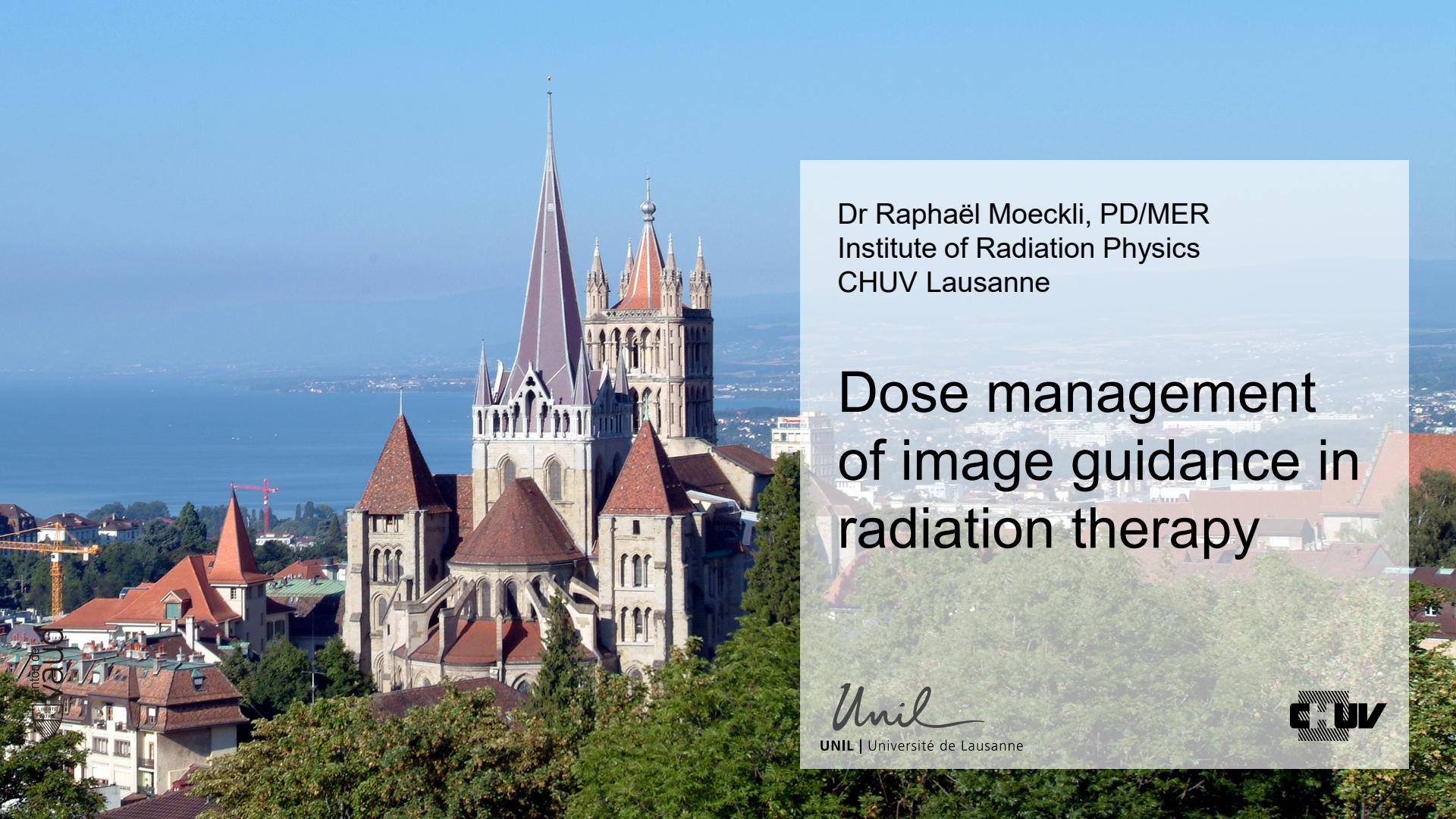

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Dose management of image guidance in radiation therapy

UNIL | Université de Lausanne

Conflict of interest

I am holding a grant from Accuray for a research project in Tomotherapy

Some of the results presented were obtained partly thank grants from FOPH

Justification

- IGRT is used in RT to visualize the position of the target to be irradiated
  - Might be static or dynamic (tracking)
- Improvement of irradiation techniques
  - IMRT, VMAT, tomotherapy, etc…
- Need of a more performant and more frequent imaging
  - Increased dose to the tissues
  - Increased risk of secondary cancer

Justification

With a good visualization

- Hit the target
- Reduction of margins
  - i.e. reduction of high dose to tissues

Without a good visualisation

- « We are at increased risk of missing very precisely »

Somehow, IGRT is more important than IMRT

(if we had to choose!)

