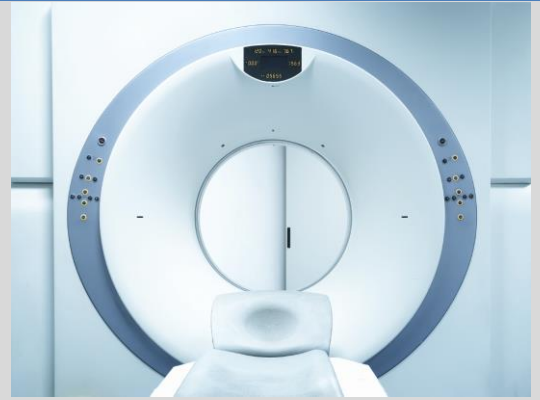


Province-wide dose optimisation in CT and PET-CT through a collaborative and multidisciplinary approach, in Canada

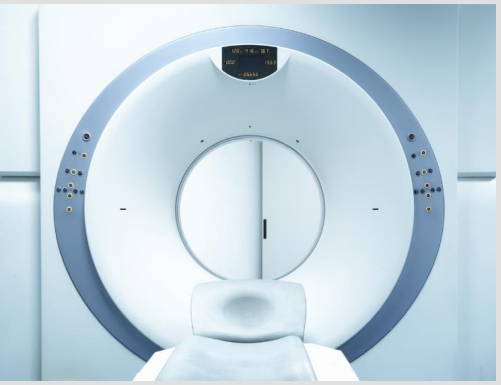
Manon Rouleau, Canada

2nd IRPA Workshop on the Reasonableness in the Implementation of the ALARA Principle

manonr@radioprotection.qc.ca 1-855-649-5213

Disclosure Statement

- VP Operation and Quality at Radioprotection Inc.
- Chair of the Dose & Imaging WG at the *Canadian Radiation Protection Association* (CRPA)
- BoD member of the *Association des physiciens et ingénieurs biomédicaux du Québec* (APIBQ)



- Former director of the *Centre d'expertise clinique en radioprotection* (CECR)
- Former coordinator of the CT and PET-CT provincial tour for CECR

Summary

- Canada and Quebec Context in ***Doses due to Medical Exposure***
- Quebec's ***Dose Survey*** and ***Optimisation Task Force***
- Optimisation ***Results*** in CT and PET-CT
- ***Recommendations*** and Discussion

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CT and PET-CT Optimisation Results

CT Optimisation

Average Dose Reduction for Standard Protocols

- ✓ **19%** for Head protocol
- ✓ **24%** for Chest protocol
- ✓ **20%** for Abdomen-Pelvis protocol

PET-CT Optimisation

Average Dose Reduction for Standard Protocol

- ✓ **27%** for CT full body protocol
- ✓ **26%** from FDG-F18 injection

Geography 101

Canada

- Surface area ≈ Europe
- Population ≈ 5% Europe
- Confederation: 10 provinces and 3 territories

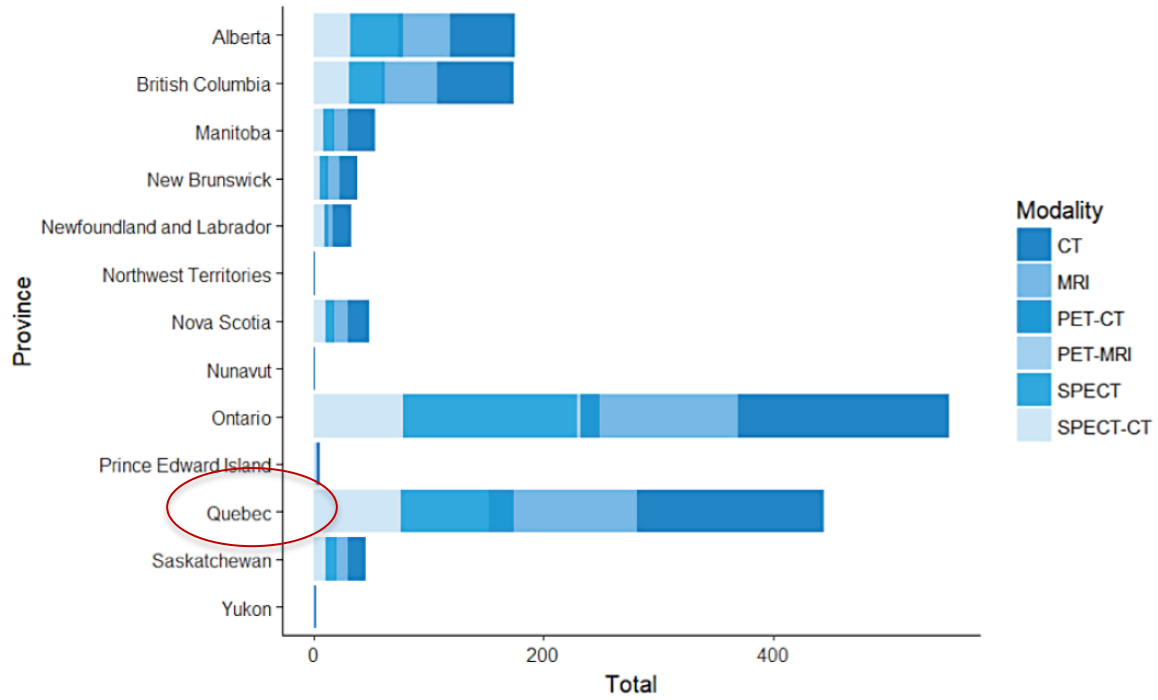
Province of Quebec:

- Surface area ≈ 2x France
- Population ≈ 13% France
- Population: 22% of Canada

Hospitals & X-rays are under provincial jurisdiction

Canada and Québec

Figure 1: Overall Provincial or Territorial Inventory of CT, MRI, PET-CT, PET-MRI, SPECT, and SPECT-CT in 2017



The Canadian Medical Imaging Inventory, 2017. Ottawa: CADTH; 2018 Mar.

Canada

- 561 CT
- 51 PET-CT

Québec:

- 29% CT (163)
- 41% PET-CT (21)

Summary

- Canada and Quebec Context in Doses due to Medical Exposure
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Annual Effective Dose per capita, due to Medical Imaging

