Challenges facing medical radiation protection: a few avenues for exploration

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International Radiation Protection Association

Mendoza, October 2013

The 2001 Malaga Conference, the International Action Plan for the Radiological Protection of Patients

• The relevant actions considered were:

– 1) **Education and training (including digital radiology, CT,** interventional. new techniques in radiotherapy, etc)

– 2) **Information exchange (including prevention of** accidents)

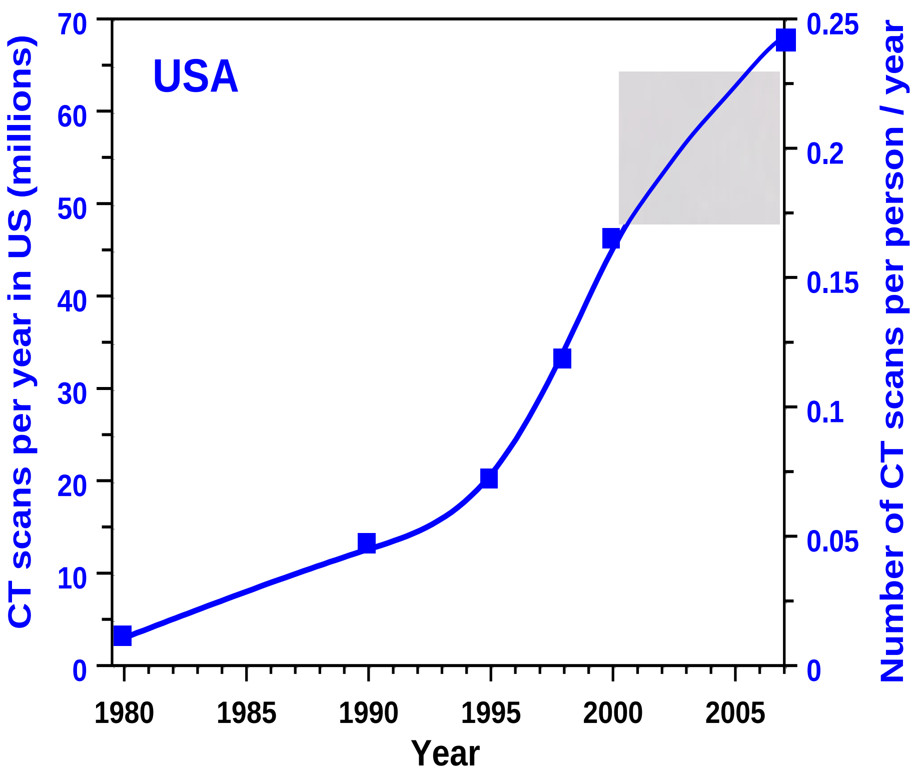
– 3) **Assistance (including the role of medical physicists,** technologists, audit services, etc)

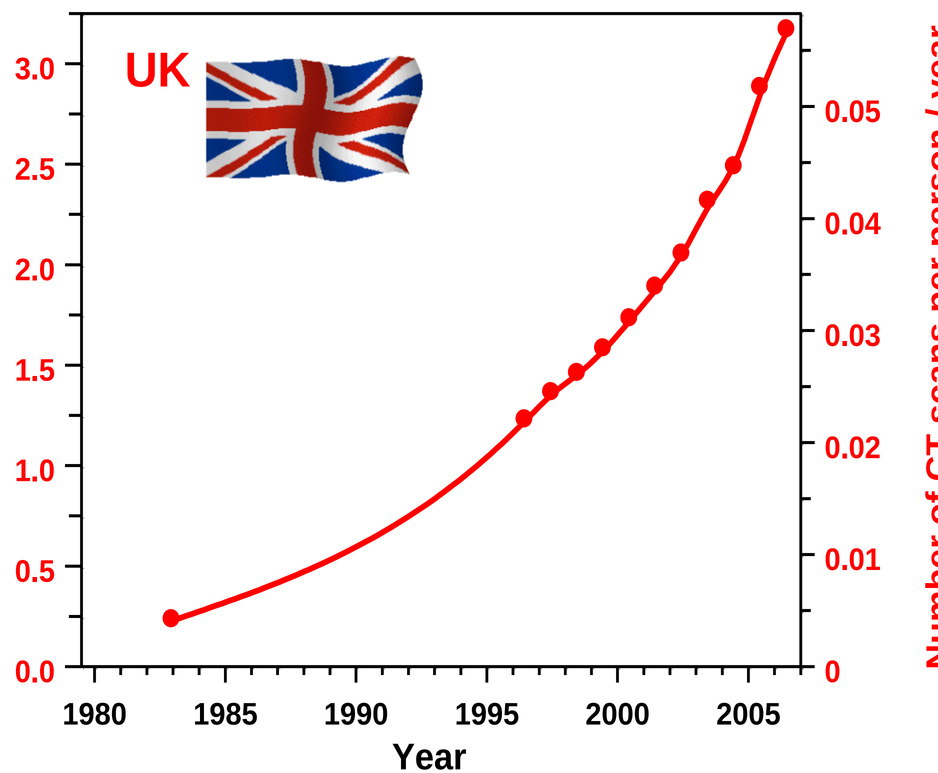
– 4) **Guidance (including cooperation with the radiology** industry)

– 5) **Appraisal and other services (including development of** local diagnostic reference levels, infrastructure, QA etc)

– 6) **Coordinated research activities.**

Doses to patient : large increase of CT scan exam

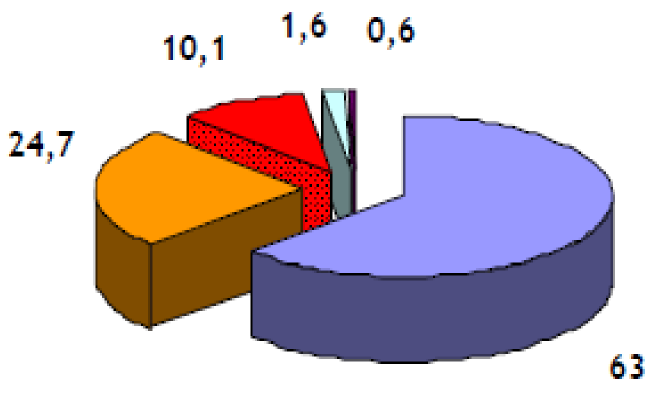


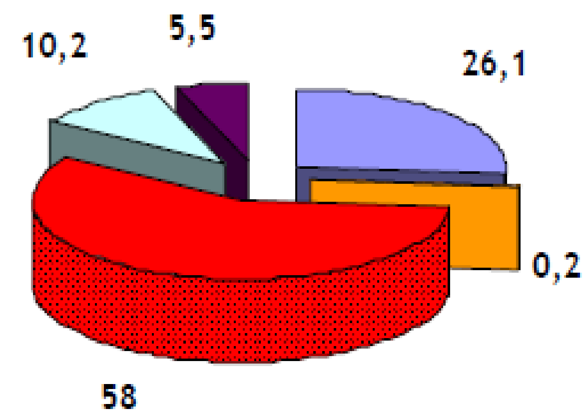


Year 2007: Overview in France

Number of examinations (%)

Average effective dose per head of population(%)



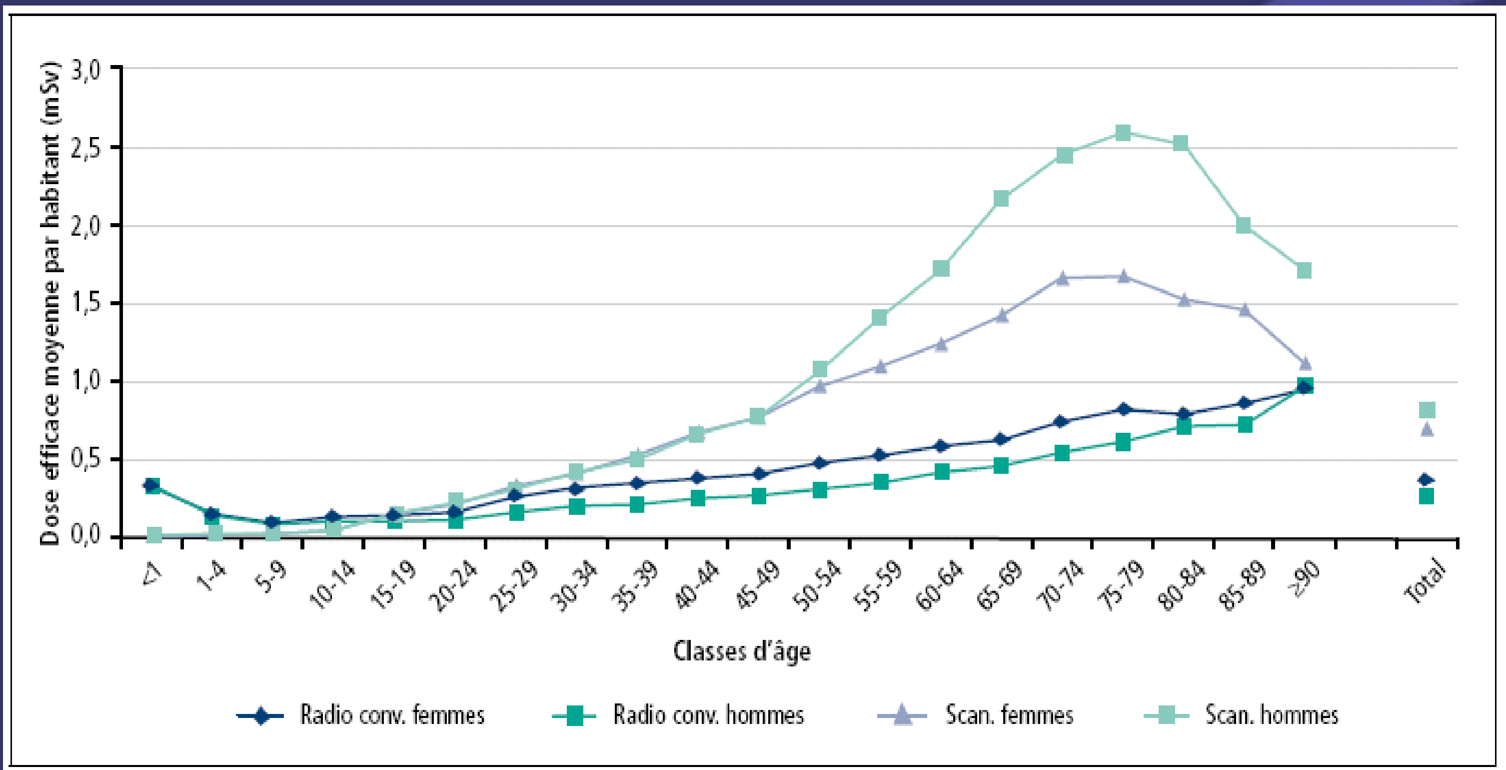


Institut de veille sanitaire. Exposition de la population française aux rayonnements ionisants liée aux actes de diagnostic médical en 2007.

