APPENDIX VI

Quality Control in Radiation Therapy*

* Taken from: American Association of Physicists in Medicine. Comprehensive QA for radiation oncology: Report of the AAPM Radiation Therapy Committee Task Group No. 40. *Med Phys* 1994:21(4):581-618.

Table I
QA of Cobalt-60 units

Frequency	Procedure	Tolerance[a]
Daily	Safety	
	Door interlock	Functional
	Radiation room monitor	Functional
	Audiovisual monitor	Functional
	Mechanical	
	Lasers	2 mm
	Distance indicator (ODI)	2 mm
Weekly	Check of ***source*** positioning	3 mm
Monthly	Dosimetry	
	Output constancy	2%
	Mechanical checks	
	Light/radiation field coincidence	3 mm
	Field size indicator (collimator setting)	2 mm
	Gantry and collimator angle indicator	1 deg.
	Cross-hair centering	1 mm
	Latching of wedges, trays	Functional
	Safety interlocks	
	Emergency off	Functional
	Wedge interlocks	Functional
Annual	Dosimetry	
	Output constancy	2%
	Field size dependence of output constancy	2%
	Central axis dosimetry parameter constancy (PDD/TAR)	2%
	Transmission factor constancy for all standard accessories	2%
	Wedge transmission factor constancy	2%
	Timer linearity and error	1%
	Output constancy vs ***gantry*** angle	2%
	Beam uniformity vs ***gantry*** angle	3%
	Safety Interlocks	
	Follow test procedures of manufacturers	Functional
	Mechanical Checks	
	Collimator rotation isocenter	2 mm diameter
	Gantry rotation isocenter	2 mm diameter
	Couch rotation isocenter	2 mm diameter
	Coincidence of collimator, ***gantry***, couch axis with isocenter	2 mm diameter
	Coincidence of radiation and mechanical isocenter	2 mm diameter
	Table top sag	2 mm
	Vertical travel of table	2 mm
	Field-light intensity	Functional

[a] The tolerance listed in the tables should be interpreted to mean that if a parameter either: (1) exceeds the tabulated value (e.g., the measured isocenter under ***gantry*** rotation exceeds 2 mm diameter); or (2) that the change in the parameter exceeds the nominal value (e.g., the output changes by more than 2%), then an action is required. The distinction is emphasized by the use of the term constancy for the latter case. Moreover, for constancy, percent values are ± the deviation of the parameter with respect to its nominal value; distances are referenced to the isocenter or nominal SSD.

Table II
QA of Medical *Accelerators*

Frequency	Procedure	Tolerance[a]
Daily	Dosimetry	
	X-ray output constancy	3%
	Electron output constancy[b]	3%
	Mechanical	
	Localizing lasers	2 mm
	Distance indicator (ODI)	2 mm
	Safety	
	Door interlock	Functional
	Audiovisual monitor	Functional
Monthly	Dosimetry	
	X-ray output constancy[c]	2%
	Electron output constancy[c]	2%
	Backup monitor constancy	2%
	X-ray central axis dosimetry parameter (PDD, TAR) constancy	2%
	Electron central axis dosimetry parameter constancy (PDD)	2 mm @ therapeutic depth
	X-ray beam flatness constancy	2%
	Electron beam flatness constancy	3%
	X-ray and *electron* symmetry	3%
	Safety Interlocks	
	Emergency off switches	Functional
	Wedge, *electron* cone interlocks	Functional
	Mechanical Checks	
	Light/radiation field coincidence	2 mm or 1% on a side[d]
	Gantry/collimator angle indicators	1 deg
	Wedge position	2 mm (or 2% change in transmission factor)
	Tray position	2 mm
	Applicator position	2 mm
	Field size indicators	2 mm
	Cross-hair centering	2 mm diameter
	Treatment couch position indicators	2 mm/1 deg
	Latching of wedges, blocking tray	Functional
	Jaw symmetry[e]	2 mm
	Field light intensity	Functional
Annual	Dosimetry	
	X-ray/electron output calibration constancy	2%
	Field size dependence of *x-ray* output constancy	2%
	Output factor constancy for *electron* applicators	2%
	Central axis parameter constancy (PDD, TAR)	2%
	Off-axis factor constancy	2%
	Transmission factor constancy for all treatment accessories	2%
	Wedge transmission factor constancy[f]	2%
	Monitor chamber linearity	1%
	X-ray output constancy vs *gantry* angle	2%
	Electron output constancy vs *gantry* angle	2%
	Off-axis factor constancy vs *gantry* angle	2%
	Arc mode	Mfrs. specs.

