Radiotherapy workflow

Mario Ciocca

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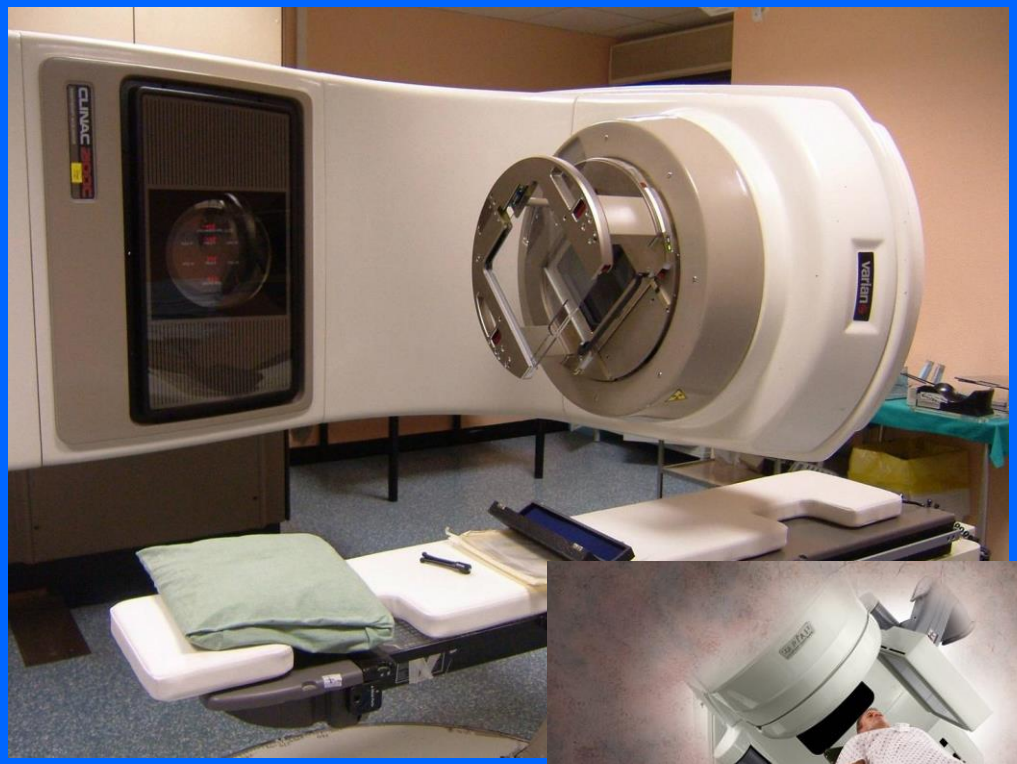
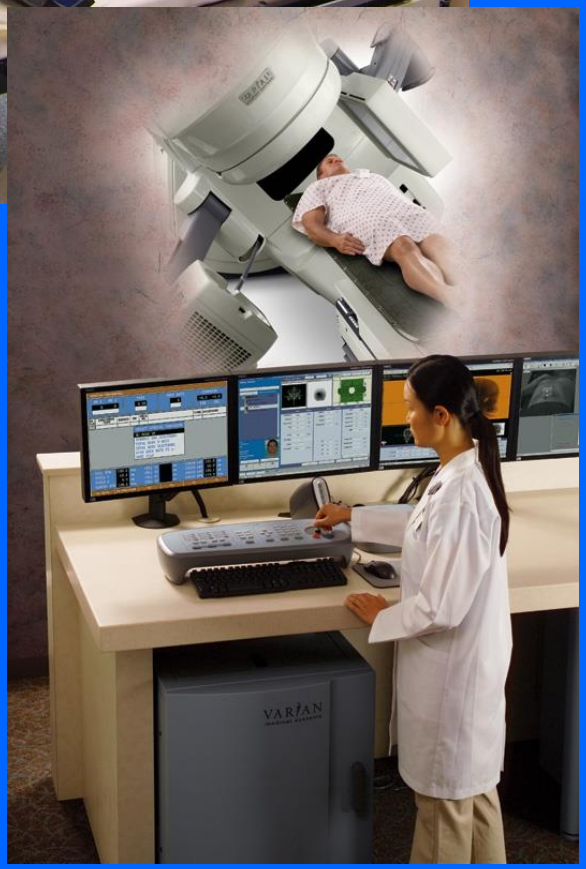
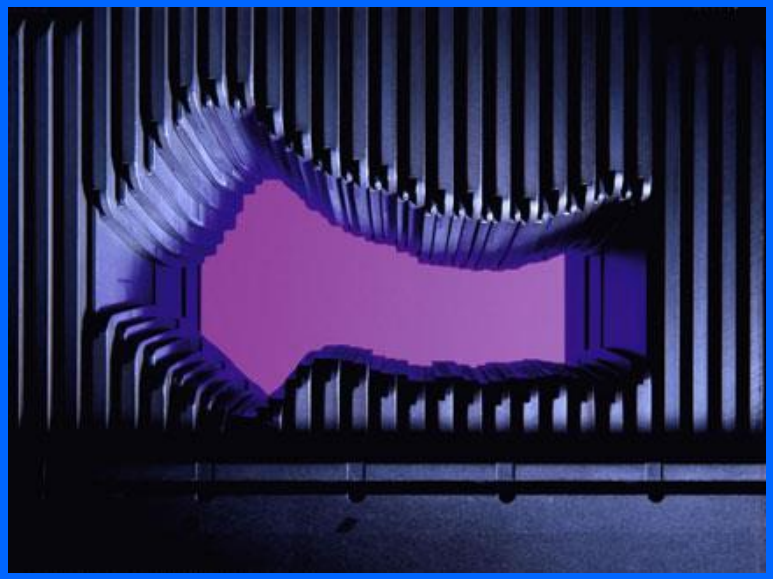
CNAO