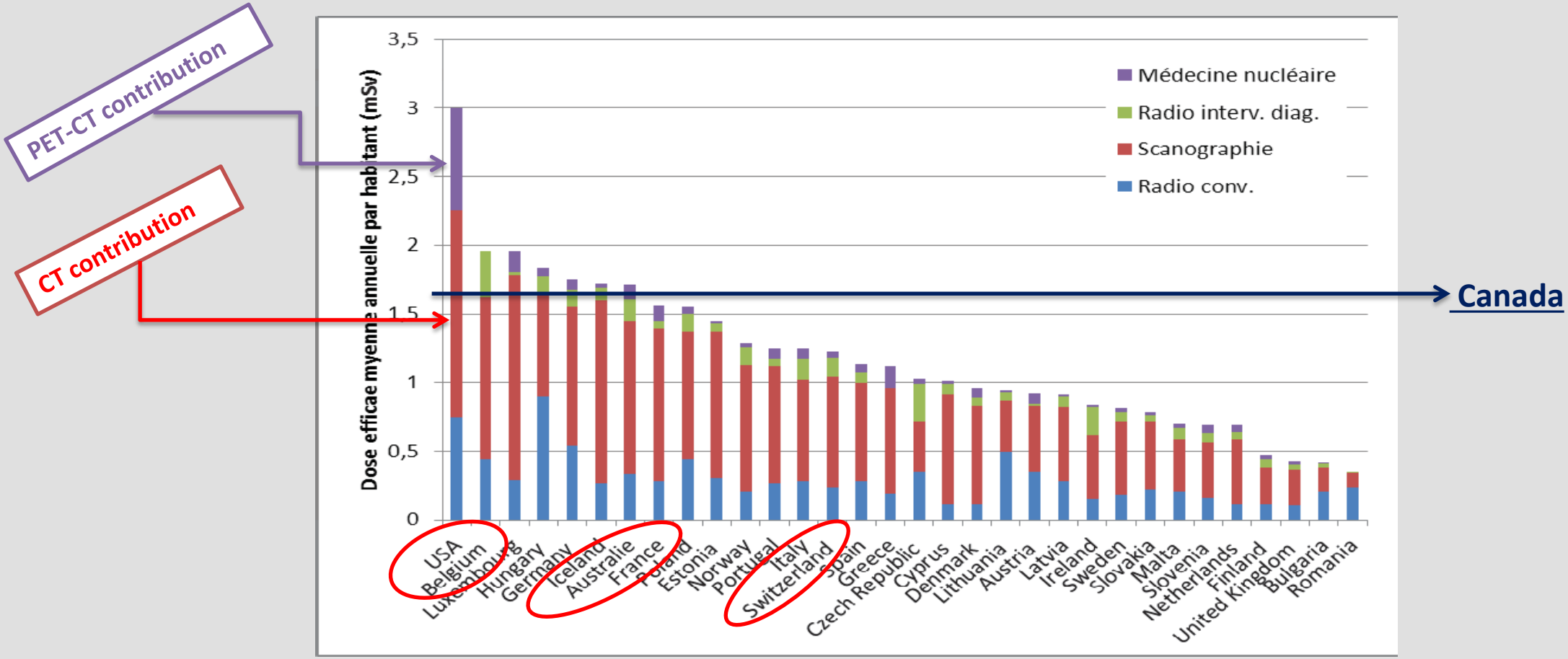


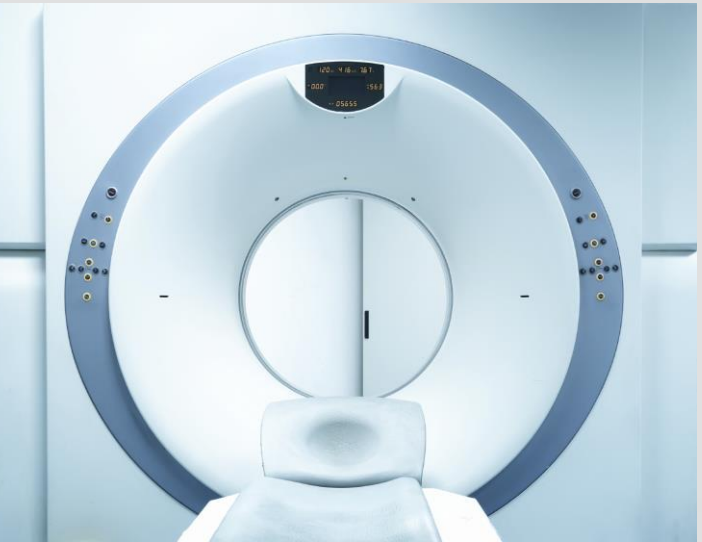
Figure 24 - Répartition de la dose efficace annuelle individuelle par type d'exploration diagnostique dans les 27 pays de l'UE, la Suisse, la Norvège, l'Islande, les Etats-Unis et l'Australie [38 - 40]. La contribution de la radiologie dentaire n'est pas disponible pour les Etats-Unis, ainsi que celle de médecine nucléaire pour la Belgique.

IRSN, Exposition de la population française aux rayonnements ionisants liés aux actes de diagnostic médical en 2012, Rapport PRP-Hom no 2014-6

389 % Increase of the Annual Effective Dose per Capita, between 1990 and 2007

Table 3. Summary of the number of CT scanners in Canada, CT examinations per 1000 Canadians, and annual population effective dose due to diagnostic CT exams for the periods of 1990–1991 and 2006–2007.

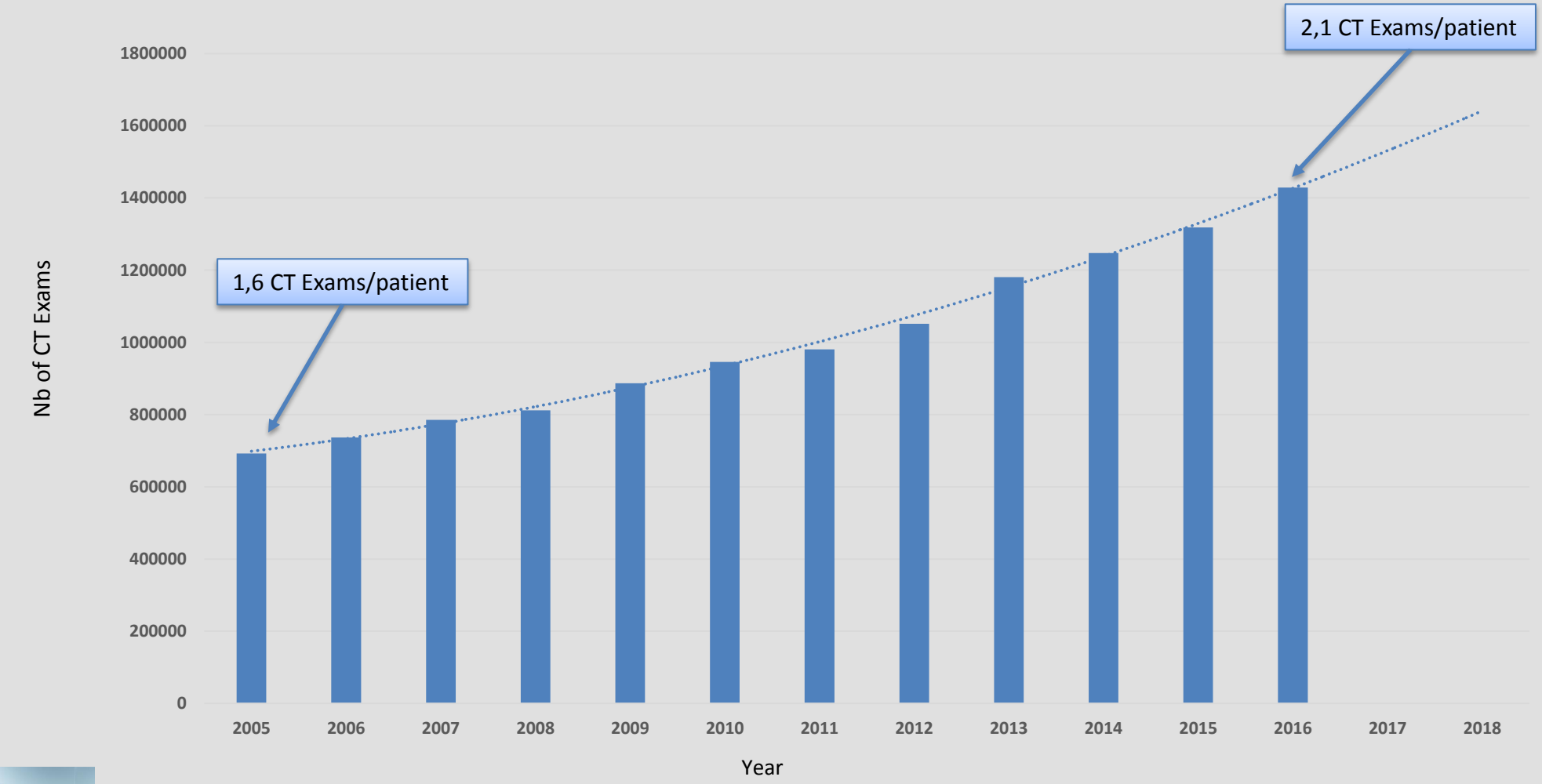
Number of CT scanners		Exams per 1000 population		Annual effective dose per capita	
1990–1991	2006–2007	1990–1991	2006–2007	1990–1991	2006–2007
199	419	37	103	0.19 mSv	0.74 mSv



