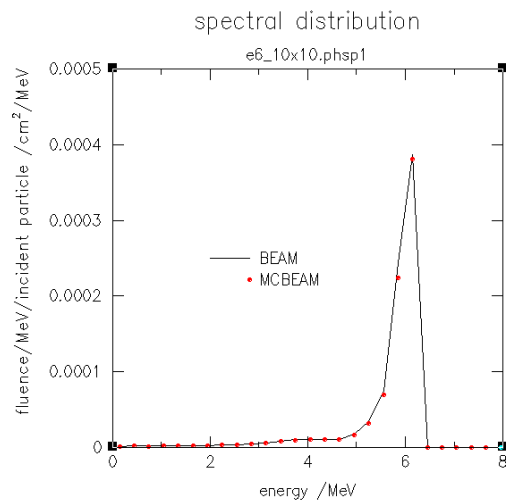
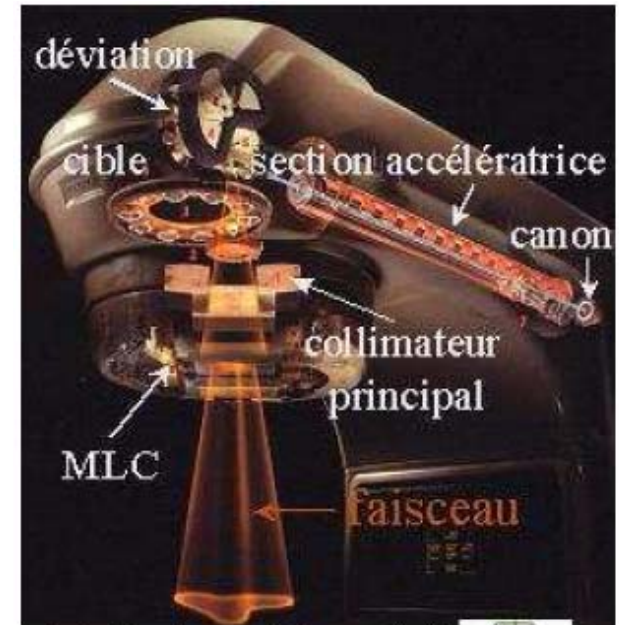


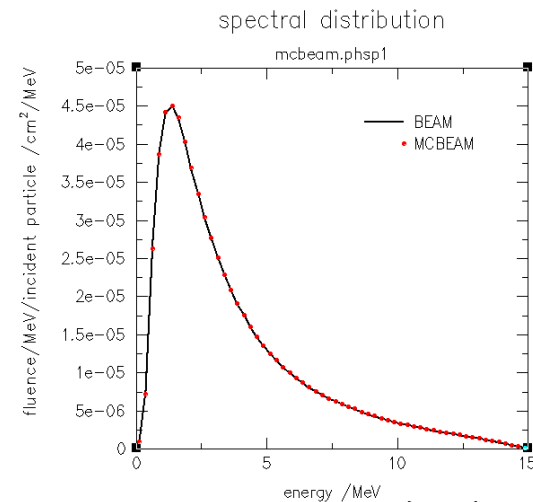
S. Derreumaux (IRSN)

Accidents in radiation therapy in France: causes, consequences and lessons learned

