Diagnostic reference levels in medical practice

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Contents

✓ Rationale for RP in medicine
✓ Diagnostic reference levels
✓ DRL parameters
✓ A DRL strategy
Rationale for RP in medicine (1)

Medical exposures

- Cosmic rays: 7%
- Radon: 34%
- Food: 6%
- Water: 11%
- Earth: 11%
- Others: 1%
- Medical exposures: 41%

Rationale for RP in medicine (1)

Effective dose per caput 0.5 – 3.5 mSv
Rationale for RP in medicine (2)

- Medical exposures = largest source of exposition of artificial origin
- Medical exposures are increasing with medical imaging growth: diagnosis, therapeutic strategy, therapy
- Domain of low doses? except in therapy, repeated CT and interventional radiology
- High collective dose: the total population is concerned although most examinations in old patients, but children are more sensitive
Rationale for RP in medicine (3)

The principles of radiation protection

- Justification: Yes
- Optimisation: Yes
- Limitation of dose: No

- A good quality image is necessary in order not to compromise the clinical value associated with the exposure, i.e., the diagnosis or the therapeutic strategy,
- The highest possible dose must be delivered to cure a tumor
Rationale for RP in medicine (4)

Justification principle

- The clinical benefit outweighs the risk associated with the exposure: the benefit is immediate and the risk of low doses of IR, if it exists, is small at a long term!
- Goal: to perform only useful exposure, i.e., examinations which result being positive or negative is expected to comfort the diagnosis or to change patient management
- Referral criteria for imaging guide to help fulfill the justification principle
Rationale for RP in medicine (5)

Optimisation principle

- Once an examination has been decided, the corresponding procedure must be optimized: ALARA
- Procedure guide to help fulfill the optimisation principle
- Attention to be paid to the most frequent examinations and those delivering the highest doses
- Attention to be paid to children, young adults, pregnant women
Diagnostic reference levels in medical practice

Rationale for RP in medicine (6)
Diagnostic reference levels

A tool for optimisation
Council directive 97/43/Euratom of 30 juin 1997 on health protection of individuals against the dangers of ionizing radiation in relation to medical exposure and repealing directive 94/466/Euratom.

Art 4 : Member States promote the establishment and the use of diagnostic reference levels for radiodiagnostic examinations

Recommendation 73, 1996

Diagnostic reference levels in medical practice
DRLs are defined in the Council Directive 97/43 Euratom as
“dose levels in medical radiodiagnostic practices or, in the case of radiopharmaceuticals, levels of activity, for typical examinations for groups of standard-sized patients or standard phantoms for broadly defined types of equipment. These levels are expected not to be exceeded for standard procedures when good and normal practice regarding diagnostic and technical performance is applied”.

Thus DRLs apply only to diagnostic procedures in radiology or nuclear medicine and do not apply to radiation therapy.
Diagnostic reference levels (1)

Needs

- Need for the evaluation that procedures are optimized and remained optimized
- Need for quantitative indicators of the doses delivered
- Indicators must provide an evaluation of the performance of the examination
- Indicators to be used to continuously improve the procedures
Diagnostic reference levels in medical practice

Diagnostic reference levels (2)

Strategy: to perform a longitudinal monitoring of Indicators

• in each department
• for each medical device
• for comparison between institutions at a national and international level
• as a mean to know the necessity for further optimisation of exposures
Diagnostic reference levels (3)
Which criteria for the indicators?
They must

- be clearly defined
- easy to measure or to calculate
- give directly an indication of the importance of the dose delivered
- allow easy correlations with the technical parameters of the examination
- be adapted to all type of equipements
Diagnostic reference levels (4) are not

- dose limits or constraints
- optimal values
- separated from the image quality
- applicable to individual exposures
- indicators of radiological risk
- a line of separation between good and poor practice
Diagnostic reference levels (5) are

- established for the most frequent and irradiating routine examinations
- for groups of standard size patients (70 ± 3 kg and 20cm antero-posterior trunk thickness)
- or for standard phantoms
- obtained for specific groups of children (age, size, weight)
- guides for optimisation
• DRLs should not be exceeded in routine when examinations are performed in accordance with the procedures (good and normal practice)
• The goal is not to deliver doses constantly lower than DRLs because images of “poor quality” would not provide the diagnostic information (large patients)
Diagnostic reference levels (7)
The use of DRLs for optimisation

