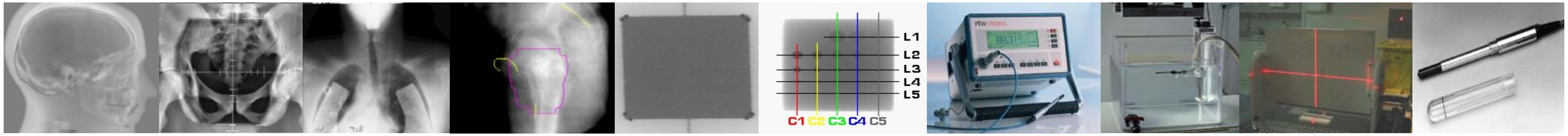


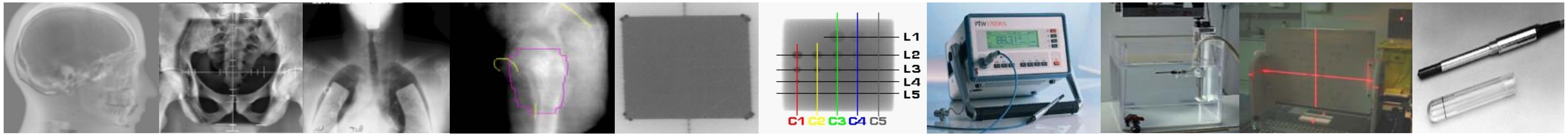
إعداد
م. أنور صلاح عطا

Quality assurance in radiotherapy

م. أنور صلاح عطاالله

ماجستير فيزياء طبية

فرنسا



إعداد
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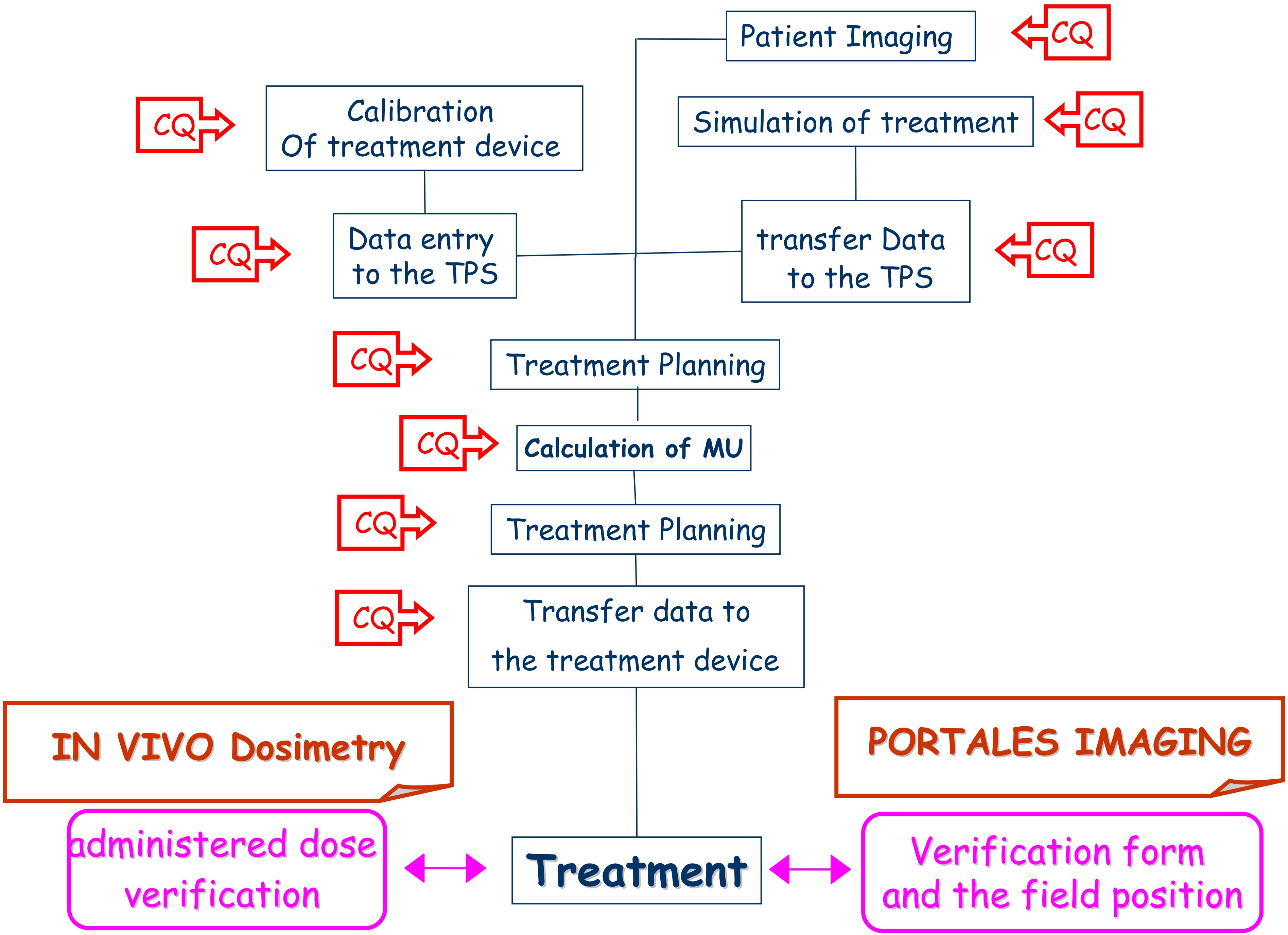
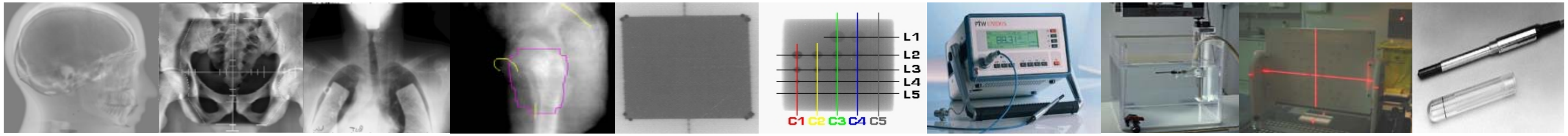
Circuit of Radiotherapy

- Imaging => CT, MRI, PET
- Simulation => Conventional, virtual
- Dosimetry => Calculations on TPS, Transfer (R & V)
- Controls => Radiography, portal imaging or dosimetry in vivo
- Irradiation => Accelerator or cobalt


Patient Imaging
CQ
Calibration
Of treatment device
CQ
Simulation of treatment
CQ
Data entry
to the TPS
CQ
transfer Data
to the TPS
CQ
CQ
Treatment Planning
CQ
Calculation of MU
CQ
Treatment Planning
CQ
Transfer data to
the treatment device
IN VIVO Dosimetry
PORTALES IMAGING
administered dose
verification
Treatment
Verification form
and the field position



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The « risk » of treatment

Irradiation of the tumor

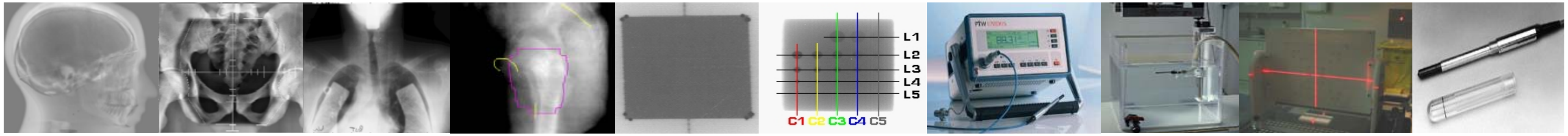
Irradiation of healthy tissue very important

Very low dose → Recidive

Very high dose → Complications

Irradiation of healthy tissue very important → Complications

Goal: <5% error



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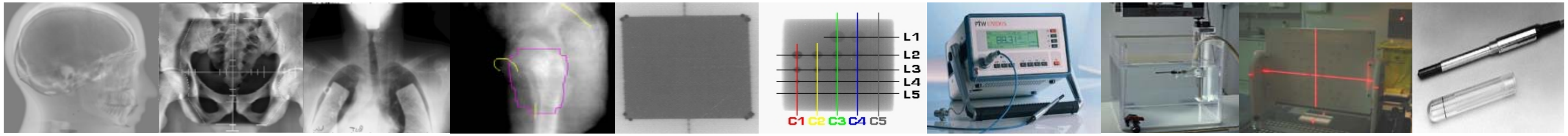
Sources of Error (uncertainty)

- **imaging**
  - Density curve , position (irreproducible)…
- **Simulation**
  - Bad position (conformation, lasers) ...
- **Dosimetry**
  - Algorithm failed, Bad parameters, Bad configuration of TPS…
- **Controls**
  - Incorrect repositioning, error measures ...
- **Irradiations**
  - The problem of R & V, machine problems, bad irradiation (filter) ...



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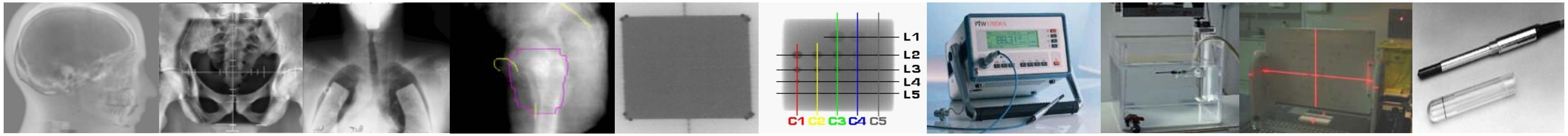
Sources of Error (uncertainty)

- Patient localization
- Organ motion
- Imaging (resolution, distortions,…)
- Definition of anatomy (outlines,…)
- Beam geometry
- Dose calculation
- Dose display and plan evaluation
- Plan implementation



إعداد

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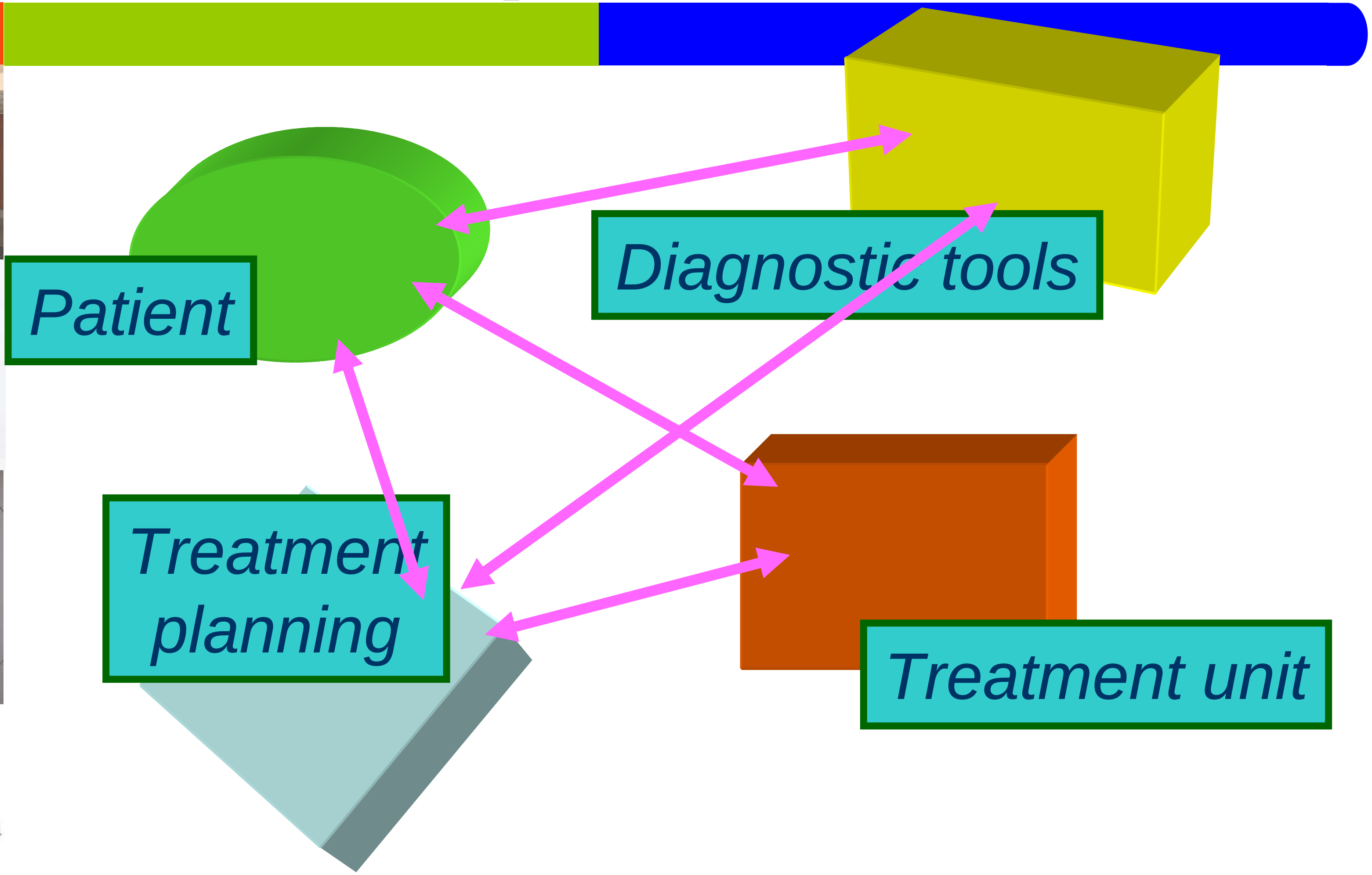
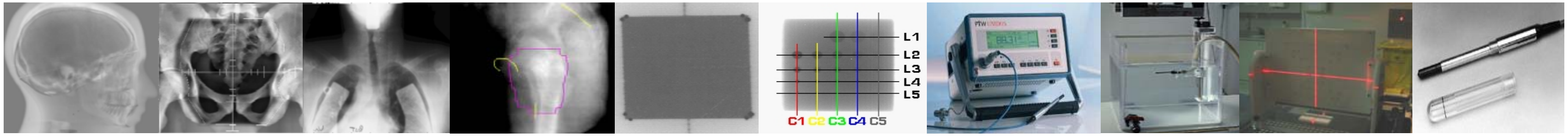
Ensure different co-ordinate systems match...