CT exams in Quebec, in 2007 ⟶ **0,79** mSv per capita

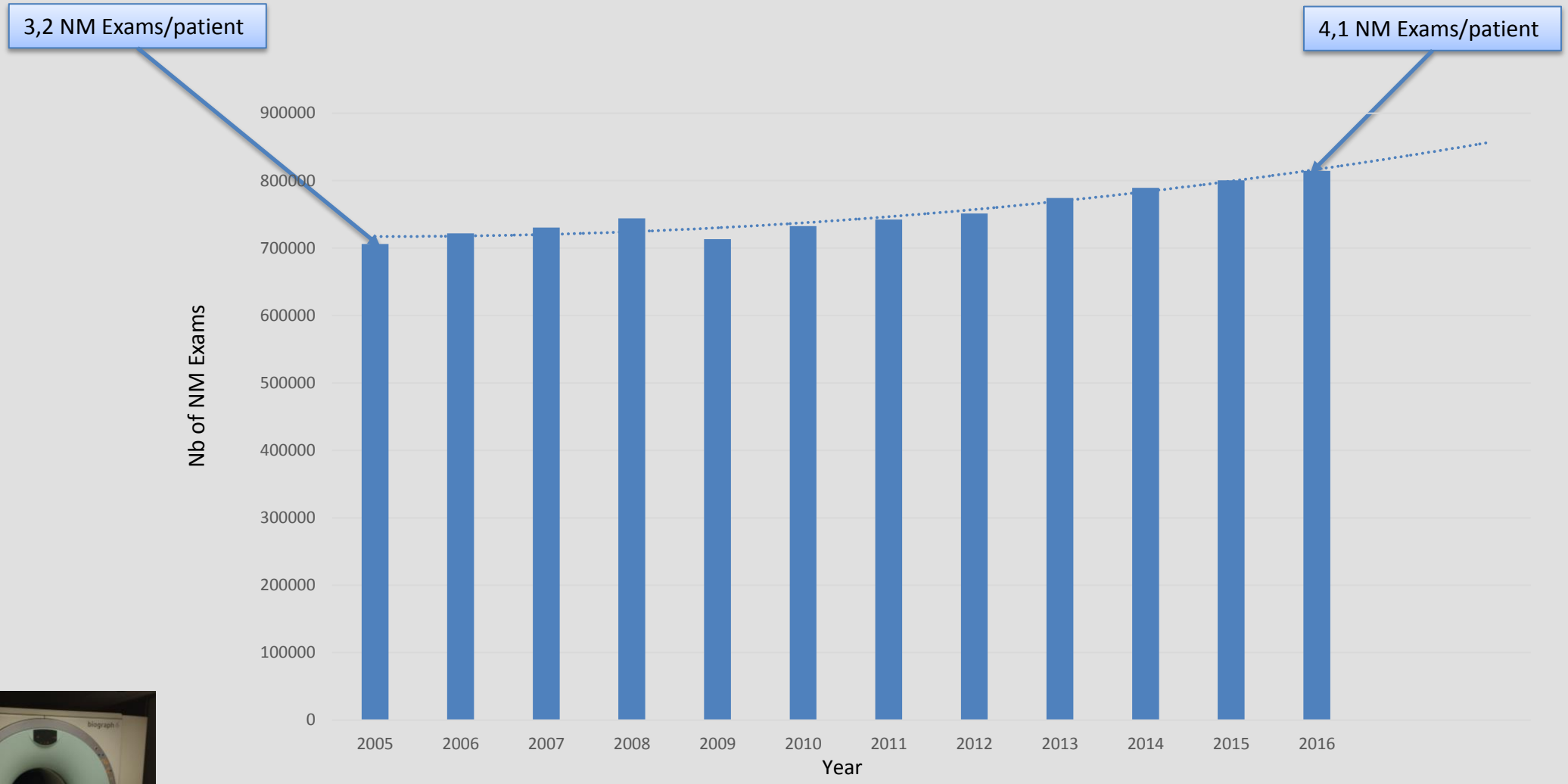
Jing Chen and Deborah Moir, **An estimation of the annual effective dose to the Canadian population from medical CT examinations**, J. Radiol. Prot. 30 (2010) 131–137, doi:10.1088/0952-4746/30/2/002

Nb of CT Exams, in Quebec from 2005 to 2016



RAMQ, Rapport d'études et Statistiques. Tableau SM31.Nombre de participants, nombre de services médicaux, nombre par participant, coût des services médicaux et coût par participant selon la région sociosanitaire du participant, le sexe, le groupe d'âge du participant et le type de service, rémunération à l'acte, médecine et chirurgie, https://www4.prod.ramq.gouv.qc.ca/IST/CD/CDF_DifsnInfoStats/CDF1_CnsulInfoStatsCNC_iut/DifsnInfoStats.aspx?ETAPE_COUR=2

Nb of Nuclear Medicine Exams, in Quebec from 2005 to 2016



RAMQ, Rapport d'études et Statistiques. Tableau SM31.Nombre de participants, nombre de services médicaux, nombre par participant, coût des services médicaux et coût par participant selon la région sociosanitaire du participant, le sexe, le groupe d'âge du participant et le type de service, rémunération à l'acte, médecine et chirurgie,
https://www4.prod.ramq.gouv.qc.ca/IST/CD/CDF_DifsnInfoStats/CDF1_CnsulInfoStatsCNC_iut/DifsnInfoStats.aspx?ETAPE_COUR=2

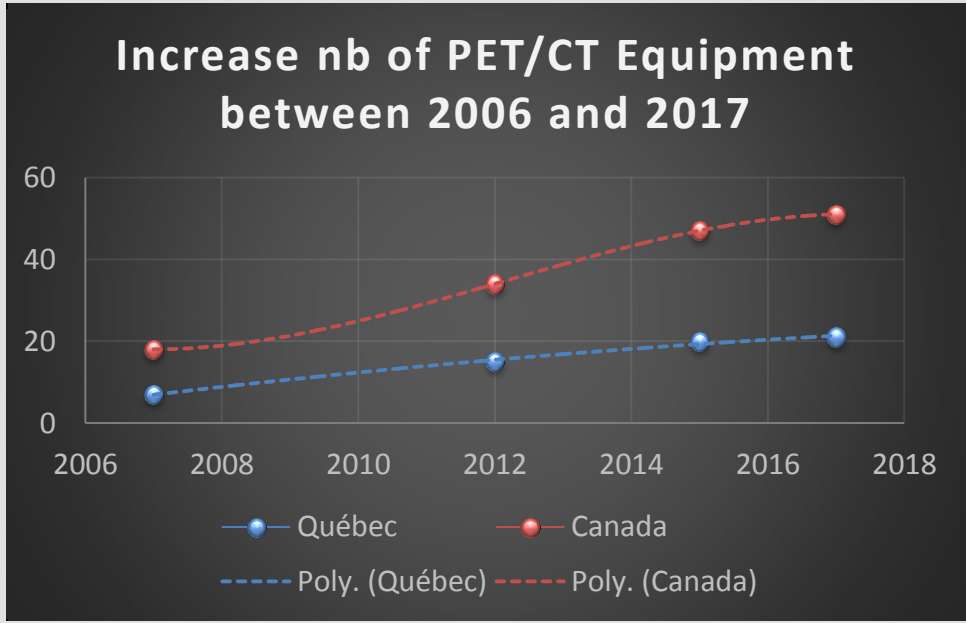
PET-CT Equipment and Exams

Increase nb of PET-CT Exams, from 2015 to 2017

	2015	2017	% Increase
Quebec	42320	50823	20%
Canada	76824	90530	18%

The Canadian Medical Imaging Inventory, 2017. Ottawa: CADTH; 2018 Mar.
The Canadian Medical Imaging Inventory, 2015. Ottawa: CADTH; 2016 Mar