Modern conventional RT





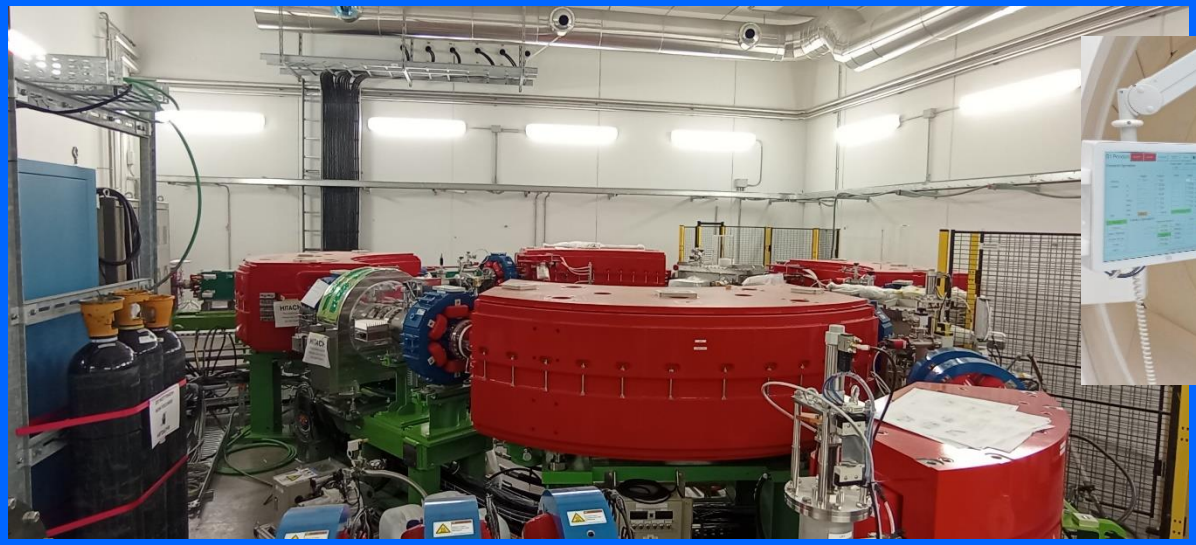
Complex treatment techniques included

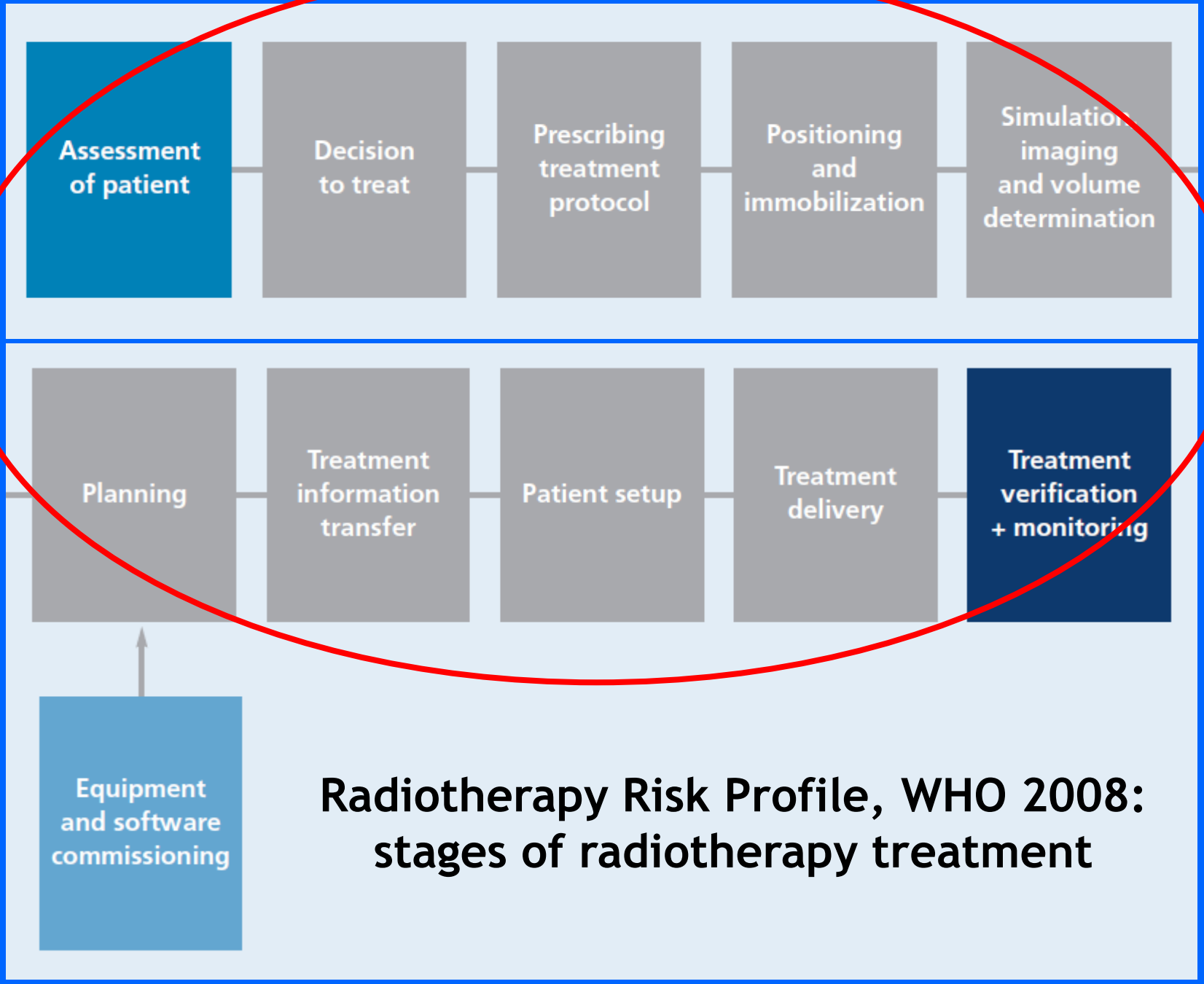


MLC

Dedicated linacs

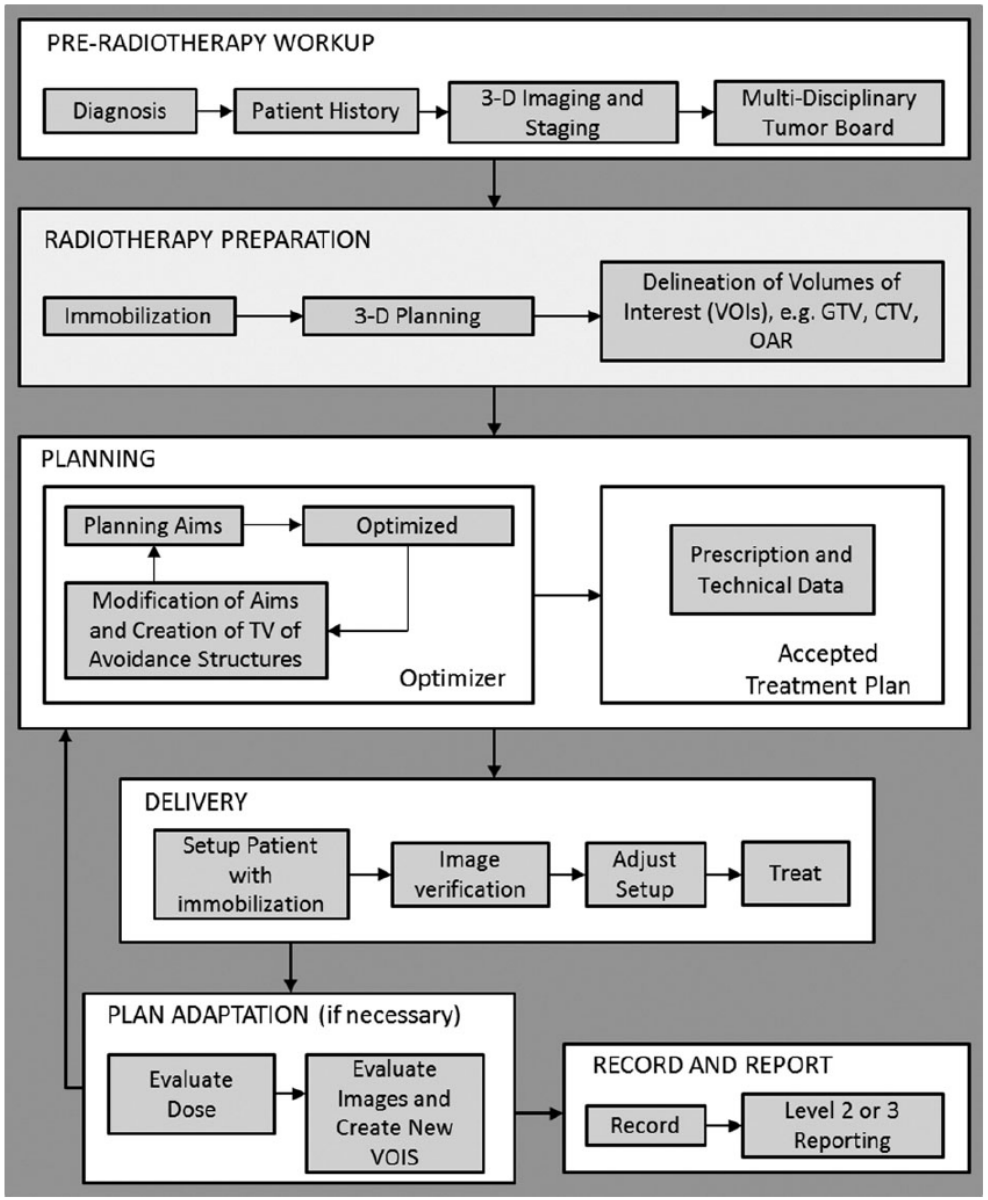
Particle RT





Radiotherapy Risk Profile, WHO 2008: stages of radiotherapy treatment

Journal of the ICRU Vol 16 No 1–2 (2016) Report 93
Oxford University Press



Main roles and responsibilities

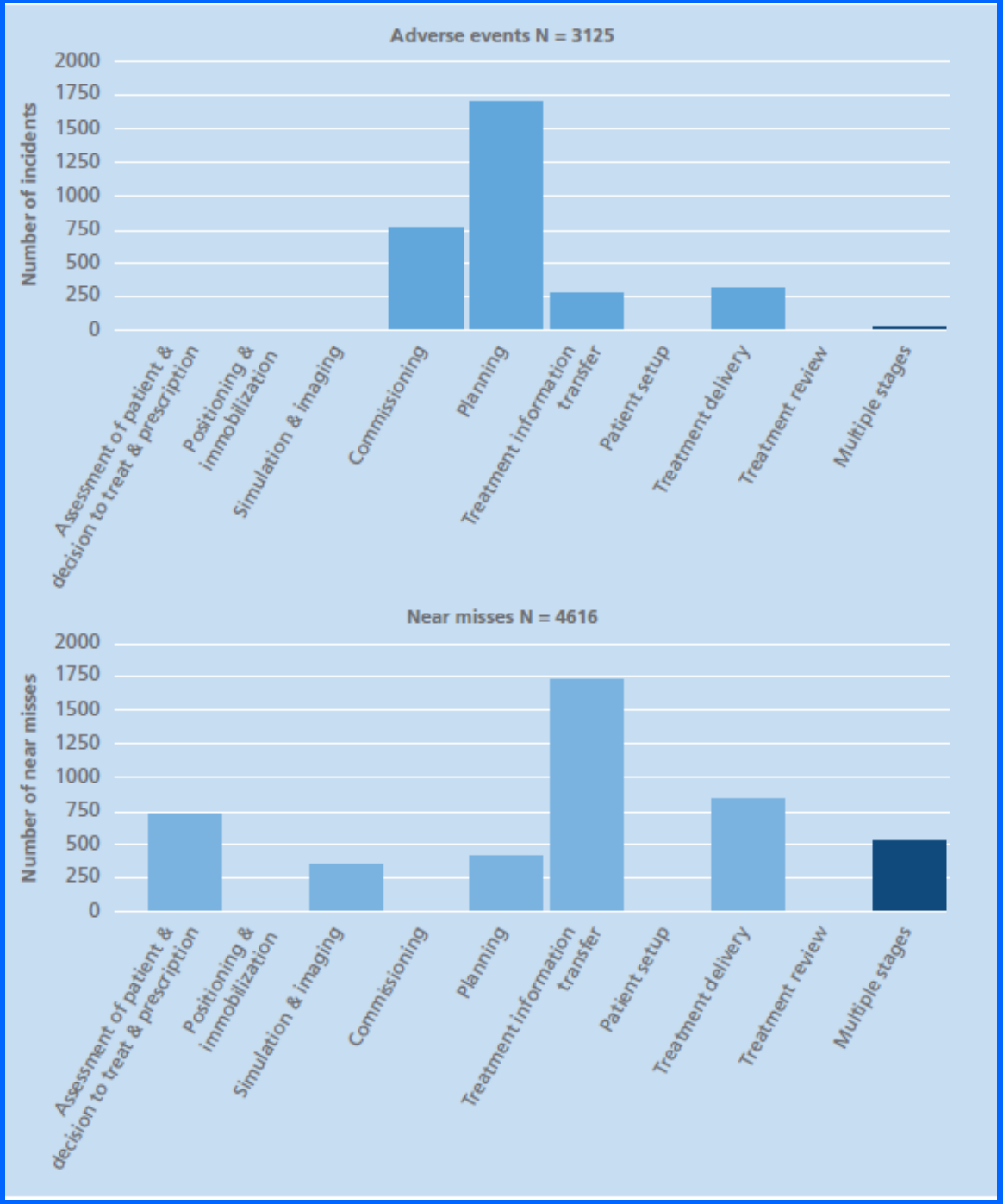
- ✓ Radiation oncologist (MD)
- ✓ Medical physicist (MPE)
- ✓ Radiotherapy technologist (RTT) and dosimetrist
- ✓ Biomedical engineer
- ✓ Nurse
- ✓ Anesthesiologist
- ✓ Psychologist

Stage	Description	Responsibility		
		RO	RT	MP
1 Assessment of patient	History taking, physical examination, review of diagnostic material	●		
2 Decision to treat	Consideration of guidelines, patient wishes	●		
3 Prescribing treatment protocol	Determination of site, total dose, fractionation and additional measures such as dental review or concurrent chemotherapy	●		
4 Positioning and immobilization	Setting up the patient in a reproducible position for accurate daily treatment		●	
5 Simulation, imaging and volume determination	Determining region of the body to be treated using diagnostic plain X-ray unit with the same geometry as a treatment unit (simulator) or dedicated CT scanner	●	●	
6 Planning	Determining X-ray beam arrangement and shielding then calculating dose to achieve prescription		●	●
7 Treatment information transfer	Transfer beam arrangement and dose data from treatment plan to treatment machine		●	●
8 Patient setup	Placing patient in treatment position for each treatment		●	
9 Treatment delivery	Physical delivery of radiation dose		●	●
10 Treatment verification and monitoring	Confirmation of treatment delivery using port films and dosimeters Monitoring of the daily setup Monitoring of tolerance by regular patient review	●	●	●

Risk management

A "near miss" is defined as:

A potential significant event that could have occurred as the consequence of a sequence of actual occurrences but did not occur owing to the plant conditions prevailing at the time.