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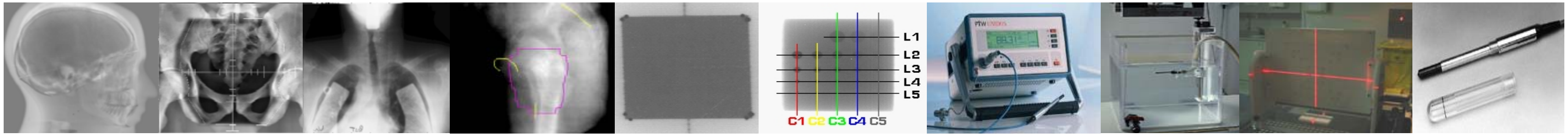
The types of errors

- Random errors **(one seance)**
  - Positioning
  - Irradiation, location

Systematic errors **(all seances)**
  - Positioning, location
  - Dosimetric Calculations
  - Configuration of TPS, accelerator ...

All errors are human but the machines must be <u>reliable</u>



إعداد
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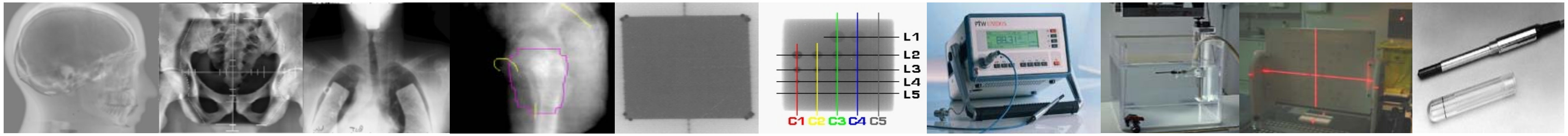
QUALITY as a goal

The totality of features or characteristics that bear on our ability to satisfy the stated or implied goal of effective patient care.”

What is Quality Assurance?

“All those planned and systematic actions necessary to provide confidence that a product or service will satisfy given requirements for quality.”

ISO 9000



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QA and QC

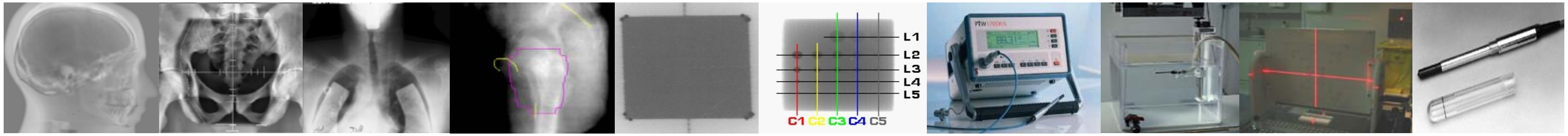
- ➢ Quality Assurance is the overall process which is supported by Quality Control activities

- ➢ Quality Control describes the actual mechanisms and procedures by which one can assure quality

- ❖ **<u>Good QA systems in radiotherapy</u>**

  - ✓ Improves work practices
  - ✓ Would have prevented most of the major accidents

ISO 9000



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QA systems

AS/NZS ISO 9000.1:1994

Australian/New Zealand Standard

Quality management and quality assurance standards

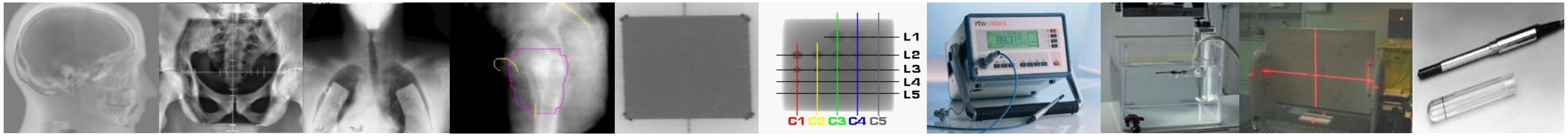
Part 1: Guidelines for selection and use

First published in Australia as
AS 3900—1987/ISO 9000:1987.

First published in New Zealand as NZS 5600.1:1987.

AS 3900—1987/ISO 9000:1987 and NZS 5600.1:1987
redesignated in 1990 and issued as Joint Standard
AS 3900—1987/NZS 9000:1990/ISO 9000:1987.
Redesignated in 1992 as Joint Standard
AS 3900.1—1987/NZS 9000:1990/ISO 9000:1987.
Jointly revised and redesignated as Joint Standard
AS/NZS ISO 9000.1:1994.

- Many QA systems exist - one important example is the ISO 9000 system
- They are highly successful in manufacturing industry because they do improve productivity and avoid costly mistakes



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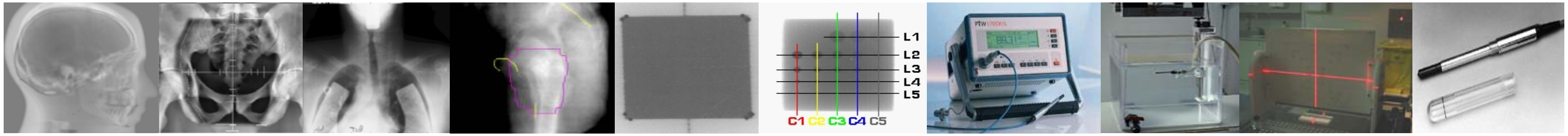
ISO 9000




- Comprehensive set of standards for QA (mainly in manufacturing and service industry)
- Adapted eg. by ESTRO to the radiotherapy environ
    - European Society for Therapeutic Radiology and Oncology (ESTRO) Advisory Report to the Commission of the European Union for the 'Europe Against Cancer Programme'. Quality Assurance in radiotherapy. Radiother. Oncol. 35: 61-73; 1995.



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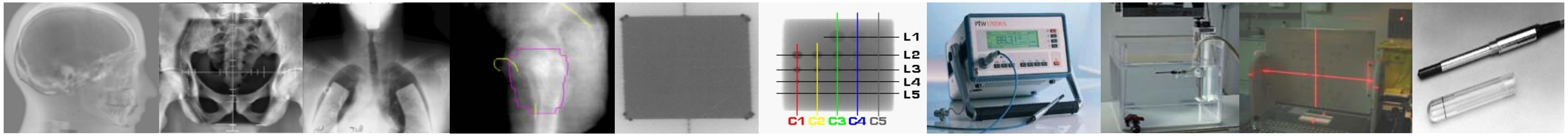
A Comprehensive QA Program typically comprises of

- Quality Assurance Committee
- Policies and Procedures Manual
- Quality Assurance team
- Quality audit
- Resources



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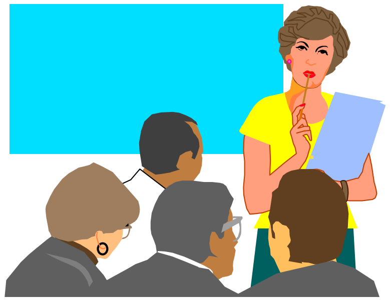
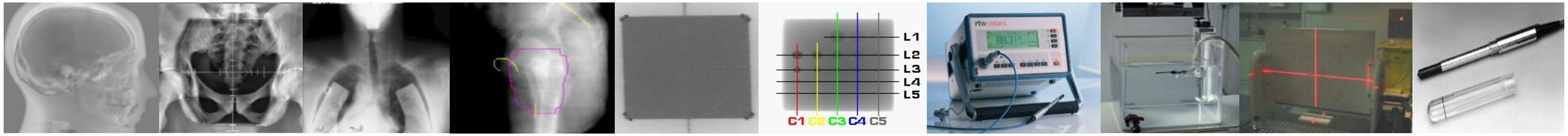
QA Committee Membership

- Must represent the many disciplines within the department
- Should be chaired by the Head of Department
- As a minimum must include a medical doctor, a physicist, a radiotherapy technologist and an engineer responsible for service and maintenance
- Must be appointed and supported by senior management
- Must have sufficient depth of experience to understand the implications of the process
- Must have the authority and acces to the resources to instigate and carry out the QA process





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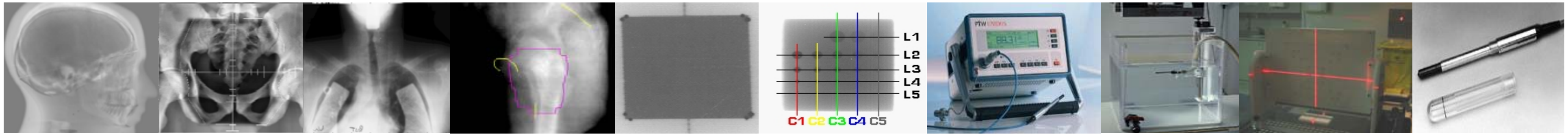
Quality Assurance Committee

- Should 'represent' the department
- Should be 'visible' AND accessible to staff
- Oversees the entire Quality Assurance program
- Writes policies to ensure the quality of patient care
- Assists staff in tailoring the program to meet the needs of the Department (using published reports as a guide)
- Monitor and audit the program to ensure that each component is being performed and documented



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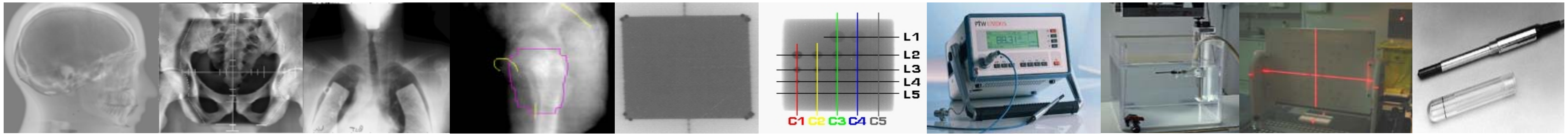
Policies and Procedures Manual

- As a minimum, sections should exist for
  - Administrative procedures
  - Clinical procedures
  - Treatment procedures
  - Physics procedures
  - Radiation safety



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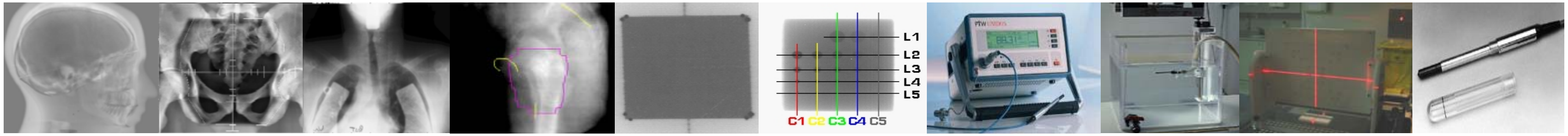
Continuous Quality Improvement

- CQI - many other acronyms are available for this
- Part of virtually all QA systems
- Improved methods on cancer patient management are documented in clinical trial reports.
- Quality assurance protocols are continuously under development in many countries
- Regular Quality Assurance meeting for all members of a Section
- Continuing education - lectures, workshops, journal clubs and must be available for all staff