45% of all the PET-CT exams in Canada, are done in Quebec



The impact of PET-CT on Nuclear Medicine doses

PET/CT is the largest contributor to NM doses

In France , PET/CT provide 41% of all NM doses for 21% of all NM exams

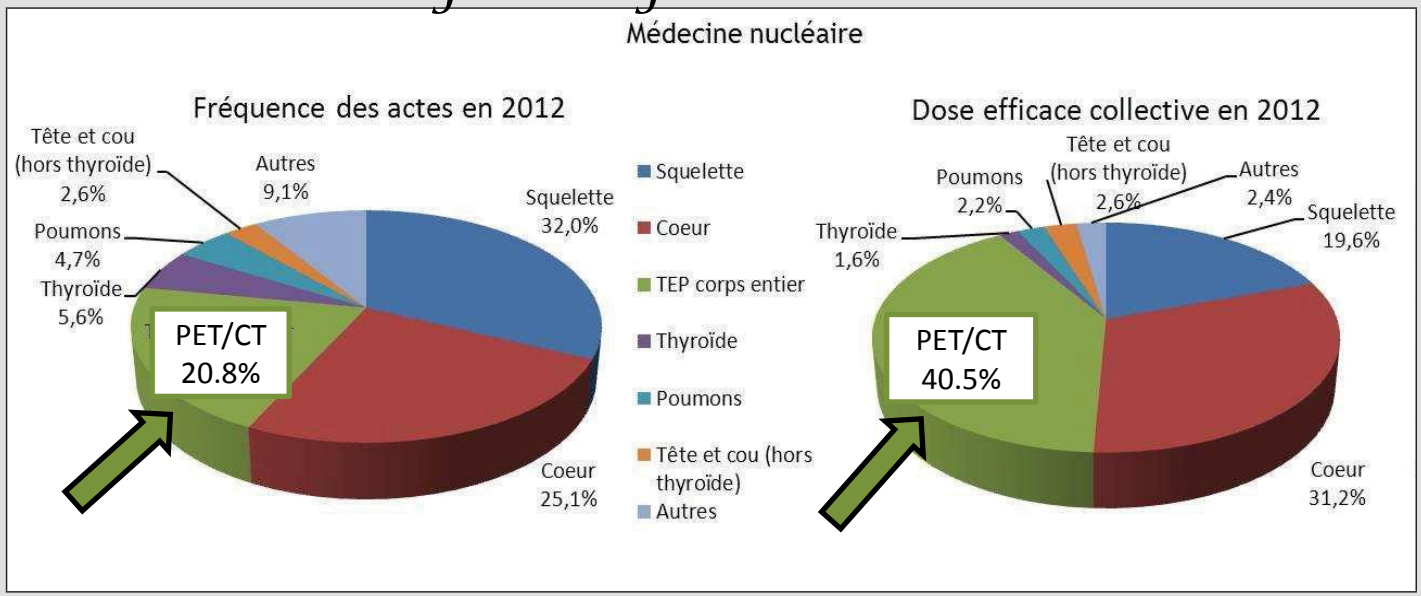


Figure 6, p.20 - Répartition de la fréquence des actes et de la dose efficace collective par anatomique explorée, en médecine nucléaire, France entière, 2012. - Exposition de la population française aux rayonnements ionisants liée aux actes de diagnostic médical en 2012, Rapport PRP-HOM N°2014-6, IRSN, www.irsn.fr/FR

Summary

- Canada and Quebec Context in Doses due to Medical Exposure
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- Recommendations and Discussion

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A First Provincial CT Dose Survey

Why?

- ❖ Concerns from the health professionals involved

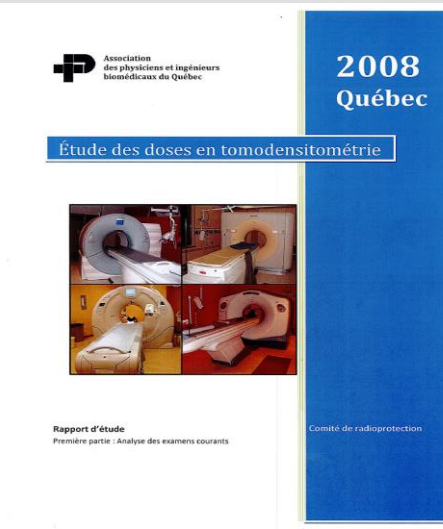
  (i.e. radiologist, technologist, engineers and physicist)

Who conducted it?

- ❖ APIBQ : the Association of biomedical physicist and engineers of the province of Québec
- ❖ Supported by Ministry of Health and all health professional associations

Conclusion

- ✓ CT Dose = 50% doses due to medical exposure
- ✓ Wide variation of CT protocols across Quebec hospitals
- ✓ Optimisation of standard CT protocols is required



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Following the CT dose Survey… in 2009

Ministry of Health and Social Services (MSSS)

✓ Publication of a **Dose Reduction Action Plan**

✓ Creation of a **Provincial Center of Clinical Expertise in Radiation Protection** (CECR)

CECR
CENTRE D'EXPERTISE CLINIQUE EN RADIOPROTECTION

CECR's Mandate and mission

❖ **Assist** the MSSS in the implementation of the Dose Reduction Action Plan

❖ **Provide support** to Hospitals dealing with complex radiation safety issues

❖ **Recommend** & **Promote** best practices in radiation safety in medical imaging

CECR : Independent group of experts working in a collaborative multidisciplinary approach

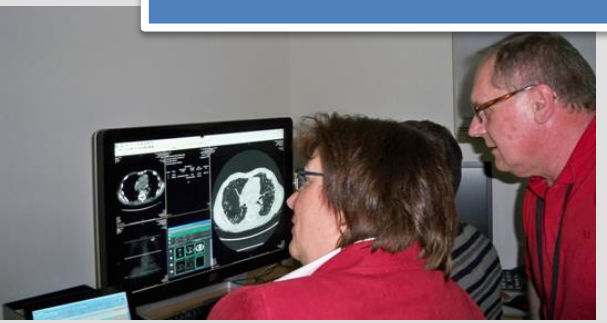
- Funded by Quebec's Ministry of Health
- Located in and supported by, a University Health Center
- Guided by a Steering Committee comprised of key stakeholders
- To provide free of charge support to all publicly-funded hospital

CECR
CENTRE D'EXPERTISE CLINIQUE EN RADIOPROTECTION

Key element:

Active commitment of key stakeholders
to improve radiation safety of patient

CECR's Structure



- 3 Engineers
- 5 Medical imaging technologists
- 2 Physicians
- 4 Physicists

Small Permanent Team ⟷ **Part time teams**

- **Specific expertise by modality**
- **Service loan from Health Network**
- **Involvement as necessary**

Key element:

Multidisciplinary team **without hierarchy**

Facilitate knowledge sharing

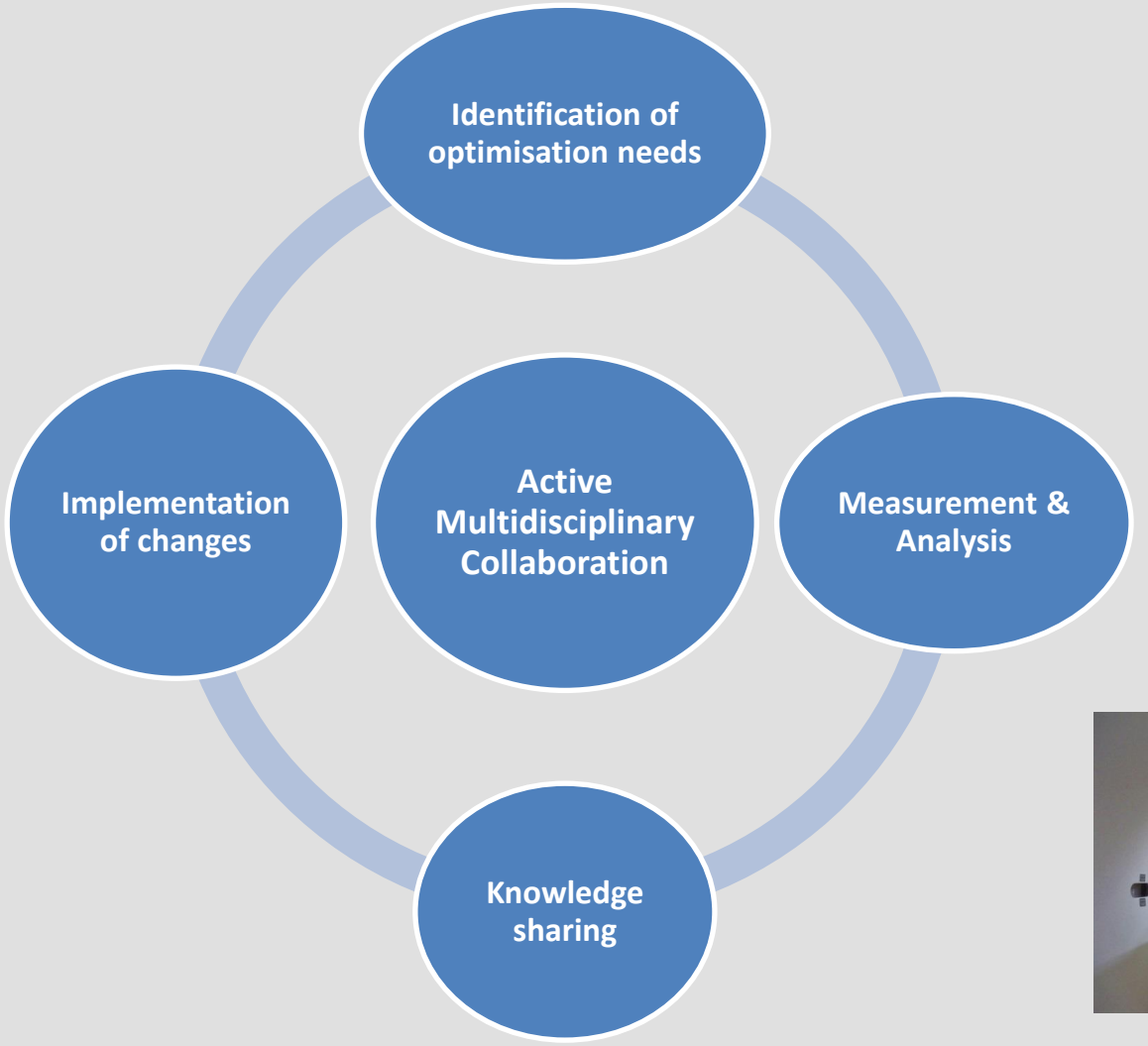
The challenges in optimisation

- Patient dose optimisation is a continuous process
  - ❖It must take into account **evolution of technology**, clinical practices and knowledge
  - ❖It demands **commitment of all stakeholders**, including senior management and authorities
  - ❖It requires **multidisciplinary collaboration**, knowledge sharing and monitoring

Key element:

Development of **Standard Optimisation Approach** to be able to compare results

Optimisation, a continuous process



Mission of the Provincial Tour

*To **initiate dose optimisation** in each hospital*

and

*To provide **training**, **tools** and **support** to the local team*

GOAL:

*So local team **take ownership***

of the optimisation process

CT and PET-CT Provincial Tour Objectives

OBJECTIVE

ALADA

- **Quality Assurance** evaluation of devices and practices
- Initiate **dose Optimisation** process, with the local team
- **Support & guide** the local imaging team, with regards to dose reduction strategies & radiation safety

- ALADA : *As Low As Diagnostically Achievable*

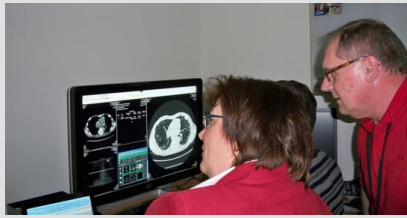
Provincial Tour Methodology

Before the visit:

- Survey hospitals
- Data analysis

Visit : Day 1

- Meet with local team
- Radiation safety assessment
- Performances assessment
- Clinical cases analysis



Visit: Day 2

- Meet with local team
- Optimisation proposal
- Clinical cases and analysis with MD
- Report Submission

Following the visit:

- Image qualification by local MD
- Data analysis & feedback

Key element:

Direct Field Work with local team,
Allow more efficient optimisation

Multidisciplinary Team Required for each visit

CECR Team

- ✓ 1-2 Engineer and/or Physicist
- ✓ 1-2 Medical Imaging Technologist

Local Team

- ✓ 1 Physician
- ✓ 1 Engineer or Physicist
- ✓ 1 Medical Imaging Technologist
- ✓ 1 Administrator

Key element:

Rotation of team members for the visit

Allow transfer of expertise across the entire task force

Summary

- Canada and Quebec Context in Doses due to Medical Exposure
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RADIOPROTECTION INC.

CT : patient dose Optimisation

- 1st Focus on standard protocols : Head, Chest & Abdomen-pelvis
- On request, other specific CT protocols

From 2011 to 2016 → 112 CT scans optimised

Table 2. Proportion of protocols modified during the CT tour.

Routine protocols	With contrast (%)	Without contrast (%)
Head	82	82
Chest	92	85
Abdomen-pelvis	86	84

Table 3. Achieved dose reduction per modified protocols.

Routine protocols	Avg. (%)	min (%)	max (%)	SD (%)
Head	19	6	60	12
Chest	24	2	50	11
Abdomen-pelvis	20	5	52	11

M.A. Nassiri, M. Rouleau, P. Després, CT DOSE REDUCTION:APPROACHES, STRATEGIES AND RESULTS FROM A PROVINCE-WIDE PROGRAM IN QUEBEC, Journal of Radiological Protection, Volume 36, Number 2, 2016

2nd CT Dose Survey - 2014

- In 2014 another CT dose survey was conducted (with Health Canada)

Table 4. CT doses in Quebec from 2008 and 2014 surveys for standard adult patients (60–80 kg).

	Mean DLP (mGy · cm)			75 percentile DLP (mGy · cm)		
Routine protocols	2008	2014	Reduction (%)	2008	2014	Reduction (%)
Head	1209	1013	16	1352	1115	18
Chest	432	323	25	496	405	18
Abdomen-pelvis	766	634	17	850	764	10

DRL improvement

*DLP : Dose Length Product

*DRL : Dose Reference Level

DRL = 75th percentile of DLP distribution

M.A. Nassiri, M. Rouleau, P. Després, CT DOSE REDUCTION:APPROACHES, STRATEGIES AND RESULTS FROM A PROVINCE-WIDE PROGRAM IN QUEBEC, Journal of Radiological Protection, Volume 36, Number 2, 2016