• DRL parameters are measured in each institution
• DRLs are established nationally
• Local reviews of DRL parameters are undertaken routinely
• Comparison is made with national values
• Actions are taken if DRLs are exceeded consistently
The necessity to establish DRLs

- Large dispersion of doses
- Limitation of dose dispersion
- Necessity to harmonize good practices
- Suppression of useless doses
Dispersion of doses

Variability of mean entrance dose (mGy) to patients in different countries for the same examination

(European Commission Trial 1991)

<table>
<thead>
<tr>
<th>Country</th>
<th>Lumbar spine (face)</th>
<th>Lumbar spine (profile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Espagne</td>
<td>46,2</td>
<td>56,8</td>
</tr>
<tr>
<td>Irlande</td>
<td>17,1</td>
<td>50,1</td>
</tr>
<tr>
<td>Allemagne</td>
<td>30,6</td>
<td>46,7</td>
</tr>
<tr>
<td>Norvège</td>
<td>14,6</td>
<td>45,4</td>
</tr>
<tr>
<td>France</td>
<td>23,1</td>
<td>36,5</td>
</tr>
<tr>
<td>UK</td>
<td>14,9</td>
<td>35,3</td>
</tr>
<tr>
<td>Italie</td>
<td>26,1</td>
<td>30,3</td>
</tr>
<tr>
<td>Belgique</td>
<td>11,5</td>
<td>27,4</td>
</tr>
<tr>
<td>Pays-Bas</td>
<td>8,4</td>
<td>27,1</td>
</tr>
<tr>
<td>Danemark</td>
<td>9,9</td>
<td>19,9</td>
</tr>
</tbody>
</table>
Dispersion of doses
French study (2001-2002)
Variation of mean entrance dose in different French institutions for lumbar spine X ray

Diagnostic reference levels in medical practice
Dispersion of doses

Variability of mean entrance dose in different French institutions (2001-2002)

<table>
<thead>
<tr>
<th>Examination</th>
<th>Chest Post-Anterior</th>
<th>Abdomen</th>
<th>Lumbar spine Face</th>
<th>Lumbar spine Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of institutions</td>
<td>24</td>
<td>21</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td><strong>Mean De (mGy)</strong></td>
<td>0.28</td>
<td>5.2</td>
<td>8.2</td>
<td>19.5</td>
</tr>
<tr>
<td><em><em>Mean De (Maximale</em>)</em>*</td>
<td>0.70</td>
<td>10.4</td>
<td>19.2</td>
<td>36</td>
</tr>
<tr>
<td><em><em>Mean De (Minimale</em>)</em>*</td>
<td>0.09</td>
<td>2.4</td>
<td>5.2</td>
<td>9.5</td>
</tr>
<tr>
<td>Max/Min between institution</td>
<td>7.8</td>
<td>4.3</td>
<td>3.7</td>
<td>3.8</td>
</tr>
</tbody>
</table>

*per institution
Dispersion of doses

French study (2001-2002)

Mean = 0.28 mGy.  3rd perc. = 0.35 mGy.
Min. = 0.06 mGy.  Max. = 1.13 mGy.

Diagnostic reference levels in medical practice
## Dispersion of doses

French study (2001-2002)

Variability of mean DLP for different CT examinations for different institutions

<table>
<thead>
<tr>
<th>Examination</th>
<th>Chest standard</th>
<th>Chest high resolution</th>
<th>Abdomen standard</th>
<th>Brain standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of institutions</td>
<td>15</td>
<td>12</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td><strong>Mean DLP (mGy.cm)</strong></td>
<td>316</td>
<td>81</td>
<td>384</td>
<td>735</td>
</tr>
<tr>
<td>Absorbed Dose*</td>
<td>14 mGy</td>
<td>4 mGy</td>
<td>15 mGy</td>
<td>50 mGy</td>
</tr>
<tr>
<td>Effective Dose*</td>
<td>4,5 mSv</td>
<td>1,1 mSv</td>
<td>6 mSv</td>
<td>1,5 mSv</td>
</tr>
<tr>
<td><strong>DLP max (mGy.cm)</strong></td>
<td>675</td>
<td>241</td>
<td>921</td>
<td>2117</td>
</tr>
<tr>
<td><strong>DLP min (mGy.cm)</strong></td>
<td>156</td>
<td>27</td>
<td>186</td>
<td>267</td>
</tr>
<tr>
<td>Ratio max/Min</td>
<td>4,3</td>
<td>8,9</td>
<td>4,9</td>
<td>7,9</td>
</tr>
</tbody>
</table>

*rough evaluation
Which DRL parameters?
They must be

- clearly defined
- easy to measure or to calculate
- directly correlated with the parameters of the procedure
- easily accessible
- adapted to all types of equipment

- in nuclear medicine: injected activities
- in radiology: doses
Diagnostic reference levels in medical practice

The choice of DRL parameter in classical radiology (1)

Which dose?