74.6 million examinations => 1.3 mSv/year/head of population

More than 59% of effective dose per head of the French population was due to scans in 2007.

Conventional radiology and CT scans



Institut de veille sanitaire. Exposition de la population française aux rayonnements ionisants liée aux actes de diagnostic médical en 2007.

Directive 97/43/Euratom
Article 4: optimisation

- Any dose received from medical exposure for radiological purposes, with the exception of radiotherapy procedures, is kept as low as reasonably achievable for obtaining the required diagnostic information, bearing in mind economic and social factors.

- Member states advocate the development and use of diagnostic reference levels for radio-diagnostic examinations.

For ex, why optimise interventional cardiology procedures?

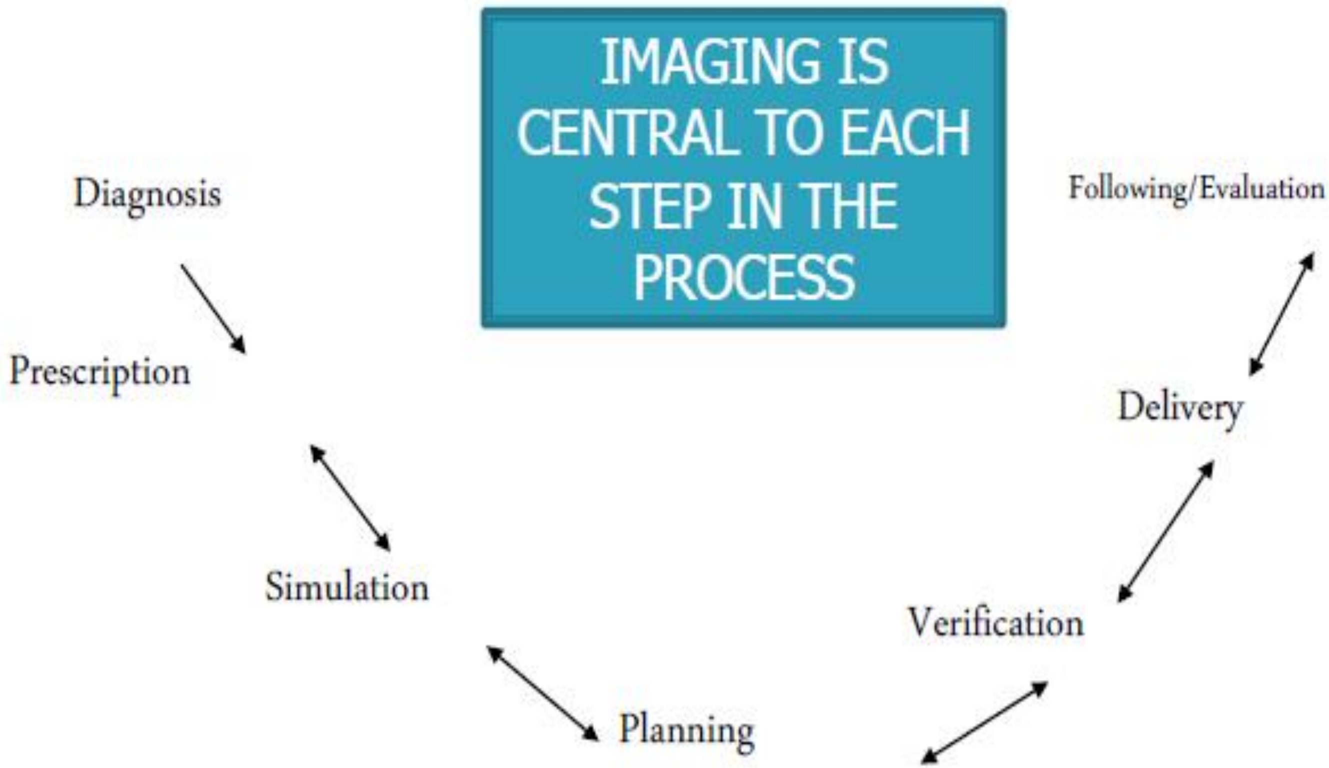
- The purpose of optimising procedures is to improve the risk/benefit ratio
- ALARA: As Low As Reasonably Achievable
- No statutory limit on patient dose for medical purposes
- Statutory limit for personnel, including radiologists…

Dose (patient) without benefit = Unwarranted dose

Position of the Radiation Protection Professional

- **Need to develop:**
  - Relationship with Physician and Health Physicist
  - Relationship with Patients
  - Relationship with the regulators
  - Involvement with other relevant stakeholders

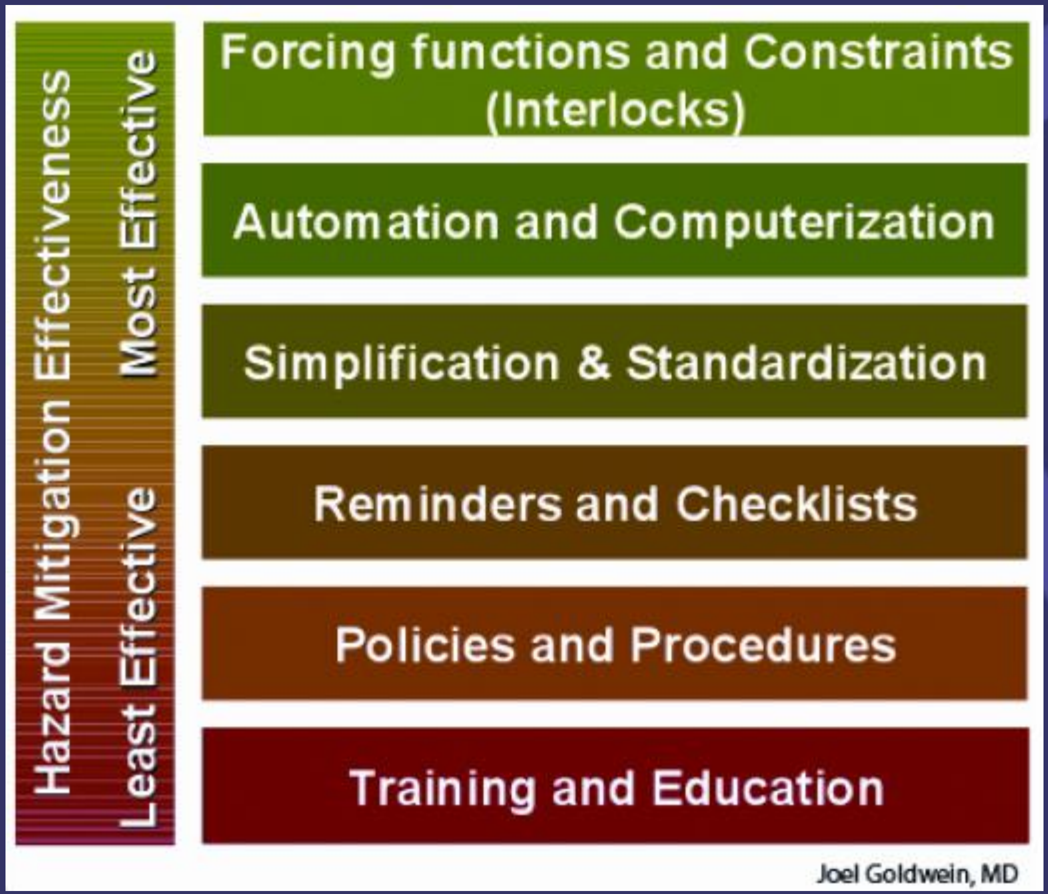
THE PROCESS OF RADIATION TREATMENT (WILLIAM HENDEE)



The zero risk doesn’t exist , Process must be fault tolerant that’s why …

- Responsibilities must be Understood
- Responsibilities must be Manageable
- Early Warnings must be Available
- Must Learn from others Mistakes
- Corrective Actions must Occur
- Audits must be Conducted
- Peer Review must Happen
- Process should be Accredited

From the least effective to the most effective (William Hendee presentation in Bonn)



Towards the next decade.
What is still missing
in radiation protection in medicine – E Vano

- **Justification of medical procedures**. Also considering theimpact of external factors as infrastructure, existing protocols and trained professionals.
- **Optimization of RP for new technology in medicine**.

New technology with not enough time to train operators on aspects of radiation safety. Industry involvement.

- **Management of patient and staff protection as a global approach.**
- **Occupational lens doses and extremity doses**.

Interventionists and nuclear medicine operators.

- **Radiation risk communication to patients**.

Towards the next decade.
What is still missing
in radiation protection in medicine – E Vano

- **Tissue reactions**. Especially during some complex interventional procedures. Training on that topic.
- **Patient exposure tracking in imaging, with special attention to paediatrics**.
- **Expanding the use of Diagnostic Reference Levels for optimization**.
- **Radiation risk assessment in Radiotherapy**. Increasing complexity =>involves increasing probability for errors.
- **Sufficient trained staff in RP** (medical, and paramedical including medical physicists, radiographers and nurses).

Part 1: RP optimisation in paediatric imaging

Mendoza, October 2013

Specific features of paediatric imaging

Challenges (H Ducou le Pointe)

- **Higher stochastic risk**
  - Children are more radiosensitive
  - Longer life expectancy
- **Estimation of effective doses**
  - Inappropriate W_t weighting factors
  - Inappropriate dose indexes
  - Inappropriate computation coefficients and software programs
- **More difficult acquisition of images**
  - Risk or patients moving
  - Highly variable patient morphotypes
  - No imaging equipment specifically designed for paediatric medicine

Justification and optimisation of procedures must remain a constant priority in paediatric medicine.