MEDICAL LINEAR ACCELERATORS

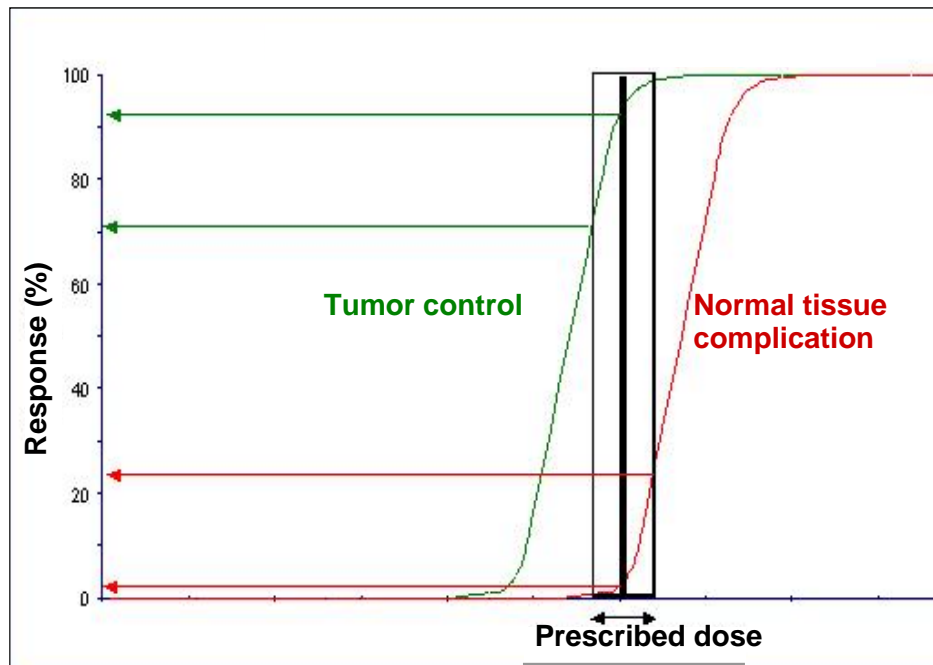


Electron beam (MeV)



Photon beam (MV)

PRECISION REQUIRED IN RADIOTHERAPY



Precision required by radiation therapists :

$$2\sigma = 5\% \text{ (ICRU 24, 1976)}$$

	Present technique $100 \times \Delta D(1\sigma)/D$	Future development $100 \times \Delta D(1\sigma)/D$
Absorbed dose determination at the calibration point	2.0	1.0
Additional uncertainty for other points	1.1	0.5
Monitor stability	1.0	0.5
Beam flatness	1.5	0.8
Patient data uncertainties	1.5	1.0
Beam and patient set-up	2.5	1.6
Overall excluding dose calculation	4.1	2.4
Dose calculation	1.0 2.0 3.0 4.0 5.0	0.5 1.0 2.0 3.0 4.0
Resulting overall uncertainty	4.2 4.6 5.1 5.7 6.5	2.4 2.6 3.1 3.8 4.7

Precision goal for
physicists (1σ)

(Ahnesjö and
Aspradakis, 1999)

WHAT IS AN ACCIDENT IN RADIOTHERAPY ?

- ICRP 86 (2000) :
 - Accidental exposure = any substantial discrepancy between prescription and delivery (identification of the patient, definition of target volume, fractionation, dose distribution...)
 - FDA class I risks (AAPM TG35, 1993) :
 - Type A : overdose $\geq 25\%$: can directly cause complications threatening the patient's life
 - Type B : overdose ≥ 5 and $< 25\%$ or under-dose : increases the probability of an unacceptable consequence of the treatment (higher risk of complications or reduced tumor control)

ACCIDENTS DECLARED IN FRANCE SINCE 2005

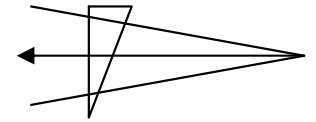
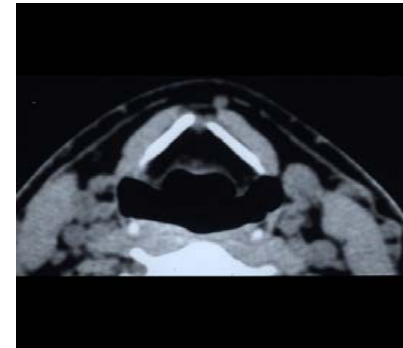
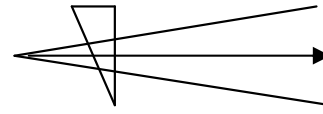
Where	When	Patients involved	ASN/SFRO score
Case 1	2003	1	4
Case 2	2004	1	5
Case 3	2004	1	4
Case 4.1	May 2004 - May 2005	24	6
Case 4.2	2001-2006	397	3
Case 4.3	1987-2000	312	n.d.*
Case 5	April 2006 - April 2007	145	n.d.*

* Not determined

Why ?

Because declaration to the national authorities is mandatory since 2001...

CASE 1



- Treatment of head and neck cancer :

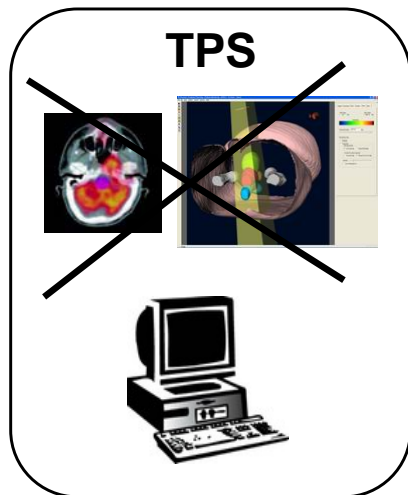
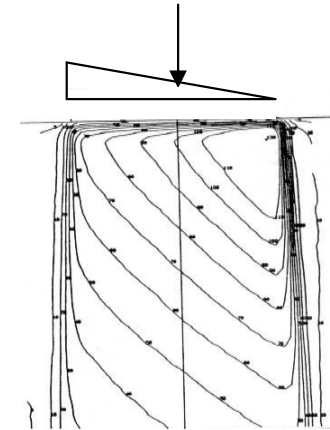
New linac with internal motorized wedge

