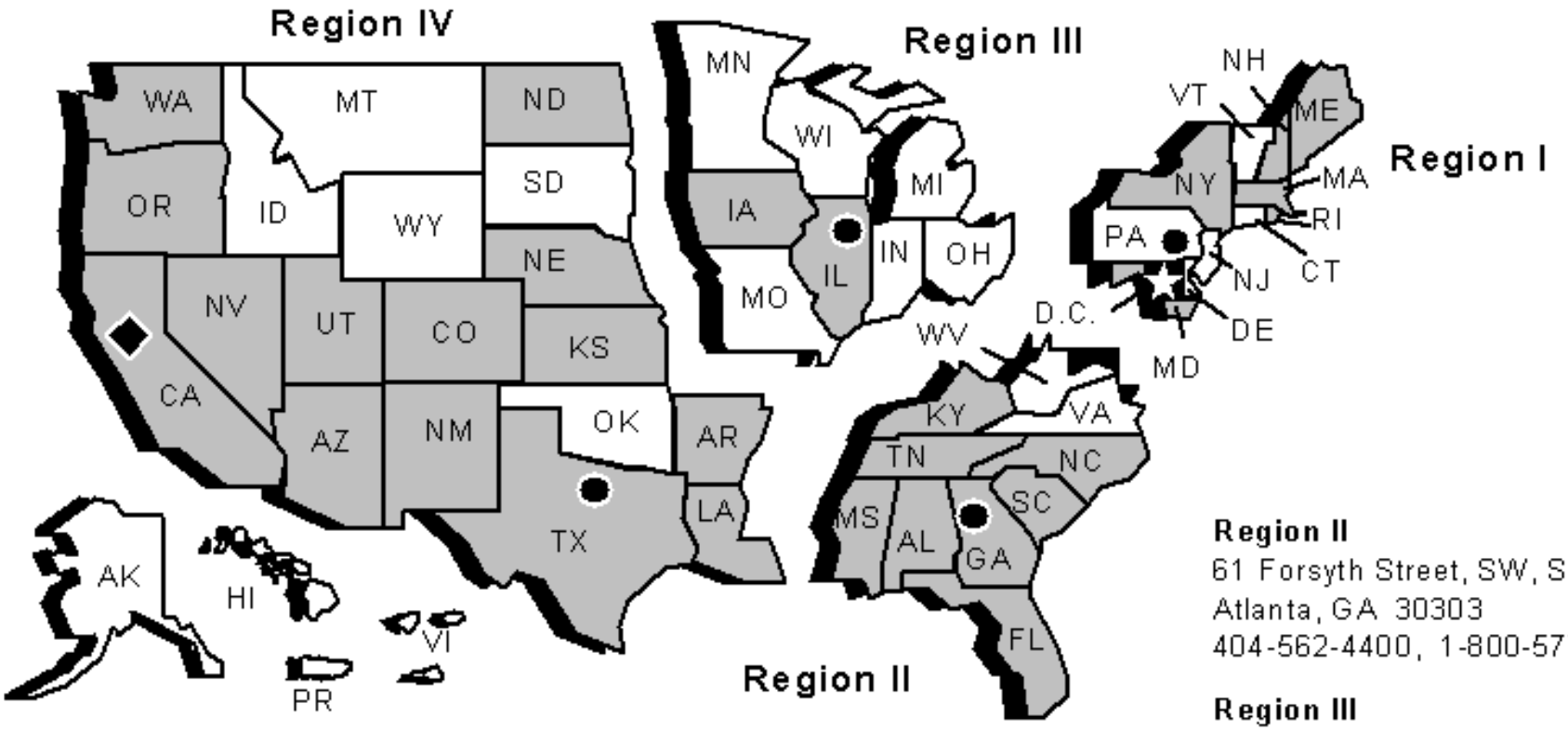
Other QA

- Management of Respiratory Motion – TG76
- Treatment Planning System – TG 53
- IMRT QA – TG 119

Nuclear Regulatory Commission (NRC)

- The NRC controls the use of all-reactor produced materials (by-product materials) in the US.
- The use of “naturally” occurring radioactive materials and x-ray machines is regulated by individual states.
- Agreement states – States than have an agreement with the USNRC that allow these stated to enforce NRC regulations.