Comparison between Canada and Quebec 2014 Canadian CT Dose Survey

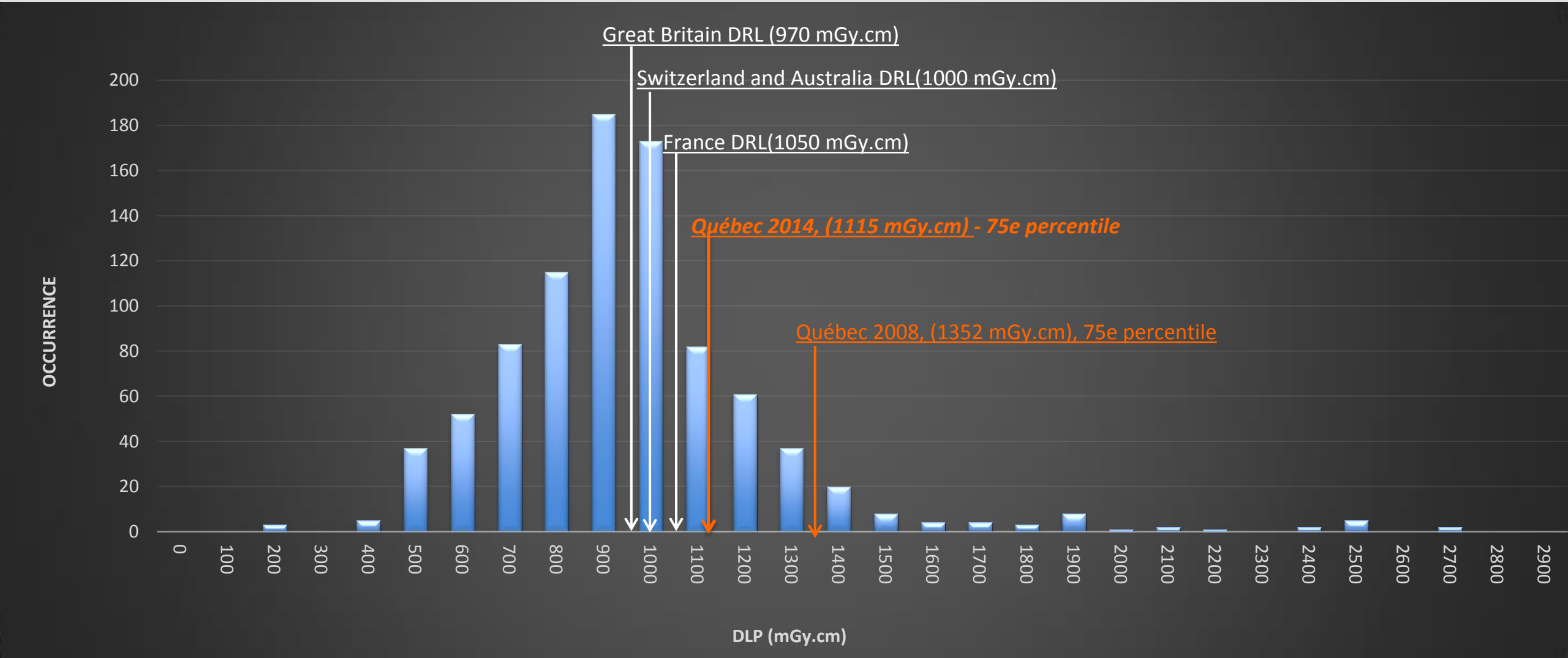
Standard Protocol	Canada's DRL (mGy.cm)	Quebec's DRL (mGy.cm)
Head	1302	1115
Chest	521	405
Abdomen-pelvis	874	764

Radiological Protection, Volume 36, Number 2, 2016

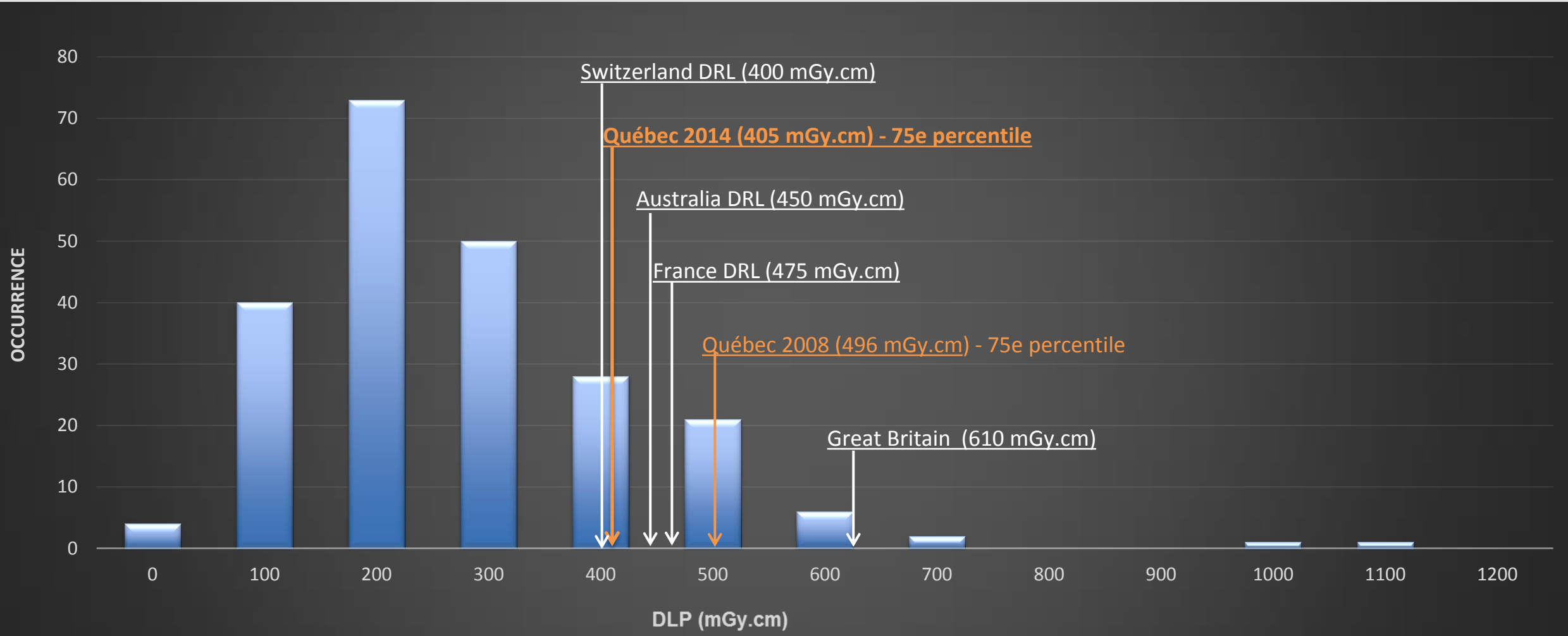
- Health Canada, CANADIAN COMPUTED TOMOGRAPHY SURVEY - NATIONAL DIAGNOSTIC REFERENCE LEVELS, Health Canada 2016

2014 Canada's DRL ≈ 2008 Quebec's DRL

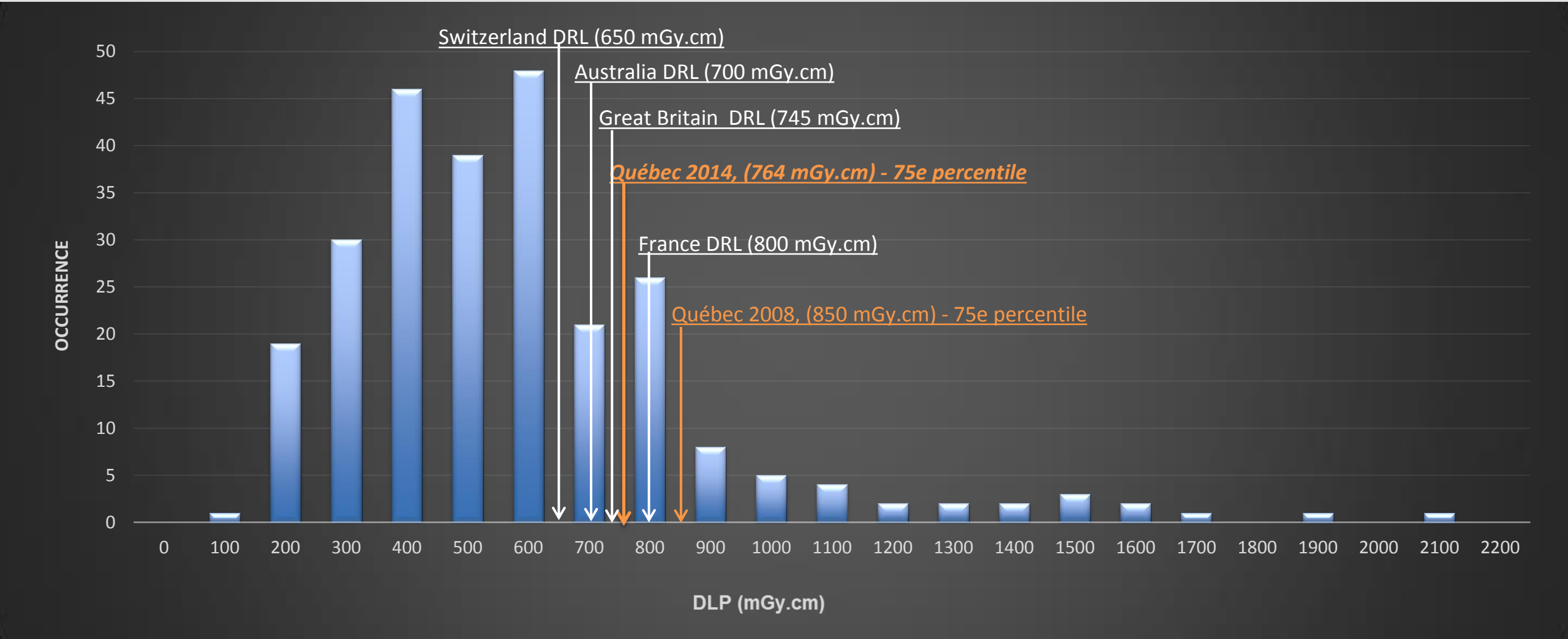
Quebec's 2014 CT Survey distribution of DLP : Head Protocols