Frequency	Procedure	Tolerance[a]
Annual	Safety Interlocks	
	Follow manufacturers test procedures	Functional
	Mechanical Checks	
	Collimator rotation isocenter	2 mm diameter
	Gantry rotation isocenter	2 mm diameter
	Couch rotation isocenter	2 mm diameter
	Coincidence of collimator, *gantry*, couch axes with isocenter	2 mm diameter
	Coincidence of radiation and mechanical isocenter	2 mm diameter
	Table top sag	2 mm
	Vertical travel of table	2 mm

[a] The tolerances listed in the tables should be interpreted to mean that if a parameter either: (1) exceeds the tabulated value (e.g , the measured isocenter under *gantry* rotation exceeds 2 mm diameter); or (2) that the change in the parameter exceeds the nominal value (e.g , the output changes by more than 2%), then an action is required. The distinction is emphasized by the use of the term constancy for the latter case. Moreover, for constancy, percent values are ± the deviation of the parameter with respect its nominal value; distances are referenced to the isocenter or nominal SSD.

[b] All *electron* energies need not be checked daily, but all *electron* energies are to be checked at least twice weekly.

[c] A constancy check with a field instrument using temperature/pressure corrections

[d] Whichever is greater. Should also be checked after change in light field source.

[e] Jaw symmetry is defined as difference in distance of each jaw from the isocenter.

[f] Most wedges' transmission factors are field size and depth dependent.

Table III
QA of simulators

Frequency	Procedure	Tolerance[a]
Daily	Localizing lasers	2 mm
	Distance indicator (ODI)	2 mm
Monthly	Field size indicator	2 mm
	Gantry/collimator angle indicators	1 deg
	Cross-hair centering	2 mm diameter
	Focal spot-axis indicator	2 mm
	Fluoroscopic image quality	Baseline
	Emergency/collision avoidance	Functional
	Light/radiation field coincidence	2 mm or 1%
	Film processor sensitometry	Baseline
Annual	Mechanical Checks	
	Collimator rotation isocenter	2 mm diameter
	Gantry rotation isocenter	2 mm diameter
	Couch rotation isocenter	2 mm diameter
	Coincidence of collimator, *gantry*, couch axes and isocenter	2 mm diameter
	Table top sag	2 mm
	Vertical travel of couch	2 mm
	Radiographic Checks	
	Exposure rate	Baseline
	Table top *exposure* with fluoroscopy	Baseline
	kVp and mAs calibration	Baseline
	High and low contrast resolution	Baseline

[a] The tolerances mean that the parameter exceeds the tabulated value (e.g., the measured isocenter under *gantry* rotation exceeds 2 mm diameter).

Table IV
QA of measurement equipment

I, initial use for each mode used or following malfunction and repairs; E, each use (measurement sequence) or ongoing evaluation; B, each batch or box at appropriate energy (dosimeter element position should also be considered); D, documented and correction applied or noted in report of measurement; M, monthly.

Instrument type	Test	Frequency	Tolerance[a]
Local standard[b]	ADCL calibration	2y[c]	D
	Linearity	2y[c]	0 5%
	Venting	2y[c]	D
	Extra-cameral signal (stem effect)	I	0.5%
	Leakage	E	0.1%
	Redundancy check[d]	E	2%
	Recombinanon	I	D
	Collecting potential	E	D
Field instruments	Local std. comparison	2y	1%
	Linearity	2y	D
	Venting	2y	D
	Extra-cameral signal	2y	D
	Leakage	E	0.1%
	Recombination	I	D
	Collecting potential	E	D
Output check	Local std. comparison	M	1%
Relative *dose*			
TLD	Calibration	E	D
	Linearity	I	D
Film	*Dose* response	B	D
	Densitometer linearity	1y	D
	Processor uniformity/reproducibility	E	D
Ion chamber	Linearity	1y	D
	Extra-cameral signal	I	1%
Diodes	Energy dependence	I	D
	Extra-cameral signal	I	D
	Linearity	I	D
Positioning	Accuracy	E	2 mm
	Hysteresis	E	2 mm
Automated Scanners	Mechanical	I	2 mm
	Positional accuracy	E	1 mm
	Collecting potential of detector	E	D
	Detector linearity	I	0.5%
	Extra-cameral signal	I	0.5%
	Detector leakage	E	0.5%
	Accuracy of data analysis	I	1%
	Accuracy of printouts	I	1 mm