Image gently
One size does not fit all

Conventional radiology for paediatric imaging
Dose evaluation

- **Dose index: Dose Area Product (DAP)**
  - Monitoring with ionisation chamber or by calculation
  - Results must be documented in a report
  - Multiple manufacturers !
  - Need for automated data gathering system

- **Calculation of effective dose or entry dose based on DAP**
  - No consensus on effective dose calculation method
  - DAP conversion coefficients not suitable for paediatrics

EXAMEN	AGE	De EN mGy pour une exposition
Thorax (postéro-antérieur)	0-1 an	0,08
Thorax (postéro-antérieur)	5 ans	0,1
Thorax (latéral)	5 ans	0,2
Crâne (postéro-antérieur ou antéro-postérieur)	5 ans	1,5
Crâne (latéral)	5 ans	1
Pelvis (antéro-postérieur)	0-1 an	0,2
Pelvis (antéro-postérieur)	5 ans	0,9
ASP (postéro-antérieur ou antéro-postérieur)	5 ans	1

Arrêté du 12 février 2004 relatif aux niveaux de référence diagnostiques en radiologie et en médecine nucléaire

- **Reference levels (DRL)**
  - Specific reference levels for paediatrics
  - Difficult to take 20 readings due to lack of patients for certain examinations

Conventional radiology for paediatric imaging
Choosing the right technique

- ☐ Comparative study between fluorography/film or fluorography/amplifier
  - e.g. Bourlière – Najean, Ph. Devred
  - Survey of 293 children aged 0 to 15 years
  - **<u>Results: conventional/digital dose ratio > 2</u>**

- ☐ A comparative survey of digital acquisition methods also needs to be performed

Conventional radiology for paediatric imaging

Patient movement taking into account

- **Challenges**
  - Risk of repeat x-rays
  - Decrease in image quality
  - Increase in required field of exposure

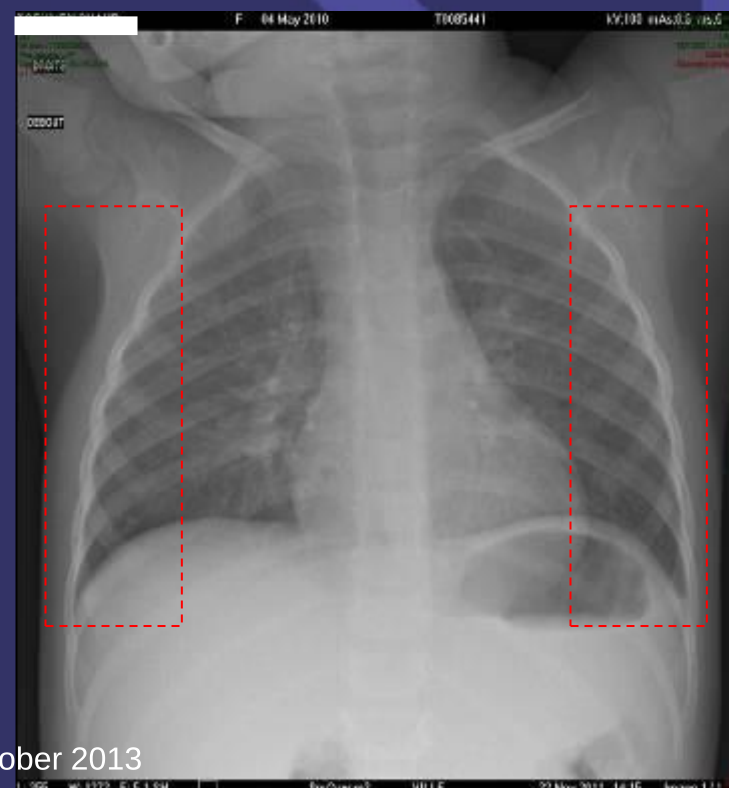
Solutions

- Restraint
- Reduced exposure time (high-performance generators needed)

Conventional radiology for paediatric imaging
Parameter adjustment

- **Full automation is actually impossible**
  - **Programming by age group or morphotypes**
  - **Inappropriate cell sizes of automatic exposure systems**

- **Adjustment of constants only by operators**
- **Education is essential**



CT Scan for children in US

1989: ~½ million

2007: ~3½ à 7 million !

(5 to 10% du nombre total de scan)

(~ 1.5 millions for children < 5 years)

CT scans

Dose evaluation and optimisation (H Ducou le Pointe)

- **Reference levels**
  - Still no statutory dose reference levels (DRL)
- **Dose indexes: DLP and CTDI**
  - Automatic calculation by scanner
  - DLP must be documented in report +++
  - Normalised DLP not suited to child diameters
- **Optimisation of child protocols per age group in France ++++**
  - Scanner PHILIPS MX 8000 IDT 16 slices

Examen	Protocoles d'acquisition 2007				Protocoles d'acquisition 2008				Recommandations SFIPP/IRSN 2009	
	Âge	haute tension (kV)	charge par coupe (mAs)	pitch**	Âge	haute tension (kV)	charge par coupe (mAs)	pitch**	Âge	haute tension (kV)
	bébé	90	90	1	< 2 ans	90	70	0,9	1 an	80–100
thorax standard	-	-	-		2–11 ans	90	90	0,9	5 ans	80–100
	adolescent	120	130	1	> 11 ans	120	80	0,9	10 ans	100–120

Part 2: RP optimisation for CT scans

Mendoza, October 2013

Optimisation for paediatric imaging

Image quality and radiation exposure: The right mixture!

1-2-4-6-8-10-16-32-40-64-128-256-320..slices

3 Rotations per second

50-60-72-80-100-120…… kW

French proverb: It’s not the number of eggs that gives the omelette its taste

From abel’s presentation in Bonn

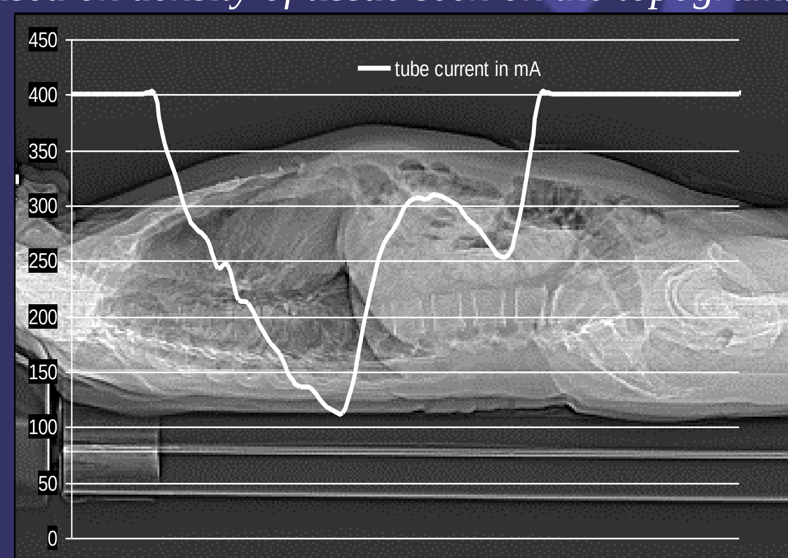
This is what you need!

This is what you did!

CT scans
Computer-aided dose reduction methods

- **Automatic current control system**
  - ☐ Available on all recent equipment
  - ☐ Variable methods depending on manufacturers
  - ☐ Expected 30% dose reduction
  - ☐ **Paediatrics: No blind trust! said H Ducou le Pointe**
    - **Possible dose increase**
    - **Systems to be assessed prior to routine use**

Current control dependent on longitudinal axis based on density of tissue seen on the topogram.

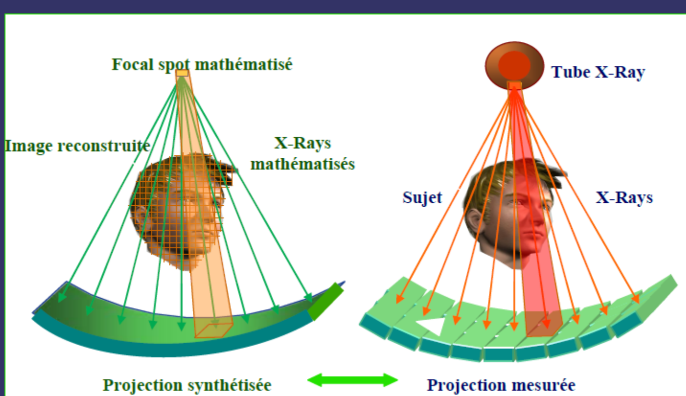


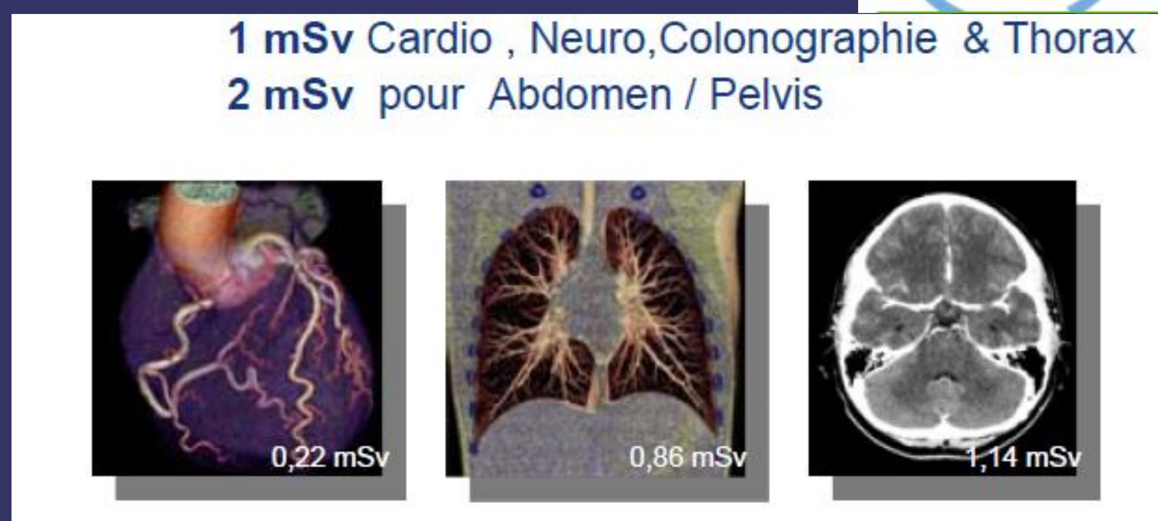
A practical example of engagement with stakeholders (role of manufacturers)

- How to involve manufacturers, designers, and vendors with compelling evidence showing that RP is a selling point, thereby decreasing radiation dose received from x-rays.

