Radiation Protection of Patients in Film-based and Digital Radiography, Diagnostic Fluoroscopy and Mammography

Summary of Contributed Papers

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University of Ulsan, College of medicine
Korean Society of Radiology
Contributed papers

- 28 papers from
- **Asia**: Nepal, UAE (2), Indonesia, India
- **Africa**: Ghana, Kenya
- **Europe**: Belgium, France, Lithuania, United Kingdom (2), Spain, Poland, Albania, Ukraine
- **Latin America**: Brazil (11), Cuba
Contents

- Quality control
  - CR phantom development
  - Shielding calculation
  - Quality index
  - Quality control methods standardization (Calibration)
- Mammography QC and patient dose
- Evaluation of patient doses
  - Optimization of radiography
  - Dose survey
    - Adults
    - Pediatrics
  - Dose tracking
The objective was to construct a simple, low cost and efficient phantom to evaluate the image quality of the CR systems.

This phantom allows the evaluation of high and low contrast resolution, noise to signal ratio, radiographic contrast, uniformity and length measure accuracy.

They validated each parameters and it is adequate for quality control of CR systems.

The low cost of this phantom will facilitate its accessibility for radiological services in Latin America.
FANR in UAE developed software for shielding calculations for imaging medical facilities and intends to make it available for applicants and licenses.

This software based on NCRP report No.147 algebraic computation Model.
For primary beam shielding calculation, it is important to consider attenuation effect of patient’s body into account in mathematical models.
Quality Index

QUALITY INDEX IN MEDICAL RADIOLOGY

- Quality Index is a modification in the concept of potential Risk
- MARP (Model for Potential Risk)
- Indicator definitions
  - Management
  - Image processing
  - Conventional X-ray equipment
  - Computed tomography
- Critical vs. less critical indicator
- Conclusions
  - Relatively simple, and applicable as an aid in the processes of regulation, audit or accreditation

L.A.G. MAGALHAES, et al. (Brazil)
QUALITY CONTROL OF IONIZATION CHAMBERS IN THE RANGE OF DIAGNOSTIC RADIOLOGY

- a set of four ionization chambers
- the measures were well repeatable with standard deviations around ±1%
- the results of stability tests are within acceptable limits, ± 5%
- In view of the performance, it is viability of using this equipment in quality control programs in diagnostic radiology

L.A.G. MAGALHAES, et al (Brazil)
IAEA created in 2009 a project of a survey of the patient dose in medical procedures in Latin America.

The radiochromic film was selected as dose measurement method due to the different regions of skin exposed to X ray.

The results showed that the calibration procedure can be adapted to different X ray equipment.

E.L. CORRÊA et al. (Brazil)
QUALITY CONTROL FOR THE RADIOGRAPHY INSTRUMENT “PHILIPS DUO DIAGNOST” USED IN MOTHER TERESA HOSPITAL, TIRANA, ALBANIA

D.KISHTA, et al (Albania)

EXPLORING THE UNCERTAINTIES ON THE FITTING PARAMETERS OF A WIDELY USED MATHEMATICAL MODEL OF X RAY TRANSMISSION

P.R. COSTA, D.V. VIEIRA (Brazil)

- Beam quality optimization

DEVELOPMENT OF A CALIBRATION METHODOLOGY OF THE PATIENT DOSE CALIBRATOR

N.A. COSTA, M.P.A. POTIENS(Brazil)
Mammography

- Mammography quality control: 5 contributed papers
- Evaluation of patient’s dose: 4 contributed papers
- MMG is the most effective method for breast cancer Dx, but it employs X-ray beams of low energy whose potential for biological damage has been the subject of several studies.
- Radiation risk in MMG: related with radiosensitive glandular cells
- Good image quality with minimal radiation exposure is goal for quality control of MMG.
EVALUATION OF PARAMETERS OF IMAGE QUALITY IN DIGITAL MAMMOGRAPHY ACCORDING TO THE EUROPEAN COMMISSION USING THE PHANTOM PAS 1054

L. PEREIRA, et al (Brazil)

PRELIMINARY EXPERIENCE WITH A NEW TEST METHOD FOR THE AUTOMATIC EXPOSURE CONTROLLER IN DIGITAL MAMMOGRAPHY, AND ITS LINK TO PATIENT DOSIMETRY

J. BINST, et al (Belgium)
SPECTRA AND DEPTH-DOSE DEPOSITION IN A PMMA BREAST PHANTOM OBTAINED BY EXPERIMENTAL AND MONTE CARLO METHODS