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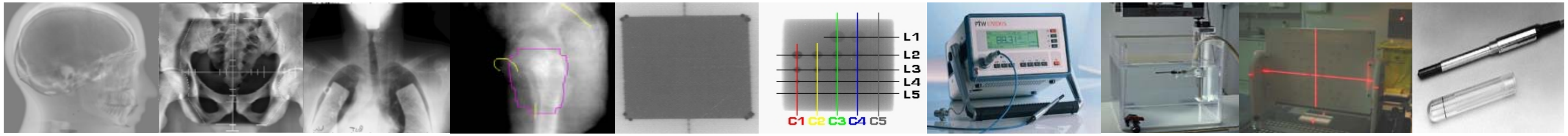
Quality Assurance Program

- Control of machines
  - The imaging devices and the simulator
  - Particles Accelerators
- Control of TPS and R&V
- Control of treatment (of patients)
  - Control of Positioning:
    - radiography and portal imaging
    - The cone beam CT
  - Control of dose
    - In vivo dosimetry
    - Pre-Treatment Controls



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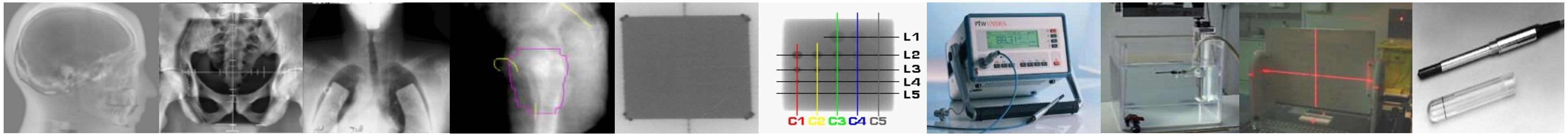
Imagers

- The simulator (-CT)
- The CT simulation



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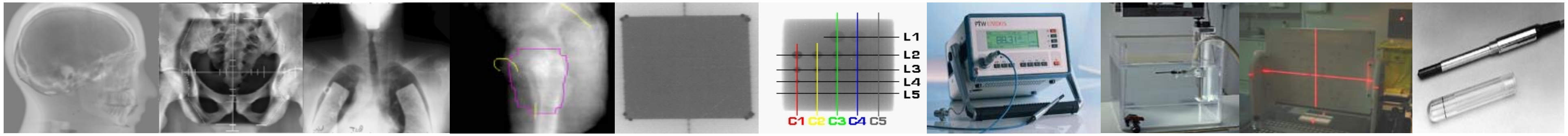
The simulator (-CT)



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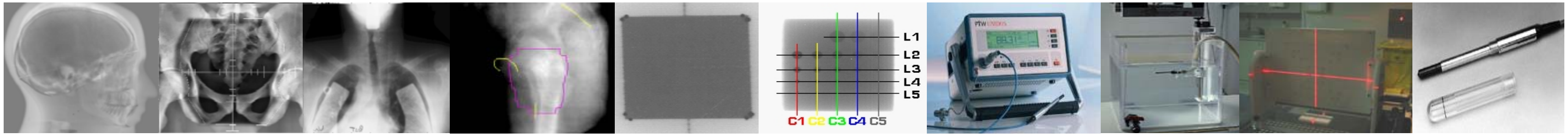
The simulator (CT)

- Mechanical Control

  - Table (Coach) Movements (Levels and security)
  - Telemeter
  - Diaphragms
  - Scales of rotation
  - Movements of the intensifier
  - Anti-collision System
  - Iso centric Verification
  - Correspondence with light field and irradiated field
  - Lasers



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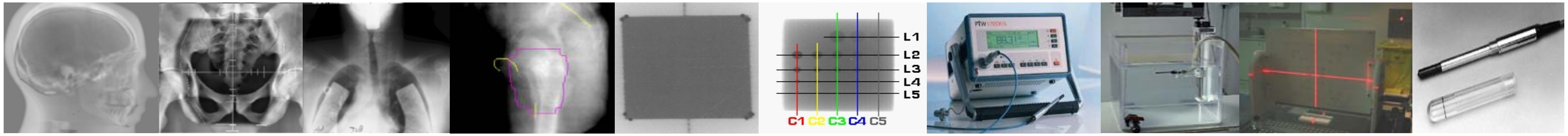
The simulator (-CT)

- Image Control
  - Graphic / fluoroscopy
  - Adapted Phantom
  - Spatial resolution
  - Distortion, focal spot size
- Dose Control
  - Measurement of parameters of low energy (50-130 kV) => kV, mAs



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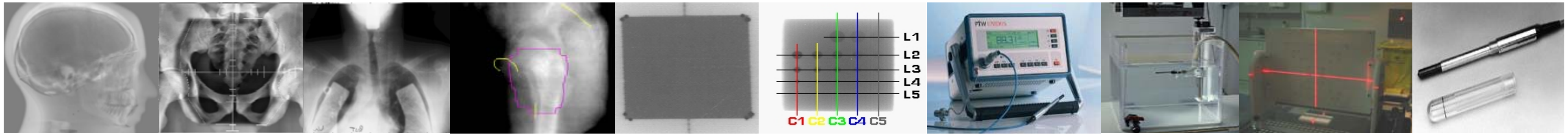
The CT simulation



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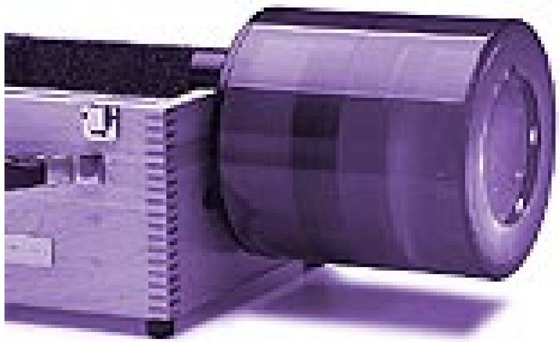
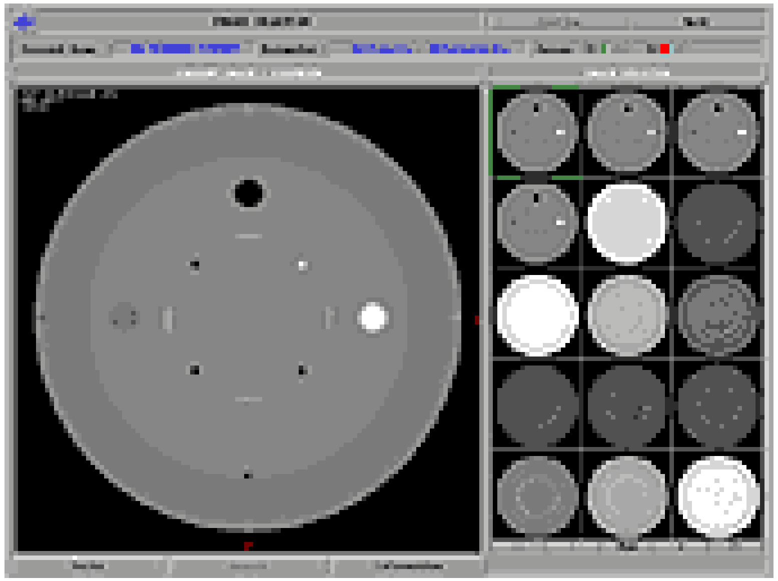
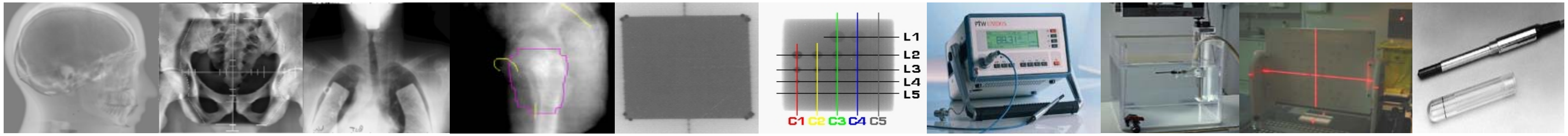
The CT simulation

AQUILAB
quality • therapy • systems

- - Uniformity of Phantom
  - Scale densities (dosimetry)







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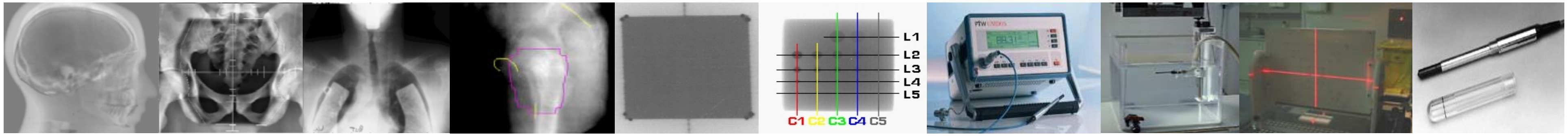
The Accelerators









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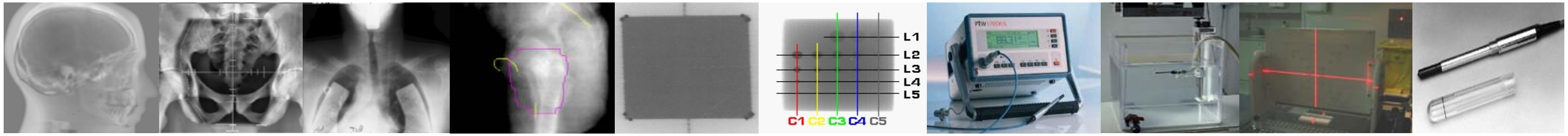
The Accelerators




- Internal control
  - **Daily CQ**
    - Mechanical and dosimetric
  - **Weekly CQ**
    - Mechanical
  - **Monthly CQ**
    - Mechanical and dosimetric
  - **Semestriel CQ**
    - Mechanical and dosimetric
  - **Annual CQ**
    - Mechanical and dosimetric
- External Dose Control



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External Beam Radiotherapy Examples for daily QA

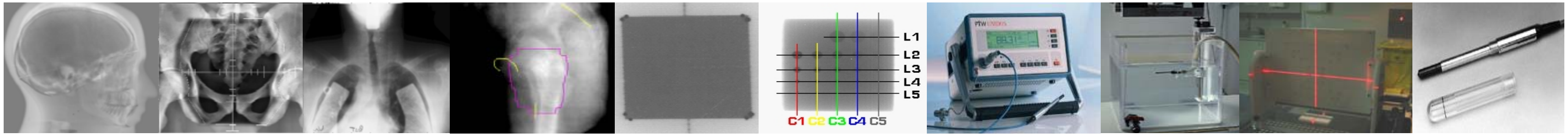



- Safety
  - door and other interlocks
  - radiation warning lights (door, bunkers, equipment room)
  - Verification of surveillance systems (camera + intercom)
  - radiation area monitor

- Mechanical/optical “pointers”
- Radiation constancy check

TOPS

PTW Linacheck



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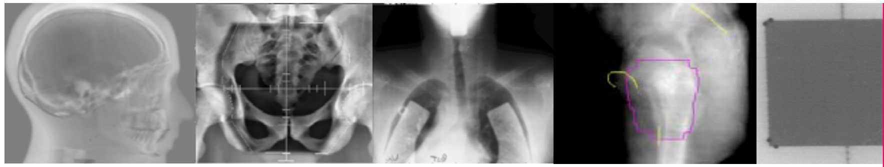
The TOPS

- Every day, for all photon energies and at least one electron energy

Tolerance < 2 %



إعداد

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Example for weekly QA summary

- From Constantinou 1992

Pass = ✓ or ✗
Fail = F
Not Applicable = N/A
Replaced/Corrected = R/C

Summary of Weekly QA Checks

From ___/___/___ to ___/___/___

Linear Accelerator ______________________

B. Radiation Accuracy (Summary from data forms)

2. Symmetry/Flatness — Criteria — One gantry angle per week
   a. Photon High Energy ____ MV — Baseline Values: Symmetry = ______%, Flatness = ______%
      i. Gantry Angle (°)
      ii. Symmetry/Flatness (%)
      iii. Difference from Baseline (2%)
   b. Photon Low Energy ____ MV — Baseline Values: Symmetry = ______%, Flatness = ______%
      i. Gantry Angle (°)
      ii. Symmetry/Flatness (%)
      iii. Difference from Baseline (2%)
   c. Electron Beams — One electron energy per week
      i. Electron Energy (MeV)
      ii. Baseline: Symmetry/Flatness (%)
      iii. Gantry Angle (°)
      iv. Symmetry/Flatness (%)
      v. Difference from Baseline (2%)

3. Light/Radiation Field Coincidence — One gantry angle per week
   a. Photon Energy (MV)
   b. Gantry Angle (0°/180°, 90°, 270°)
   c. Field Edges Difference (2 mm)
   d. Field Centers Difference (2 mm)