Instrument type	Test	Frequency	Tolerance[a]
Accessories	Thermometer Calibration	I	0.1 deg/C
	Barometer Calibration	3 mo	1 mm/Hg
	Linear rule Calibration	I	0.3%

[a] Percent values are ± the deviation of the parameter with respect to the nominal, and distances are referred to the isocenter or nominal SSD.

[b] Local standard instrument has a calibration directly traceable to NIST and should be reserved for calibration of radiation beams, field instruments, and intercomparisons.

[c] Two years required by NRC. Without a redundancy program, this may be inadequate; with a redundancy program, dosimetry systems maintain calibration factors for significantly longer periods of time.

[d] With a ***radionuclide*** (e.g., Sr-90) or chamber intercomparison.

Table V
QA for treatment planning systems and monitor unit calculations

Frequency	Test	Tolerance[a]
Commissioning and following software update	Understand algorithm	Functional
	Single field or ***source*** iso***dose*** distributions	2%[a] or 2 mm[b]
	MU calculations	2%
	Test cases	2% or 2 mm
	I/O system	1 mm
Daily	I/O devices	1 mm
Monthly	Checksum	No change
	Subset of reference *QA* test set (when checksums not available)	2% or 2 mm[c]
	I/O system	1 mm
Annual	MU calculations	2%
	Reference *QA* test set	2% or 2 mm[d]
	I/O system	1 mm

[a] % difference between calculation of the computer treatment planning system and measurement (or independent calculation).

[b] In the region of high ***dose*** gradients the distance between iso***dose*** lines is more appropriate than % difference. In addition, less accuracy may be obtained near the end of single ***sources***.

[c] These limits refer to the comparison of ***dose*** calculations at commissioning to the same calculations subsequently.

[d] These limits refer to comparison of calculations with measurement in a water tank

Table VI
Treatment planning process

Process	Related *QA* procedures
Positioning and immobilization	Port films. Laser alignment
Simulation	Simulator *QA* including image quality and mechanical integrity
Patient data acquisition (CT, MRI, manual contouring)	CT, MRI *QA* including image quality and mechanical integrity. Accuracy of mechanical contouring
Data transfer to treatment planning system	*QA* of the entire data transfer process, including digitizers, digital data transfer, etc.
Definitions of target volumes	Peer review, e.g., new patient planning conference, chart rounds
Aperture design	Independent check of delivery (e.g., port films), and peer review
Computation of *dose* distributions	Machine data from commissioning and *QA* of treatment machines. Accuracy and *QA* of treatment planning system
Plan evaluation	Peer review of plan, e.g., during chart rounds Independent check by radiation oncology physicist
Prescription	Written, signed, and dated
Computation of monitor units	Treatment planning system *QA*. Independent check within 48 h
Production of blocks, beam modifiers	*QA* for block cutting and compensator systems Port film review
Plan implementation	Review of set-up by treatment planning team. Chart review
Patient *QA*	Treatment plan review. Chart review after new or modified field, weekly chart review, port film review. *In vivo* dosimetry for unusual fields, critical *organ doses* (e.g., gonadal *dose*). Status check, follow up

Table VII
Factors affecting monitor unit (minute) calculations

Parameter	Related *QA*
Patient surface contour	Periodic checks of caliper accuracy. Redundant patient measurements. Treatment planning system monthly *QA*
Collimator setting	Monthly simulator & treatment machine *QA* (Tables I-III)
Dose per monitor unit (minute) on the central axis as a function of collimator settings	Part of daily & monthly machine *QA* for a 10 x 10 cm field (Tables I and II) and annual recommissioning for output vs field size
Depth of the calculation (prescription) point	Periodic checks of caliper accuracy. Use of both lasers and ODI during patient setup to verify depth. Repeat patient measurements during course of treatment
Target-to-patient-surface or target-to-isocenter distance	Monthly *QA* on simulators and treatment machines (Tables I-III)
Relative *dose* factors (PDD, TPR, TMR, etc.)	Monthly *x-ray* and *electron* energy constancy checks (Table II)
Aperture size and shape	Redundant check of magnification factor
Wedge and compensator transmission	Annual machine recommissioning. Monthly check of latches and positioning of accessories (Table II)
Blocking tray transmission	Annual machine recommissioning. Monthly check of latches and positioning of accessories (Table II)