- Better deliver the wrong dose to the right place than the opposite

Justification

814.501.513

Ordonnance du DFI sur la radioprotection s'appliquant aux accélérateurs de particules utilisés à des fins médicales

(Ordonnance sur les accélérateurs, OrAc)

Annexe 5
(art. 15, al. 5)

Art. 15 Consignation des irradiations

[1] Le médecin traitant doit établir pour chaque patient, une prescription médicale de traitement avant le traitement par irradiation. Les modifications ultérieures sont consignées par écrit et justifiées.

[2] Pour chaque patient, une planification individuelle de l'irradiation doit être établie avant l'irradiation sous la responsabilité du physicien médical.

[3] Sur la base de la planification individuelle de l'irradiation, les personnes responsables aux termes des al. 1 et 2 établissent, dans une directive d'irradiation spécifique du patient, les indications nécessaires à l'exécution de l'irradiation; celles-ci comprennent en particulier les éléments concernant le réglage de l'accélérateur et le positionnement du patient. En cas de modification du plan de traitement, la directive d'irradiation est actualisée.

[4] Chaque séance d'irradiation effectuée sur le patient est enregistrée par le personnel d'exploitation dans une attestation d'irradiation. Celle-ci doit être disponible auprès de l'installation où l'irradiation du patient est effectuée.

[5] Les documents indiqués aux al. 1 à 4 comprennent au moins les indications prévues à l'annexe 5.

Indications minimales dans la documentation de l'irradiation

3 Attestation d'irradiation

L'attestation d'irradiation contient au moins les éléments suivants:

a. identification du patient;

b. date, heure et numéro de la séance;

c. installation d'irradiation, dans le cas où les irradiations sont effectuées sur plusieurs installations;

d. mode d'irradiation, type de rayonnement, énergie du rayonnement;

e. désignation des champs d'irradiation ou de la séquence d'irradiation;

f. dose appliquée par champ ou par séquence d'irradiation (en unités du moniteur);

g. dose au volume-cible (par fraction et accumulée par toutes les irradiations) et estimation des doses accumulées dans les organes à risque;

h. grandeurs de dose permettant d'estimer la dose au patient accumulée lors des processus d'imagerie;

i. paramètres géométriques et physiques d'irradiation s'écartant de la prescription de traitement spécifique du patient;

j. identification de la personne responsable de l'exécution de l'irradiation.