Adaptive Statistical Iterative Reconstruction

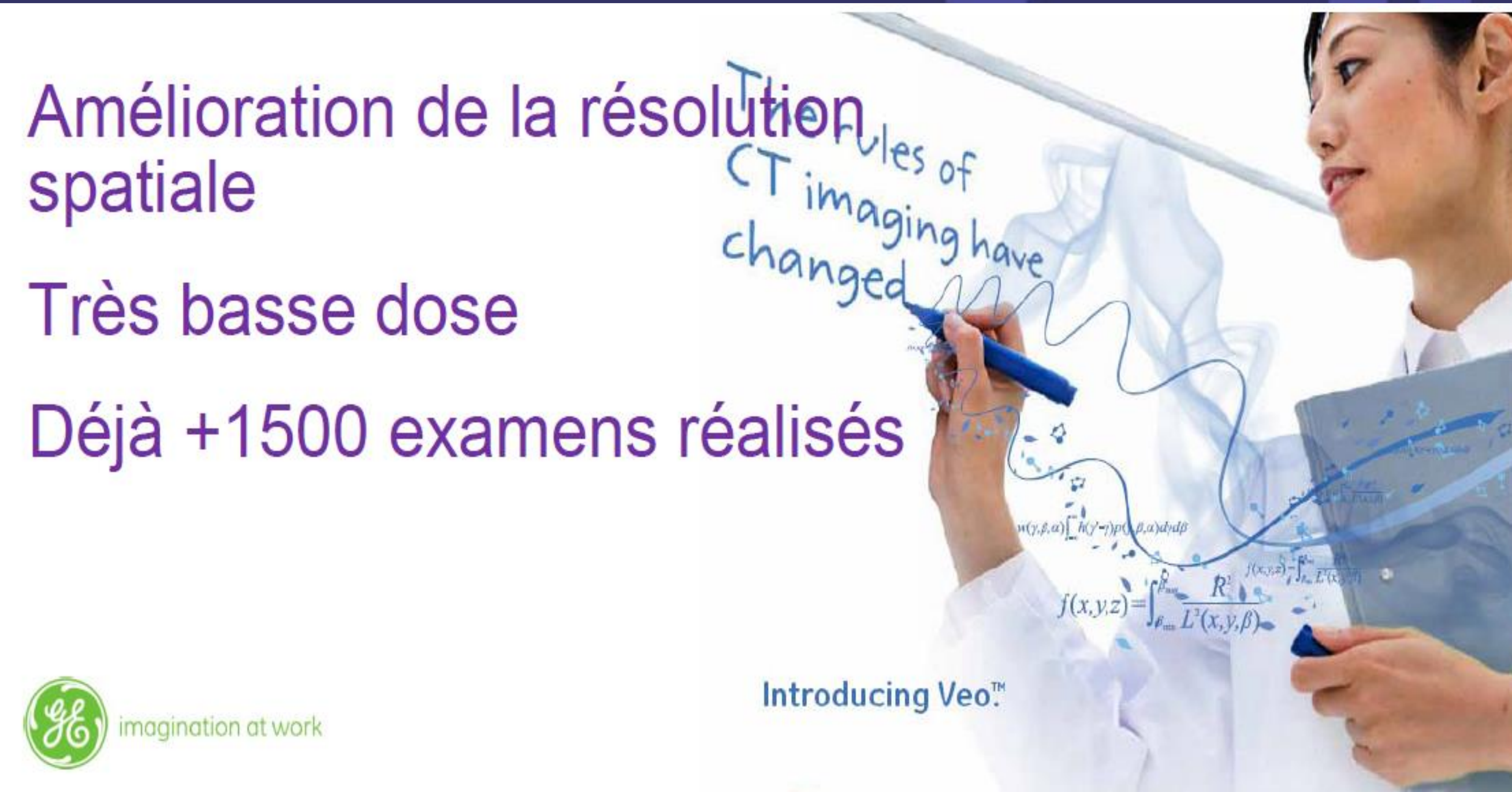
- **Iterative reconstruction e.g. ASIR system**
  - ☐ Gradual implementation
  - ☐ 20% dose reduction in adults
  - ☐ Need for paediatric-specific evaluation



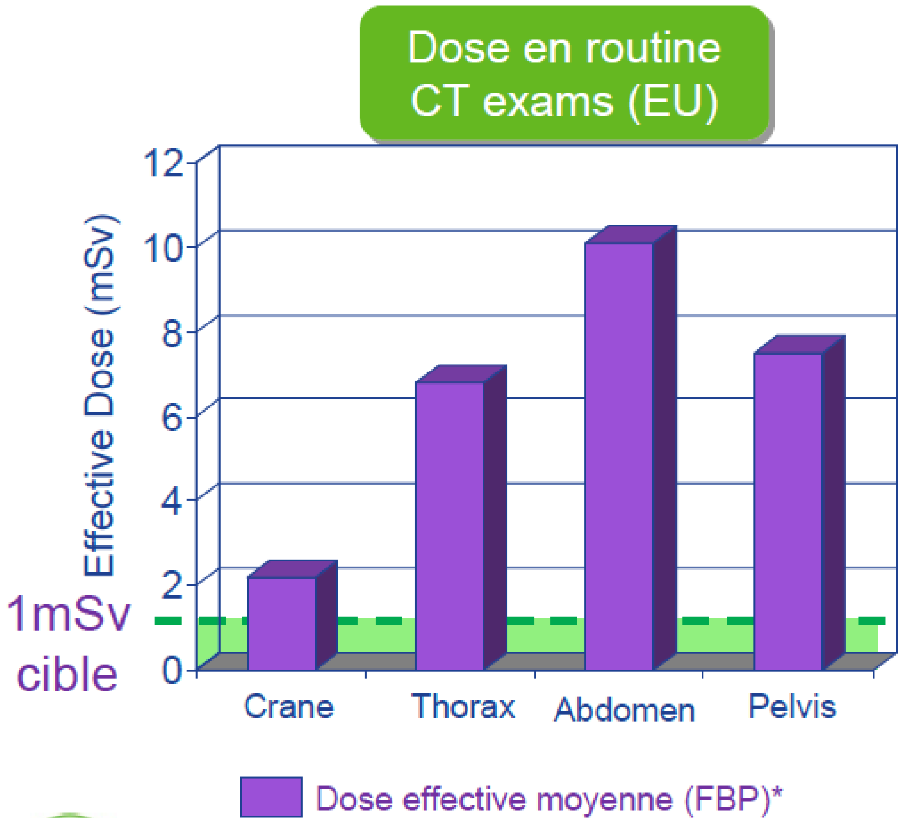


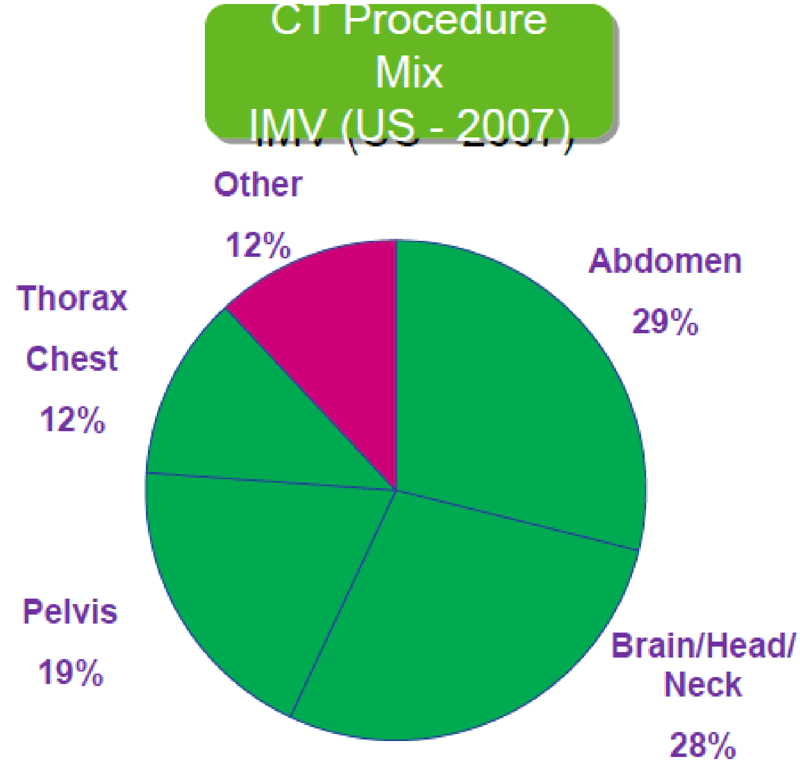
Tomorrow is today
Just an example with a designer

- **Veo:** the rules of CT imaging have changed.
  Changes in image reconstruction (GE Commercial)



Goal : to perform a CT scan <1mSv announced GE





imagination at work

*Source: Collective Radiation from MDCT: Critical Review of Surveys Studies. G. Stamm, Phd, Diagnostic Radiologie; Mean Dose values: Germany (2002), UK (2003), Austria (2000), Switzerland (1998).