FMEA

AAPM TG 100

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0360-3016/08/$–see front matter

ELSEVIER

doi:10.1016/j.ijrobp.2007.06.081

QA FOR RT SUPPLEMENT

A METHOD FOR EVALUATING QUALITY ASSURANCE NEEDS IN RADIATION THERAPY

M. Saiful Huq, Ph.D.,* Benedick A. Fraass, Ph.D.,† Peter B. Dunscombe, Ph.D.,‡ John P. Gibbons, Jr., Ph.D.,§ Geoffrey S. Ibbott, Ph.D.,¶ Paul M. Medin, Ph.D.,‖ Arno Mundt, M.D.,**

Int. J. Radiation Oncology Biol. Phys., Vol. 82, No. 2, pp. e305–e311, 2012

0360-3016/$ - see front matter

ELSEVIER

doi:10.1016/j.ijrobp.2011.05.010

PHYSICS CONTRIBUTION

APPLICATION OF FAILURE MODE AND EFFECTS ANALYSIS TO INTRAOPERATIVE RADIATION THERAPY USING MOBILE ELECTRON LINEAR ACCELERATORS

Mario Ciocca, M.S.,* Marie-Claire Cantone, Ph.D.,†‡ Ivan Veronese, Ph.D.,†‡ Federica Cattani, M.S.,§ Guido Pedroli, M.S.,§ Silvia Molinelli, M.S.,* Viviana Vitolo, M.D.,‖ and Roberto Orecchia, M.D.¶**††

RADIATION ONCOLOGY

Open Access

Application of failure mode and effects analysis to treatment planning in scanned proton beam radiotherapy

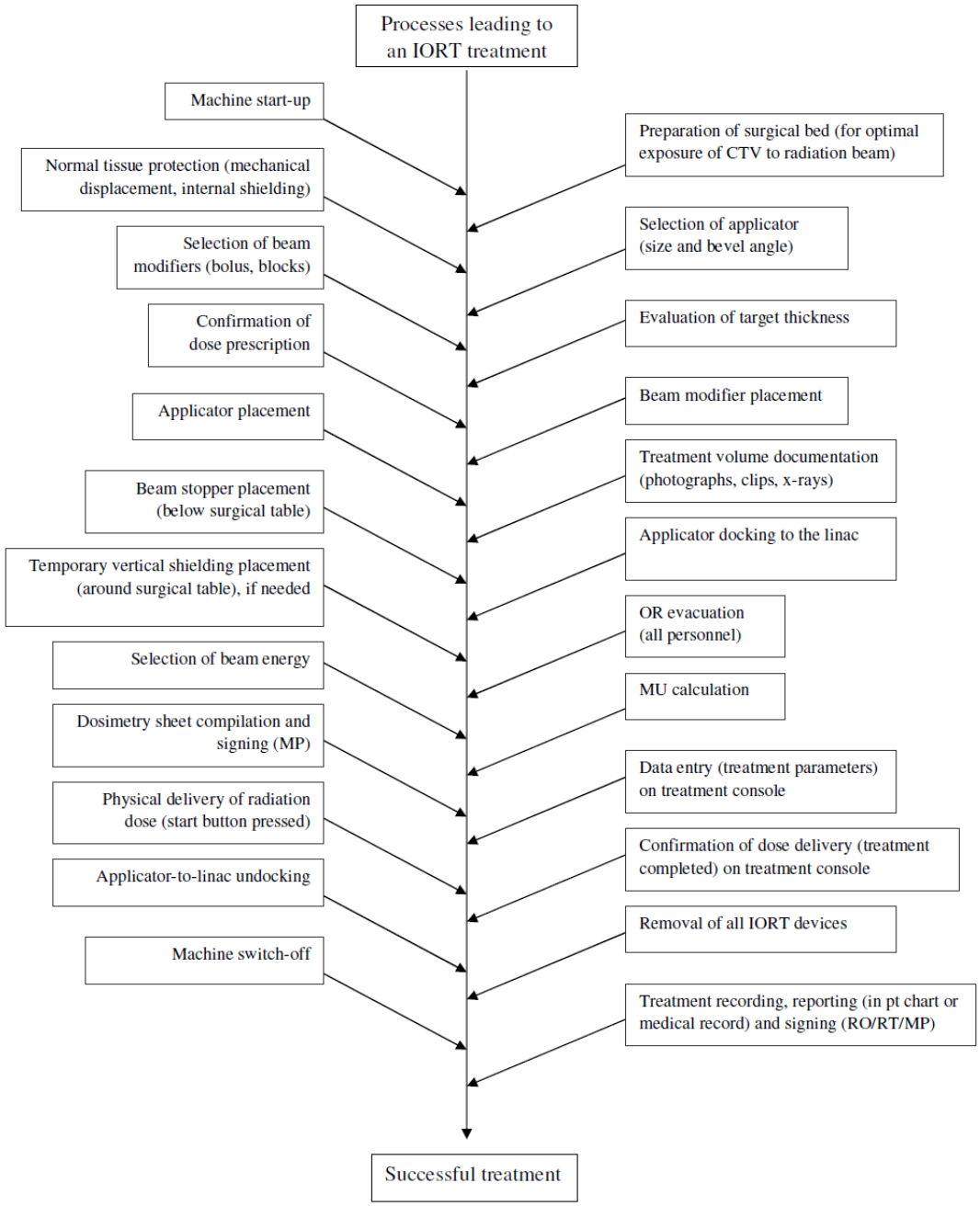
Marie Claire Cantone[1], Mario Ciocca[2], Francesco Dionisi[3], Piero Fossati[2,5], Stefano Lorentini[3], Marco Krengli[2,4], Silvia Molinelli[2], Roberto Orecchia[2,5], Marco Schwarz[3,6], Ivan Veronese[1*] and Viviana Vitolo[2]