- dose rate in air mGy/s
- entrance dose mGy
- absorbed dose mGy
- product (dose x area),
  DAP Gy.cm²
- effective dose mSv.
Diagnostic reference levels in medical practice

The choice of DRL parameter in classical radiology (2)

(mGy or mSv : one example)

3 « doses » for one single view !!!

<table>
<thead>
<tr>
<th>Examination</th>
<th>Entrance Dose De</th>
<th>Mean absorbed Dose</th>
<th>Effective Dose E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doses ...*</td>
<td>Milligrays (mGy)</td>
<td></td>
<td>Millisieverts (mSv)</td>
</tr>
<tr>
<td>Abdomen</td>
<td>10</td>
<td>uterus</td>
<td>1,5</td>
</tr>
</tbody>
</table>
Diagnostic reference levels in medical practice

The choice of DRL parameter in classical radiology (3)

Entrance dose: $D_e$

$D_e = D_{air} \times BSF$

BSF: backscatter factor
$1.2 < BSF < 1.50$

Dose in air $\rightarrow$ $D_e$ (mGy) $\rightarrow$ Backscatter radiations
Diagnostic reference levels in medical practice

The choice of DRL parameter in classical radiology (4)

Entrance dose \( D_e = K_0 \times BSF \times (U/100)^2 \times Q \times (1/DSS)^2 \)

- Tension \( U \) (kV)
- Charge \( Q \) (mAs)
- Distance ‘Source-skin’ DSS(m)
- Coefficient \( K_0 \) (mGy/mAs à 1m) characteristic of the installation: dose rate in air
- Factor BSF (between 1.2 and 1.5)

Calculation: \( D_e = 0.15 \times (U/100)^2 \times Q \times (1/DSS)^2 \)

Measurement:

*Immediate with electronic detectors*

*Delayed with TLDs*
Diagnostic reference levels in medical practice

The choice of DRL parameter in classical radiology (5)
Calculation of De: \[ De = 0.15 \times \left( \frac{U}{100} \right)^2 \times Q \times \left( \frac{1}{DSS} \right)^2 \]

Example for Abdomen X ray

<table>
<thead>
<tr>
<th>Tension U kV</th>
<th>Charge Q mAs</th>
<th>DSS m</th>
<th>De mGy</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>66</td>
<td>0.75</td>
<td>10*</td>
</tr>
<tr>
<td>75</td>
<td>80</td>
<td>0.75</td>
<td>12</td>
</tr>
<tr>
<td>75</td>
<td>30</td>
<td>0.80</td>
<td>4</td>
</tr>
<tr>
<td>80</td>
<td>30</td>
<td>0.80</td>
<td>4.5</td>
</tr>
<tr>
<td>80</td>
<td>40</td>
<td>0.75</td>
<td>6.8</td>
</tr>
<tr>
<td>70</td>
<td>75</td>
<td>0.75</td>
<td>9.8</td>
</tr>
</tbody>
</table>

* NRD value for abdomen X ray

→ patient thickness: 25cm (DSS =0.75m) or 20cm (DSS =0.80m)
Diagnostic reference levels in medical practice

The choice of DRL parameter in classical radiology (6)

**Dose area product : DAP**

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**Units !**

\[
1 \text{ Gy.cm}^2 = 100 \text{ cGy.cm}^2 = 1000 \text{ mGy.cm}^2
\]

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Dose Area Product

- Surface proportional to \( d^2 \)
- Dose proportional to \( 1/d^2 \)
- Product dose.area independent of \( d \)
Diagnostic reference levels in medical practice

The choice of DRL parameter in classical radiology (7)

Calculation of De from DAP: \( \text{De} = (\text{DAP}/\text{Ae}) \times \text{BSF} \)

Examples for abdomen (BSF = 1.35)