IGRT techniques

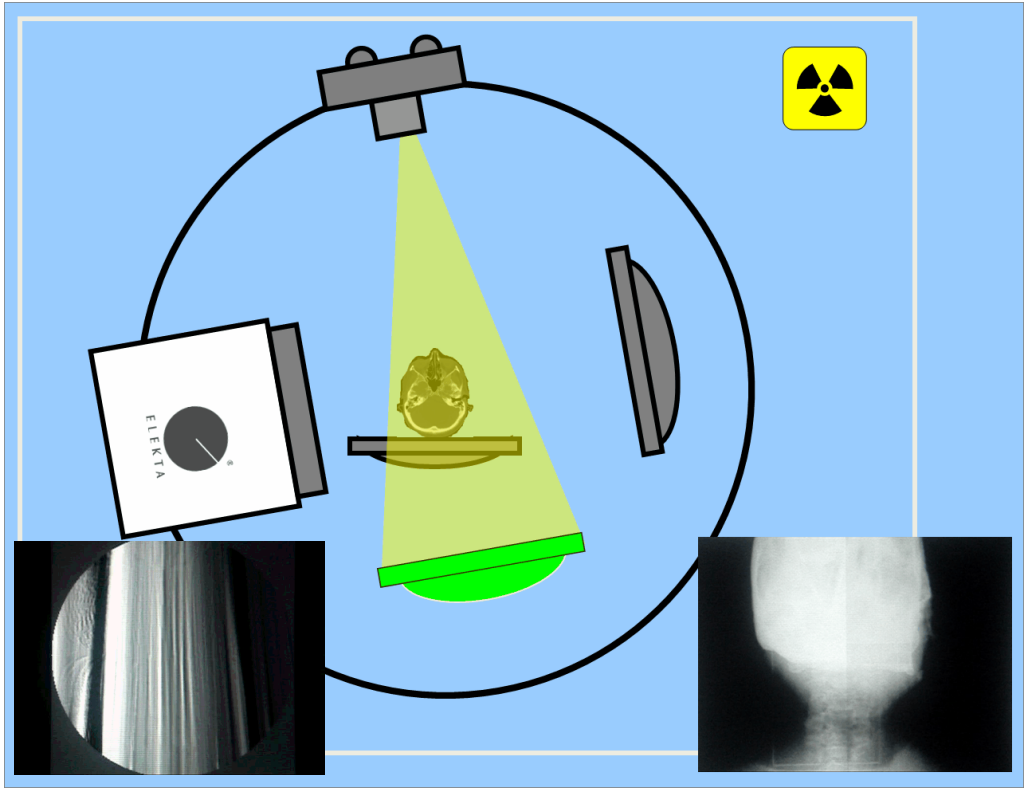
CBCT

4D CBCT

MVCT

Stereoscopic imaging

Cone beam CT



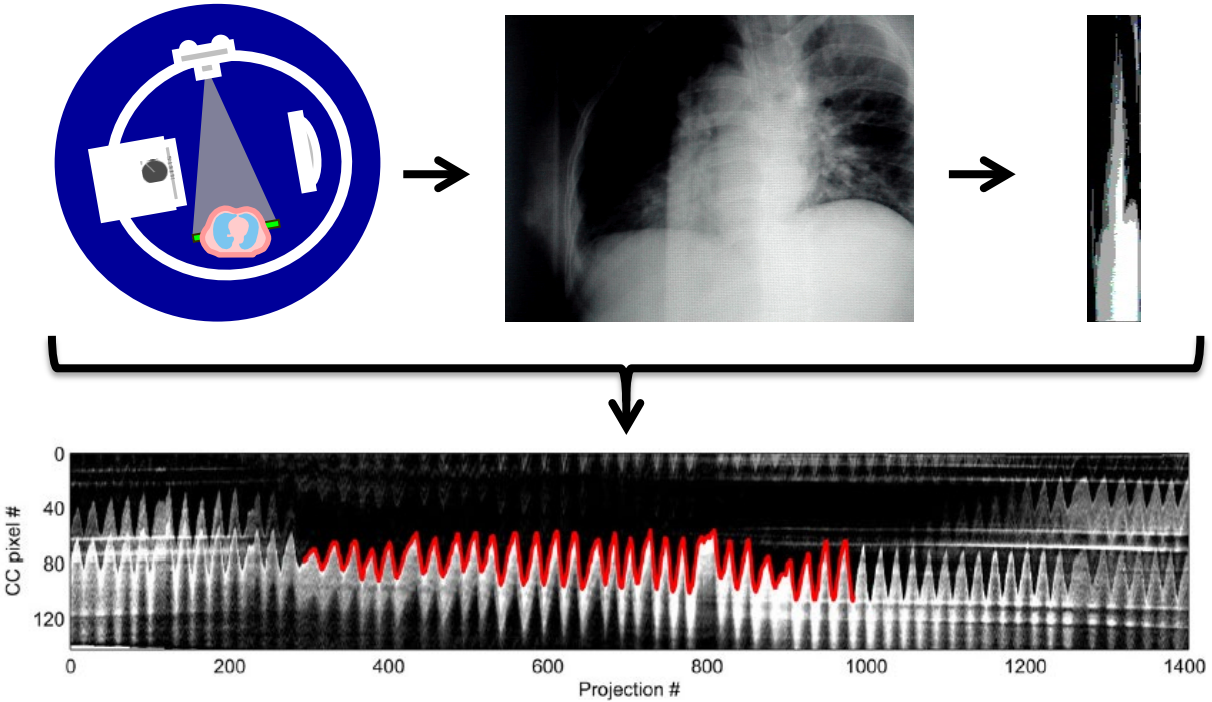
Courtesy J.-F. Germond

4D CBCT

200° rotation