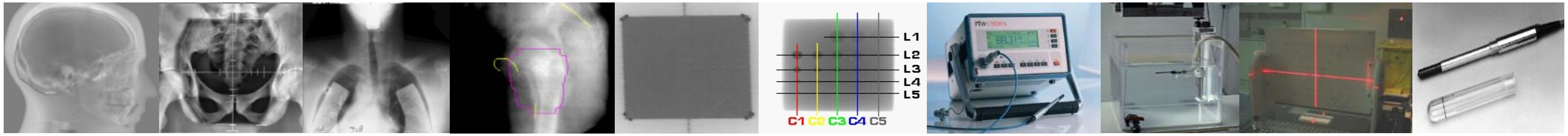
C. Safety System Functioning
1. Collision Avoidance (Touchguards)
2. Motion Enable (Deadman) Switch(es)
3. Door Interlock
4. BEAM ON Light Above Door
5. Accessory Tray
   a. Locking Mechanism (2 mm)
   b. Tray Interlock
   c. Tray Movement
6. Couchside Emergency Off
7. Electron Lockout in Photon Mode
8. Electron Beam Safety — One applicator per week
   a. Electron Cone (Number)
      i. Cone Integrity
      ii. Cone Code
   b. Photon Jaw Position
   c. Photon Lockout Interlock
   d. Photon Portal Film
   e. Cone Touchguard

D. Processor Sensitometry

Date:

Physicist's/Technologist's Initials:

Comments: ______________________



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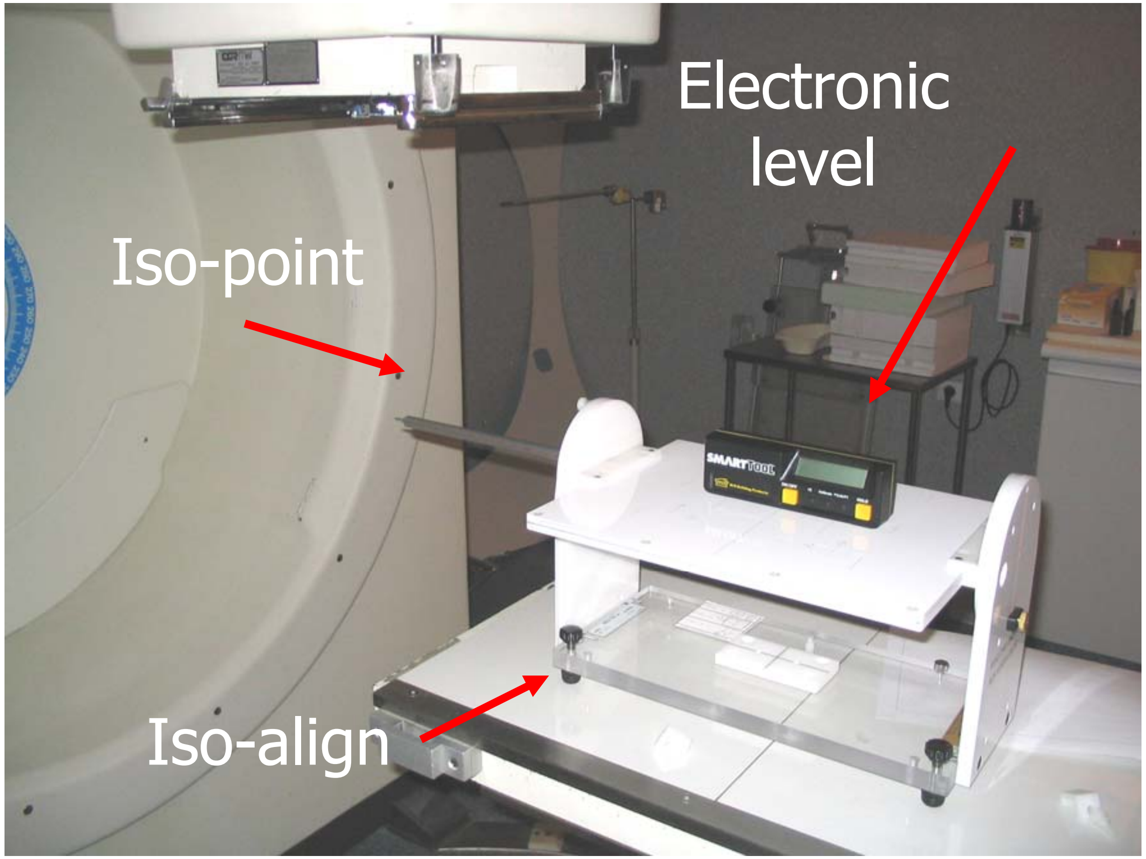
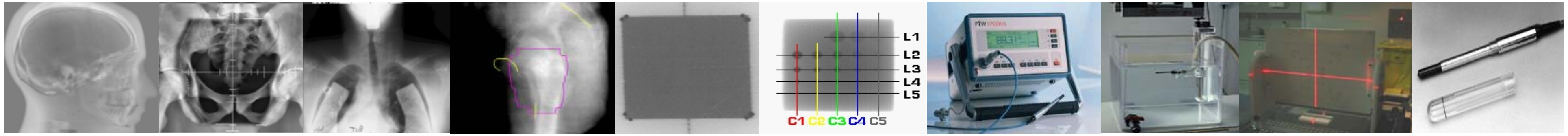
weekly QA





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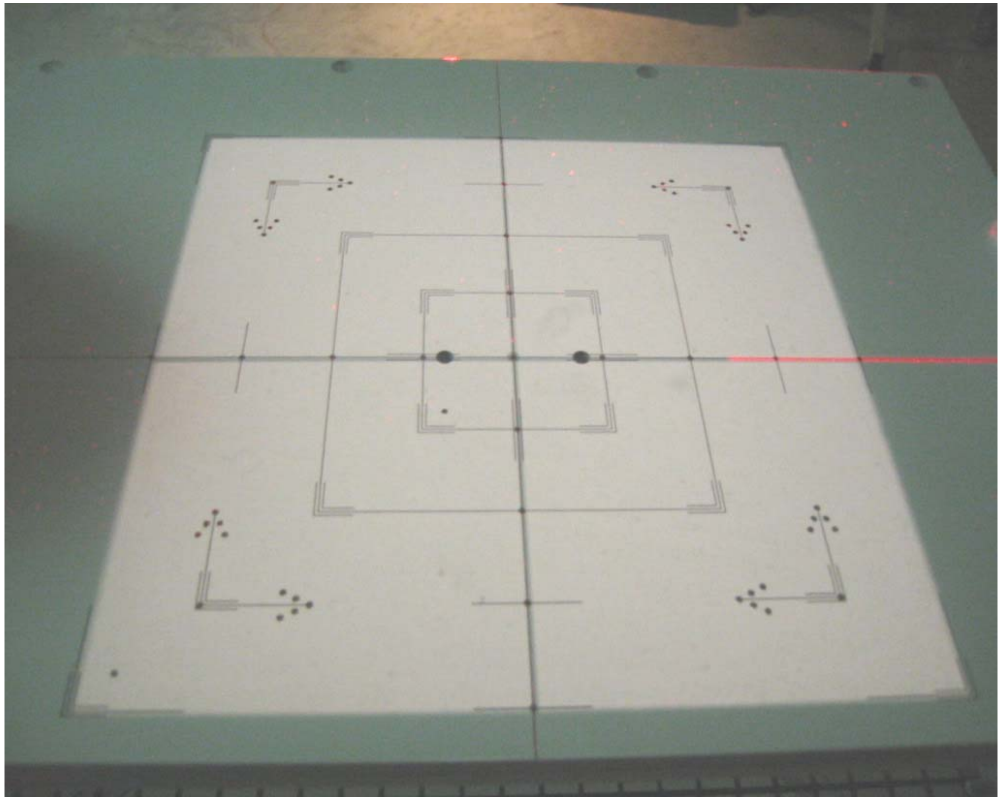
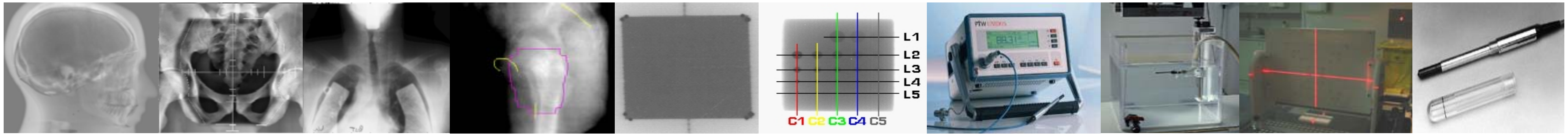
weekly QA

- Checking the reference field size

Field size 20 x 20 cm
SSD = 100 cm

Tolerance < 2 mm





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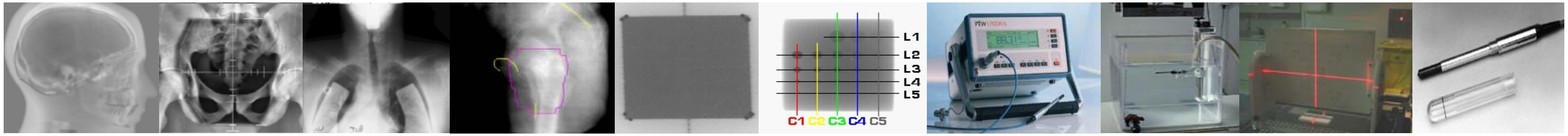
Quality Assurance - Monthly

- **Dosimetry**
  - Output constancy
  - Backup monitors
  - Central axis %DD constancy
  - Flatness/symmetry constancy
  - Timer end effect



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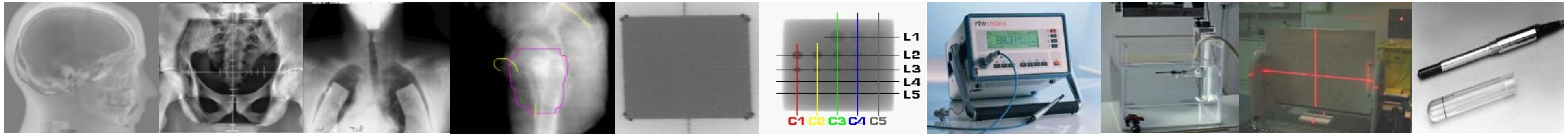
Quality Assurance - Monthly

- Safety interlocks
  - emergency
  - wedge etc
- Light/ radiation field coincidence
- Scales
- Isocentre position
- Cross hair position



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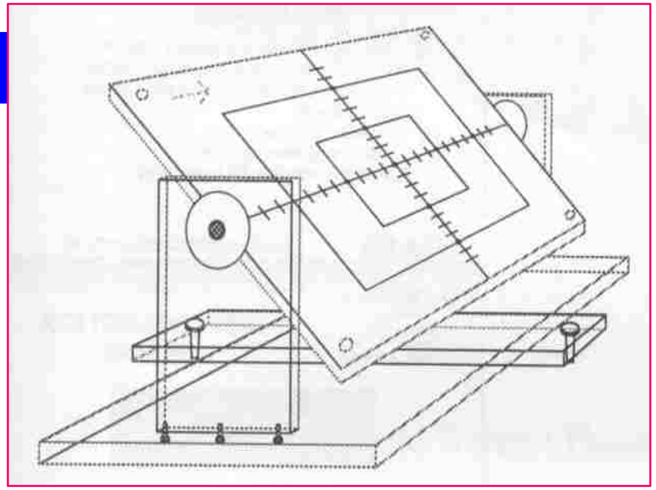
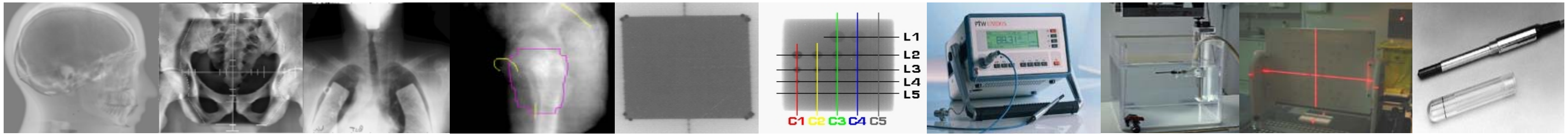
Quality Assurance - Monthly



- Field size indicators
- Distance measuring indicators
- Jaw symmetry
- Latching of wedges, trays etc.
- Wedge position (factors etc.)