RX 6 MV

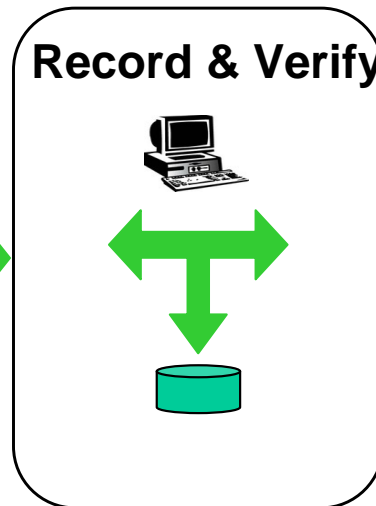
Fields : wedged

5 cm x 5 cm + 4 cm x 4 cm boost

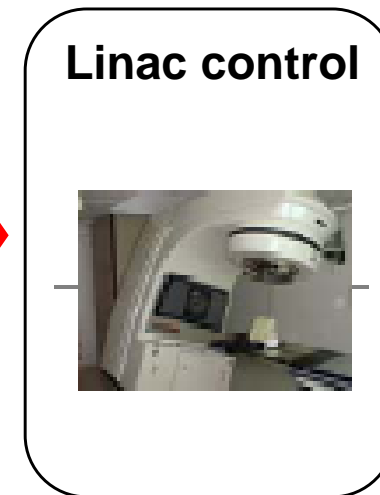
- 4 cm x 4 cm boost with wedge :



In-house MU calculation software
Never used for internal wedge



Nb of total MU : ok
Nb of filtered MU = 0



All MU without wedge

CASE 1

- Consequences :
 - Overdose at prescription point > 20%
 - Complications : necrosis \Rightarrow total laryngectomy

- Lessons learned :
 - Potential errors :
 - In-house software : not tested, not qualified
 - Connection between softwares : not tested, not qualified
 - Prevention:
 - QA for softwares and connections (computer network)
 - *In vivo* dosimetry

CASE 2

- Treatment of intracranial AVM

Linac + additionnal cylindrical collimator

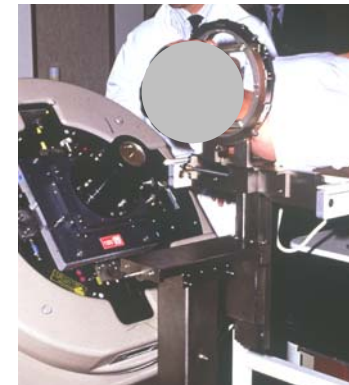
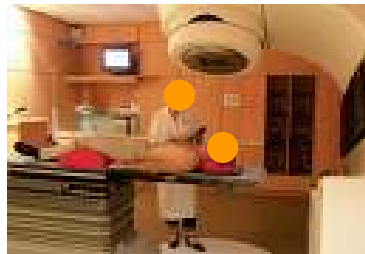
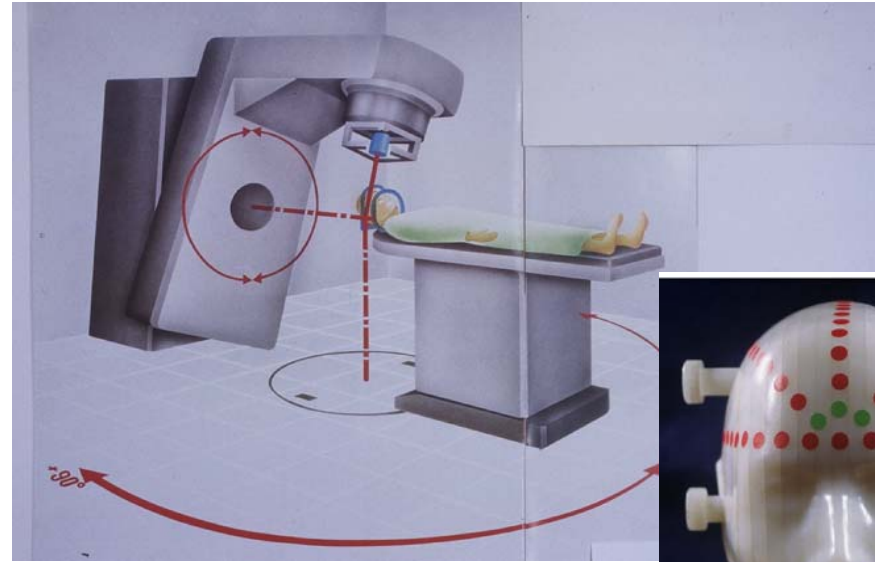
RX 6 MV