Acquisition of 1320 frames in ~4 min

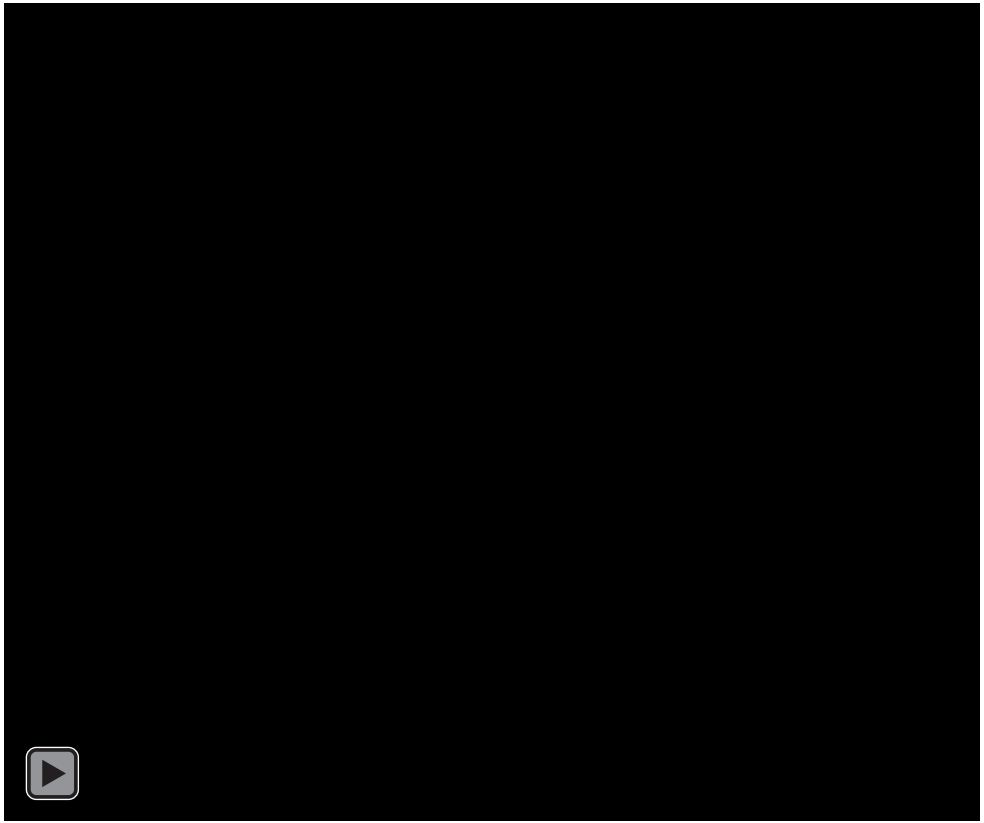
"Amsterdam shroud"



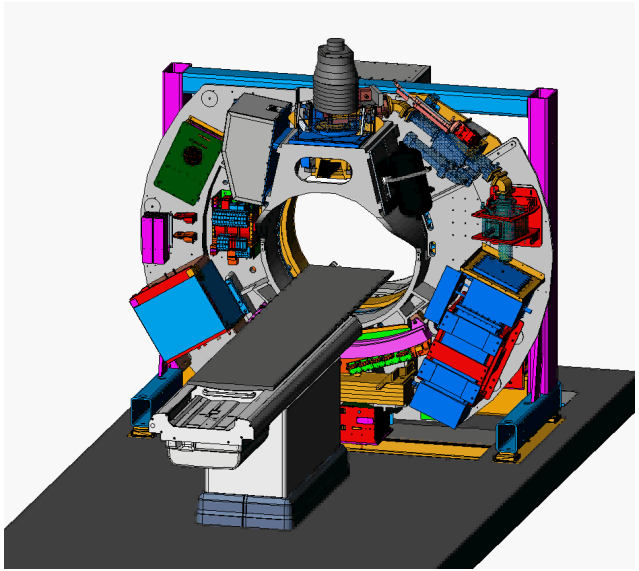
Diaphragm position determination for each projection -> phasing