Table VIII
Summary of *QA* recommendations for individual patients

Procedure	Recommendation
Monitor unit (minutes) calculations	1. Reviewed prior to treatment by an authorized individual who did not perform initial calculation, or when not possible (e.g., emergency treatment), then prior to 3rd fraction or before 10% of the ***dose*** has been delivered, whichever occurs first.
Graphical treatment plan review	1 Reviewed prior to treatment, or when not possible, then prior to 3rd fraction or before 10% of the ***dose*** has been delivered, whichever occurs first. 2. Reviewed by a radiation oncology physicist who did not formulate treatment plan. Where only one physicist and that person performed the plan, then reviewed by another authorized individual. 3. Review includes calculated monitor units, input-output and plan quality. 4. Independent calculation of ***dose*** at a point: Compare for each field—with an independent calculation of ***dose*** to a point using the calculated monitor units—the prescribed and calculated ***dose***. 5. If these differ by more than 5%, then the discrepancy should be resolved before continuing treatment.
Plan set-up	Radiation oncologist present at first setup or for major changes in treatment.
Beam (portal) films—curative and high morbidity ***risk*** palliative patients	Initial films reviewed by radiation oncologist prior to first treatment. In addition, ongoing portal films (the standard is weekly) also reviewed by the radiation oncologist
Beam (portal) films—palliative patients	Films reviewed prior to second fraction.
In-vivo dosimetry	1. All institutions should have access to TLD or other *in vivo* dosimetry systems. 2. Should be used to measure ***dose*** to critical structures (e.g., lens, gonads). 3. May be used to record ***dose*** for unusual treatment conditions.

Table IX
QA tests for brachytherapy *sources*

I, initial purchase; D, documented, and E, at every use

Type of *Source*	Test	Frequency	Tolerance
Long ***half-life***: description	Physical/chemical form	I	D
	Source encapsulation	I	D
	Radionuclide distribution and uniformity	I	D
	Location of ***radionuclide***	I	1 mm
Long ***half-life***: calibration	Mean of batch	I	3%
	Deviation from mean	I	5%[a], D
	Calibration verification	E	
Short ***half-life***: description	Physical/chemical form	I	D
	Source encapsulation	I	D
Short ***half-life***: calibration	Mean of batch	E	3%
	Deviation from mean[b]	E	5%
	Radionuclide distribution and ***source*** uniformity	E	V[c]

[a] Visual check of ***source*** color code or measurement in a ***calibrator***.

[b] For short ***half-life sources*** this may not always be practical.

[c] V, visual check, autoradiograph, or ionometric check.

Table X
QA tests for brachytherapy *source calibrator*

I, initial use or following malfunction and repairs, S, ***isotope/source*** specific, D, documented and correction applied or noted in report of measurement, when appropriate, and E, each use (measurement sequence) or ongoing evaluation.

Instrument Type	Test	Frequency	Tolerance
Well ***ionization chamber***	ADCL calibration	I,S[a]	D
	Precision	I	2%
	Linearity	I, 2 year	1%
	Collection Efficiency	I	1%
	Geometrical/length dependence	I	D
	Energy dependence	I	D
	Wall dependence	I	D
	Venting	I	D
	Redundant check	E	2%
	Leakage	E	D
In-air calibration ***chamber*** and external holder	ADCL calibration	I,S[a]	D
	Accuracy of chamber distance	1 yr, S	1%, D
	Redundancy	E	D
	See Table IV for other tests		

[a] Instrument or source have a calibration directly traceable to NIST.

Table XI
QA tests for brachytherapy applicators

I, initial use or following malfunction and repairs; D, documented and correction applied or noted in report of measurements, when appropriate; and E, as a minimum, a visual inspection to verify that the dummy source fairly represent the active ***source*** distribution.