Locations of NRC Offices and Agreement States



Region II
61 Forsyth Street, SW, Suite 23T85
Atlanta, GA 30303
404-562-4400, 1-800-577-8510

Region III
801 Warrenville Road
Lisle, Il 60532-4351
630-829-9500, 1-800-522-3025

Region IV
611 Ryan Plaza Drive, Suite 400
Arlington, TX 76011-8064
817-860-8100, 1-800-952-9677

Headquarters
Washington, D.C. 20555-0001
301-415-7000, 1-800-368-5642

Region I
475 Allendale Road
King of Prussia, PA 19406-1415
610-337-5000, 1-800-432-1156

Walnut Creek Field Office
1450 Maria Lane
Walnut Creek, CA 94596-5368
510-975-0200, 1-800-882-4672

Key Radiation Protection Regulations

Code of Federal Regulations, Title10

- Part 20 – Standards for Protection Against Radiation.
- Part 35 – Medical Use of By-product Material
- Part 71 – Packaging and Transportation of Radioactive Material

http://www.nrc.gov/reading-rm/doc-collections/cfr/cfr-title-10.zip

10 CFR 20.1301 Dose Limits

- Total effective dose equivalent to individual member of the public $\leq$ 0.1 rem (1mSv)

- Visitors to an individual who cannot be released from the hospital because of radioactive treatment material can receive a dose $>$ than 0.1 rem (1mSv) if:
  - Radiation dose received $\leq$ 0.5 rem (5mSv)
  - AU has determined before the visit that the visit is appropriate

10 CFR 35.4002 Criminal Penalties

- (a) Section 223 of the Atomic Energy Act of 1954, as amended, provides for criminal sanctions for willful violation of, attempted violation of, or conspiracy to violate, any regulation issued under sections 161b, 161i, or 161o of the Act. For purposes of Section 223, all the regulations in 10 CFR part 35 are issued under one or more of sections 161b, 161i, or 161o, except for the sections listed in paragraph (b) of this section.
- (b) The regulations in 10 CFR part 35 that are not issued under subsections 161b, 161i, or 161o for the purposes of Section 223 are as follows: §§35.1, 35.2, 35.7, 35.8, 35.12, 35.15, 35.18, 35.19, 35.65, 35.100, 35.200, 35.300, 35.4001, and 35.4002.

Medical Use

- The NRC defines Medical Use as “the intentional internal or external administration of byproduct material, or the radiation from byproduct material, to patients or human research subjects under the supervision of an authorized user.

10 CFR 35.2 Definition of Authorized User (AU)

- Certified by ABR (Therapeutic Radiology)

  or
- 200 hours classroom/laboratory training in Radiation Physics, Radiation protection, Math pertaining to radioactivity, Radiobiology
- 500 hours of supervised work experience under an AU
- Three years of supervised clinical experience that includes one year in formal training approved by Residency Review Committee under ACGME.

10 CFR 35.2 Definition of Written Directive

- An authorized user's written order for the administration of byproduct material or radiation from byproduct material to a specific patient or human research subject, as specified in § 35.40.

10 CFR 35.40 Written Directive

Must contain the patient's name and:

- (1) For any administration of quantities greater than 1.11 MBq (30 μCi) of sodium iodide I-131: the dosage;
- (2) For an administration of a therapeutic dosage of unsealed byproduct material other than sodium iodide I-131: the radioactive drug, dosage, and route of administration;
- (3) For gamma stereotactic radiosurgery: the total dose, treatment site, and values for the target coordinate settings per treatment for each anatomically distinct treatment site;
- (4) For teletherapy: the total dose, dose per fraction, number of fractions, and treatment site;

10 CFR 35.40 Written Directive

- (5) For high dose-rate remote afterloading brachytherapy: the radionuclide, treatment site, dose per fraction, number of fractions, and total dose; or
- (6) For all other brachytherapy, including low, medium, and pulsed dose rate remote afterloaders:
- (i) Before implantation: treatment site, the radionuclide, and dose; and
- (ii) After implantation but before completion of the procedure: the radionuclide, treatment site, number of sources, and total source strength and exposure time (or the total dose).