<table>
<thead>
<tr>
<th>DAP</th>
<th>Length (skin)</th>
<th>Width (skin)</th>
<th>De</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>7000</td>
<td>31,5</td>
<td>30</td>
</tr>
<tr>
<td>2,08**</td>
<td>2080</td>
<td>31</td>
<td>29</td>
</tr>
<tr>
<td>0,90**</td>
<td>900</td>
<td>34</td>
<td>27</td>
</tr>
<tr>
<td>4,5 Gy.cm²</td>
<td>4.5 x 1000 mGy.cm²</td>
<td>30 cm</td>
<td>30 cm</td>
</tr>
</tbody>
</table>

\[ \text{De} = (\frac{4500}{900}) \times 1.35 \]

* DRL value for abdomen X ray
** measurement in Val de Grâce hospital
Diagnostic reference levels in medical practice

The choice of DRL parameter in classical radiology (8)

Calculation of De from DAP: \( De = \frac{DAP}{Ae} \times BSF \)

Examples for abdomen (BSF = 1.35)

<table>
<thead>
<tr>
<th>DAP</th>
<th>Length (skin)</th>
<th>Width (skin)</th>
<th>De</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gy.cm(^2)</td>
<td>mGy.cm(^2)</td>
<td>cm</td>
<td>cm</td>
</tr>
<tr>
<td>7</td>
<td>7000</td>
<td>31,5</td>
<td>30</td>
</tr>
<tr>
<td>2,08**</td>
<td>2080</td>
<td>31</td>
<td>29</td>
</tr>
<tr>
<td>0,90**</td>
<td>900</td>
<td>34</td>
<td>27</td>
</tr>
<tr>
<td>4.5</td>
<td>4500</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>3 Gy.cm(^2)</td>
<td>3000</td>
<td>30 cm</td>
<td>20 cm</td>
</tr>
</tbody>
</table>

30 x 20 = 600 cm\(^2\)

\( De = \frac{3000}{600} \times 1.35 \)

* DRL value for abdomen X ray
** measurement in Val de Grâce hospital
The choice of DRL parameter in classical radiology (9)

Calculation of $D_e$ from DAP: $D_e = \left( \frac{DAP}{A_e} \right) \times BSF$

Examples for abdomen (BSF = 1.35)

<table>
<thead>
<tr>
<th>DAP (mGy.cm²)</th>
<th>Length (cm)</th>
<th>Width (cm)</th>
<th>$D_e$ (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7000</td>
<td>31.5</td>
<td>30</td>
<td>10*</td>
</tr>
<tr>
<td>2080</td>
<td>31</td>
<td>29</td>
<td>3.12</td>
</tr>
<tr>
<td>900</td>
<td>34</td>
<td>27</td>
<td>1.32</td>
</tr>
<tr>
<td>4500</td>
<td>30</td>
<td>30</td>
<td>6.75</td>
</tr>
<tr>
<td>3000</td>
<td>30</td>
<td>20</td>
<td>6.75</td>
</tr>
<tr>
<td>3000</td>
<td>30</td>
<td>30</td>
<td>4.5</td>
</tr>
</tbody>
</table>

* DRL value for abdomen X ray
** measurement in Val de Grâce hospital
The choice of DRL parameter in classical radiology (10)

Calculation of De from DAP: \( \text{De} = (\text{PDS}/\text{Ae}) \times \text{BSF} \)

Examples for abdomen (BSF = 1.35)

<table>
<thead>
<tr>
<th>DAP ( \text{mGy.cm}^2 )</th>
<th>Length (cm (skin))</th>
<th>Width (cm (skin))</th>
<th>De ( \text{mGy} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>31.5</td>
<td>30</td>
<td>10*</td>
</tr>
<tr>
<td>0.08**</td>
<td>31</td>
<td>29</td>
<td>3.12</td>
</tr>
<tr>
<td>0.90**</td>
<td>34</td>
<td>27</td>
<td>1.32</td>
</tr>
<tr>
<td>4.5</td>
<td>30</td>
<td>30</td>
<td>6.75</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>20</td>
<td>6.75</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>30</td>
<td>4.5</td>
</tr>
</tbody>
</table>

* DRL value for abdomen X ray  
** measurement in Val de Grâce hospital
Diagnostic reference levels in medical practice

The choice of DRL parameter in CT radiology (1)