Optimize algorithm to run faster on multi-core processors

example of a head scan in a child aged less than 2

Veo* – Crane pédiatrique (2 y)

Scan protocol:
80-120 mAs, 100 kV
Slice thickness: 0.625mm

Veo

Exam Description: CT HERSENEN ZONDER KON

Dose Report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Axial	S6.500-I131.000	12.27	171.82	Head 16
			Total Exam DLP:	171.82	

DLP = 171.82 mGy.cm

Equivalent dose = 1.4 mSv*

* Obtained by EUR-16262 EN, using a pediatric head factor of 0.008*DLP
Images Courtesy of Pr de Mey and Dr Nieboer, UZ Brussel, Belgium

Maxillo-facial CT with Veo* - child aged 9

scanner maxillo-facial avec Veo* - 9y

Scan protocol:
14 mAs, 100 kV
Slice thickness:
0.625mm

Veo

Exam Description: CT ORBITAE MET KONTRAS

Dose Report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Helical	I2.250-I114.750	1.17	18.04	Body 32
		Total Exam DLP:		18.04	

DLP = 18.04 mGy.cm

Efficient dose = 0.14 mSv*

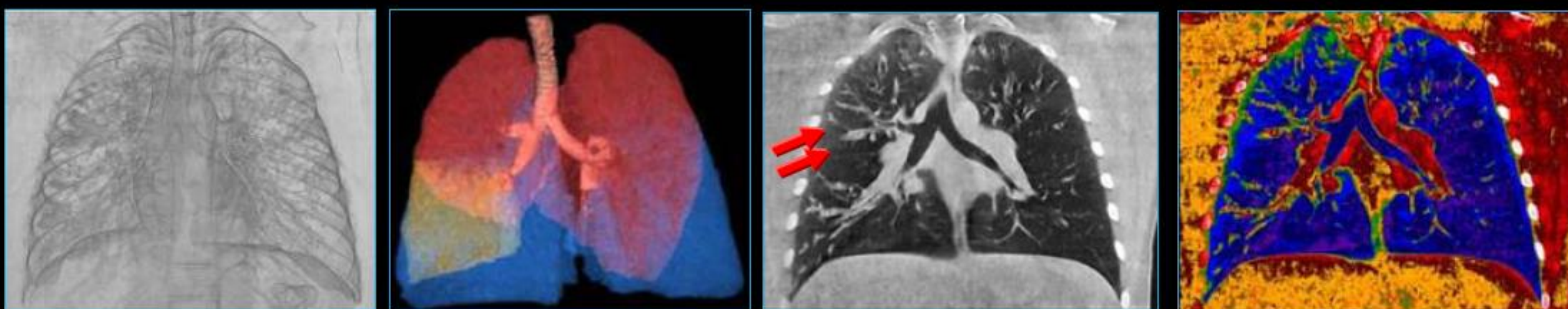
* Obtained by EUR-16262 EN, using a pediatric head factor of 0.008*DLP
Images Courtesy of Pr de Mey and Dr Nieboer, UZ Brussel, Belgium

Cystic fibrosis thoracic scan

Veo* – Thorax (Cystic fibrosis)

Scan protocol:
4 mAs, 80 kV
Slice thickness:
0.625mm

Veo



Exam Description: CT THORAX ZONDER KONTR

Dose Report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Scout	-	-	-	-
3	Helical	I309.500-I53.660	0.10	3.16	Body 32
			Total Exam DLP:	3.16	

DLP = 3.16 mGy.cm

Efficient dose = 0.05 mSv*

* Obtained by EUR-16262 EN, using a chest factor of 0.017*DLP
Images Courtesy of Pr de Mey and Dr Nieboer, UZ Brussel, Belgium

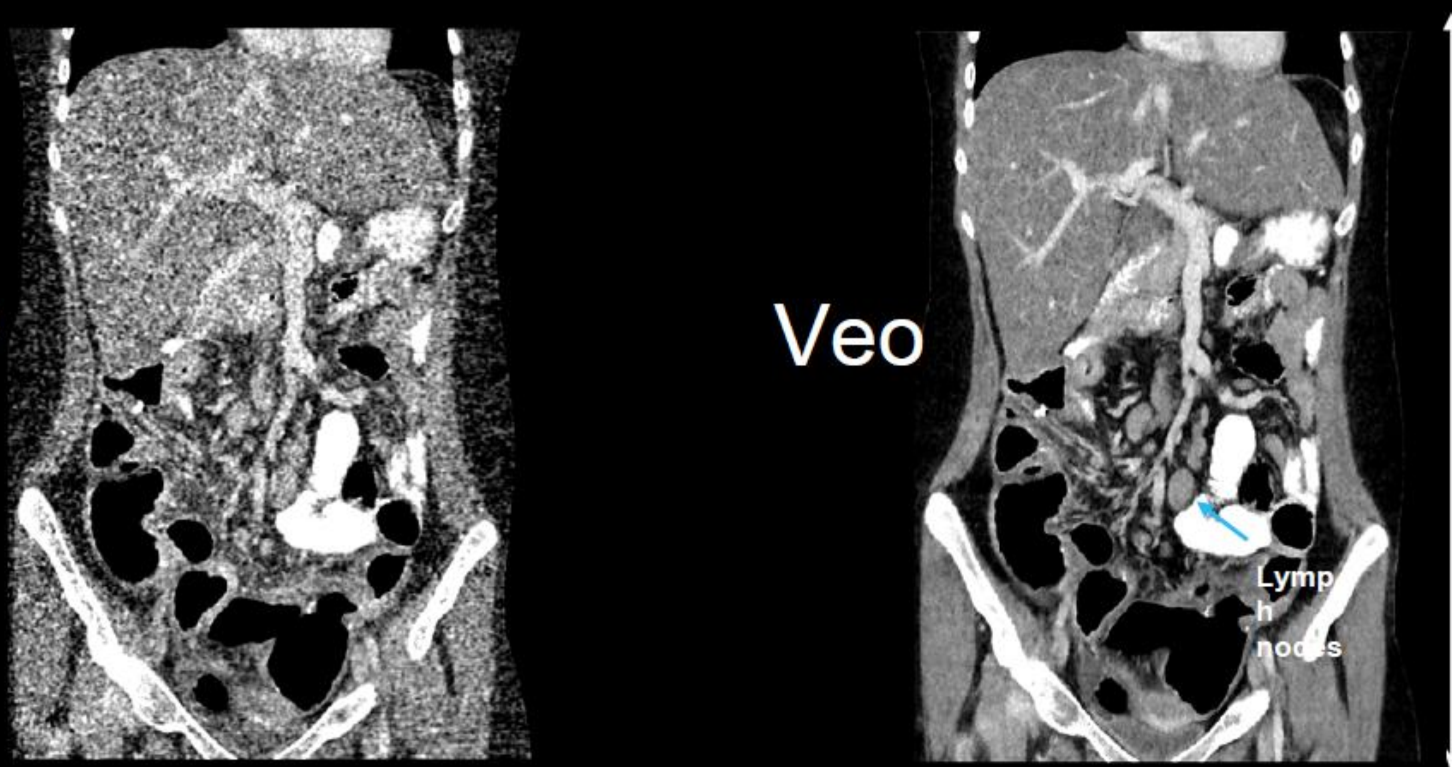
Ultra-low efficient dose for abdomen/pelvis CT scan

Abdomen Pelvis très basse dose – 0.68 mSv*

100 kVp, 35-44 mA, 0.5 rot
DLP 40, 0.68mSv*
0.625mm

FBP

Veo



imagination at work

*Obtained by EUR-16262 EN, using an abdomen factor of 0.015*DLP and a pelvis factor of 0.019*DLP

Images courtesy of Pr Maher, Cork University Hospital, Ireland

Ultra-low abdomen/pelvis CT scan

Abdomen Pelvis très basse dose– 0.61 mSv*

FBP   Veo

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)
1	Scout	-	-	-
2	Helical	S50.750-I369.250	0.74	36.02

120 kV, 10 mA, 0.5 rot time
0.625mm slice thickness

imagination at work

Images courtesy of Dr Barrau, CCN, Franc

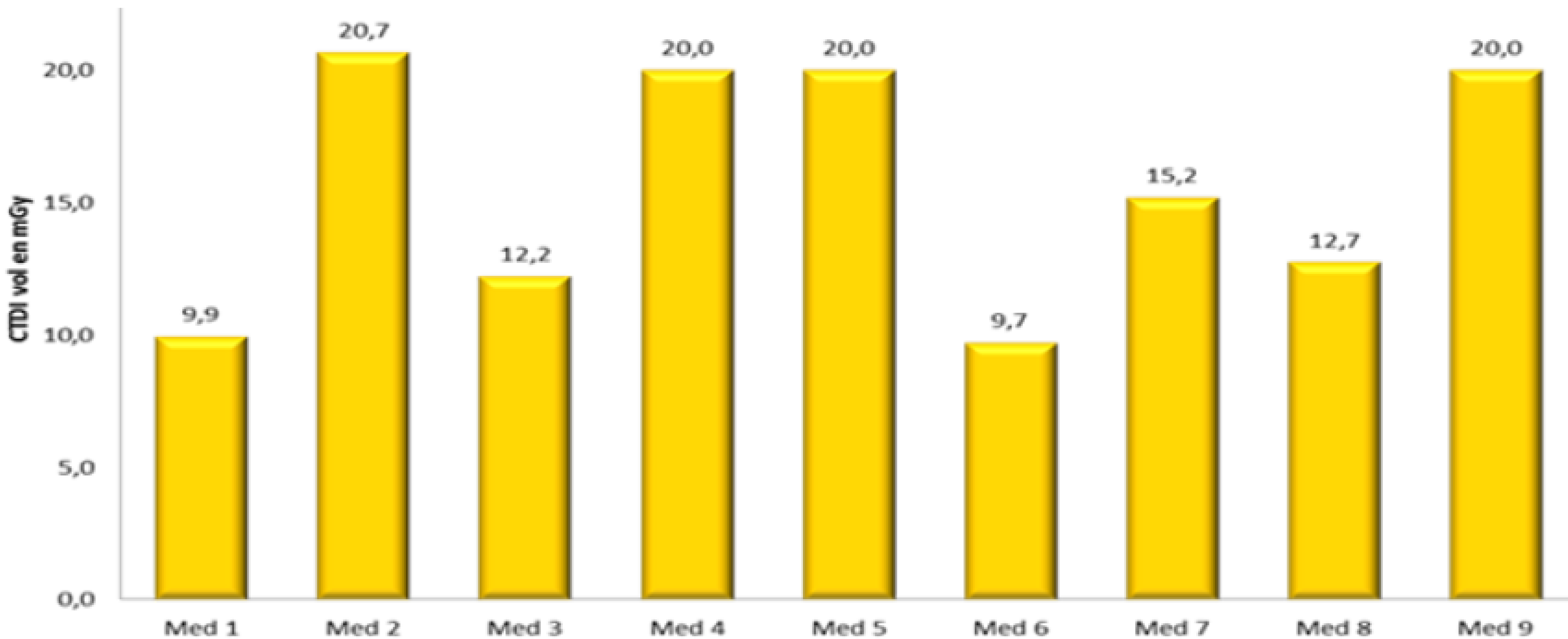
*Obtained by EUR-16262 EN, using an abdomen factor of 0.015*DLP and a pelvis factor of 0.019*DLP