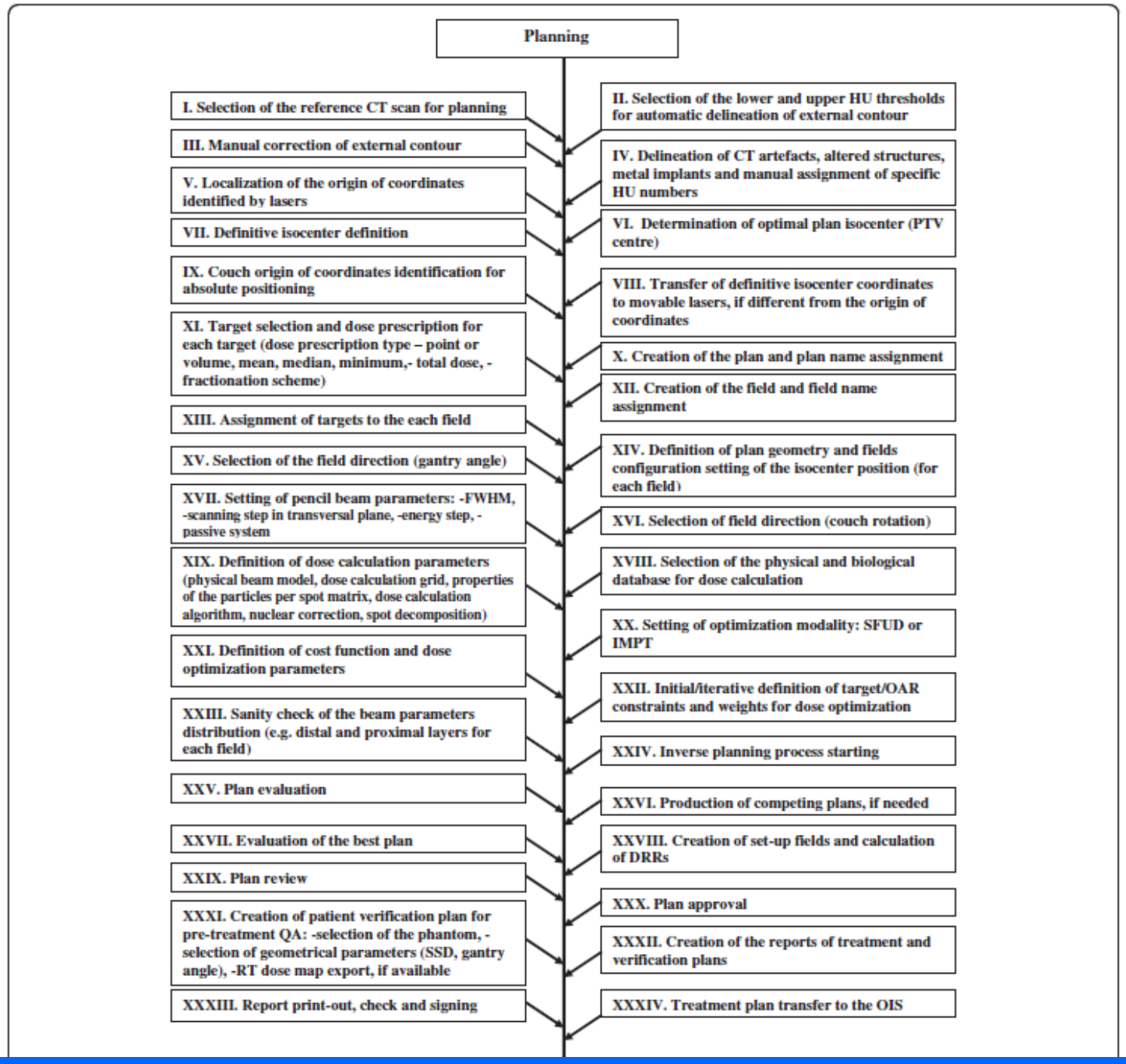
FMEA methodology
(proactive risk analysis method)

✓ **Multi-disciplinary** approach

✓ **First step:** identification of the involved sub-processes (***process tree)***

✓ Adapted to the user's **specific** context and procedure (individual case)


Processes leading to an IORT treatment
Machine start-up
Normal tissue protection (mechanical displacement, internal shielding)
Selection of beam modifiers (bolus, blocks)
Confirmation of dose prescription
Applicator placement
Beam stopper placement (below surgical table)
Temporary vertical shielding placement (around surgical table), if needed
Selection of beam energy
Dosimetry sheet compilation and signing (MP)
Physical delivery of radiation dose (start button pressed)
Applicator-to-linac undocking
Machine switch-off
Preparation of surgical bed (for optimal exposure of CTV to radiation beam)
Selection of applicator (size and bevel angle)
Evaluation of target thickness
Beam modifier placement
Treatment volume documentation (photographs, clips, x-rays)
Applicator docking to the linac
OR evacuation (all personnel)
MU calculation
Data entry (treatment parameters) on treatment console
Confirmation of dose delivery (treatment completed) on treatment console
Removal of all IORT devices
Treatment recording, reporting (in pt chart or medical record) and signing (RO/RT/MP)
Successful treatment


Planning
I. Selection of the reference CT scan for planning
II. Selection of the lower and upper HU thresholds for automatic delineation of external contour
III. Manual correction of external contour
IV. Delineation of CT artefacts, altered structures, metal implants and manual assignment of specific HU numbers
V. Localization of the origin of coordinates identified by lasers
VI. Determination of optimal plan isocenter (PTV centre)
VII. Definitive isocenter definition
VIII. Transfer of definitive isocenter coordinates to movable lasers, if different from the origin of coordinates
IX. Couch origin of coordinates identification for absolute positioning
X. Creation of the plan and plan name assignment
XI. Target selection and dose prescription for each target (dose prescription type – point or volume, mean, median, minimum,- total dose, -fractionation scheme)
XII. Creation of the field and field name assignment
XIII. Assignment of targets to the each field
XIV. Definition of plan geometry and fields configuration setting of the isocenter position (for each field)
XV. Selection of the field direction (gantry angle)
XVI. Selection of field direction (couch rotation)
XVII. Setting of pencil beam parameters: -FWHM, -scanning step in transversal plane, -energy step, -passive system
XVIII. Selection of the physical and biological database for dose calculation
XIX. Definition of dose calculation parameters (physical beam model, dose calculation grid, properties of the particles per spot matrix, dose calculation algorithm, nuclear correction, spot decomposition)
XX. Setting of optimization modality: SFUD or IMPT
XXI. Definition of cost function and dose optimization parameters
XXII. Initial/iterative definition of target/OAR constraints and weights for dose optimization
XXIII. Sanity check of the beam parameters distribution (e.g. distal and proximal layers for each field)
XXIV. Inverse planning process starting
XXV. Plan evaluation
XXVI. Production of competing plans, if needed
XXVII. Evaluation of the best plan
XXVIII. Creation of set-up fields and calculation of DRRs
XXIX. Plan review
XXX. Plan approval
XXXI. Creation of patient verification plan for pre-treatment QA: -selection of the phantom, -selection of geometrical parameters (SSD, gantry angle), -RT dose map export, if available
XXXII. Creation of the reports of treatment and verification plans
XXXIII. Report print-out, check and signing
XXXIV. Treatment plan transfer to the OIS

✓ **Second step:** identification of what might be wrong (***failure modes***), creating the ***fault tree***, together with causes and potential effects

✓ **Third step:** ranking all failure modes in terms of priority, using 3 parameters (O, S, D)

- ✓ occurrence
- ✓ severity
- ✓ detectability

Risk priority number (RPN) = O x S x D

Int. J. Radiation Oncology Biol. Phys., Vol. 74, No. 3, pp. 852–858, 2009

0360-3016/09/$–see front matter

ELSEVIER

doi:10.1016/j.ijrobp.2008.10.038

CLINICAL INVESTIGATION **Quality Improvement**

EVALUATION OF SAFETY IN A RADIATION ONCOLOGY SETTING USING FAILURE MODE AND EFFECTS ANALYSIS

Eric C. Ford, Ph.D.,* Ray Gaudette, M.S.,* Lee Myers, Ph.D.,* Bruce Vanderver, M.D.,†
Lilly Engineer, Dr.P.H., M.D., M.H.A.,† R
John Wong, Ph.D.,* and

* Department of Radiation Oncology and Molecular Radiatio
Hopkins Univ

Table 1. Example scoring system of severity, frequency of occurrence, and detectability for input into failure mode and effects analysis