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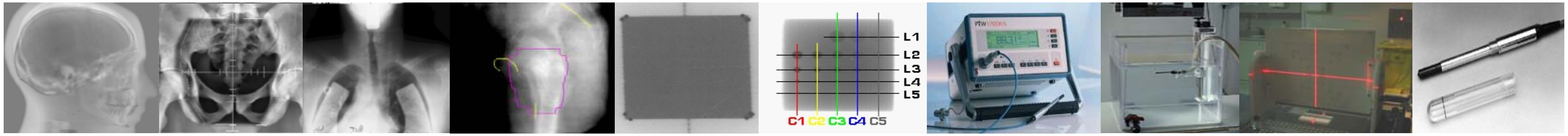
Time requirements for QA

- External beam per megavoltage unit
  - daily: 30 minutes
  - weekly: 2 hours
  - monthly: > 4 hours
  - annual: 2 days +
- These are estimates only - a qualified expert must decide on the actual requirements for a particular treatment unit

Siemens Primus Linac



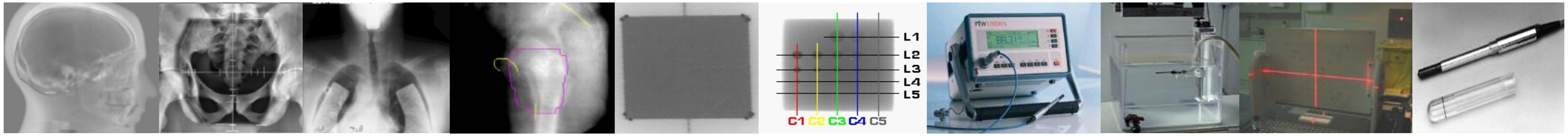
إعداد
م. أنور صلاح عطا

Monthly Mechanical CQ




- Verification of Anti collision systems

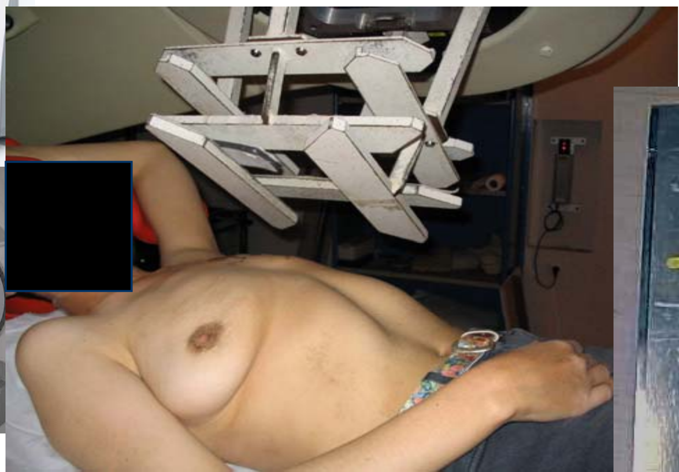

Anti collision systems

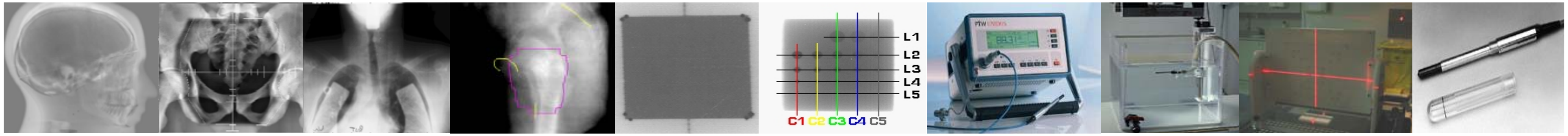


إعداد
م. أنور صلاح عطاا

Monthly Mechanical CQ

- Checking accessories (filters, door accessories, extension, ...)

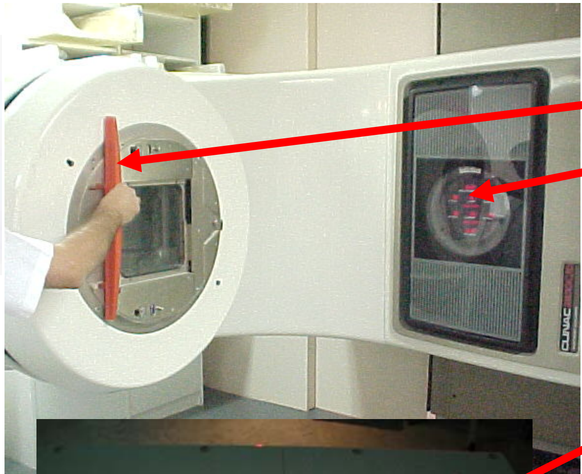


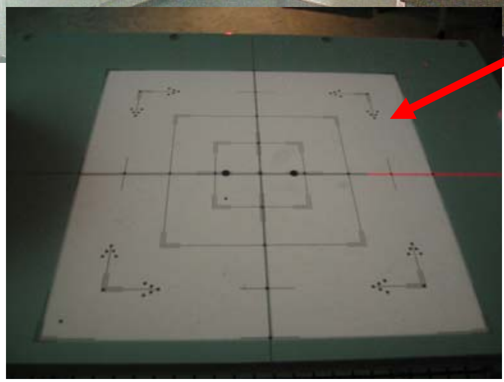


إعداد
م. أنور صلاح عطا

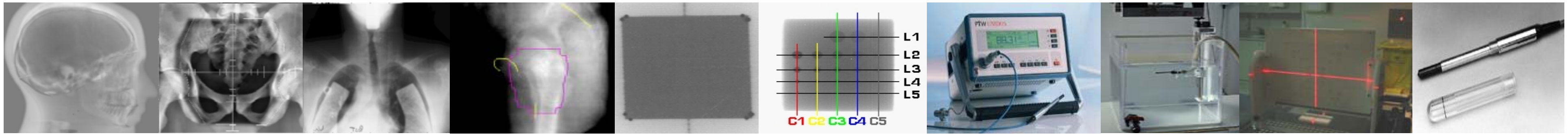
Monthly Mechanical CQ

- Checking angular scales of the collimator and Gantry





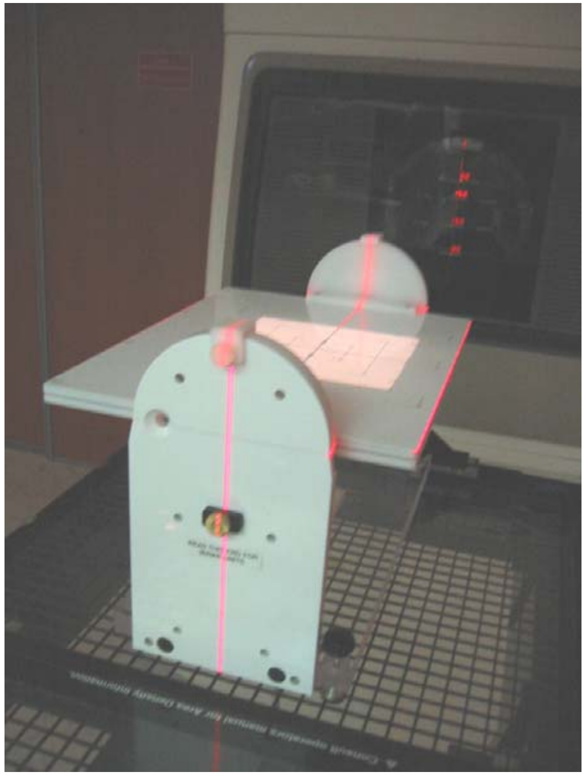
± 1° de tolerance

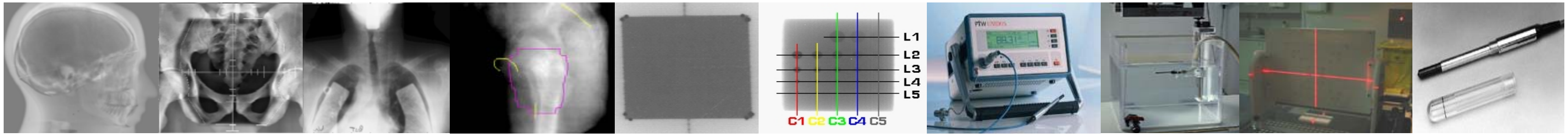


إعداد
م. أنور صلاح عطا

Monthly Mechanical CQ

- Correspondence of the mechanical axis of the collimator with the axis of the beam

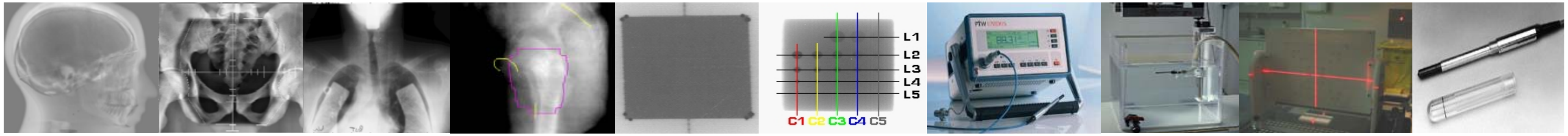




إعداد
م. أنور صلاح عطا

Monthly Mechanical CQ

- Determining the position of the isocenter



إعداد
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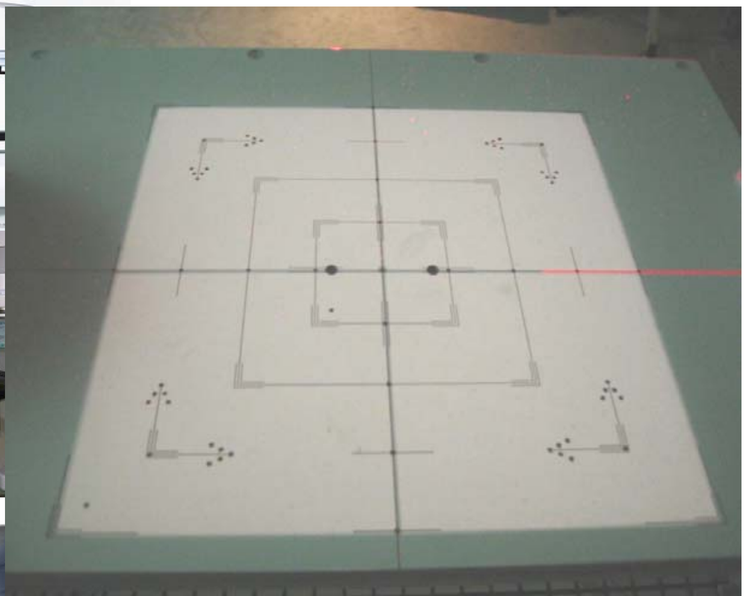
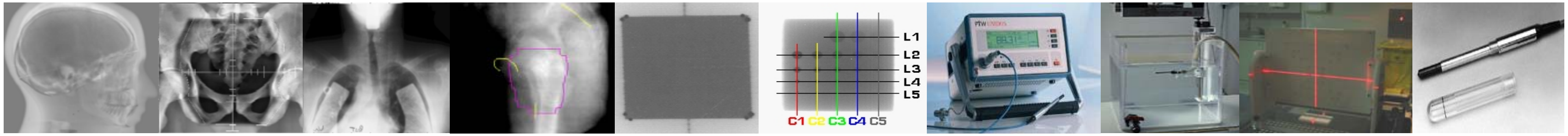
Monthly Mechanical CQ