Fields :

linac collimator : 40 mm x 40 mm

additionnal collimator : $\varnothing = 10 \rightarrow 30$ mm

- First part of the treatment :



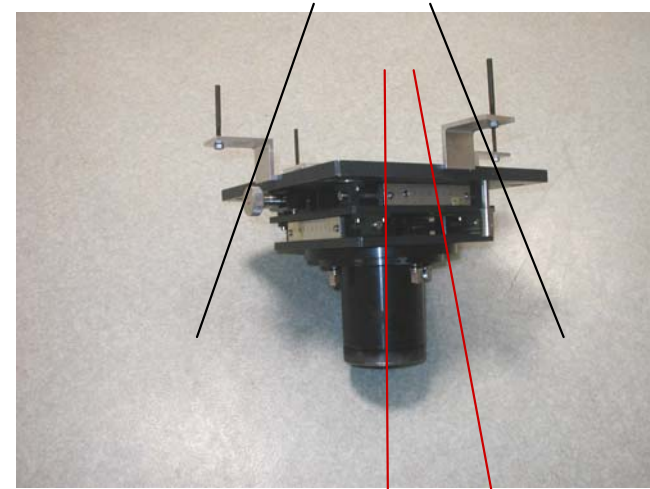
« Collimator aperture = 40 x 40 »

linac collimator : 40 cm x 40 cm

CASE 2

- Consequences :

- High dose outside target volume
- Overdose undervalued by local team
- Complications : fibrosis + oeso-tracheal fistula ⇒ surgical operation ⇒ death from brutal haemorrhage

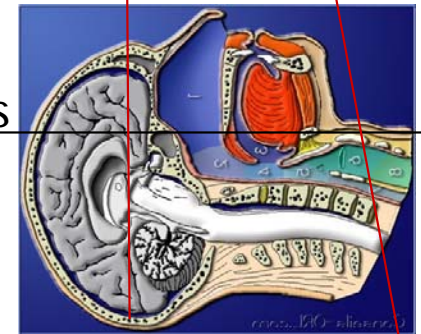


- Lessons learned :

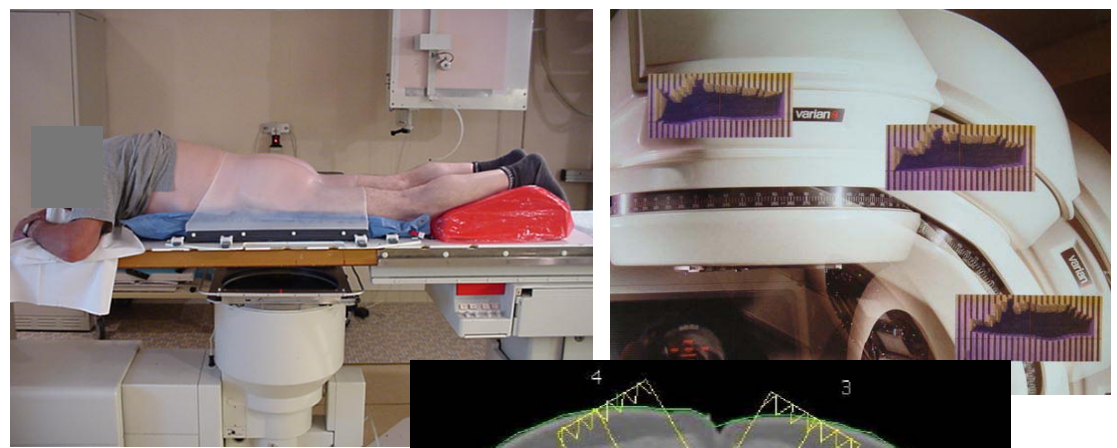
- Potential errors :
 - Additional accelerator accessory without safety device
 - Overdose evaluation by local team
- Prevention:
 - Safety of treatment machine (entire system)