Score	Severity	Occurrence	Detectability
1	No effect	Less than every 5 years	
2	Dose Δ5%	Every 2–5 years	Very easy to detect
3		Once a year	
4	Minimal delay in care	Several times a year	Easy to detect
5		Once a month	
6	Allergic reaction; moderate delay in care	Several times a month	Mildly difficult to detect
7		Once a week	
8	Dose Δ20%, reportable	Several times a week	
9		Once a day	
10	Patient dies	Several times a day	Impossible to detect

Table 2 Application of failure mode and effects analysis for the treatment planning stage in proton beam radiotherapy

Sub-process	N	Potential failure mode	Potential causes of failure	Potential effects of failure	O	S	D	RPN
(I) Selection of the reference CT scan for planning	1	Error in selecting the CT scan (e.g. incorrect patient set up, outdated representation of the anatomy) in case of multiple CT scans	Human error, failure in the communication between operators	Wrong dose distribution/ wrong dose delivery	3	8	4	96
	2	Outdated representation of the anatomy (single CT scan)	Anatomical changes (related to time delay)	Wrong dose distribution/ wrong dose delivery	3	8	8	192
(III) Manual correction of external contour	3	Incorrect external contour definition (body or patient mask countour underestimation, i.e. not fully included in the external contour)	Human error	Wrong dose distribution / wrong dose delivery	4	5	4	80
	4	Failure of object/region identification	Human error	Wrong dose distribution	3	8	4	96
(IV) Delineation of CT artefacts, altered structures, metal implants and manual assignment of specific HU numbers	5	Inaccurate delineation	Human error	Wrong dose distribution	4	6	6	144
	6	Incorrect HU number manual assignment	Human error or lack of documentation from the referring clinicians (e.g. surgeons)	Wrong dose distribution	4	7	7	196
	7	Lack of couch origin of coordinates definition	Human error	Unintended normal tissue irradiated and CTV missing	3	10	3	90

✓ **Last step:** for the most critical failure modes (RPN > 125 o S-index very high), identification of **additional safety measures** to mitigate the risk and defining a **priority** list based on

✓ expected **efficacy**

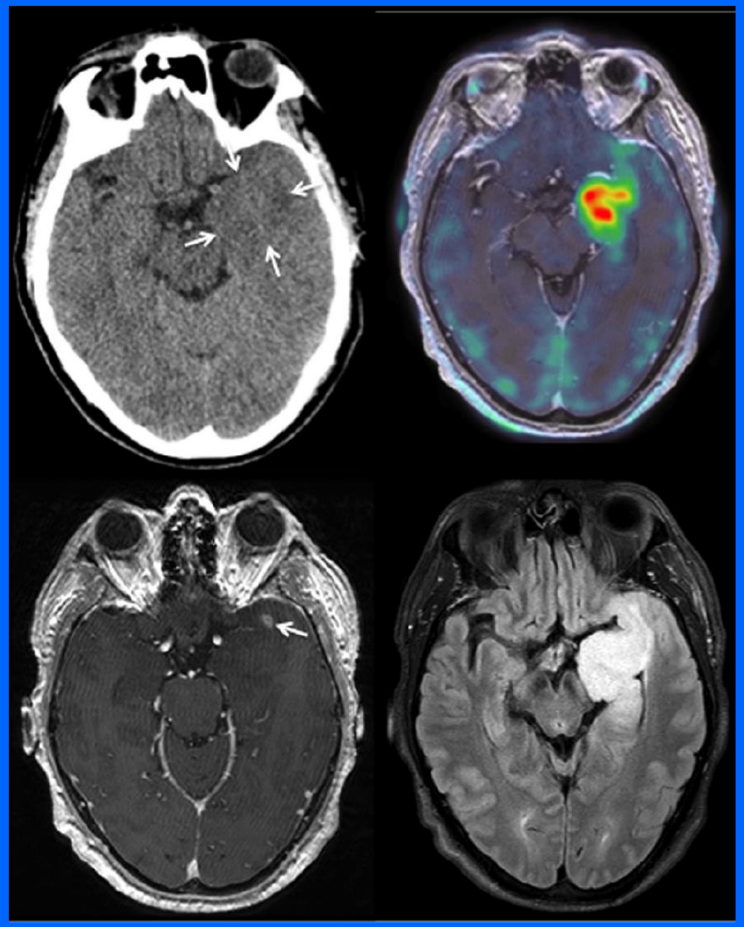
✓ **feasibility** (costs, needed resources, time)

IMPORTANT: risk mitigation strategies to be verified in the reality once defined!

✓ independent, double-checking of MU calculation and data entry to be stated as mandatory

✓identification of a dedicated radiotherapy staff, well trained to IORT procedures

✓ implementation and extensive use of real-time in-vivo dosimetry procedures, allowing immediate action levels to be applied in case of detected dose discrepancies