Type of applicator	Test	Frequency	Tolerance
Intracavitary	Location	I[a], yearly	D
	Coincidence of dummy and active ***sources***	I	1 mm
	Location of shields	I[b]	D
Interstitial	Coincidence of dummy and active ***sources***	I,E	1 mm

[a] To reduce personnel ***exposure***, the dummy ***source*** location may be checked in place of the active, if it is established that the dummy and active ***source*** locations are coincident.

[b] Location of shields should be verified by radiograph before the first use. Before every use, the applicator may be shaken to listen for loose parts.

Table XII
Procedure specific parameter verification

Endpoint	Procedure	When
Accuracy of OR implant description	Direct observation	During procedure
Prescription accuracy and consistency	Consistency of loading and prescription with disease stage, therapy chart treatment plan, department treatment policies	First half of treatment
Verify correct ***source*** chosen	Spot calibration check and visual verification	preparation and ***source*** loading
Sources correctly loaded	Therapist or physicist (or individual knowledgeable in ***source*** loading) always assists physician	loading
Treatment plan	Calculation of plan and check for accuracy/consistency	First half of treatment
Implant removal	Physicist present or contact nursing staff to verify	Expected removal time
Sources all removed	Patient survey ***source*** count Final ***source*** inventory	At removal Next working day
Review treatment	Verify treatment time	After completion of procedure
Record, *QA* audit	All *QA*, treatment, and radiation safety records complete	After completion of procedure

Table XIII
QA of remote afterloading brachytherapy units

Frequency	Test	Tolerance
Each treatment day	Room safety door interlocks, lights, and alarms	Functional
	Console functions, switches, batteries, printer	Functional
	Visual inspection of ***source*** guides	Free of kinks and firmly attached
	Verify accuracy of ribbon preparation	Autoradiograph
Weekly	Accuracy of ***source*** and dummy loading (dummies used for spacing and/or simulation/verification)	1 mm
	Source positioning	1 mm
At each ***source*** change or quarterly	Calibration[a]	3%
	Timer function	1%
	Check accuracy of ***source*** guides and connectors	1 mm
	Mechanical integrity of applicators (by ***x ray*** if appropriate)	Functional
Annual	***Dose*** calculation algorithm (at least one standard ***source*** configuration for each ***isotope***). Simulate emergency conditions. Verify ***source*** inventory	3%, 1 mm

[a] It is worthwhile at ***source*** change to calibrate both new and old ***sources*** to establish and document reproducibility of calibration method.

APPENDIX VII

Standards of the American College of Radiology*

* Taken from: American College of Radiology. *Standards*. Reston: ACR; 1997.

Diagnostic Radiology

1. ACR Standard for General (Plain) Radiography
2. ACR Standard for Communication-Diagnostic Radiology
3. ACR Standard for Teleradiology
4. ACR Standard for Diagnostic Medical Physics Performance Monitoring of Radiologic and Fluoroscopic Equipment
5. ACR Standard for the Performance of Computed Tomography in the Evaluation of Head Trauma
6. ACR Standard for Skeletal Surveys in Children
7 ACR Standard for the Performance of Pediatric and Adult Chest Radiography
8. ACR Standard for the Performance of Pediatric and Adult Bedside Chest Radiography (Portable Chest Radiography)
9. ACR Standard for the Performance of Thoracic Computed Tomography
10. ACR Standard for the Performance of Computed Tomography of the Abdomen and Pelvis
11. ACR Standards for the Performance of Screening Mammography
12. ACR Standard for the Performance of Diagnostic Mammography and Problem-Solving Breast Evaluation
13. ACR Standard for the Performance of Adult Esophagrams and Upper Gastrointestinal Examinations
14. ACR Standard for the Performance of Per Oral Barium Small Bowel Examinations in Adults
15. ACR Standard for the Performance of Adult Enteroclysis Examinations
16. ACR Standard for Performance of Adult Barium Enema Examinations
17. ACR Standard for the Performance of Pediatric Contrast Examinations of the Upper Gastrointestinal Tract
18. ACR Standard for the Performance of Pediatric Contrast Enema Examinations
19. ACR Standard for the Performance of Excretory Urography
20. ACR Standard for the Performance of Adult Cystography and Urethrography
21. ACR Standard for the Performance of Voiding Cysturethography in Children
22. ACR Standard for the Performance of Magnetic Resonance Imaging