X-rays leakage

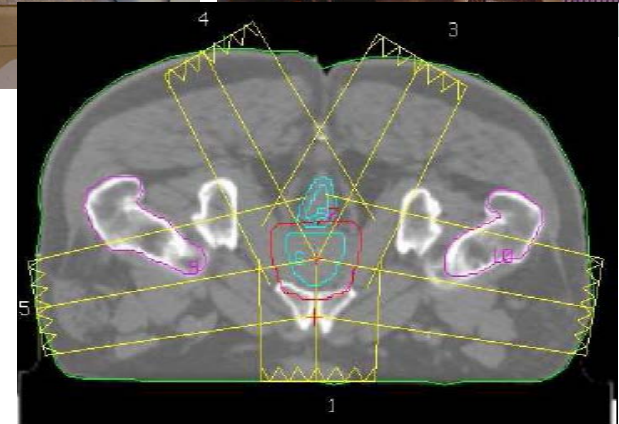
Linac's rotational axis



CASE 4.1

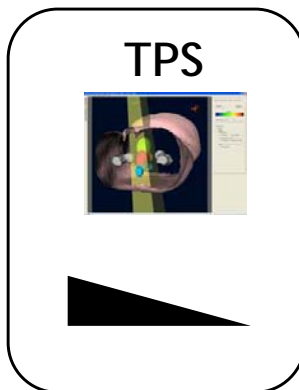


- Treatment of prostate cancer :
 - RX 25 MV
 - Fields : 5 MLC fields (4 wedged)
 - Implementation of « dynamic wedge »



Wedge factor (WF) = $\frac{\text{dose with wedge}}{\text{dose without wedge}}$

- MU calculation with physical wedge but treatment with dynamic wedge :

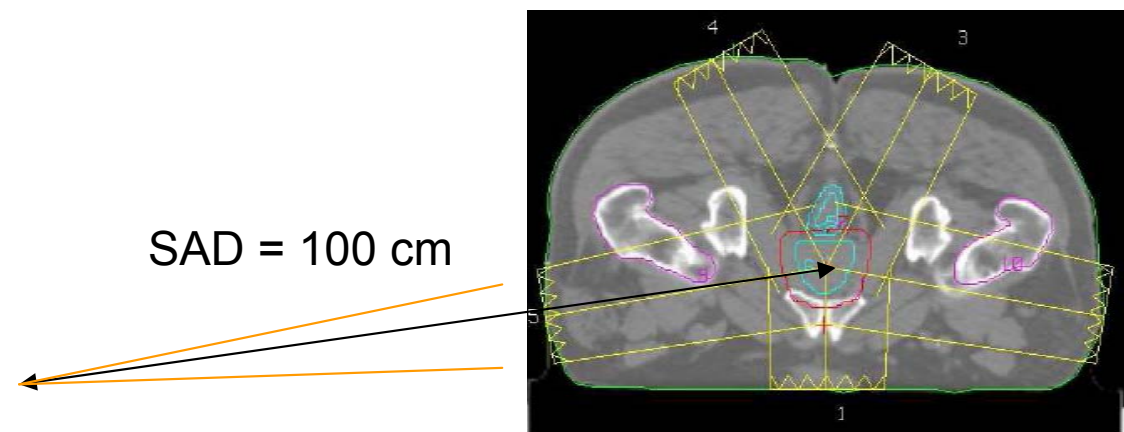


$WF_{\text{dynamic}} / WF_{\text{physical}} =$
 $1.3 (30^\circ) \rightarrow 1.5 (45^\circ)$
 $\Rightarrow \text{overdose} = 20\% \rightarrow 35\%$



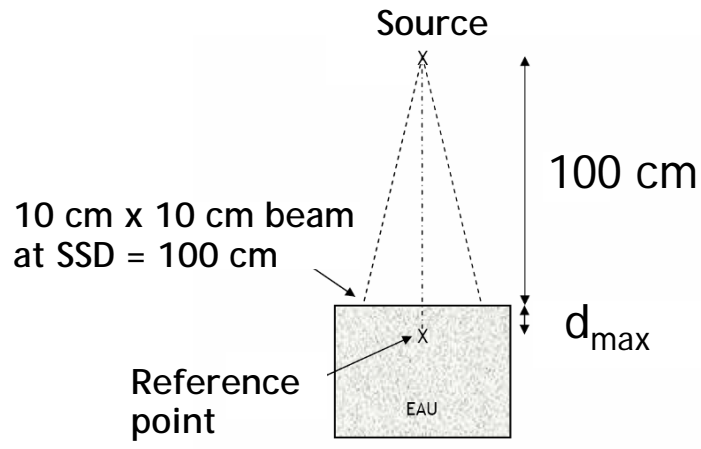
CASE 4.3

- All isocentric treatments



SAD = 100 cm

- Reference conditions for measurement of dose rate (cGy/MU) :



- $d_{max} = 1.5 \text{ cm for } 6 \text{ MV}$
- $2.7 \text{ cm for } 12 \text{ MV}$
- $3.5 \text{ cm for } 25 \text{ MV}$

- MU calculation using reference dose rate, without correction for distance :

$$\text{Nb of MU (isocentric)} = \frac{D}{\dot{D}_r \times \left(\frac{100 + d_{max}}{100} \right)^2 \times \text{OF} \times \text{TMR} \times F_w \times F_{trans}}$$