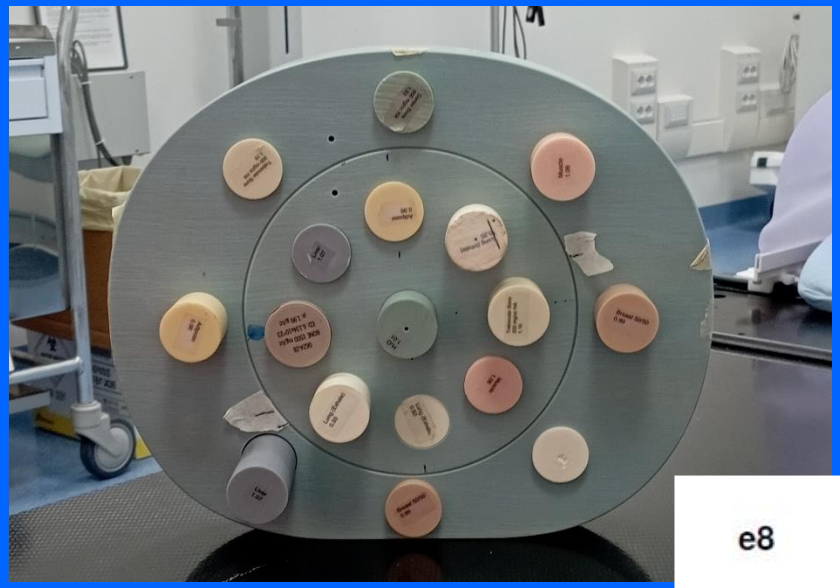


Simulation, imaging and volume determination

3-D imaging: CT, MRI, PET-CT

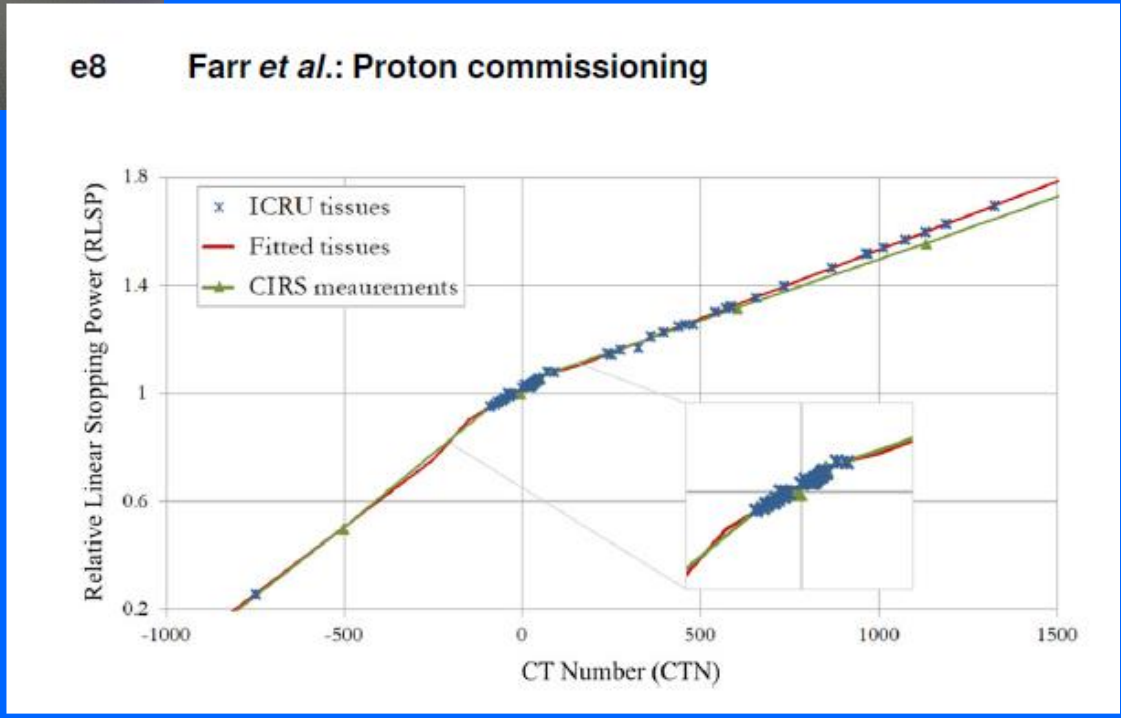
Planning CT: pt anatomy in treatment conditions

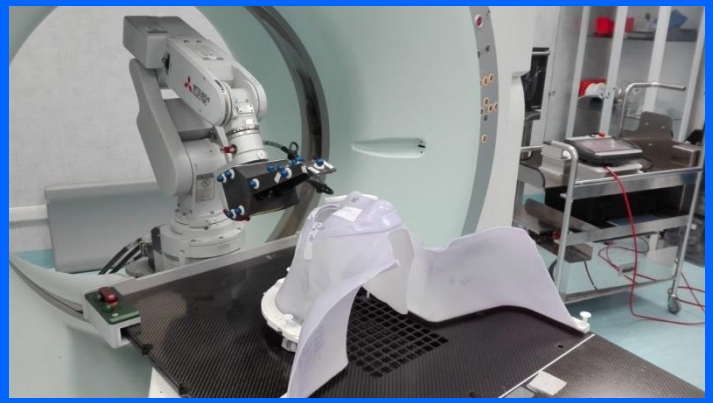
Planning CT

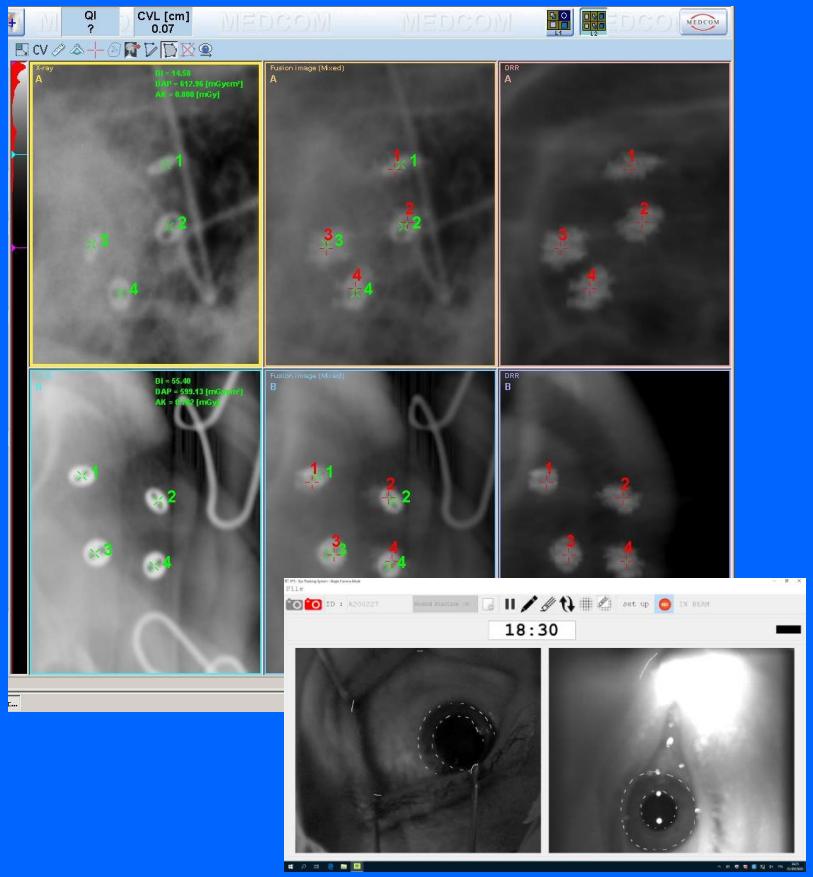


HU (CT N) conversion to relative ED or SP

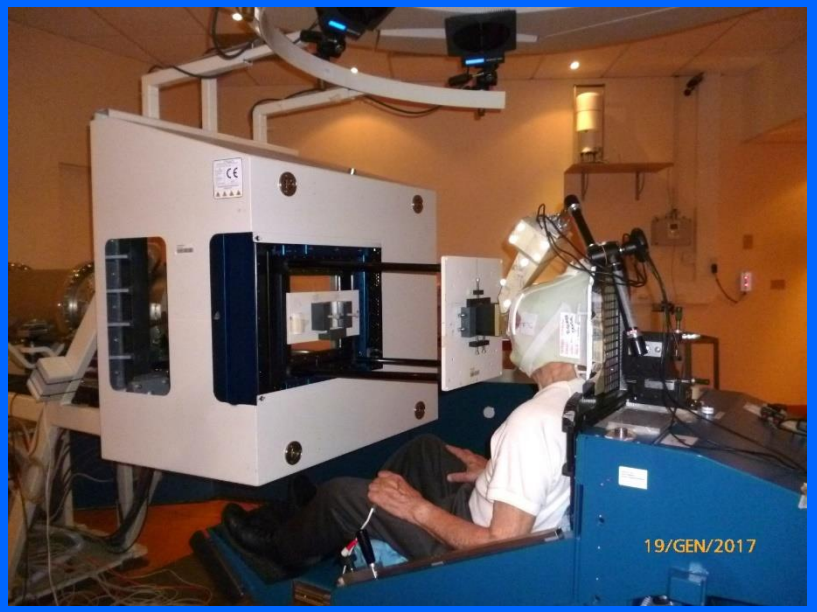
Simulation, imaging and volume determination







> 600 ocular melanoma pts treated in upright position since 2016 at CNAO



Measuring eye deformation between planning and proton beam therapy position using magnetic resonance imaging