- **CTDI**: computerized tomographic dose index (measured in air, in phantoms at the center and periphery, normalized for 100 mAs)
- **CTDI<sub>w</sub>**: weighted CTDI (normalized)
- **CTDI<sub>vol</sub> = CTDI<sub>w</sub> / Pitch** (helix mode)
- **DLP**: Dose x Length product (Gy.cm)
- **Effective dose**: E (mSv)

\[
\text{CTDI} = \frac{1}{T} \int_{-\infty}^{+\infty} D_1(z) \, dz
\]

\[
\text{CTDI}_w = \frac{1}{3} \text{CTDI}_C + \frac{2}{3} \text{CTDI}_P
\]
The choice of DRL parameter in CT radiology (2)

Interest of $\text{CTDI}_\text{vol}$

- Defined in norm CEI 60601-2-44 and $\text{CTDI}_\text{vol}$ value in mGy must be displayed on the screen
- $\text{CTDI}_\text{vol}$ is measurable
- $\text{CTDI}_\text{vol}$ is a good indicator of dose: best represents the mean absorbed dose in the exposed volume
- Linked to a given protocol of examination ($\text{kV}$, $\text{mA}$, $\text{s}$)
Diagnostic reference levels in medical practice

The choice of DRL parameter in CT radiology (3)

Dose x Length Product in helix mode $mGy \times cm$

$$\text{DLP} = n\text{CTDI}_W \times A \times t \times n \times T$$

- $n\text{CTDI}_W$ : CTDI$_W$ normalized (mGy/mAs)
- $A$ : intensity (mA)
- $t$ : time per rotation (s)
- $n$ : number de rotations
- $T$ : width of collimation (cm)
  
  \[\text{(width of one slice } \times \text{ number of slices per rotation)}\]

$$\text{DLP} = \text{CTDI}_{\text{vol}} \times \text{Length explored}$$
Diagnostic reference levels in medical practice

The choice of DRL parameter in CT radiology (4)

Necessity of a parameter for clinical use: DLP

1 slice 10 mm:
CTDI = 15 mGy

20 slices, 20 cm?

DLP = 300 mGy x cm

Dose x Length product (DLP)
Standard chest protocol: influence of mAs

- CT Scanner 16 slices
  - $U = 120$ kV
  - 200 mAs
  - Slice thickness: 5 mm
  - Pitch = 1
  - Length: 30 cm

CTDI$_{vol} = 7$ mGy
DLP = 210 mGy.cm

300 mAs

CTDI$_{vol} = 10.5$ mGy
DLP = 315 mGy.cm
The choice of DRL parameter in CT radiology (6)

Standard chest protocol:
  - influence of pitch

- CT Scanner 16 slices
  - $U = 120$ kV
  - 200 mAs
  - Slice width : 5 mm
  - pitch = 1
  - length : 30 cm
    - $\text{CTDI}_{vol} = 7 \text{ mGy}$
    - $\text{PDL} = 210 \text{ mGy.cm}$

- pitch = 2
  - $\text{CTDI}_{vol} = 3.5 \text{ mGy}$
  - $\text{PDL} = 105 \text{ mGy.cm}$
Standard chest protocol: influence of explored length

- CT Scanner 16 slices
  - $kV = 120$ kV
  - 200 mAs
  - Slice thickness: 5 mm
  - pitch = 1
  - length: 30 cm

$CTD_{vol} = 7$ mGy
$PDL = 210$ mGy.cm

length = 15 cm

$CTD_{vol} = 7$ mGy
$PDL = 105$ mGy.cm
Diagnostic reference levels in medical practice

The choice of DRL parameter in CT radiology (8)

**Conversion DLP \(\rightarrow\) effective dose \(E\)**

<table>
<thead>
<tr>
<th>Body Part</th>
<th>CTDI(_{w})</th>
<th>DLP (\text{mGy.cm})</th>
<th>(f_{\text{pdl}}) (\text{mSv/mGy.cm}^2)</th>
<th>(E) (\text{mSv})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>58</td>
<td>1050</td>
<td>0.0021</td>
<td>2.2</td>
</tr>
<tr>
<td>Neck</td>
<td>12</td>
<td>350</td>
<td>0.0052</td>
<td>1.8</td>
</tr>
<tr>
<td>Chest</td>
<td>27</td>
<td>650</td>
<td>0.017</td>
<td>9.1</td>
</tr>
<tr>
<td>Abdomen</td>
<td>33</td>
<td>770</td>
<td>0.015</td>
<td>9.5</td>
</tr>
<tr>
<td>Pelvis</td>
<td>33</td>
<td>570</td>
<td>0.016</td>
<td>9.1</td>
</tr>
</tbody>
</table>
Diagnostic reference levels in medical practice