10 CFR 35.40 Written Directive

- (c) A written revision to an existing written directive may be made if the revision is dated and signed by an authorized user before the administration of the dosage of unsealed byproduct material, the brachytherapy dose, the gamma stereotactic radiosurgery dose, the teletherapy dose, or the next fractional dose.

10 CFR 35.3045 Medical Event

Dose differs from Rx dose by more than 0.05 Sv (5rem) EDE, 0.5Sv to an organ, 0.5Sv shallow dose equivalent to the skin

and

Total dose delivered differs from Rx dose ≥20%

or Single fraction ≥ 50%

or Wrong isotope

or Wrong Route

or Wrong individual

or Wrong mode of treatment

or Leaking source

10 CFR 35.3045 Medical Event

- Report to NRC Operation Center within 24hrs
- Written report within 15 days
  - Licensee's name
  - Name of AU
  - A brief description
  - Why the event occurred
  - The effect on the patient
  - What actions taken or planned to prevent recurrence
  - Certification that the AU notified the patient/why not
  - Referring physician

Administrative Requirements

- License application, renewal, amendment
- List AU, authorized nuclear pharmacists, authorized medical physicists
- Radiation Safety Officer
- Radiation Safety Committee
- Written Directive
- Written Procedure

Quality Management Program

- Prescription (written directive)
  - Name of Patient
  - Medical Record Number
  - Dose for the treatment
  - Temporary or Permanent
  - Site of Administration
  - Source Material
  - Source Strength

- Post Implantation, but prior to completion
  - Possibly revised source strength
  - Possibly revised number of sources
  - Possibly revised dose
  - Total duration

LDR QMP

- QMP before Implant
  - Inventory of Total number of sources in the safe
  - Number of Sources moved from the safe (Strength)
  - Number of sources left in the safe (Strength)
  - Before loading the patient has to be identified by two methods
  - Name, Picture, Date of Birth, Photo I.D., Hospital I.D. Bracelet, Hospital Card etc.
  - Record of Time
  - Record of Exposures

- QMP after Implant
  - Removal of Sources
  - Record of Exposures
  - Inventory of number of sources in the safe
  - Return of number of Sources (strength)
  - Total number of sources in the safe

Technical Requirements

- Instrumentation
  - Calibration, NIST traceable, retain records for 3 years with model and serial number
  - Survey instruments calibrated, <20%, retain records for 3 years with model and serial number
- Activity
  - Direct measurement
  - Indirect measurement
  - Retain records for 3 years
  - Handle it as per manufacturer

Technical Requirements

- Leak Testing
  - Intervals not to exceed 6 months
  - First use source, should be tested or certificate < 6 months
  - Sensitivity 185Bq (0.005µCi)

- No leak Test
  - $T_{1/2}$ < 30 days, only byproduct is gas, 3.7 MBq of β/γ source, 0.37 MBq of α source, Ir-192 in ribbons, sources not being used.

Technical Requirements

- Inventory
  - Semi-annual of all sealed/brachytherapy sources except gamma stereotactic
- Release of patients
  - Total Effective Dose Equivalent < 5mSv (0.5 rem) to other individuals
  - If TEDE > 1 mSv, ALARA instructions to individuals, parents/guardian
  - If TEDE > 1 mSv to nursing or child, instructions should include guidance of breast feeding, consequences of failure; retain records for 3 years

Technical Requirements

- Manual Brachytherapy, High Dose Rate remote afterloaders, Teletherapy Units, Gamma Stereotactic Units
  - Installations, maintenance, adjustments, repair, equipments, calibrations, periodic spot checks, and therapy related computer systems