Interventional Radiology

1. ACR Standard for the Use of Intravenous Conscious Sedation
2. ACR Standard for the Performance of Cerebral Angiography
3. ACR Standard for the Performance of Myelography
4. ACR Standards for Diagnostic Arteriography in Adults
5. ACR Standard for the Performance of Stereotactically-Guided Breast Interventional Procedures
6. ACR Standard for the Performance of Ultrasound-Guided Percutaneous Breast Interventional Procedures

7. ACR Standard for the Performance of Imaging-Guided Trans-Thoracic Needle Biopsy in Adults
8. ACR Standard for the Performance of Imaging-Guided Percutaneous Thoracic Aspiration on Catheter Drainage in Adults
9. ACR Standard for the Performance of Percutaneous Nephrostomy

Nuclear Medicine

1. ACR Standard for Imaging for Radiopharmaceuticals
2. ACR Standard for the Performance of Cerebral Scintigraphy for Brain Death
3. ACR Standard for the Performance of Skeletal Scintigraphy
4 ACR Standard for the Performance of Cardiac Scintigraphy
5. ACR Standard for the Performance of Thyroid Scintigraphy and Uptake Measurements
6. ACR Standard for the Performance of Parathyroid Scintigraphy
7. ACR Standard for the Performance of Pulmonary Scintigraphy
8. ACR Standard for the Performance of Gastrointestinal Scintigraphy
9. ACR Standard for the Performance of Hepatobiliary Scintigraphy
10. ACR Standard for the Performance of Liver/Spleen Scintigraphy
11. ACR Standard for the Performance of Renal Scintigraphy
12. ACR Standard for the Performance of Radionuclide Cystography
13. ACR Standard for the Performance of Scrotal Scintigraphy
14. ACR Standard for the Performance of Infectious and Inflammatory Conditions
15. ACR Standard for the Performance of Tumor Scintigraphy
16. ACR Standard for the Performance of Therapy with Unsealed *Radionuclide* Sources

Radiation Oncology

1. ACR Standard for Radiation Oncology
2. ACR Standard for the Performance of Radiation Oncology Physics for External Beam Therapy
3. ACR Standard for the Performance of High-Dose-Rate Brachytherapy
4. ACR Standard for the Performance of Low-Dose-Rate Brachytherapy
5. ACR Standard for the Performance of Brachytherapy Physics: Manually-Loaded Sources
6. ACR Standard for 3D External Beam Radiation Planning and Conformal Therapy
7. ACR Standard for the Performance of Stereotactic Radiation Therapy/Radiosurgery
8. Standard for Diagnosis and Management for Invasive Breast Carcinoma
9. Standards for Diagnosis and Management of Ductal Carcinoma In-Situ of the Breast (DCIS)
10. ACR Standard for the Performance of Therapy with Unsealed Radionuclide Sources

Ultrasound

1. ACR Standard for Performing and Interpreting Diagnostic Ultrasound Examinations
2. ACR Standard for the Performance of an Ultrasound Examination of the Extracranial Cerebrovascular System
3. ACR Standard for Performance of the Pediatric Neurosonology Examination
4. ACR Standard for the Performance of Peripheral Arterial Ultrasound Examination
5. ACR Standard for Performance of the Peripheral Venous Ultrasound Examination
6. ACR Standard for the Performance of the Thyroid and Parathyroid Ultrasound Examination
7. ACR Standard for the Performance of Breast Ultrasound Examination
8. ACR Standard for the Performance of Abdominal, Renal, or Retroperitoneal Ultrasound Examination in Infants, Children, and Adults
9. ACR Standard for the Performance of Ultrasound Examination of the Female Pelvis
10. ACR Standard for the Performance of Antepartum Obstetrical Ultrasound
11. ACR Standard for the Performance of Ultrasound Evaluation of the Prostate (and surrounding structures)
12. ACR Standard for the Performance of Scrotal Ultrasound Examination

Credentialing

1. ACR Standard for Continuing Medical Education (CME)

Magnetic Resonance Imaging

MRI Monograph

APPENDIX VIII

Radiation Protection Data

Appendix VIII-A

Values of the Radiation Weighting Factor (W_R)

and the Tissue Weighting Factor (W_T)[*]

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* Taken from: Food and Agriculture Organization of the United Nations, International Atomic Energy Agency, International Labour Organisation, Nuclear Agency of the Organisation for Economic Co-operation and Development, Pan American Health Organization, World Health Organization. *International basic safety standards for protection against ionizing radiation and for the safety of radiation sources*. Vienna: International Atomic Energy Agency; 1997. (Safety series 115).