- Check the dimensions of the radiation field



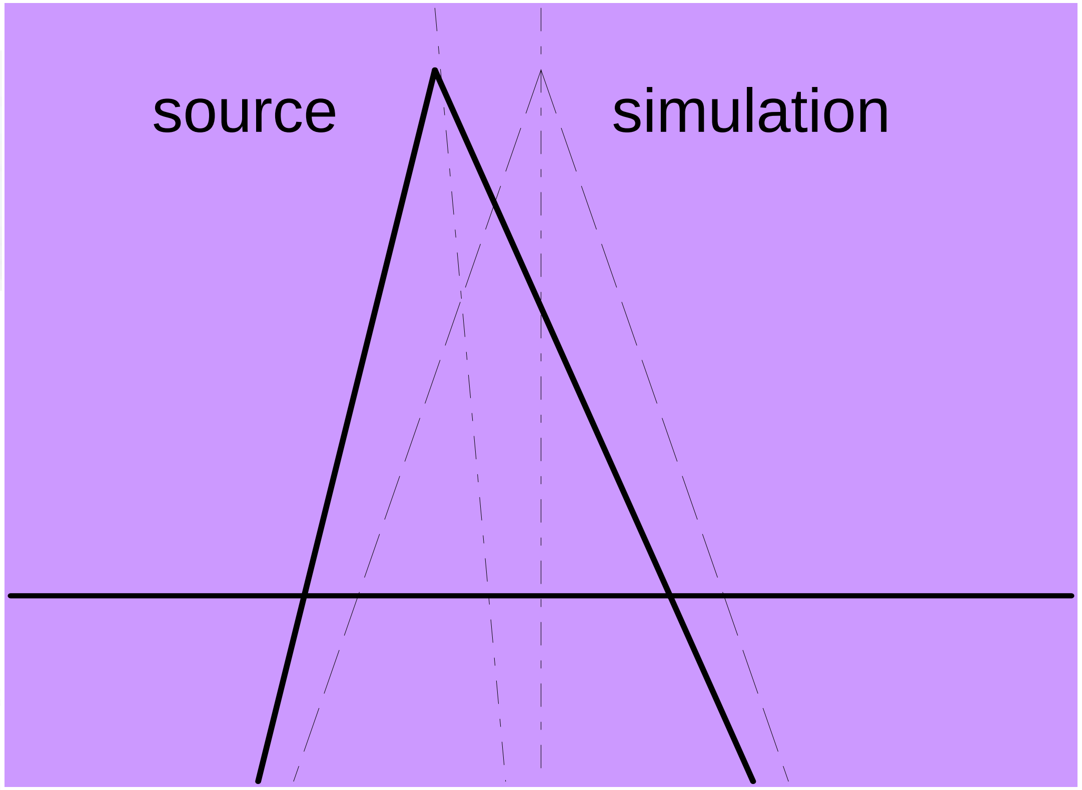
2 mm of tolerance



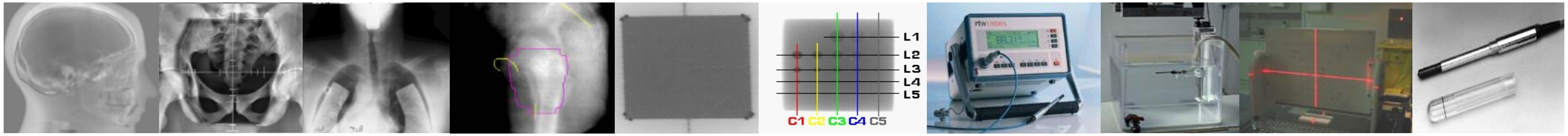
إعداد
م. أنور صلاح عطا

Monthly Mechanical CQ

- Correspondence between the irradiated field and light field

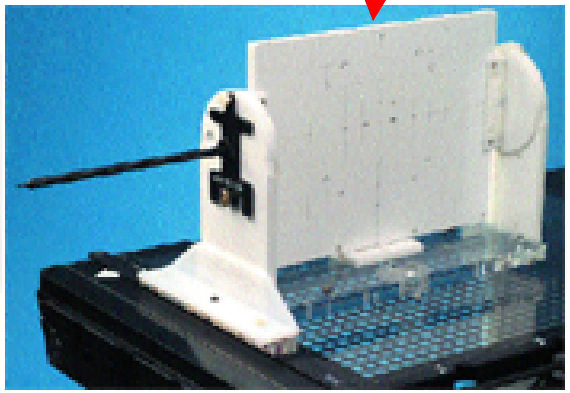


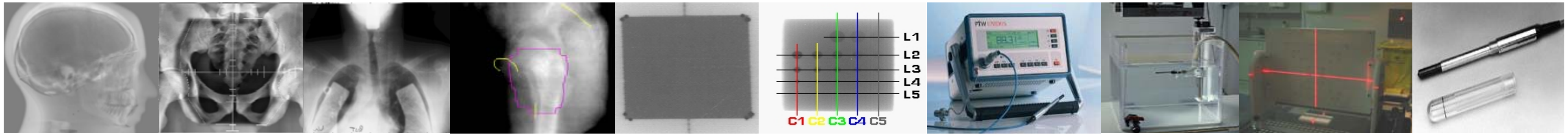
Correspondance ?



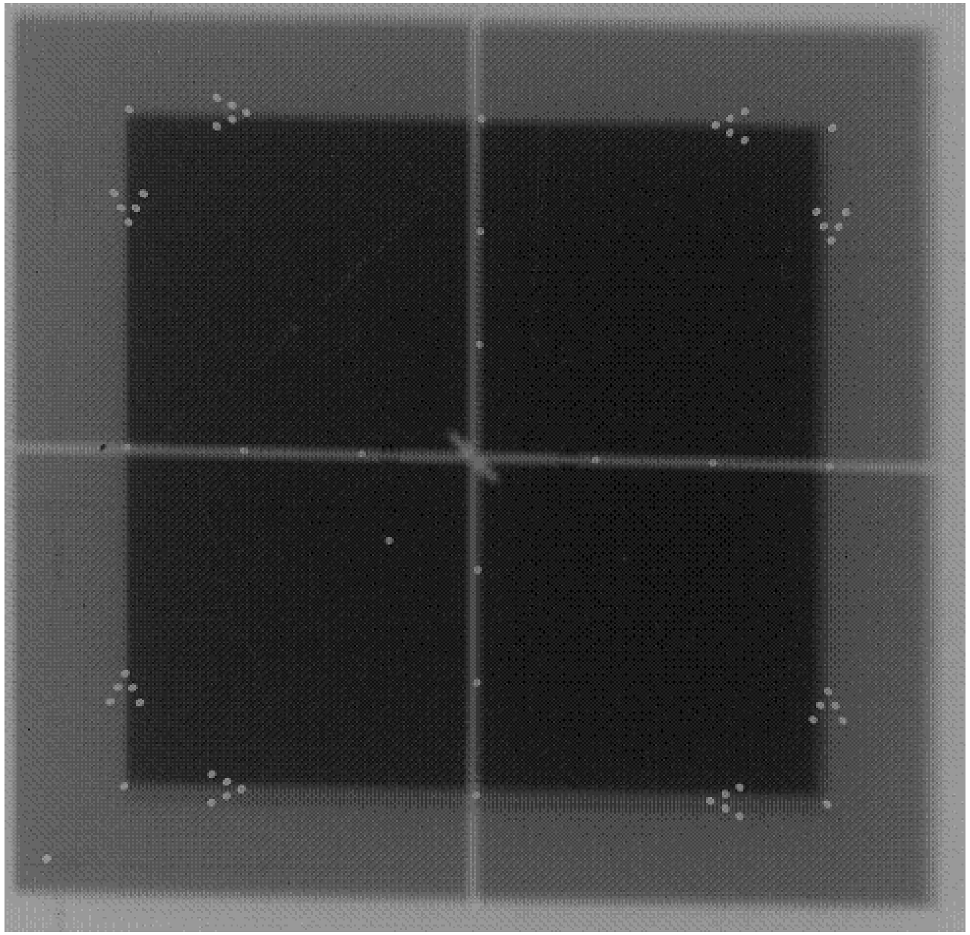
إعداد
م. أنور صلاح عطا

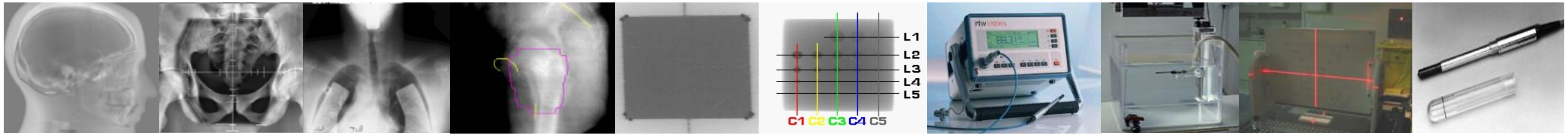
Monthly Mechanical CQ





إعداد
م. أنور صلاح عطاا

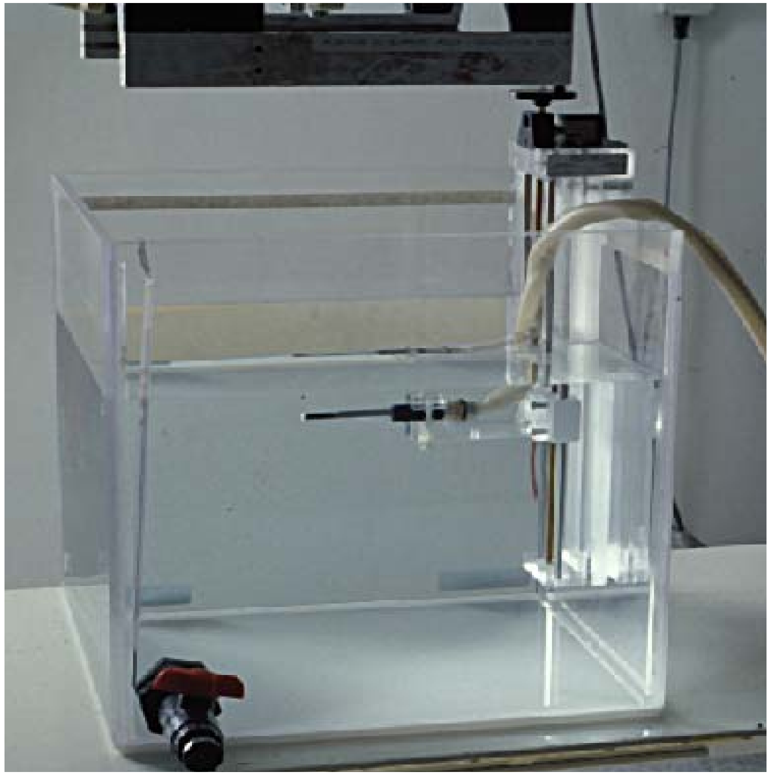


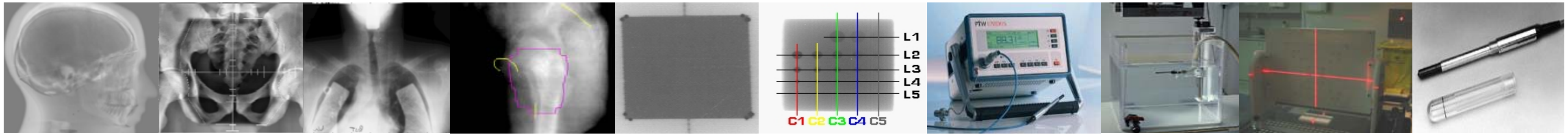


إعداد
م. أنور صلاح عطا

Monthly Dosimetric (Beam performance) CQ

- Using of the water phantom (with its software), ionization chambers, cable and electrometer:

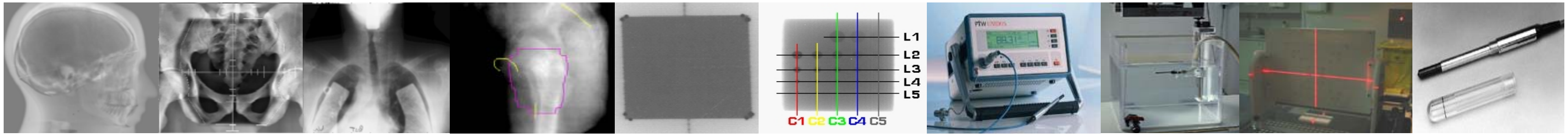




إعداد
م. أنور صلاح عطا الله

Monthly Dosimetric CQ

- Ionisation chambers:

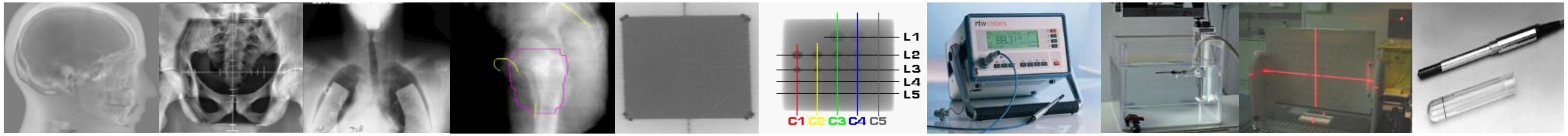


إعداد
م. أنور صلاح عطا

Monthly Dosimetric CQ

- PDD Acquisitions of photons :
  - Measuring conditions:

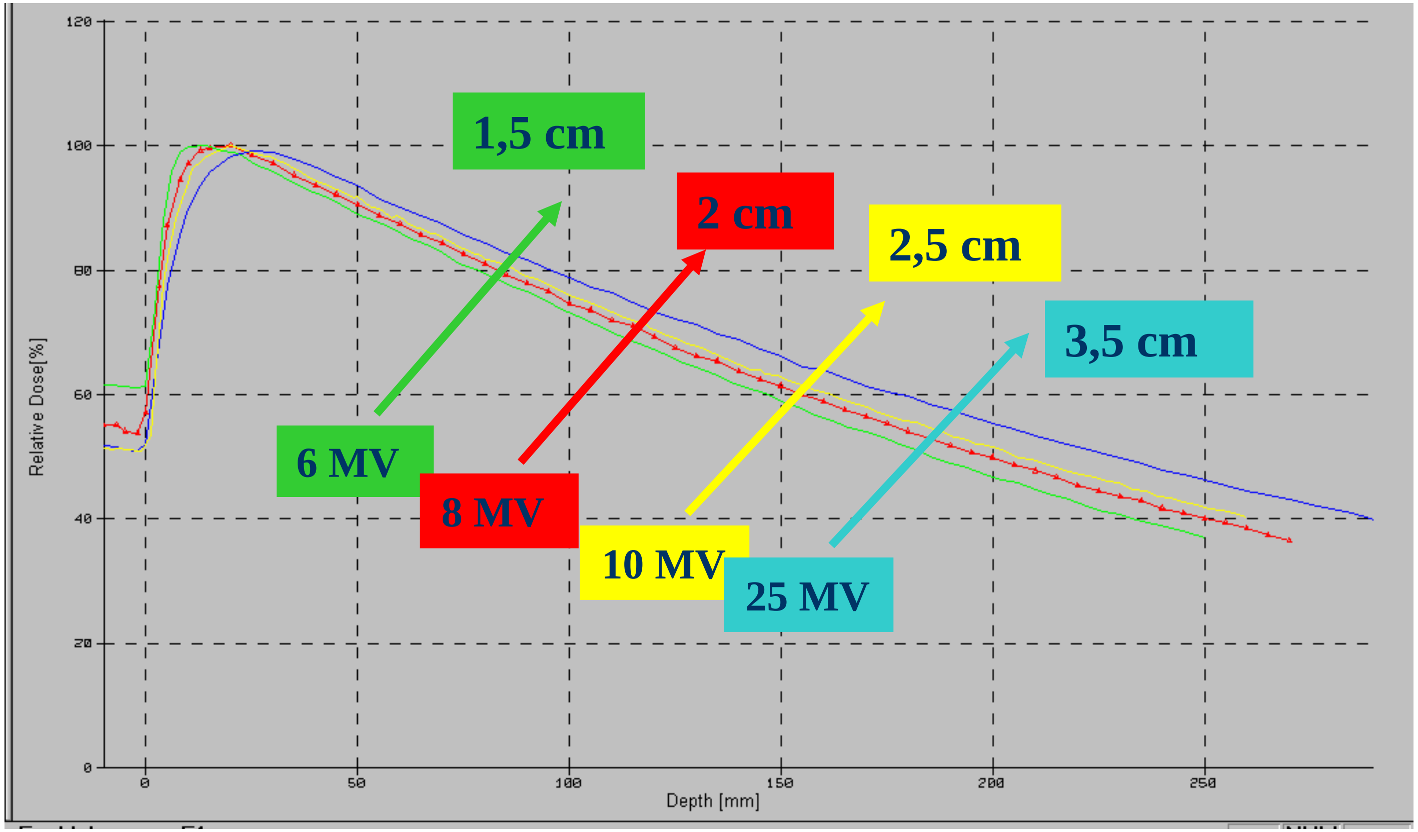
    - SSD = 100 cm, normalization to the depth of maximum dose
    - Field Size 10 x 10 cm
    - All energy photons
    - 0 to 25 cm depth

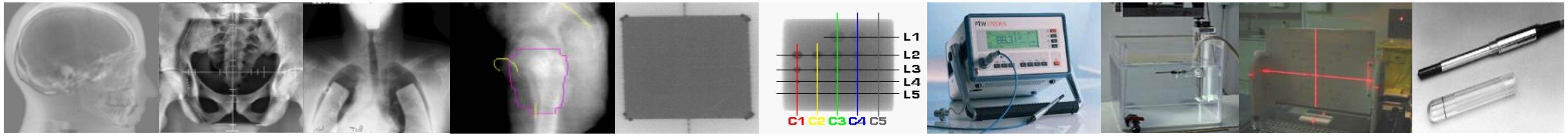


إعداد
م. أنور صلاح عطا

Monthly Dosimetric CQ

- PDD Acquisitions of photons :

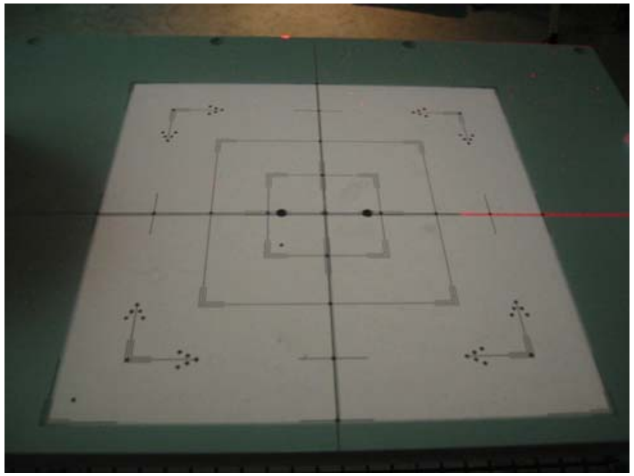


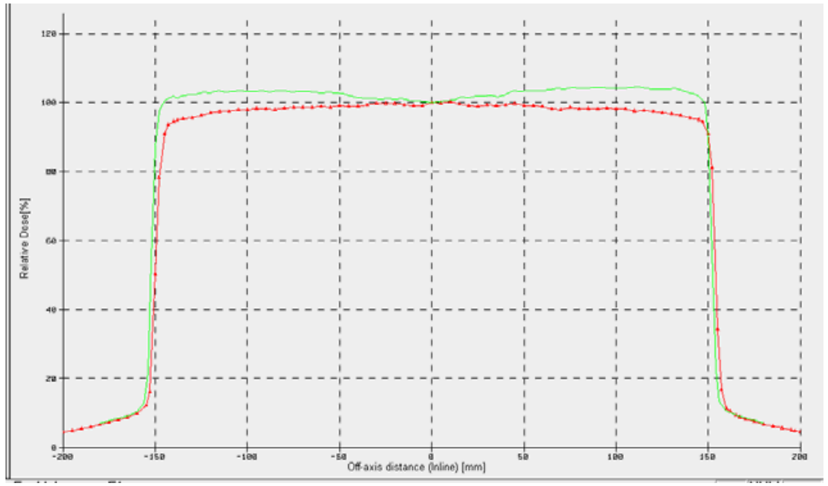


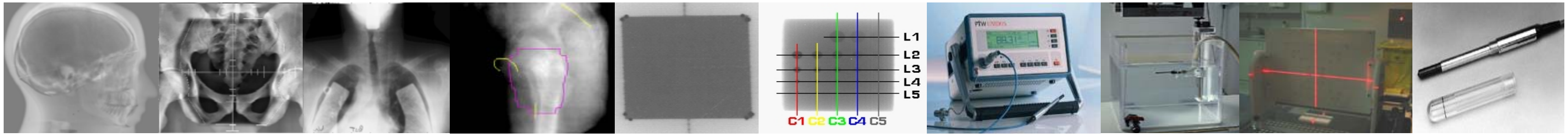
إعداد
م. أنور صلاح عطا

Monthly Dosimetric CQ

- Acquisitions profiles for uniformity and symmetry of photon fields:



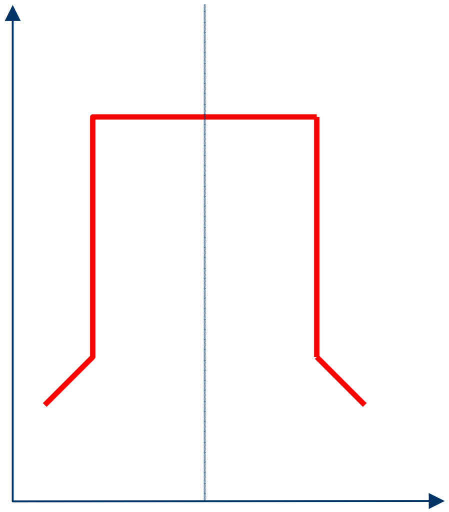


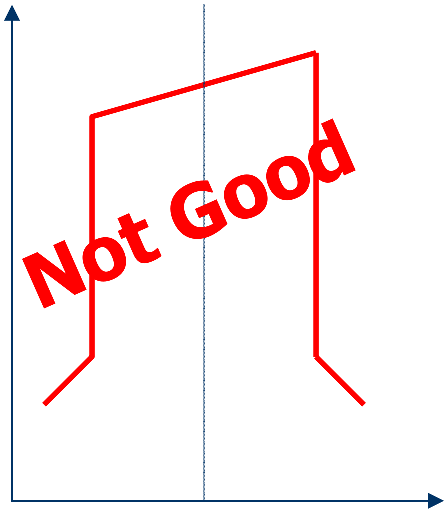


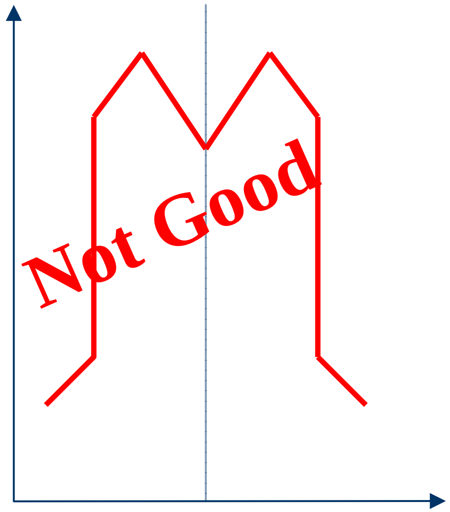
إعداد
م. أنور صلاح عطا

Monthly Dosimetric CQ

- Homogeneity and symmetry

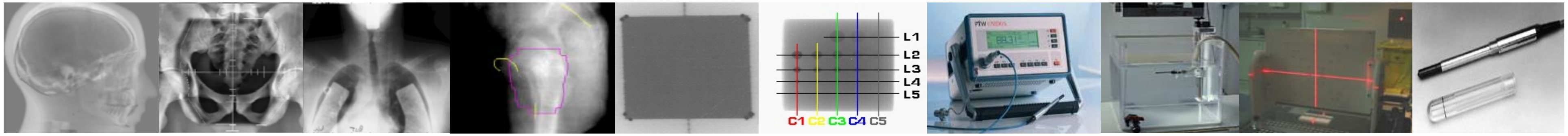






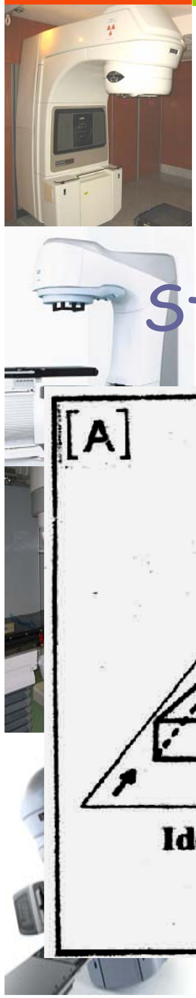
Symetric | Non sym | Non homogene

Homogene



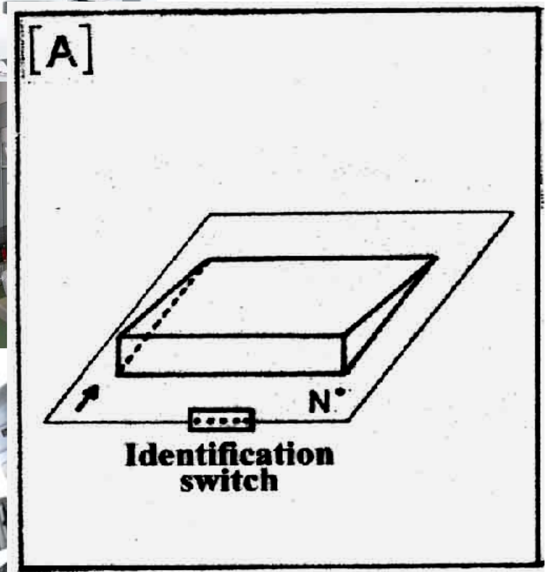
إعداد
م. أنور صلاح عطا

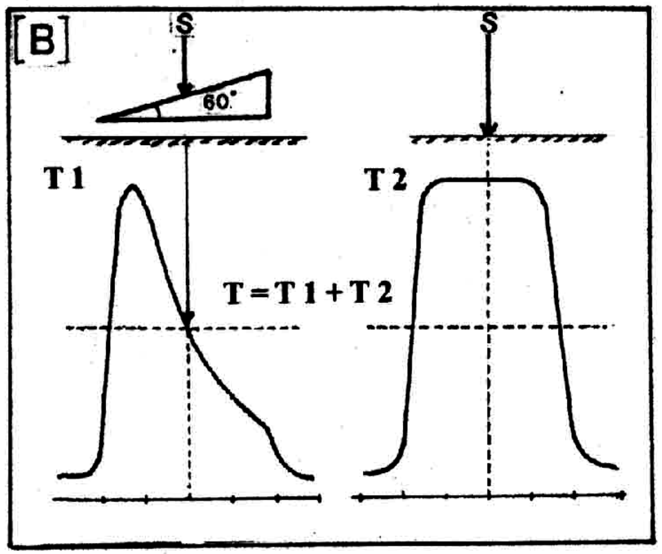
Monthly Dosimetric CQ

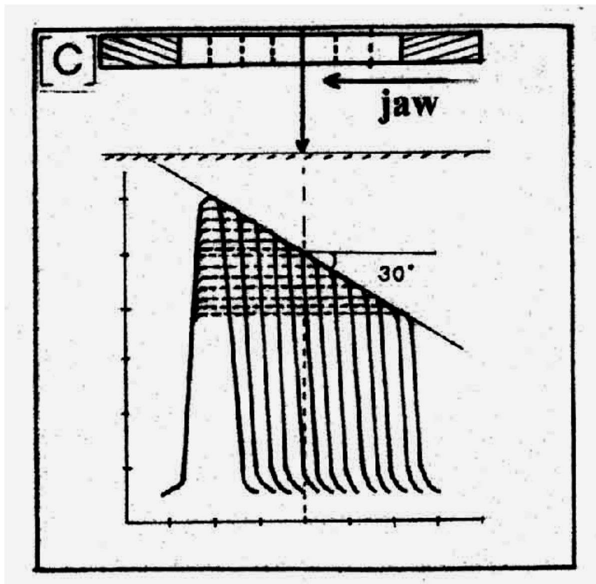


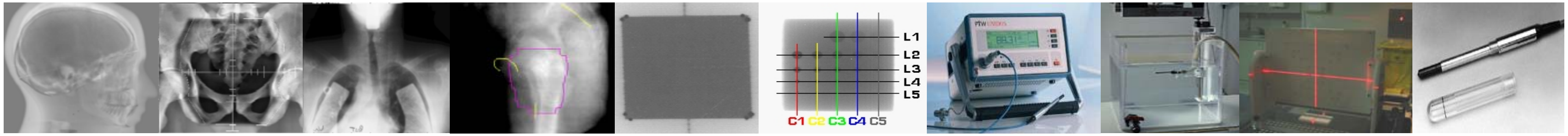
- Transmission of filter :
  - Measure in the presence and absence of filter
    - tolerance <2% compared to the reference