Myriam G. Jaarsma-Coes [a,b,*], Marina Marinkovic [a], Eleftheria Astreinidou [c], Megan S. Schuurmans [b], Femke P. Peters [c], Gregorius P.M. Luyten [a], Coen R.N. Rasch [c], Jan-Willem M. Beenakker [a,b]

[a] Ophthalmology, Leiden University Medical Centre, Leiden, Netherlands
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[c] Radiotherapy, Leiden University Medical Centre, Leiden, Netherlands

Change in gravity direction produced no substantial changes in sclera and tumour shape, therefore supinely acquired images can be used to plan ocular-PBT in seated position

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DOI: 10.1002/acm2.14129

JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS

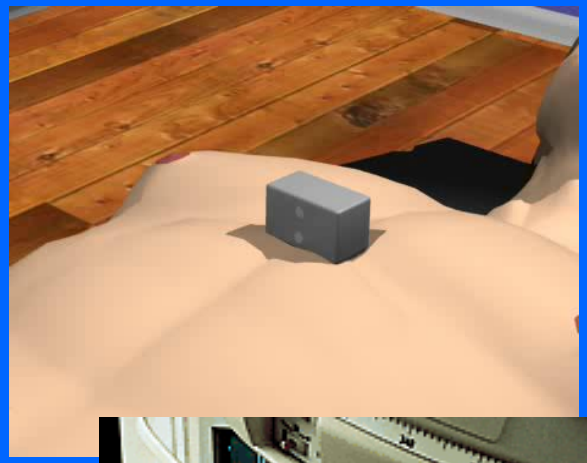
RADIATION ONCOLOGY PHYSICS

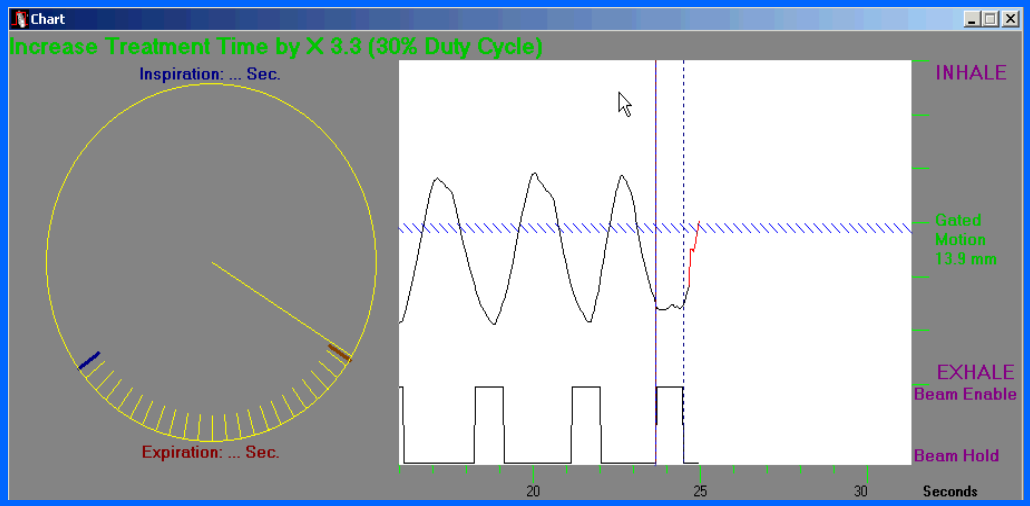
Relative thoracic changes from supine to upright patient position: A proton collaborative group study

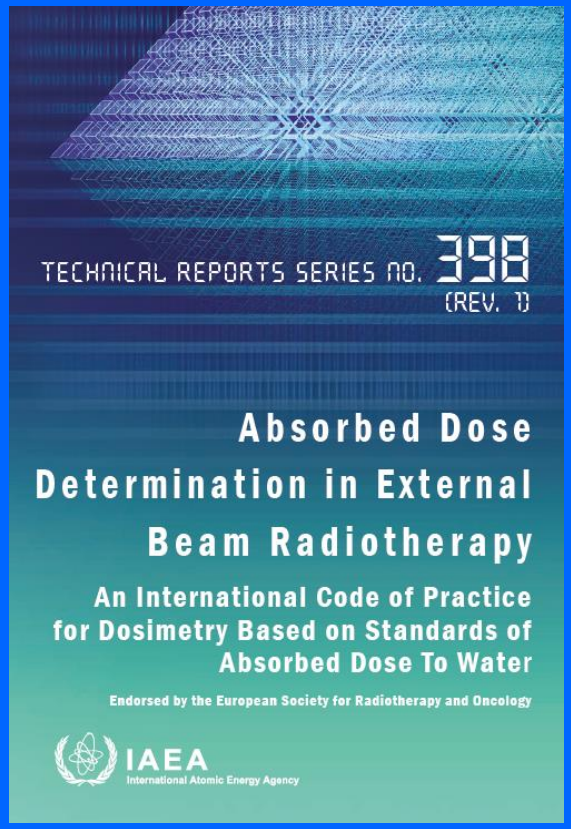
Joseph Marano[1] | Michael W. Kissick[2] | Tracy S. A. Underwood[3] | Steven J. Laub[1] | Michelle Lis[2] | Andries N. Schreuder[2] | Brad Kreydick[1] | Mark Pankuch[1]

- ✓ Organ position changes and deformation due to gravity do occur when positioning from supine to upright
- ✓ Larger lung volumes associated with upright positioning may allow for a reduction in mean lung dose
- ✓ The change in heart position relative to the sternum could potentially reduce radiation induced cardiovascular disease

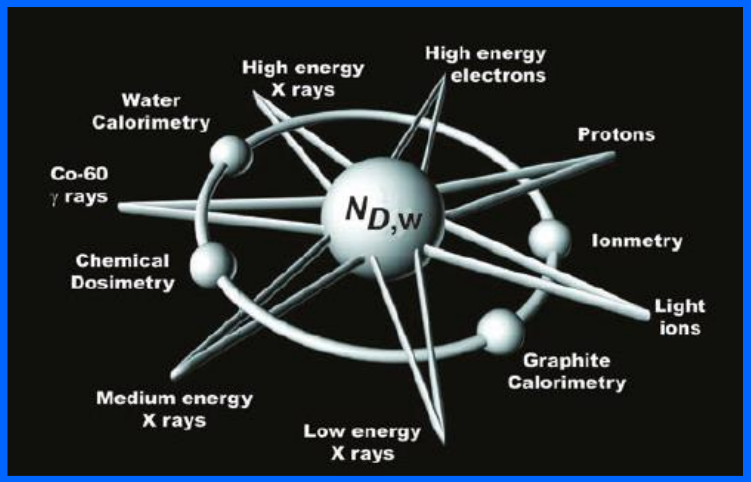
Organ motion management: 4-D imaging







Equipment and software commissioning



When a dosimeter is used in a beam of quality Q different from that used in its calibration, Q_o, the absorbed dose to water is given by

$$D_{w,Q} = M_Q N_{D,w,Q_o} k_{Q,Q_o} \qquad (3.2)$$

where the factor k_{Q,Q_o} corrects for the effects of the difference between the reference beam quality Q_o and the actual user quality Q, and the dosimeter reading M_Q has been corrected to the reference values of influence quantities, other than beam quality, for which the calibration factor is valid.