Challenges about Dose reduction
CT SCAN

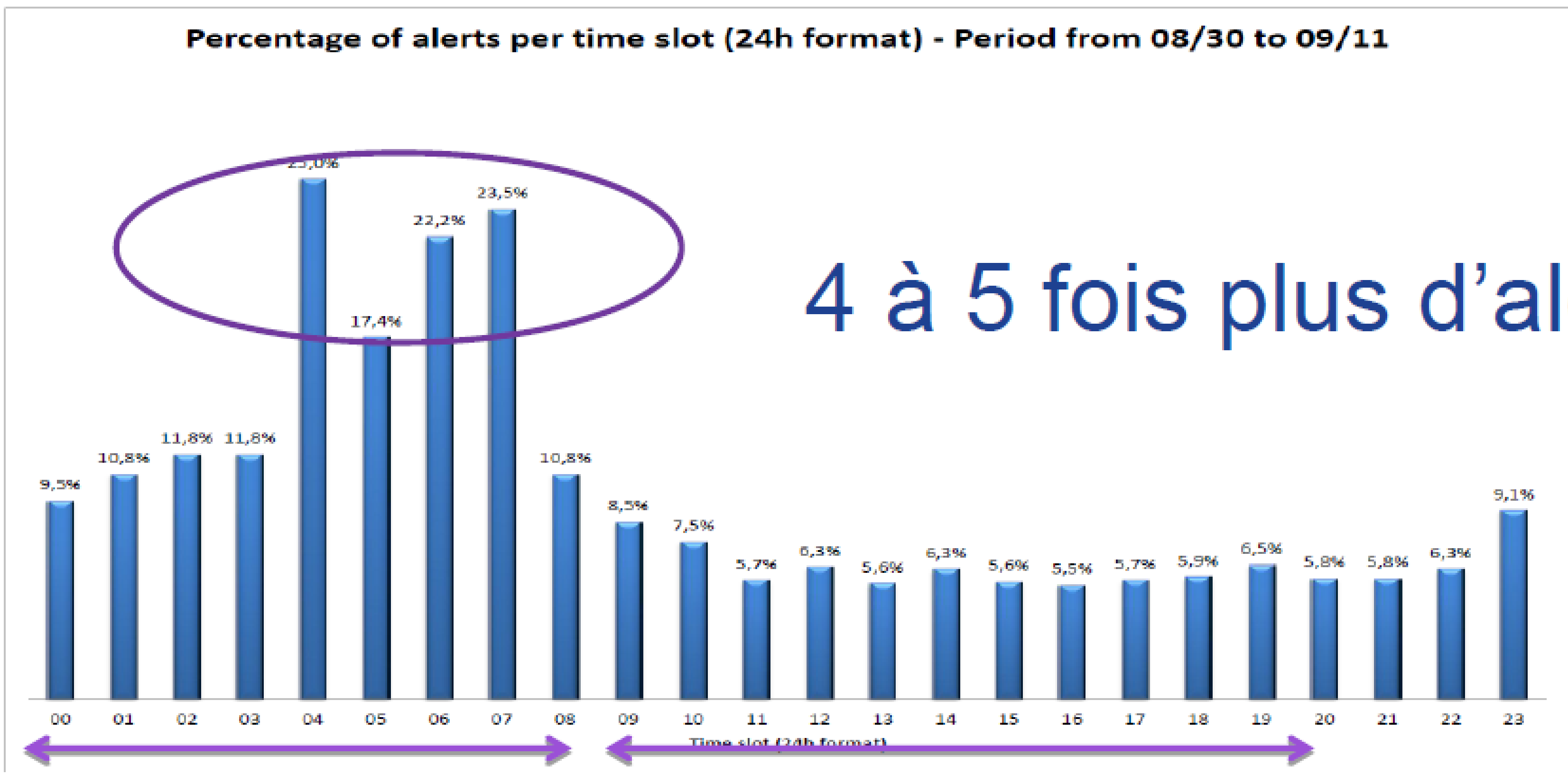
- For many CT procedures, effective doses < 1mSv are achievable
- Optimized spectra (kVp) adult and child
- Efficient detectors
- Beam collimation
- Dedicated CT scanners
- Image reconstruction – iterative
- Surrogate dose measurements

Part 3: But technique is not enough; let's start by challenging our own practices…

Same CT exam- abdomen and pelvis – doses delivered by different radiologists



Analysing one's own practices: same hospital, same equipment. Night shift VS day shift



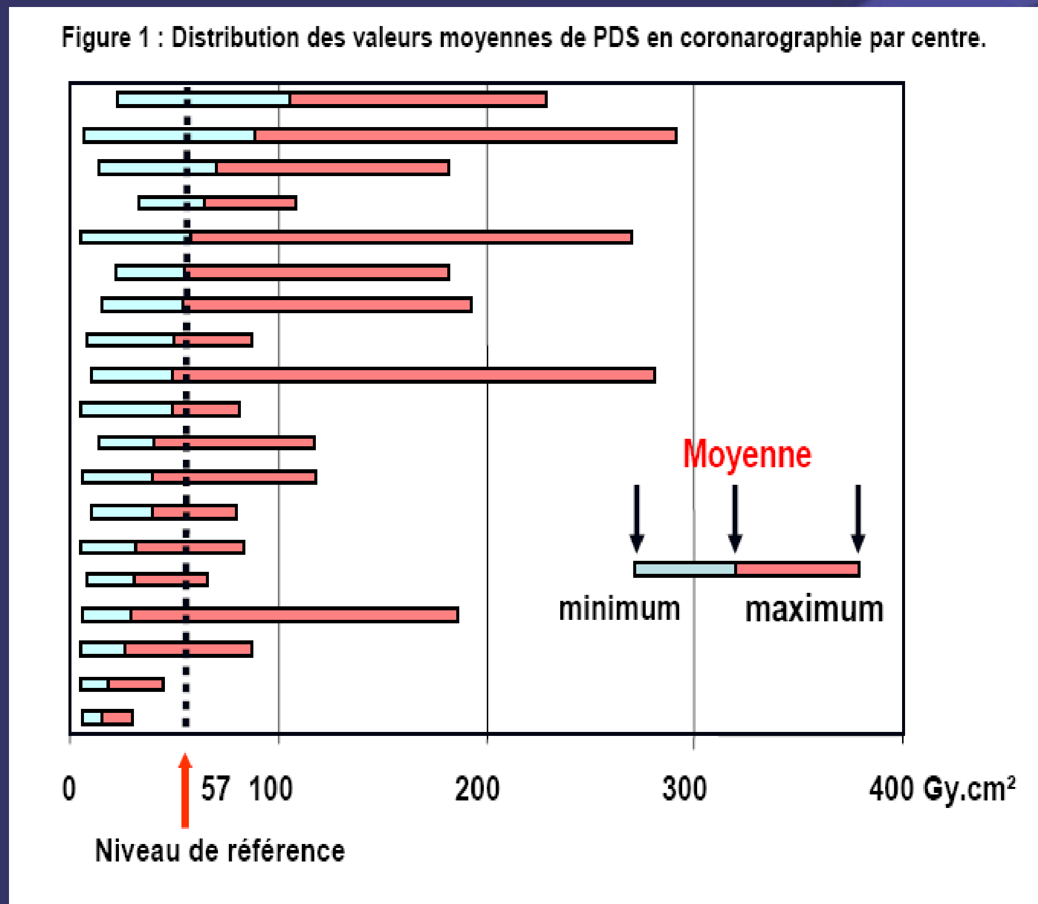
4 à 5 fois plus d'alertes

Equipe de nuit

Equipe de jour- Equipe dédiée

GACI-PDS survey 2006 (1/2)
19 centres, 60 radiologists, 813 examinations (40 per centre on average)

Coronarography (50 Gy.cm^2, 10 mSv)

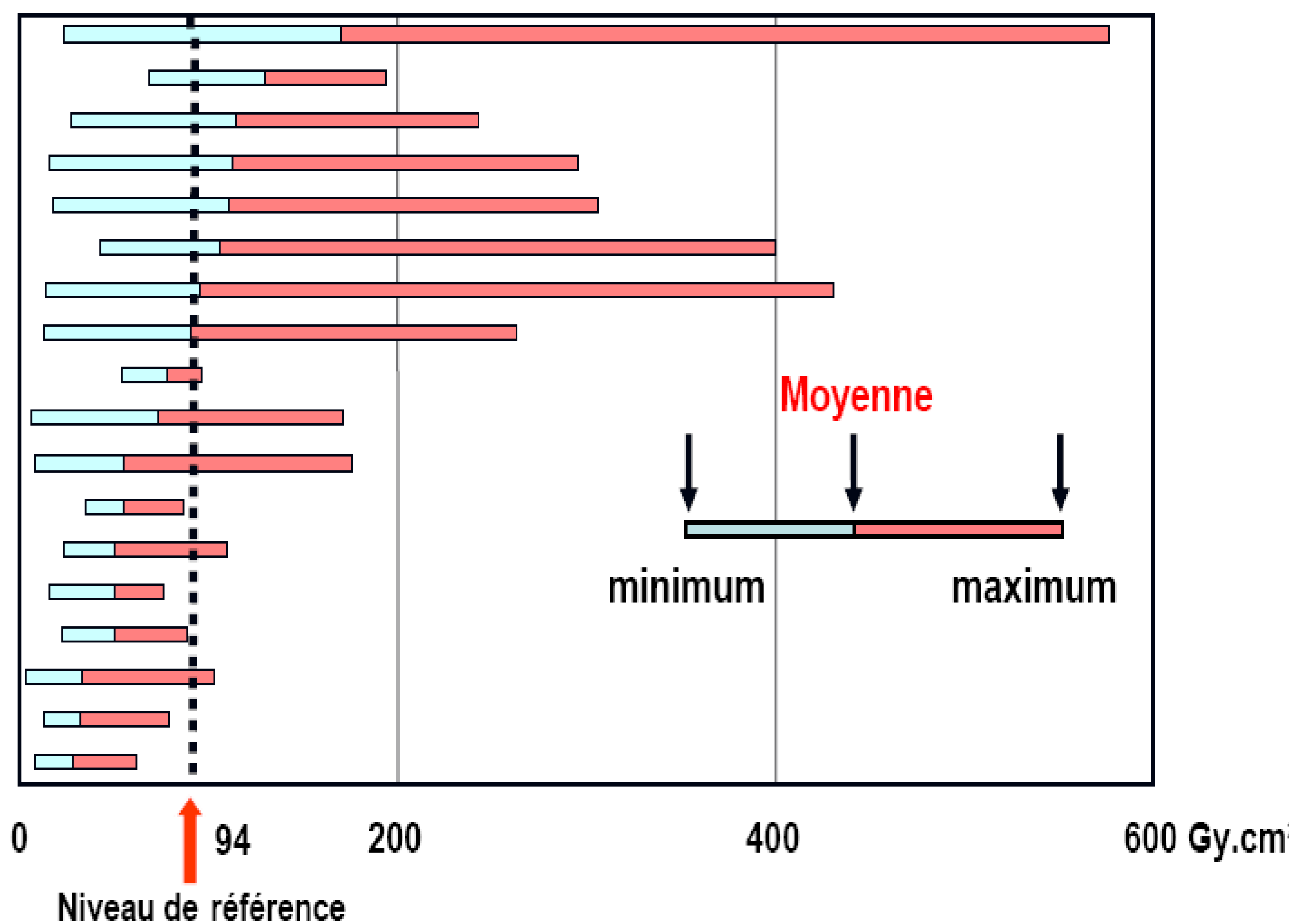


DRL : Value of a parameter given respected in 75% of the exams (so 75% of the procedures are achieved below the Reference Level !)