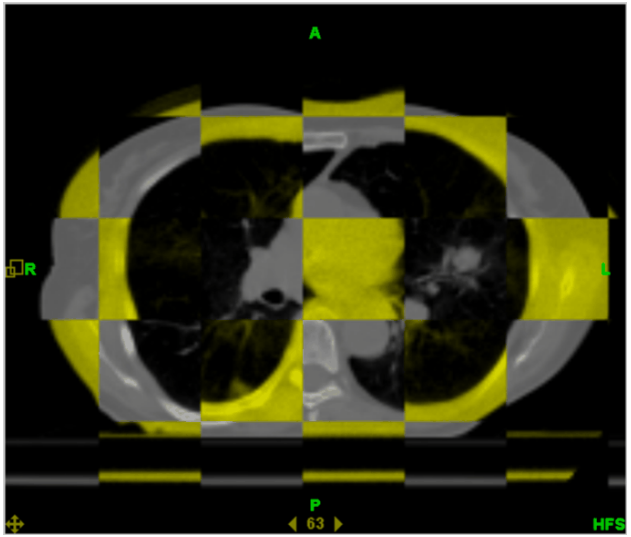
Sonke, Med. Phys., 2005

4D CBCT



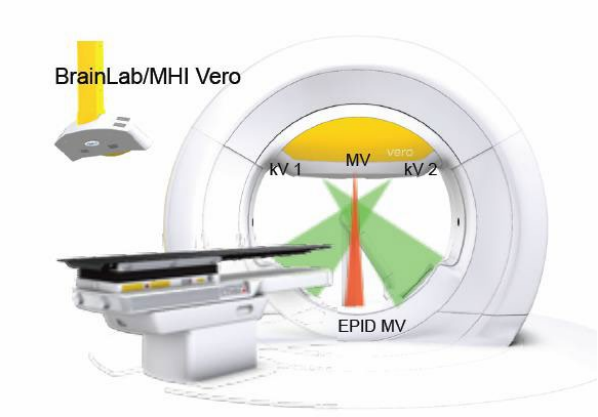
MVCT (Tomotherapy)





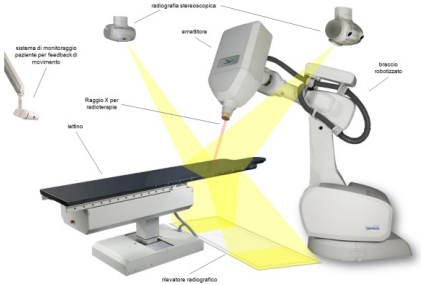
Stereoscopic imaging

Gantry mounted



Room mounted

Varian Novalis system



Accuray Cyberknife

Dose quantification

Technical

Based on risk

- Effective dose

Gy or Sv…

Technical dose

- CTDI and related indicators
  - Cone beam dose index
  - Multi slice average dose
- Surface dose (?!)
- Absorbed dose to water or to tissue
  - Monte Carlo simulations
  - (Anthropomorphic) phantoms

Technical indicators

Advantages

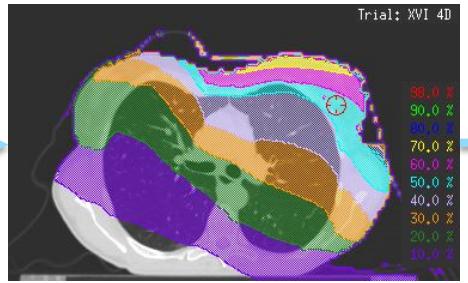
- Rather easy to determine

Drawbacks

- Not directly related to patient (and risk)
- Spread of techniques

Effective dose method

Dose calculation model



Organ doses

Effective dose

Risk

Irradiation parameters

Effective dose method

Advantages

- Related to the risk

Drawback

- Not easy to calculated

Present situation

- AAPM TG 180 recommendation
  - Sort of mix between recommendations and review of existing data
  - Spread indicators for practical work
- In Switzerland
  - Nothing, but the legislation
  - SSRMP working on a recommendation
    - Work in progress
    - In short, the general concept is as follows

SSRMP recommendation

Work in progress - Not approved

Report the imaging dose in radiation therapy in a two-step process

- Store the relevant imaging parameters
- Calculate the dose from stored imaging parameters with lookup tables if required