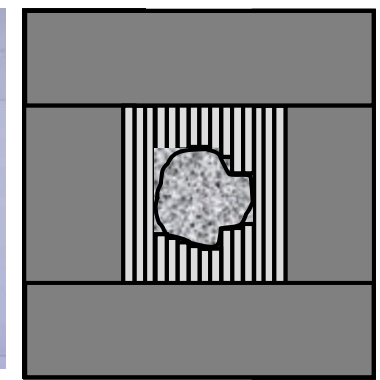
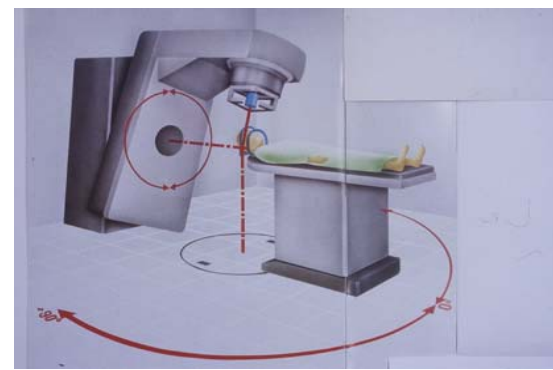
Overdose:

6 MV	: 3 %
12 MV	: 5.5 %
25 MV	: 7 %

CASES 4.1 and 4.3

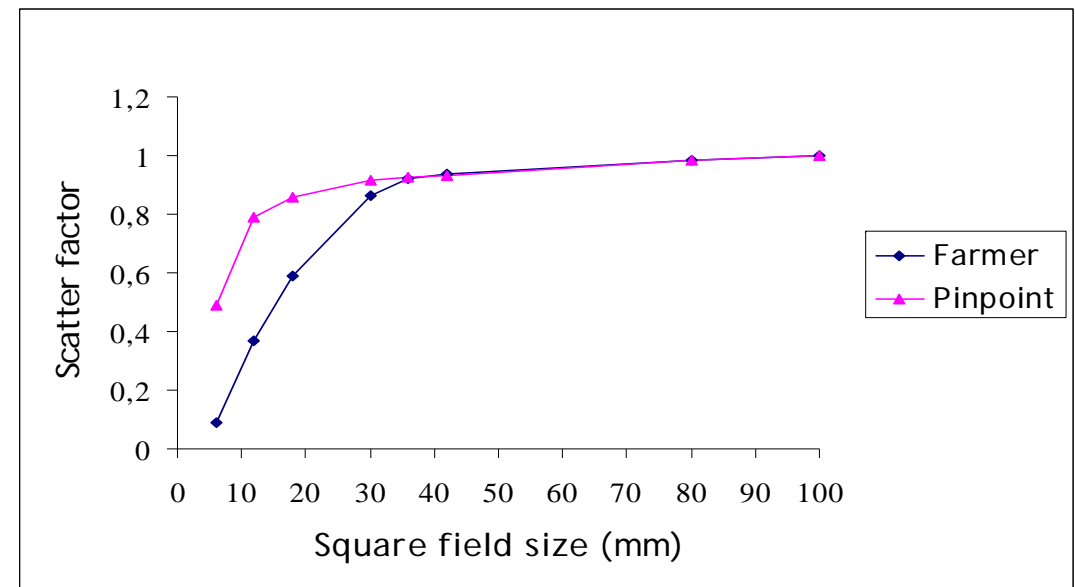
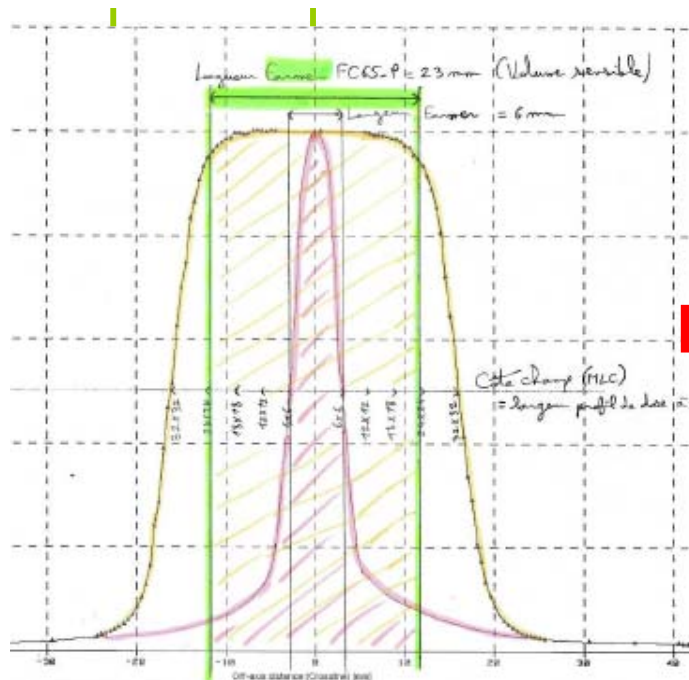
- Consequences:
 - Case 4.1: 1+4 deaths and 10 severe/disabling complications (rectitis, cystitis, fistula)
 - Case 4.3: Follow up of the « 25 MV cohort » at risk (n=120)
- Lessons learned:
 - Potential errors :
 - Wrong use of TPS due to lack of training + unsafe screen display
 - Calculation error due to in-house software, not tested, not qualified
 - Prevention :
 - Time and organisation for continuous training
 - Softwares with safe human-computer interaction
 - *In vivo* dosimetry and second independent calculation