Proton QA

1. Automatic procedures to ensure correct beam energy being transported in the treatment nozzle and subjected to correct beam modulation to create the desired SOBP
2. For a pencil beam scanning system, QA procedures to monitor scanning patterns determined by the treatment-planning system
3. QA procedures to monitor the functionality of various interlocks related to beam delivery and patient safety
4. Daily check of monitor unit calibration
5. Verification of each treatment portal and monitor units
6. Verification of correct installation of auxiliary equipment and patient-specific treatment aids
7. Checking of patient setup and positioning systems
8. QA of treatment-planning system and imaging devices

Acknowledgements and References

- Rupak K. Das, PhD – Univ of Maryland Review Course 2012
- Steve Grimm, MS – Radiation Safety, Emory University
- 10 CFR Part 20
- 10 CFR Part 35
- 10 CFR Part 71
- 49 CFR Part 172
- Faiz Khan – The Physics of Radiation Therapy**, 4th edition**
- Peter Metcalfe et al., The Physics of Radiotherapy X-rays and Electrons

NRC Guidelines on Prostate Implant Reportable Event

The following criteria require action:

For prostate:

D90 < 80% of prescription Dose (90% of the PTV receives at least 80% of the RX dose)

V100 < 80% of total Volume (80% of the PTV receives at least 100% of the RX) dose.

Corrective action may include a supplemental implant, approximately one week after the initial implant. If post-implant analysis of this supplemental implant does not meet these criteria, a reportable event has occurred.

NRC Guidelines on Prostate Implant Reportable Event

Additionally, it will also be considered a reportable event if:

For Rectum:

D2cc > 150% of prescription Dose

or:

The wrong radioisotope is used

The dose is administered to the wrong patient

Proton QA

Frequency	*Procedure*
Daily	*Dosimetry and beam delivery* Proton beam output check for a defined operating condition to verify correct operation of beam monitoring system and monitor unit calibration. For a scattered beam verification of the integrity of scatterers, alignment of scatterers and beam penetration. Checks of Bragg peak width and lateral beam profile including flatness and symmetry, for scattered beam, uniform scanned (beam) and pencil beam scanning. Back-up monitor constancy. *Mechanical* Localization lasers Snout alignment Beamline inspection Distance indicator (ODI) Modulator wheel interlocks (barcodes etc) Beam delivery system interlocks *Safety* Door interlocks Audiovisual patient monitors Treatment room area radiation monitors Function of motion stops on all moving systems (gantry, patient position, etc).

Proton QA

Weekly	*Dosimetry and beam delivery*
	For a randomly selected patient, compare calculated planned dose at selected points to measured dose points in a phantom.
	Respiratory gating equipment
	Mechanical
	Gantry/Collimator angle indicators
	Imaging equipment
	Alignment of x-ray imaging devices relative to beam axis and/or isocenter (orthogonal imaging, cone beam CT, etc).
	Quality of images
Monthly	*Dosimetry*
	Verify integrity of modulator system
	Mechanical
	Light/Radiation Field Congruence
	Field size indicators (MLC)
	Jaw symmetry
	Cross-hair centering
	Patient positioner readouts and tolerances.
	For gantry determine isocenter location and check tolerances.
	Coincidence of collimator, gantry and couch axes at isocenter
	Safety
	Emergency off switches

Proton QA

Annually	*Dosimetry and beam delivery* Extensive recalibration of output under a wide variety of operating conditions. Checks of modulators, range shifters or energy selection systems as appropriate. Lateral profile flatness and symmetry as a function of gantry angle. Check location of virtual source. Primary MU linearity check. Check beam monitors for saturation conditions. Measure dose per MU for primary and backup channels as a function of gantry angle Check dose per MU against standard laboratory or other institution using independent standard (e.g. ion chamber or TLD) *Mechanical* Patient position tolerances including table sag. *Safety* Calibrate area radiation monitors throughout facility. Comprehensive test of all accelerator, beam line, gantry and nozzle safety systems. *Imaging equipment* X-ray kVp, mA, timer and magnification. CT unit HU calibration Full check of all simulation devices CT, PET/CT. MRI