Standard | Motorise | Dynamique





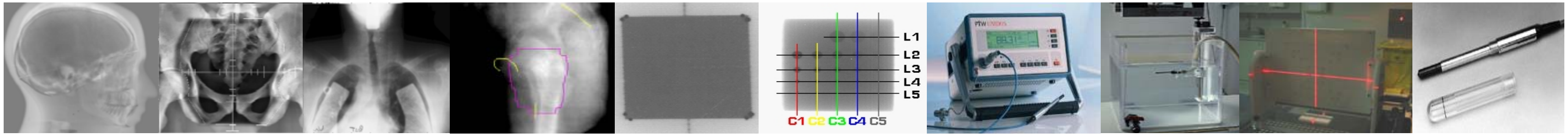




إعداد
م. أنور صلاح عطا

Monthly Dosimetric CQ

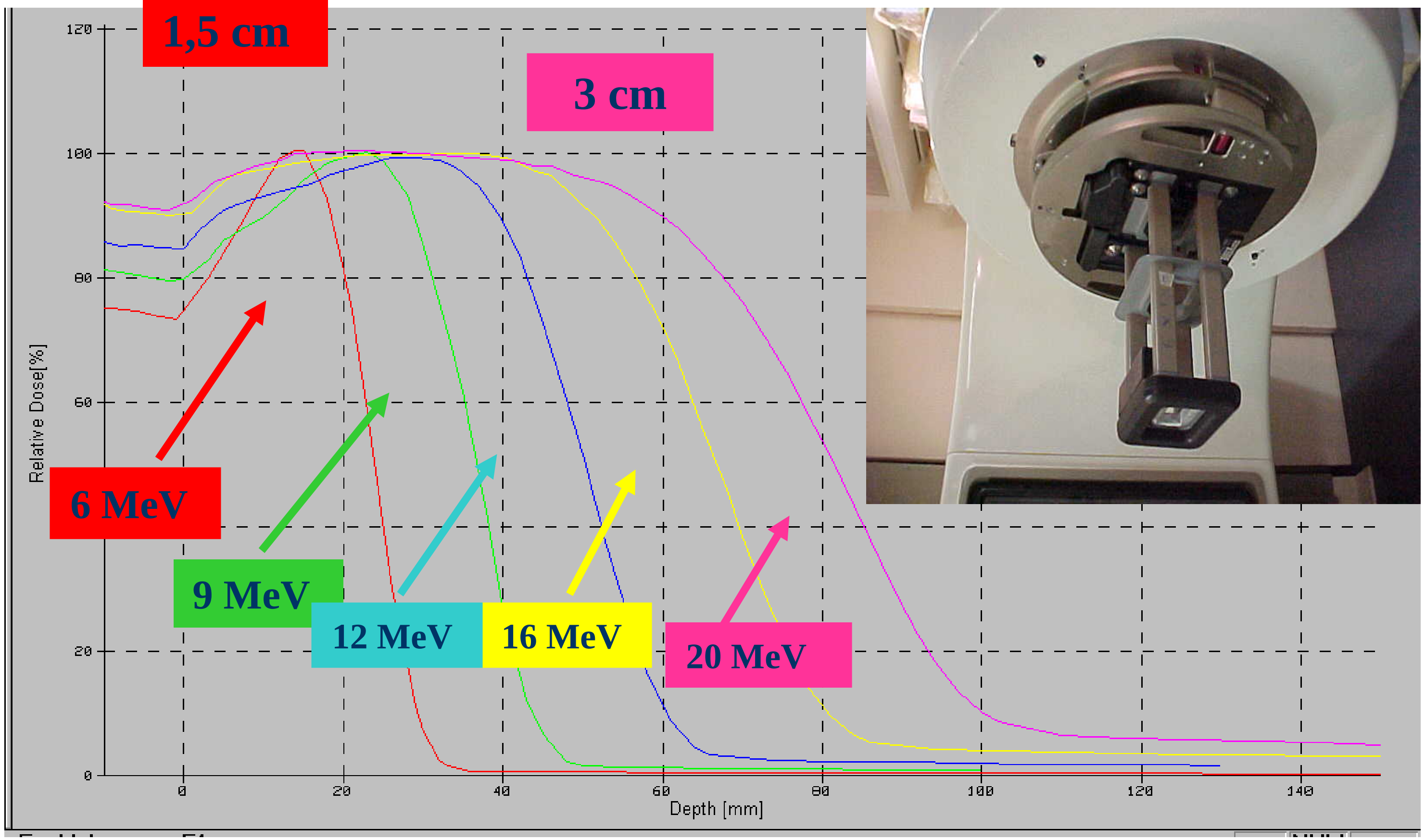
- PDD Acquisitions of electron:
  - Conditions of Measurement:
    - SSD = 100 cm, normalisation à la profondeur du maximum de dose
    - SSD = 100 cm, normalization to the depth of maximum dose
    - Field Size 10 x 10 cm
    - Applicator 10 x 10 cm
    - All energy electrons
    - 0 to 25 cm depth

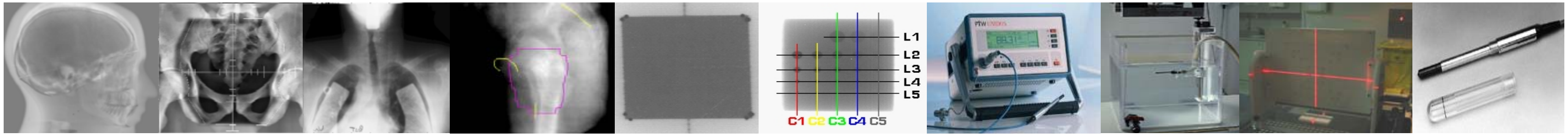


إعداد
م. أنور صلاح عطا

Monthly Dosimetric CQ

- PDD Acquisitions of electron:

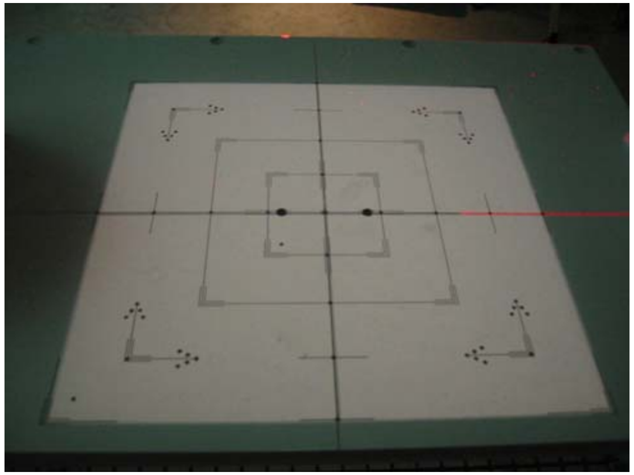


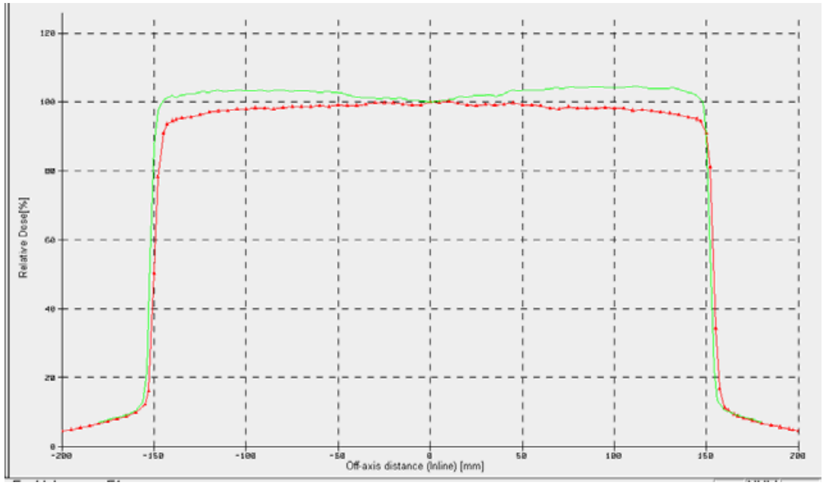


إعداد
م. أنور صلاح عطا

Monthly Dosimetric CQ

- Acquisitions profiles for uniformity and symmetry of photon fields:





CRITERIA FOR ACCEPTABILITY OF RADIOTHERAPY INSTALLATIONS

These criteria are valid for the normal clinical use of radiation therapy equipment and not (necessarily) for brachytherapy, intraoperative, dynamic, palliative and whole body radiation therapy equipment. In addition, radiation therapy treatment simulators are excluded from consideration. As indicated in the Introduction, the criteria presented may be used as remedial levels at which corrective action needs to be initiated. In a very few occasions, it might be justified to use the equipment clinically, even if the remedial level has been exceeded. Such a decision can only be taken after careful consideration of the responsible clinical physicist, with the knowledge of the clinicians and radiographers. For example, curative treatments demand a high stability of the treatment table height, especially during lateral irradiation. If due to mechanical tolerances the table height cannot be adjusted within the tolerance level, it still may be justified to perform palliative posterior anterior

or anterior-posterior treatments if no alternatives are present at all.

The values given in Table 1 are based on recommendations in WHO (1988) and NCS (1995), with some modifications.

Test	remedial action level
❖**Gantry rotation:**	± 1°
❖**Yoke rotation:**	± 0,2°
❖**Isocentre:**	± 2 mm
❖**Source distance indicators:**	± 2 mm
❖**Beam axis indicators:**	± 2 mm
❖**Numerical field indicators:**	± 2 mm
❖**Light field indication:**	± 2 mm
❖**Collimation system rotation:**	± 1°
❖**Treatment couches:** - lateral and longitudinal scales - vertical scales - vertical deflection (with patient load)	 2 mm 2 mm 5 mm
Treatment verification systems: (gantry angle, field size, collimator rotation, treatment time or monitor units, beam energy, etc.)	manufacturer's specification
❖**Immobilization devices**	± 2 mm
moulds, casts, breast bridges, head supports, arm or leg supports, bite-blocks, etc.)	
Patient alignment devices	± 2 mm
Beam Performance and light- field accuracy	
❖**Light field indication (density measurements):**	± 1 mm per edge
❖**Central axis dose calibration at reference position in phantom:**	± 3% (photons) ± 4% (electrons)
❖**Constancy checks**	

Test	remedial action level
❖**X-ray beam** - beam flatness - beam symmetry	± 3% ± 3%
❖**Cobalt-60 and cesium-137 units** - beam symmetry	± 3%
❖**Orthovoltage X-ray units** - beam symmetry	± 6%
❖**Electron beams** - flatness and symmetry	± 3%
❖**Transmission factor of wedges and compensators**	± 2%
❖**Dose monitoring system** - Precision - Linearity - dose rate effect - Stability - gantry angle	± 0.5% ± 1% ± 2% ± 2% ± 3%
❖**Treatment Planning System**	
A computerized dose distribution can be considered as sufficiently accurate if calculated and measured doses differ by less than 2% at points of relevance for the treatment.	
– In regions involving very steep dose gradients, the observed position of a given isodose curve should differ from its calculated position by less than 0.3 cm.	