The final choice of dosimetric parameters as DRLs

In classical radiology
- Entrance dose (De) in mGy for one exposure
- Dose Area Product (DAP) in Gy.cm\(^2\) for one exposure or for a complete examination

In CT
- CTDI\(_w\) in mGy for one exposure
- Product dose x length (PDL) in mGy.cm for one acquisition and a complete examination
The final choice of dosimetric parameters as DRLs

Why did not we select the effective dose as a DRL?

- Not a measurable physical entity
- No link with the parameters of the examination
- Not helpful for optimizing medical procedures
- Can be calculated from DRLs parameters
Diagnostic reference levels
Their determination (1)

• From dosimetric studies, a national dose distribution is established for each DRL parameter
• DRLs are fixed nationally by experts representing the medical and scientific community who decide the values to be retained
Diagnostic reference levels

The DRL is the 3rd quartile of the dose distribution

- In theory, the dose distribution is obtained and representative of the practice in the country
- European recommendation
Diagnostic reference levels
Their determination (3)

• In France, the 3rd quartile method was not applicable because we did not benefit from an accurate dose distribution for each DRL parameter
• Then, the ASN organized in 2001-2003, with the expertise of IRSN, a national campaign of dose measurements with the help of the learned societies of radiologists (SFR), medical physicists (SFPM) and technologists (AFPPE)
Diagnostic reference levels in medical practice

Diagnostic reference levels

Their determination (4)

The national campaign (2001-2003)

The departments of radiology involved in the dosimetric study
Diagnostic reference levels in medical practice

Diagnostic reference levels in France

In classical radiology

<table>
<thead>
<tr>
<th>Examination</th>
<th>Chest P/A</th>
<th>Abdomen</th>
<th>Lombar spine F</th>
<th>Lombar spine P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of services</td>
<td>24</td>
<td>21</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Number of patients</td>
<td>511</td>
<td>331</td>
<td>195</td>
<td>194</td>
</tr>
<tr>
<td>Mean De * (mGy)</td>
<td>0.28</td>
<td>5.2</td>
<td>8.2</td>
<td>19.5</td>
</tr>
<tr>
<td>3rd quartile* (mGy)</td>
<td>0.35</td>
<td>6</td>
<td>10.4</td>
<td>24</td>
</tr>
<tr>
<td>Ratio **</td>
<td>7.8</td>
<td>4.3</td>
<td>3.7</td>
<td>3.8</td>
</tr>
<tr>
<td>European DRL (mGy)</td>
<td>0.30</td>
<td>10</td>
<td>10</td>
<td>30</td>
</tr>
</tbody>
</table>

* For all patients
** Ratio of Mean De max and Mean De min
# Diagnostic reference levels in France

## Values in classical radiology

<table>
<thead>
<tr>
<th>Examination</th>
<th>$D_e$ in mGy for one exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest face (postero anterior)</td>
<td>0,3</td>
</tr>
<tr>
<td>Chest profile</td>
<td>1,5</td>
</tr>
<tr>
<td>Lumbar spine face</td>
<td>10</td>
</tr>
<tr>
<td>Lumbar spine profile</td>
<td>30</td>
</tr>
<tr>
<td>Abdomen</td>
<td>10</td>
</tr>
<tr>
<td>Pelvis face (postero anterior)</td>
<td>10</td>
</tr>
<tr>
<td>Mammography</td>
<td>10</td>
</tr>
<tr>
<td>Skull face</td>
<td>5</td>
</tr>
<tr>
<td>Skull profile</td>
<td>3</td>
</tr>
</tbody>
</table>
### Diagnostic reference levels in medical practice