SSRMP recommendation

Work in progress - Not approved

Relevant imaging parameters

IGRT modality	Parameters to be stored
MV EPID portal images	Number of images per fraction, MU per image, energy, field size, SSD, gantry angle, and number of fractions with IGRT
MV CBCT	Number of MU, start and stop gantry angle, number of acquisitions per fraction and number of fractions with IGRT
Tomotherapy MVCT	Pitch, number of acquisitions per fraction and number of fractions with IGRT
kV CBCT, 4D CBCT	mAs/acquisition,kVp, number of frames or degrees of gantry rotation, type of filter (full or half fan), number of acquisitions per fraction and number of fractions with IGRT
CyberKnife	mAs, kVp, SSD, number of images per fraction and number of fractions with IGRT

SSRMP recommendation

Work in progress - Not approved

Example of look-up table for CyberKnife

Loc.	Eff. Dose [mSv]	Parameters	Ref	Dose [mGy]	Parameters	Ref
Brain	0.6 ± 0.3	35 images, 120 kV, 10 mAs	[20]	0.25	1 image, 105-125 kV, 10 mAs	[21]
H&N	1.4 ± 0.4	35 images, 120 kV, 10 mAs	[20]	0.25	1 image, 105-125 kV, 10 mAs	[21]
Thorax	15.5 ± 10.3	120 images, 120 kV, 10 mAs	[20]	0.25-0.5	1 image, 120-125kV, 10-20mAs	[21]
Pelvis male	7.1 ± 2.1	141 images, 120 kV, 10 mAs	[20]	0.25-2.0	1 image, 120-125kV, 10-90mAs	[21]
Pelvis female	6.1 ± 1.1	141 images, 120 kV, 10 mAs	[20]	0.25-2.0	1 image, 120-125kV, 10-90mAs	[21]

Discussion

We will fulfil the regulation

We do fulfil the justification principle

We still need to optimize

- Should be reasonable, really (alaRa)
- We treat cancer patients with high doses

Some numbers

TABLE II. Comparison of effective dose for image-guided radiation therapy (IGRT) of CyberKnife, Elekta XVI, and Varian OBI for a single fraction (reproduced from Ref. 14).

	CyberKnife		OBI	XVI	
Loc.	Modality	E (mSv)	E (mSv)	Modality	E (mSv)
	100 kV, 10 mAs	0.3 ± 0.2	0.42 ± 0.16	Head	0.04 ± 0.01
Brain	120 kV, 10 mAs	0.6 ± 0.3			
	140 kV, 10 mAs	0.8 ± 0.5			
	100 kV, 5 mAs	0.4 ± 0.1	1.22 ± 0.16	Head	0.12 ± 0.02
H&N	120 kV, 10 mAs	1.3 ± 0.4			
	140 kV, 10 mAs	1.9 ± 0.6			
	100 kV, 5 mAs	4.9 ± 3.3	3.12 ± 0.33	Thorax	9.34 ± 0.90
Thorax	120 kV, 10 mAs	15.5 ± 10.4		4D	7.63 ± 0.65
	140 kV, 20 mAs	42.4 ± 28.5			
	100 kV, 5 mAs	2.0 ± 0.6	–	–	
Pelvis	120 kV, 10 mAs	6.6 ± 1.6			
	140 kV, 20 mAs	18.9 ± 4.4			

Moeckli, Med. Phys., 2020

Discussion

We will fulfil the regulation

We do fulfil the justification principle

We still need to optimize

- Should be reasonable
- We treat cancer patients with high doses

Remaining question: « What to do with that? »

- Summation of Gy with Sv

Discussion

We will fulfil the regulation

We do fulfil the justification principle

We still need to optimize

- Should be reasonable
- We treat cancer patients with high doses

Remaining question: « What to do with that? »

- ~~Summation~~ of Gy with Sv

Alternative solutions (US, MR, etc…)

Conclusions

- « Technical dose » and « effective dose » are coherent
- Justification is fulfiled
- Optimization to be done
  - But reasonably
- Effective dose between 0.1 and 10 mSv
  - Per treatment
  - In most cases
- Related risk: ~1% at maximum
  - In most cases
  - Much less in most cases