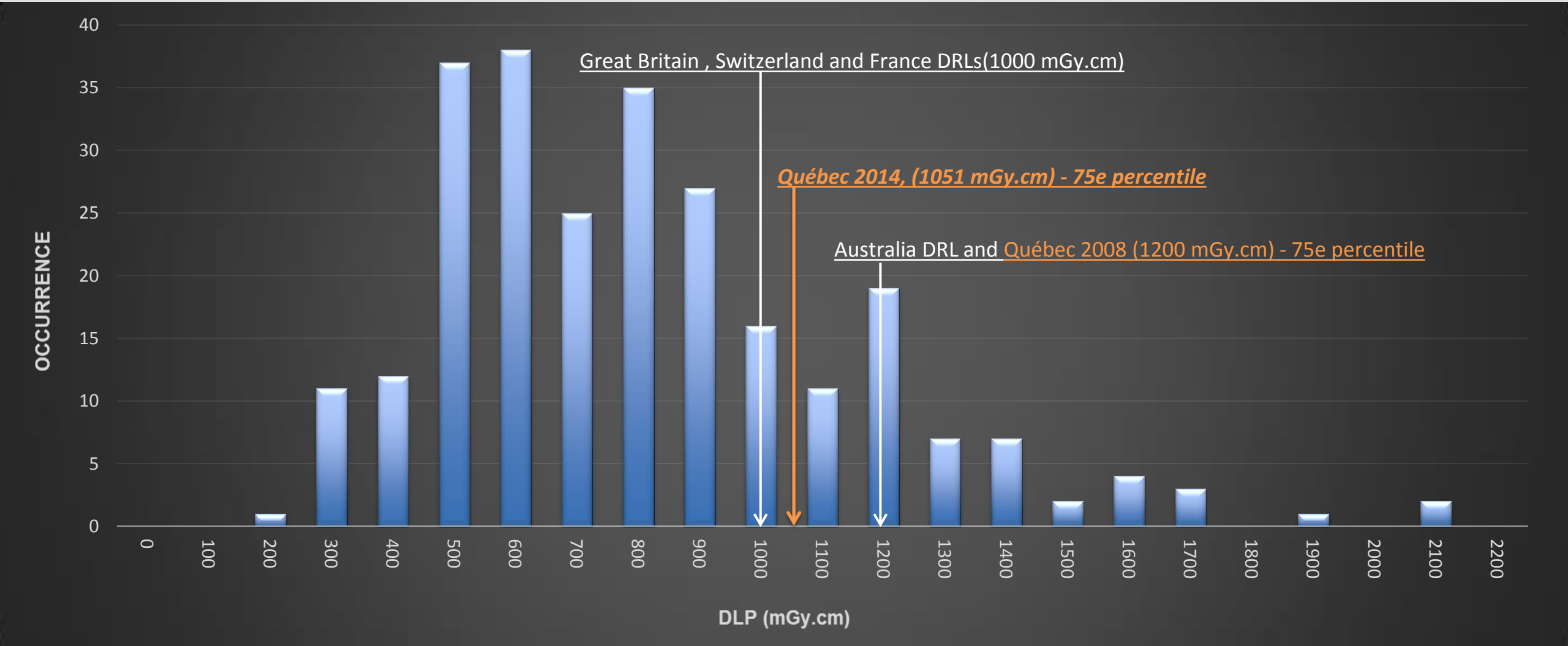
Quebec's 2014 CT Survey distribution of DLP : Chest Protocols



Quebec's 2014 CT Survey distribution of DLP : Abdomen-Pelvis Protocols

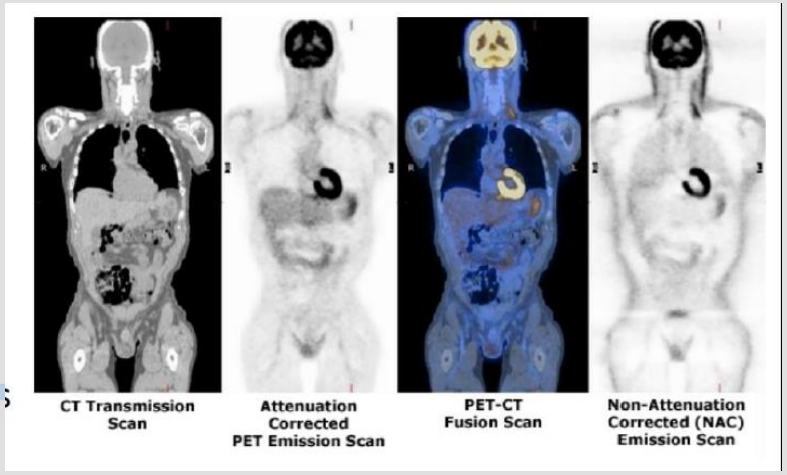


Quebec's 2014 CT Survey distribution of DLP : Chest-Abdomen-Pelvis Protocols



PET-CT patient dose optimisation

- **Focus on Full Body standard protocol**
  - *^{18}F-FDG injected dose optimisation*
  - *CT protocols optimisation*



Source: Notes du cours DÉTERMINANTS ONCOLOGIE PARTIE II, Collège Ahuntsic

^{18}F-FDG Injection Guidelines - Adults

Guidelines	Publication date	Recommendations
EANM (Europe)	2009	➢ Bed overlap 25 % : 13.8 (MBq/Kg)/(bed/min) ➢ Bed overlap 50% : 6.9 (MBq/Kg)/(bed/min) ➢ Maximum : 530 MBq
ACR-SPR (USA)	2014	370 to 740 MBq
Japanese guideline : synopsis of Version 1.0	2010	Based on minimal criteria of quality image on phantom and patients

❖ 3D Adult's oncologic protocols

DRLs and recommandations for ^{18}F-FDG

Table 1 DRLs for ^{18}F-FDG/PET scans in adult cancer patients.

Country	DRLs ^{18}F-FDG		
	MBq	MBq.kg^{-1}	mCi.kg^{-1}
Germany (2003)	370 (2D) 200 (3D)	2.86 (3D)	0.08 (3D)
Australia and New Zealand (2009)	385	5.5	0.148
Finland (2009)	370	5.3	0.143
France (2012)	350	5.0	0.135
United Kingdom (2006)	400 – tumor and heart	5.7	0.154
Switzerland (2007)	350	5.0	0.135
Sweden (2006)	350	5.0	0.135

Oliveira CM, Sá LV, Alonso TC, Silva TA. Suggestion of a national diagnostic reference level for ^{18}F-FDG/PET scans in adult cancer patients in Brazil. Radiol Bras. 2013 Set/Out;46(5):284–289.