Values of the Radiation Weighting Factor (W_R) and the Tissue Weighting Factor (W_T)

Type and energy range of radiation	Radiation weighting factor, W_R
Photons	1
Electrons	1
Neutrons	
< 10 keV	5
100 keV to 2 MeV	20
2 MeV to 20 MeV	10
> 20 MeV	5
Protons > 2 MeV	5
Alpha particles	20

Tissues or organs	Tissue weighting factor, W_T
Bone surfaces - skin	0.01
Liver - breast - bladder - oesophagus - thyroid - remainder	0.05
Bone marrow (red) - colon - lung - stomach	0.12
Gonads	0.20

Appendix VIII-B

*Sources of Exposure to Ionizing Radiation**

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* Taken from: United Nations Scientific Committee on the Effects of Atomic Radiation. *Sources and effects of ionizing radiation.* New York: UN; 1993. (UNSCEAR 1993 Report to the General Assembly).

Natural Sources	Average Annual *Effective Dose* (mSv)
Cosmic rays	0.39
Terrestrial gamma rays	0.46
Radioisotopes in the body (except ***radon***)	0.23
Radon and its ***decay*** products	1.3
Total	2.4

Artificial *Sources*	Average Annual *Effective Dose* (mSv)
Medical ***sources***	0.6
Nuclear explosions	0.01
Nuclear energy	0.0002

Sources for Medical Use	Number
X-ray units (diagnosis)	720,000
X-ray units (therapy)	13,000
Cobalt therapy and caesium units	4,000
Accelerators	1,800
Nuclear medicine clinics	13,000
"Spent" Radioactive ***sources*** (in disuse)	130,000

Annual ***collective dose*** due to diagnostic radiology: 1,600,000 man Sv

Appendix VIII-C

*Threshold Dose Values for Deterministic Effects**

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* Taken from: International Commission on Radiological Protection. 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60. *Ann ICRP* 1991 21(1-3).

Threshold *Dose* Values for *Deterministic Effects*

Deterministic Effect	*Dose Equivalent* Threshold (Single Exposure) (Gy)
Permanent Sterility	
Males	3.5 - 6.0
Females	2.5 - 6 0
Lens Opacity	0.5 - 2.0
Cataracts	5.0
Hematopoietic Depression	0.5

Appendix VIII-D

Dose Limits[*]

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* Taken from: Food and Agriculture Organization of the United Nations, International Atomic Energy Agency, International Labour Organisation, Nuclear Agency of the Organisation for Economic Co-operation and Development, Pan American Health Organization, World Health Organization. *International basic safety standards for protection against ionizing radiation and for the safety of radiation sources*. Vienna: International Atomic Energy Agency; 1997. (Safety series 115).

The annual ***effective dose limit*** for ***workers*** in accordance with the ***BSS*** (*26*) is 20 mSv per year (not to exceed 50 mSv per year averaged over 5 consecutive years), and the annual ***equivalent dose*** to the extremities (hands and feet) or the skin is 500 mSv and to the lens of the eye, 150 mSv. For ***members of the public,*** the annual ***effective dose limit*** has been established at 1 mSv; the ***equivalent dose*** to the extremities is not to exceed 50 mSv, and to the lens, 15 mSv.

In monitoring compliance with these ***limits***, both ***doses***, those generated by external ***sources*** and the committed ***doses*** from ***radionuclide*** intakes into the body, must be taken into account. However, ***doses*** from natural radiation and those incurred by people as patients undergoing medical procedures with radiation ***sources*** should not be included.

In the case of pregnant female ***workers***, once pregnancy is declared and during the rest of gestation, the ***equivalent dose*** to the embryo/fetus should not exceed 1 mSv.

For students between 16 and 18 years of age, the recommended annual ***limits*** are as follows: ***Effective dose,*** 6 mSv; ***equivalent dose*** to the lens, 50 mSv, and to the skin or the extremities, 150 mSv.