**Diagnostic reference levels in France**

**Values in classical radiology (children)**

<table>
<thead>
<tr>
<th>Examination</th>
<th>Age</th>
<th>De in mGy for one exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest (antero posterior)</td>
<td>0-1</td>
<td>0.08</td>
</tr>
<tr>
<td>Thorax (postero anterior)</td>
<td>5</td>
<td>0.1</td>
</tr>
<tr>
<td>Chest (lateral)</td>
<td>5</td>
<td>0.2</td>
</tr>
<tr>
<td>Skull</td>
<td>5</td>
<td>1.5</td>
</tr>
<tr>
<td>Crâne (latéral)</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Pelvis (antero posterior)</td>
<td>0-1</td>
<td>0.2</td>
</tr>
<tr>
<td>Pelvis (antero posterior)</td>
<td>5</td>
<td>0.9</td>
</tr>
<tr>
<td>Abdomen</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Examination</td>
<td>Chest standard</td>
<td>Chest high resolution</td>
</tr>
<tr>
<td>------------------------------</td>
<td>----------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Number of services</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Mean CTDIw (mGy)</td>
<td>13,8</td>
<td>24,5</td>
</tr>
<tr>
<td>European DRL CTDIw</td>
<td>27</td>
<td>---</td>
</tr>
<tr>
<td>French DRL CTDIw</td>
<td>20</td>
<td>---</td>
</tr>
<tr>
<td>Mean PDL (mGy.cm)</td>
<td>316</td>
<td>81</td>
</tr>
<tr>
<td>European DRL PDL</td>
<td>650</td>
<td>---</td>
</tr>
<tr>
<td>French DRL PDL</td>
<td>500</td>
<td>---</td>
</tr>
</tbody>
</table>
## Diagnostic reference levels in France

### Values in CT

<table>
<thead>
<tr>
<th>Examination</th>
<th>CTDIw (mGy)</th>
<th>PDL (mGy.cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>58</td>
<td>1050</td>
</tr>
<tr>
<td>Chest</td>
<td>20</td>
<td>500</td>
</tr>
<tr>
<td>Abdomen</td>
<td>25</td>
<td>650</td>
</tr>
<tr>
<td>Pelvis</td>
<td>25</td>
<td>450</td>
</tr>
</tbody>
</table>
Diagnostic reference levels
How to collect your own local DRLs?

- In each medical department
- Measurement of the parameters (De, DAP, CTDIw or PDL) for a series of 20 standard size patients or phantoms
- The average value of each parameter can be considered as the local DRL
Diagnostic reference levels in medical practice

Diagnostic reference levels
Their optimisation

The DRL is a tool for optimisation

- If a local DRL value is above the national DRL, some optimisation is possible after searching the reasons why the local value is high.
Diagnostic reference levels in medical practice

Diagnostic reference levels
Their optimisation

The DRL is a tool for optimisation

- If local DRLs decrease, the national DRLs should also decrease
- Continuous dynamic process of optimisation
Diagnostic reference levels

National strategy for optimisation

- DRL parameters are measured in each institution
- DRLs are established nationally
- Local reviews of DRL parameters are undertaken routinely
- Comparison of local DRLs is made with national values
- Actions are taken if local DRLs are exceeded consistently
Diagnostic reference levels

The future

• The DRL strategy implies a continuous dynamic process
• National DRLs can be compared at the European / International level for optimisation
• National DRLs must be optimised:
  ▪ more values are needed
  ▪ instrumentation is changing
• European DRLs to be re-established
Diagnostic reference levels

The future in France

- Mandatory measurements of local DRLs by ministerial order 12 February 2004
- Collection of data by IRSN to periodically re-establish national DRLs
- So far, contributions of 59% of nuclear medicine departments, but only 25% of radiology departments!
- Changes take time!!
Diagnostic reference levels in medical practice

NIVEAUX DE REFERENCE DIAGNOSTIQUES
SCANOGRAPHIE
(arrêté du 12 février 2004)

Date : ........................ Etablissement : .................................................................

Nom et prénom du radiologue responsable : .................................................................

Nom, prénom et coordonnées de la personne à contacter : ...........................................

Marque et modèle de l’installation : ..............................................................................

Type :  Mono-coupe ☐  Multi-coupe ☐

Préciser l’examen radiologique retenu pour le NRD :

Encéphale ☐  Thorax ☐  Abdomen ☐  Pelvis ☐

Période de recueil des données : du .................... au .................................