- EANM DRLs recommendation, since 2009: **3.45 MBq/kg**
  - ✓ (2min/bed, 50% superposition)
  - ✓ 207 MBq to 311 MBq (for 60 to 90 kg patients)
- SNM recommendation, since 2006: 370-740 MBq

PET/CT Survey Result before Optimisation

PET/CT

- 9 to 125 cases/week-hosp
- Protocols : Full body, H&N
- **FDG injected**:
  - **3.45MBq/kg to 7.5 MBq/kg**
  - Fixed : 370 to 666 MBq/patient
  - Min-max :185MBq to 740MBq
- **CTDIvol : 1.5 to 27 mGy**

Total dose: from 8 mSv to 43 mSv per patient (average 16 mSv)

PET/CT Retake

(additional scan with delay)

- 1% to 25% of the cases/hosp.
- CT Protocols used for retake:
  - PET/CT Full Body (80%)
  - Fixed CT High Resolution Protocol (20%)

    15 to 25 mGy
- **CTDIvol : 3.5 to 25 mGy**

Total additional dose : 1 to 5 mSv per retake

Potential for dose optimisation: 30% exposure reduction

18F-FDG Optimisation

BEFORE Optimisation

3D

3.45 to 7.5 MBq/kg

(Average injection 5MBq/kg)

2D

Fixed Dose

370 to 740 MBq/patient

AFTER Optimisation

3D

Philips: 3.45 MBq/kg

GE, Siemens: 4 to 4.5 MBq/kg

*maximum: 555 MBq

2D

6.9 to 7.5 MBq/kg

*maximum: 610 to 740 MBq

26 % Average Dose Reduction

CT Optimisation – Attenuation Correction and Registration : STANDARD FULL BODY

BEFORE Optimisation

$CTDI_{vol}$

1.9 to 10.4 mGy

Average: **4.9 mGy**

***WITHOUT current modulation**

AFTER Optimisation

$CTDI_{vol}$

1.4 to 6.2 mGy

Average: **3.5 mGy**

****Scan Length Optimisation***

***WITH current modulation**

***Image quality adapted**
To diagnostic needs

27% Average Dose Reduction

Standard Patients 60 to 90 kg

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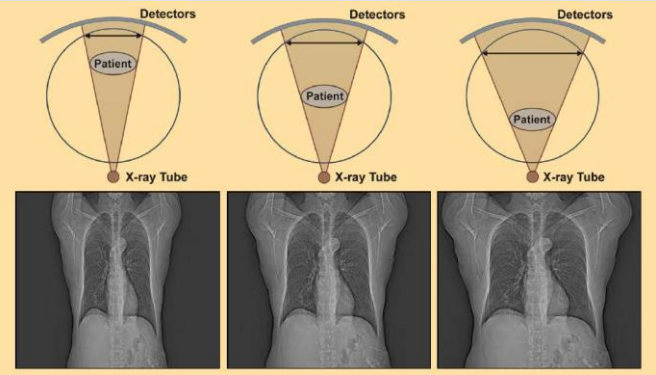
RADIOPROTECTION INC.

CT Tour : Most Frequent Recommendations

- ✓ Implementation of **low dose follow-up protocols**
  - Renal calculi
  - Pulmonary nodules
- ✓ Compliance with **scan range** (as defined by local guidelines)
- ✓ Adequate **positioning** of patients
- ✓ Adequate use of **bismuth shielding**, whenever possible
  - Training and recommendation published by CECR
  - Practical training provided on site during the visit



Source : Jim Kofler, Optimizing CT Image Protocols With Respect To Image Quality and Radiation Dose

Source : Nassiri MA, Rou;eau M. Gagnon G., Positionnement et utilization des caches au bismuth en tomodensitométrie, CECR, 2014

PET/CT Tour : Most Frequent Recommendations

- ✓ Removal of **metallic items** prior to exam
- ✓ Compliance with **injections conditions** and **resting time**
- ✓ Adequate **positioning** of patients
- ✓ Compliance with **scan range** (as defined by local guidelines)
- ✓ Usage of **CT Current Modulation**

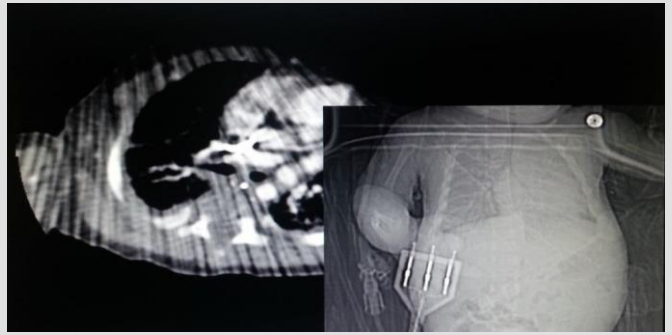
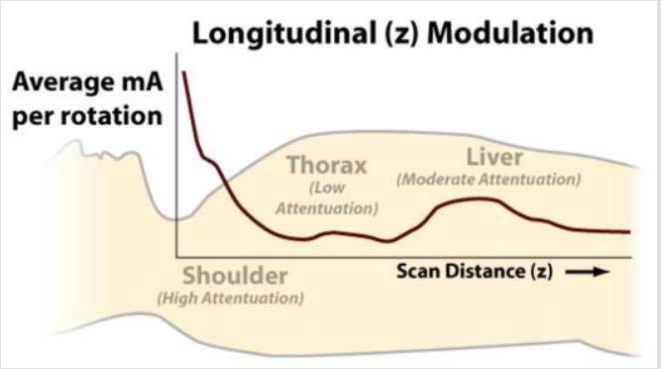


Image: Frush DP. How to best use current technology for pediatric body CT; 2013



Source : AAPM Computed Tomography Radiation Dose Education Slides, 2013 .

Training provided to local teams

CT
&
PET/CT

- Basic Principles
- Modulation Tools
- CTDIvol, DLP
- Positioning
- Quality Control
- Good practices in radiation protection

PET/CT

- How to reconstruct PET image to simulate effect of dose reduction
- Injections conditions and resting time

Achievements

- ✓ Effective dose optimisation with **significant dose reduction to patient**
- ✓ **Great field collaboration** between Optimization Task Force and Local Teams
- ✓ Improved **understanding of PET/CT and CT** technology specificity
- ✓ Raised **patient radiation safety awareness** in imaging department
- ✓ Improved **Radiation Safety Practice**

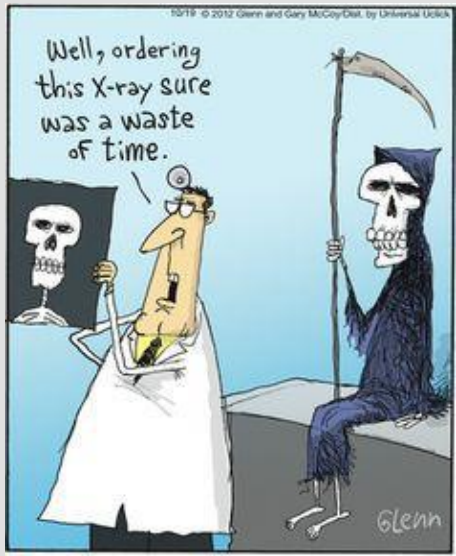
For everyone's benefit,
but especially for patient

Discussions

- Optimisation is a continuous process, work should continue
- There is still more that can be done, with:
  - **Technology improvement**
  - **Continuing education in radiation protection**

An avenue to look at with ALL the physicians :

JUSTIFICATION principle



Other Actions from the Task Force

- 2013 → Published a QC manual for CT

  → Provided formal training on CT QC

- 2015-2016 → Re-visited selected CT installations for additional support

- 2017 → Organised a Workshop on medical dose tracking

2018: RIP- Ceased operations

What about the future?

The two sides of a coin

MINUS	PLUS
➢ Risk of loosing the expertise acquired	➢ Experts and local teams can continue optimisation in their own hospitals
➢ Potentially return back to square one	➢ Informal network of experts still there

What about the future?

The two sides of a coin

MINUS

- No more:
  - Provincial RP center
  - Free access to RP expertise in hospitals
  - Concerted actions in patient RP
  - Formal forum knowledge sharing

PLUS

- Experts continue to promote optimisation through professional association by:
  - ✓ Creating working group
  - ✓ Organising workshops
  - ✓ Participating to panel
  - ✓ Giving talks

Questions

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