CASE 5



- Stereotactic radiosurgery with micro MLC :
- Calibration measurements (scatter factors) made with wrong detector :

Sensitive volume of « Farmer » ionisation chamber



« Farmer » chamber : 0,65 cm³

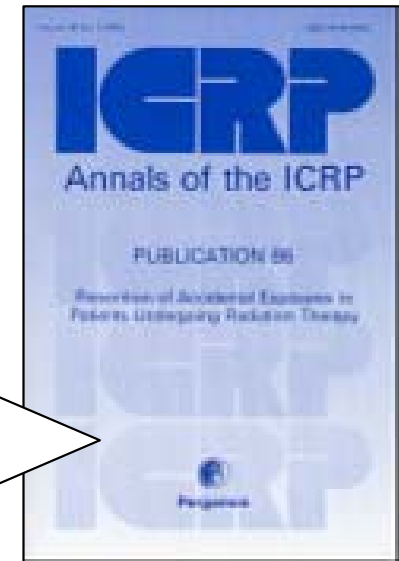
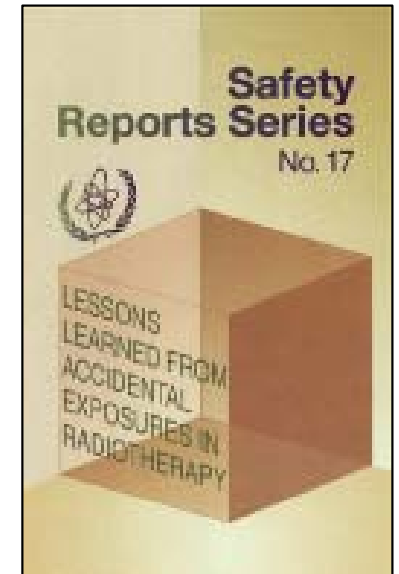
« Pinpoint » chamber : ≤ 0,03 cm³