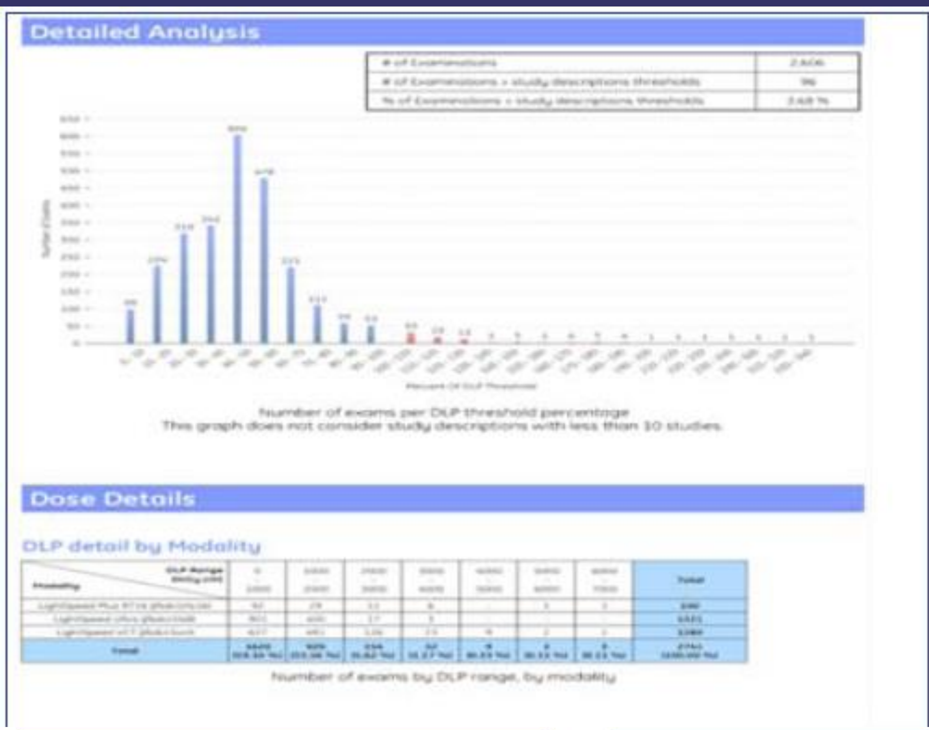
GACI-PDS survey 2006 (2/2)

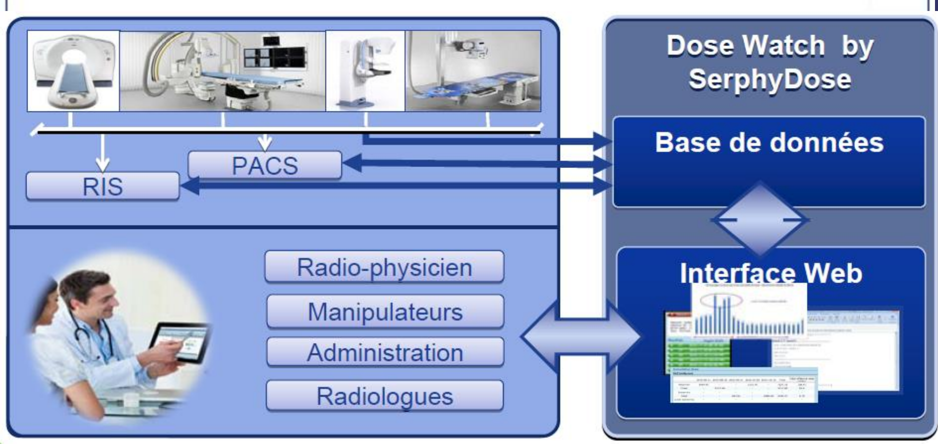
Coronary angioplasty (100 Gy.cm^2, i.e. approx. 20 mSv)

Figure 2 : Distribution des valeurs moyennes de PDS en angioplastie coronaire par centre.



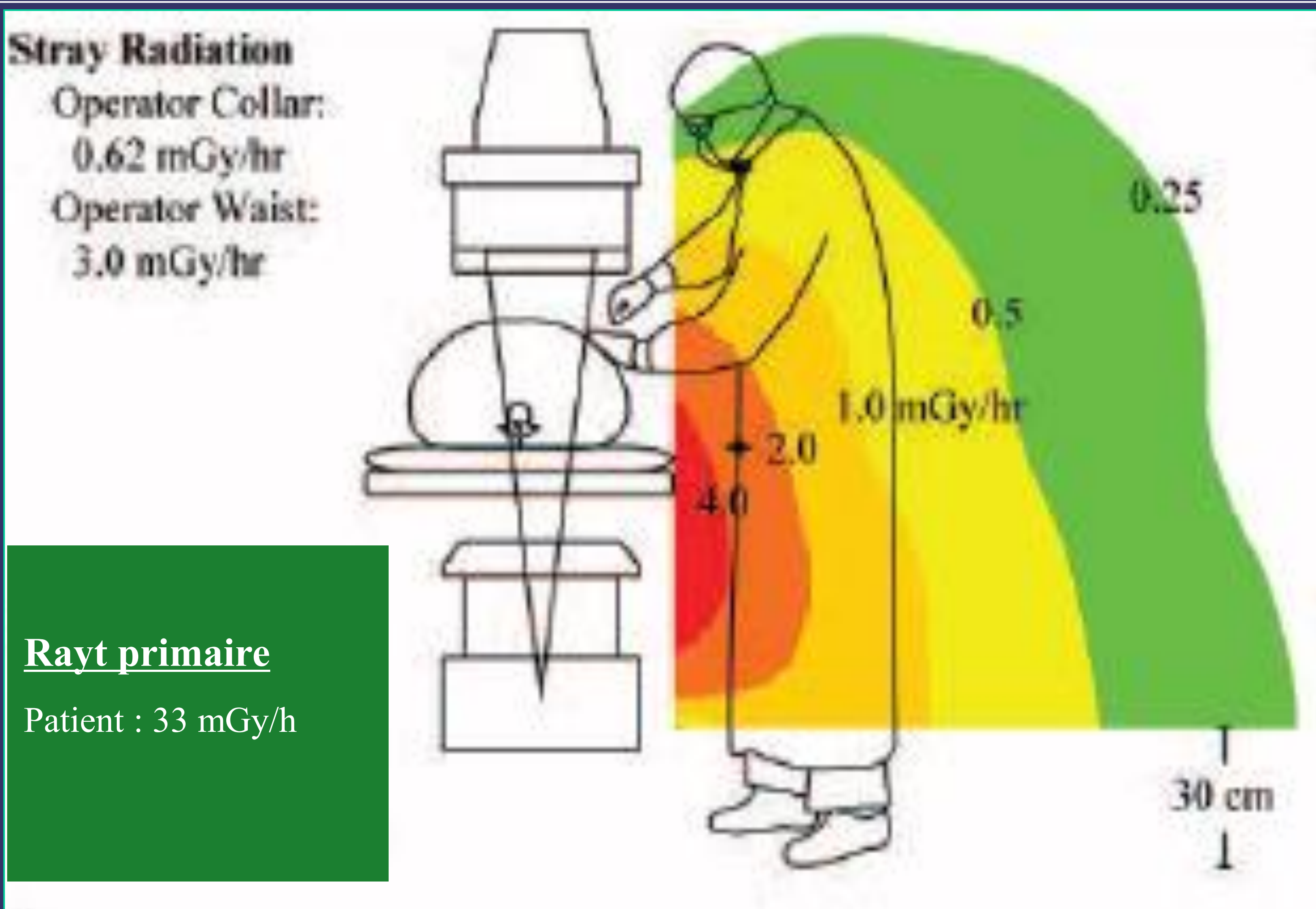
Optimisation is possible … tools are available (CT Scan)





- Dose monitoring solution fully integrated into imaging networks
- Automatically generated monthly reports
  - Integrated automatic reports generated once a month and sent to team members by email
- Defining the right image quality and dose

Professionnal exposure: interventional radiology



Rayt primaire

Patient : 33 mGy/h

D'après B.A. *Schueler et al, Radiographics (2006)*

Data published on doses received mesured by TLD (B Aubert IRSN)

For all types of procedures

Dosimeter position	Equivalent de dose procédures proches (mSv/procédure)	Equivalent de dose procédures éloignées (mSv/procédure)
Right hand	0,19 à 5,15	0,07 à 2,14
Left hand	0,34 à 4	0 03 à 5,89
Thyroïd (without prot.)	0,04 à 0,11	0,07 à 0,28
Lens eyes (without prot.)	0,05	0,01 à 0,56

- Amiel M.et al, Irradiation du médecin, du patient et du personnel médical dans les explorations cardiaques et vasculaires. J Rad Elec M N (1977)
- Cruikshang J.G. et al, Finger doses received by radiologist during chiba needle percutaneous cholangiography. Br J Radiol (1980)
- Gustafsson M. et al, Personnal exposure to radiation at some angiographic procedures. Radiology (1981)
- Santen B.C. et al, Exposure of the radiologist to scattered radiation during angiography. Radiology (1981)
- Jeans S.P. et al, An investigation of the radiation dose to staff during cardiac radiological studies. Br J Radiol (1985)
- Johnson L.W. et al, Review of radiation safety in the cardiac catheterization laboratory. Catheterization and Cardiovascular Diagnosis (1992)
- Germanaud J. et al, Radioprotection des opérateurs lors des cholangio-pancréatographies rétrogrades endoscopiques. Gastro Clin Biol (1993)
- Whitby M et al, A study of the distribution of dose across the hands of interventional radiologists and cardiologists. Br J Radiol (2005)