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sexe</th>
<th>Age</th>
<th>Poids</th>
<th>Taille</th>
<th>kV</th>
<th>mA (ou mA + tps de rotation)</th>
<th>Epaisseur de coupe (mm)</th>
<th>Config. de collimation (ex. 4x1 mm)</th>
<th>Pitch</th>
<th>Longueur d’acquisition (cm)</th>
<th>CTDI vol (mGy)</th>
<th>PDL (mGy.cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DRLs reports to IRSN : CT scan

25.1% of centers

Source IRSN
## CT – DRLs in France 2008

<table>
<thead>
<tr>
<th>EXAMINATION</th>
<th>CTDI (mGy)</th>
<th>CTDIv (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Centers</td>
<td>DRL</td>
</tr>
<tr>
<td>Chest</td>
<td>57</td>
<td>20</td>
</tr>
<tr>
<td>Brain</td>
<td>48</td>
<td>58</td>
</tr>
<tr>
<td>Abdomen</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td>Pelvis</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>AP</td>
<td>23</td>
<td>25</td>
</tr>
<tr>
<td>TAP</td>
<td>3</td>
<td>20</td>
</tr>
</tbody>
</table>

**Proposal to replace CTDI by CTDIv as DRL**

Source: IRSN
CT – DLPs in France 2008

<table>
<thead>
<tr>
<th>Examination</th>
<th>Centers</th>
<th>DRL</th>
<th>75th centile</th>
<th>DRL proposed</th>
<th>Centers &gt; DRLs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest</td>
<td>86</td>
<td>500</td>
<td>475</td>
<td>475</td>
<td>20%</td>
</tr>
<tr>
<td>Brain</td>
<td>77</td>
<td>1050</td>
<td>1150</td>
<td>1050</td>
<td>38%</td>
</tr>
<tr>
<td>Abdomen</td>
<td>11</td>
<td>650</td>
<td>423</td>
<td>450</td>
<td>0%</td>
</tr>
<tr>
<td>Pelvis</td>
<td>0</td>
<td>450</td>
<td>NA</td>
<td>-</td>
<td>0%</td>
</tr>
<tr>
<td>A + P</td>
<td>33</td>
<td>1100</td>
<td>798</td>
<td>800</td>
<td>6%</td>
</tr>
<tr>
<td>C + A + P</td>
<td>3</td>
<td>1600</td>
<td>NA</td>
<td>1300</td>
<td>0%</td>
</tr>
</tbody>
</table>

Proposal to decrease DRLs for all examinations except for the brain

Source IRSN
DRLs reports to IRSN: Nuclear medicine

+19%

59% of centers

Source IRSN
### Nuclear medicine DRL: thyroid scan with $^{99m}$Tc

<table>
<thead>
<tr>
<th>Number of centers</th>
<th>34</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRLs (Recommended by manufacturer)</td>
<td>20 à 80 MBq</td>
</tr>
<tr>
<td>Recommendations SFMN</td>
<td>70 à 110 MBq</td>
</tr>
<tr>
<td>Mean</td>
<td>151 ± 58 MBq</td>
</tr>
<tr>
<td>Min</td>
<td>37 MBq</td>
</tr>
<tr>
<td>Max</td>
<td>281 MBq</td>
</tr>
<tr>
<td>Number of centers &gt; DRLs</td>
<td>32 (94%)</td>
</tr>
</tbody>
</table>

Large gap between manufacturers’ DRL values and SFMN values

Almost all centers above

Source: IRSN
Nuclear medicine DRL: thyroïd scan with $^{123}$I

<table>
<thead>
<tr>
<th>Number of centers</th>
<th>19</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRLs (Recommended by manufacturer)</td>
<td>10 à 15 MBq</td>
</tr>
<tr>
<td>Recommendations SFMN</td>
<td>7 à 20 MBq</td>
</tr>
<tr>
<td>Mean</td>
<td>9,0 ± 2,9 MBq</td>
</tr>
<tr>
<td>Min</td>
<td>3,7 MBq</td>
</tr>
<tr>
<td>Max</td>
<td>14,6 MBq</td>
</tr>
<tr>
<td>Number of centers &gt; DRLs</td>
<td>0</td>
</tr>
<tr>
<td>Number of centers &lt; DRLs</td>
<td>14 (74%)</td>
</tr>
</tbody>
</table>

Gap between manufacturers’ values and SFMN values
All centers below maximum value

Source IRSN
Conclusions

- The DRL strategy constitutes a clever mechanism for the optimisation of doses in medical imaging.
- DICOM headers of images will be helpful since they contain most information needed.
- The process must continue at national and international level.
- But do not forget that only useful examinations need to be optimized and unjustified examinations should not be performed!