CASE 5

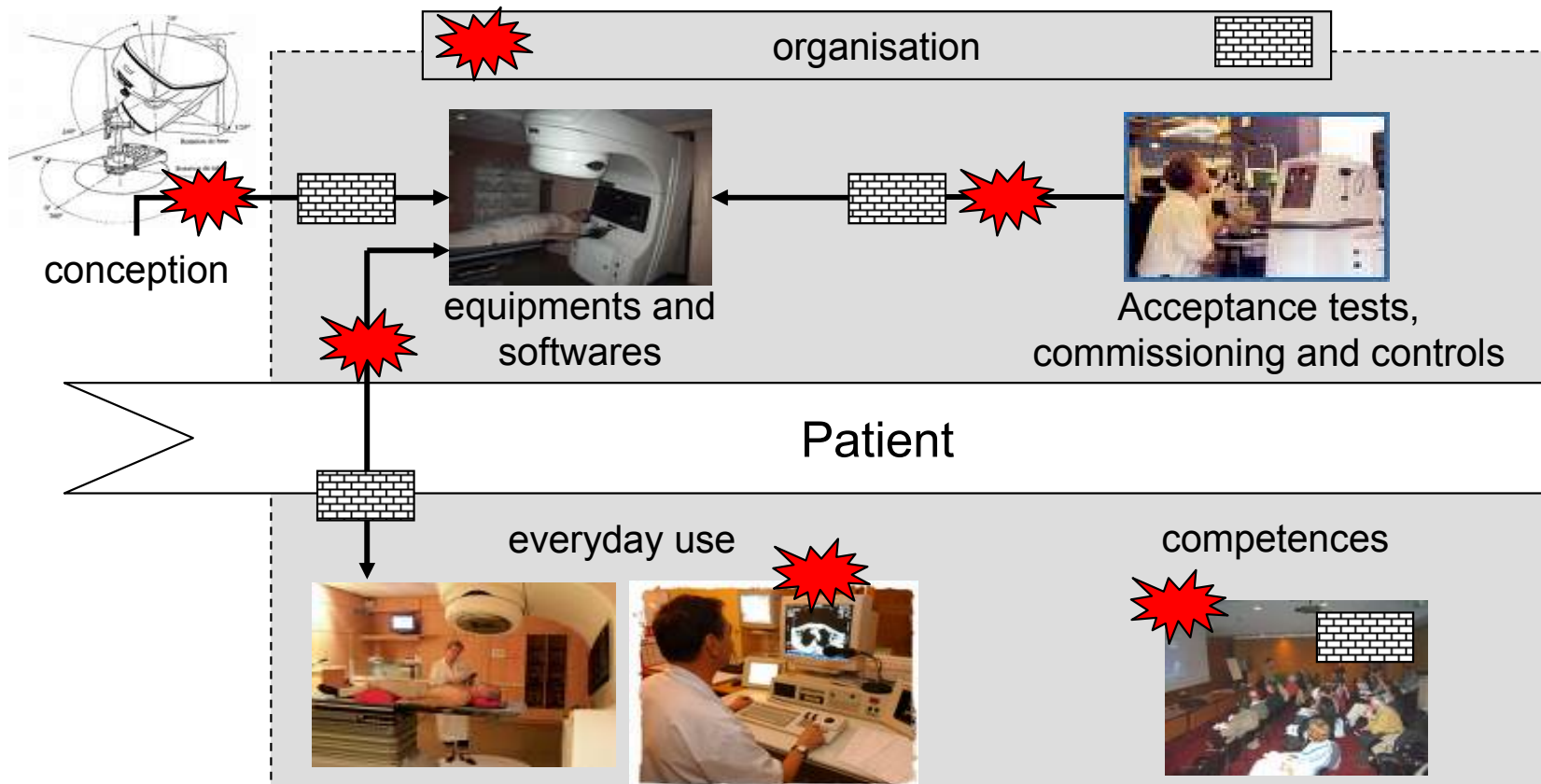
- Consequences:
 - Overdose : up to ~200 %
- Lessons learned:
 - Potential errors:
 - Usual dosimetric material not adapted to special techniques
 - Errors due to lack of expertise (special techniques)
 - Prevention:
 - Special techniques only accessible to expert teams
 - Verification of the dose delivered in treatment conditions
 - External audit also for special techniques

LESSONS LEARNED FROM ACCIDENTS

- Knowledge of potential errors on dose determination or delivery
- Prevention: QA and safety culture



(2000)



FRANCE: LESSONS LEARNED

- Publications on lessons learned from accidents in RT need to be updated:
 - Risks of new technologies and special techniques
 - Criteria to define and classify accidental exposures
- ASN/SFRO gravity scale (2007) :
 - After Common Terminology Criteria for Adverse Events (CTCAE V3.0)
 - Incidents (scale 1 to 3) and accidents (4 to 5)
- *In vivo* dosimetry and MU calculation with independent software are now mandatory in France
- External audits need to be done for all clinically relevant irradiating conditions
- Need to develop research on overdose complications

FRANCE: NATIONAL REFORM OF RADIOTHERAPY

- Quality assurance (ISO 9000; agreement criteria; protocols)
- National reporting system (guide; scale; feed-back)
- Human resources (increase; continuous training)
- Safety of installations and softwares (quality and safety standards, internal and external quality controls, human-machine interaction)
- Information of the patients, the doctors and the public
- Inspections
- National overview and follow-up

IRSN

- Research and expertise for the management of accidents: retrospective dosimetry, radiopathology (diagnosis, prognosis, treatment)
- Study on the improvement of the security of RT treatments thanks to the development of a safety culture (IRSN Report n°2008-2):
 - Immersion of IRSN experts in nuclear safety (human and organizational factors, software safety) in radiotherapy departments
 - How to apply and adapt concepts and methods of nuclear safety culture in the field of radiation therapy
- Set up of a continuous training program on risk management for RT professionals (radiotherapists, medical physicists, radiologists...):
 - Theoretical approach (defense in depth, risk management)
 - Application in the radiotherapy department

INTERNATIONAL

- ICRP: a WG is updating the report on accidents in radiation therapy
- European project ROSIS (ESTRO): international web system for anonymous and voluntary reporting of incidents in radiotherapy
- International conference “Modern radiotherapy: challenges and advances in radiation protection of patients” (Paris, 2-4 December 2009)