Interventionnal Cardiac Procedures

Eyes

- Vaño et al (1998) 0,294 mSv/proc.
- Steffenino et al (1996) 0,075 "
- Li et al (1995) **0,088** "
- Medeiros et al (1990) **0,400** "

Hands

- Vaño et al (1998) 0,364 mSv/proc.
- Steffenino et al (1996) 0,300-0,545 "
- Padovani et al (1998) **0,050** (D) " 0,150 (T) mSv/proc.
- Grant et al (1993) 0,05-0,011 (D) "
- Medeiros et al (1990) **0,680** "

(D) : Diagnostique *(T) : Thérapeutique*

Influence of the way

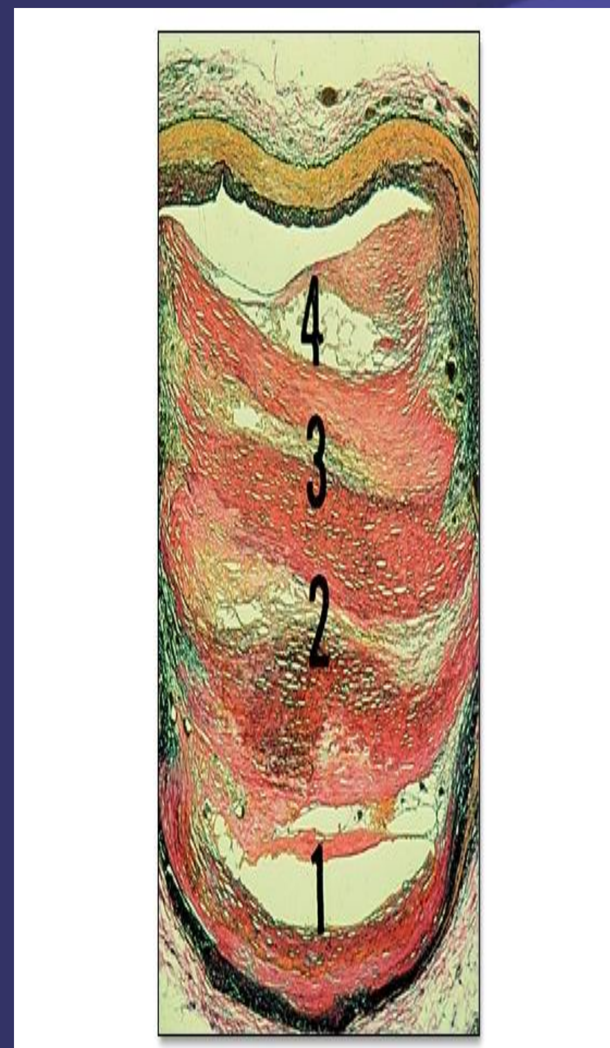
fémoral : 0,060 mSv
radial : 0,350 mSv

Whitby M et al, A study of the distribution of dose across the hands of interventional radiologists and cardiologists. BJR (2005)

Part 4: The need for a good medical practice handbook: Example: interventional cardiology

Mendoza, October 2013

The First optimisation prevent the disease!
the best dose is the avoided dose, zero dose!



Treating the typical coronary patient

- Heart scan …….
- Followed by "several" coronarography scans and "several" CTA procedures
- An initial scintigraphy, then every 3 to 5 years

- Followed by non-invasive cardiac investigations…

Survey on Technical imperfections in the field of coronarography (308 coronarography scans) *(Leape, Am Heart J 2000;139:106-13)*

No technical deficiencies	153	49.6%
No reference segment	32	11.4%
Inadequate separation from background	35	11.4%
Inadequate lesion/vessel separation	67	22%
Inadequate opacification flow	48	15.6%
Inadequate opacification technique	68	22%
Inadequate radiographic procedure	10	3.2%
Totally inadequate	7	2.3%
Epicardial vessel not injected	5	1.6%

Dose reduction is desirable in daily practice and requires the establishment of reference levels

The establishment of "good practices" requires a minimum level of <u>standardisation</u>

Good medical practices :
What objectives for interventional cardiology??

1 / Designate a lead for each centre

2 / Review and approve indicators for procedures using ionizing radiation (see existing recommendations) and for procedures forming part of recommendations, provide preliminary information préalable (informed consent)

3 / Establish a minimum technical matrix for imaging acquisition and processing tools:

- Which modulate dose to patients/personnel,
- Which provide a high level of radiation protection

Good medical practices:
What objectives for interventional cardiology??

4 / Document the procedure (approach, angle, contrast, dose reduction techniques, etc..) for patient, Physicians, aids and visitors, AND determine the best compromise between image quality and radiation exposure (ALARA)

5 / Provide radiation protection information to persons other than medical personnel (patient, doctors, aids, visitors)

Good medical practices:
What objectives for interventional cardiology??

6 / Document results which should include patient and personnel exposure data (cumulative dose!!)

7 / Establish tracking and monitoring indicators and procedures (patients, tools, personnel, visitors)

8/ Provide continuing training and periodic updating of personnel knowledge

Recommandations de la Société française de cardiologie concernant la formation des médecins coronarographistes et angioplasticiens, l'organisation et l'équipement des centres de coronarographie et d'angioplastie coronaire

P. Meyer, P. Barragan, D. Blanchard, B. Chevalier, P. Commeau, N. Danchin, J. Fajadet, A. Grand, J.-M. Lablanche, J. Machecourt, J.-P. Metzger, J.-P. Monassier, J.-L. Neimann, J. Puel et P.-G. Steg

Le texte de ces recommandations a été approuvé par le bureau et le conseil d'administration de la Société française de cardiologie (président : R. Haïat) et par le bureau du groupe « Angiographie et cardiologie interventionnelle » de la Société française de cardiologie (président : P. Meyer).

(*Tirés à part* : Dr P. Meyer).

Société française de cardiologie, 15, rue Cels, 75010 Paris.

PRÉAMBULE

La prévalence des maladies cardiovasculaires notamment coronaires demeure élevée en France. Pour y faire face, notre pays s'est doté d'un réseau de soins efficace incluant les médecins généralistes et urgentistes, les cardiologues, les moyens de transports médicalisés et de nombreuses unités d'hospitalisation publiques et privées. L'évaluation de l'état cardiaque et coronaire par cathétérisme artériel et par angiographie sélective a pris une part croissante dans l'appréciation du pronostic de ces affections. L'angioplastie coronaire est devenue la méthode de revascularisation la plus employée dans le monde.

Ces actes invasifs doivent être réalisés par des cardiologues ayant acquis une compétence spécifique et travaillant dans des centres de cathétérisme respectant des impératifs d'organisation et de fonctionnement qui ont déjà fait l'objet de recommandations de la Société française de cardiologie [1, 2]. Une réactualisation de ces textes était néanmoins nécessaire car l'essor considérable de ces méthodes diagnostiques et thérapeutiques justifie que les modalités de leur réalisation soient définies plus précisément, afin de dispenser des soins de qualité à l'ensemble de la population. C'est le rôle de la Société française de cardiologie d'apporter sa contribution scientifique et professionnelle à un projet de rationalisation des soins cardiologiques en France.

L'élaboration de ce document a respecté la démarche habituelle adoptée par la Société française de cardiologie. Dans un premier temps, elle a nommé un groupe d'experts chargé de rédiger un texte prenant en compte les travaux scientifiques les plus récents. Lorsque, sur certains sujets, les données manquaient ou s'avéraient inexploitables, voire contradictoires, l'opinion exprimée s'est fondée sur le plus large consensus recueilli au sein du comité de rédaction. Le texte a ensuite été discuté et amendé par un comité de relecture puis par le comité d'éthique et le conseil d'administration de la Société française de cardiologie qui l'a finalement approuvé.

Ces recommandations feront l'objet de réactualisations, si de nouvelles données scientifiques ou techniques le nécessitent.

Situation actuelle de la France

L'enquête du « Groupe Angiographie et cardiologie interventionnelle » de la Société française de cardiologie sur l'activité des centres de cathétérisme français en 1998 a recensé 210 centres de cathétérisme cardiaque dont

Part 5: few challenges for radiation therapy discussed during the Bonn Conference

Mendoza, October 2013

RADIATION THERAPY CHALLENGES

- Complexity
- Software domination
- Non standard beams/fields
- In Vivo dosimetry
- questions around Radiobiology (radio sensitivity, second tumors and children)
- Tissue activation
- Evidence of effectiveness (absolute/relative)
- Challenges countries with few resources
- the importance of an Event reporting system for radiation therapy which must become available and will have a major role in providing information for event reduction

Conclusions

Mendoza, October 2013

Conclusions

- Do not underestimate the significance of dose delivered by conventional radiology compared with scans for paediatric imaging
- Radiation dose optimisation in children requires a high level of technicality
  - Continuous search for the most appropriate techniques
  - Use of restraint systems
  - Choice of parameters for a multitude of morphotypes
- Decrease the doses received with a CT scan is possible
- Establish a interventional radiology good practice handbook
- The need of DRLs for all imaging procedures
- The role of software will continue to become more and more important in the use of radiation in medicine
- Periodic self-assessment of delivered dose is the only way to ensure effective dose optimisation

Conclusion

- **Events occurring in the areas of radiotherapy and interventional radiology, resulting from accidental overexposures in medical environments, As well as small events occurring in our day-to-day practices need to be reported and analysed**
- **We must pay attention to the large Increase in radiation dose due to the CT scan in the United States and Europe and more specifically, radiation exposure during childhood**
- **All this challenges have shown us that <u>in addition to good medical practices and continuous improvement of RP performance, radiation protection practices need to be embedded within a common and sustainable culture.</u>**

An ongoing process on IRPA RP culture Guidelines for professionals .... From nuclear industry to the medical sector

<u>As mentioned Abel yesterday “we finished the circle, the circle is now circled “</u>

“What you are will show in what you do”
Thomas Edison

Thank you for your attention !