M.G. DAVID, et al (Brazil)

TESTS FOR QUALITY CONTROL IN MAMMOGRAPHY FILMS

L.A.G. MAGALHAES, et al (Brazil)

COMPARING THE STABILITY OF TWO IONIZATION CHAMBERS IN STANDARD MAMMOGRAPHY RADIATION BEAMS AND USING AN Sr-90 + Y-90 CHECK DEVICE

J.O. SILVA, L.V.E. CALDAS et al (Brazil)
Evaluation of Patients’ Dose: MMG

BREAST CHARACTERISTICS AND DOSIMETRIC DATA IN X RAY MAMMOGRAPHY - A LARGE SAMPLE WORLDWIDE SURVEY

- Average glandular dose (AGD)
  - defined to quantify the risk from breast irradiation
  - quantity for dose monitoring of X ray MMG exam
  - widely accepted for regulations and guidelines
- 147,487 MMG images from Europe, North America and Asia-Pacific

<table>
<thead>
<tr>
<th>Geographical zone</th>
<th>Total number of cases</th>
<th>Number of systems</th>
<th>Manual</th>
<th>AOP Dose</th>
<th>AOP STD</th>
<th>AOP CNT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>49847</td>
<td>105</td>
<td>1.10%</td>
<td>10.50%</td>
<td>85.30%</td>
<td>2.10%</td>
</tr>
<tr>
<td>North America</td>
<td>43514</td>
<td>121</td>
<td>4.30%</td>
<td>7.70%</td>
<td>83.70%</td>
<td>4.10%</td>
</tr>
<tr>
<td>Asia-Pacific</td>
<td>54136</td>
<td>31</td>
<td>0.80%</td>
<td>1.30%</td>
<td>63.60%</td>
<td>34.30%</td>
</tr>
</tbody>
</table>

N. GEERAERT, et al (France, Belgium)
Breasts in Asia-Pacific were on average significantly thinner and denser than in Europe and North America.

Breasts in North America were on average significantly thicker and denser than in Europe.

The average AGD per image was 1.42mGy in North America and Asia-Pacific, and 1.48mGy in Europe.

Breast dosimetry can be improved by replacing the population-averaged breast density by the individual volumetric breast density.

N. GEERAERT, et al (France, Belgium)
Digital MMG units are increasing in Poland

Despite the literature evidence of advantage in DM, the calibration and exchange of the image detector made by the manufacturer service introduced changes which induced increase of the doses

Therefore, it is reasonable to determine the clinical breast dose values after every manufacturer service in order to be able to optimize the exposure parameters.
The three methods of optimization were:

- Increase the focus to detector distance (FDD)
- Patient orientation
- Centering point

<table>
<thead>
<tr>
<th>TABLE I. ESD, WBD &amp; IQ SCORE FOR DIFFERENT FFDs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ESD (mGy)</strong></td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>115 cm FFD</td>
</tr>
<tr>
<td>144 cm FFD</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE II. ESD, WBD &amp; IQ SCORE FOR BOTH ORIENTATIONS IN EACH ROOM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient orientation</strong></td>
</tr>
<tr>
<td>-------------------------</td>
</tr>
<tr>
<td>‘Head-towards’</td>
</tr>
<tr>
<td>‘Feet-towards’</td>
</tr>
</tbody>
</table>

P. CHARNOCK, et al (United Kingdom)
Organ doses of female patients in the child bearing age undergoing chest PA, pelvis AP and lumbar spine exam in three hospitals, total 80 patients.

An inverse linear relationship was observed between BMI and uterus and ovary dose for pelvis AP exam.

<table>
<thead>
<tr>
<th>Examination</th>
<th>Body mass index (kg/m²)</th>
<th>Organ dose (µGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Uterus</td>
</tr>
<tr>
<td>Chest PA</td>
<td>27.9 (15.5–40.5)</td>
<td>0.5 (0.1–1.7)</td>
</tr>
<tr>
<td>Lumbar spine AP</td>
<td>28.0 (14.8–36.4)</td>
<td>0.9 (0.1–1.9)</td>
</tr>
<tr>
<td>Lumbar spine LAT</td>
<td>27.7 (14.8–36.4)</td>
<td>0.9 (0.4–1.9)</td>
</tr>
<tr>
<td>Pelvis AP</td>
<td>22.9 (14.6–39.4)</td>
<td>50.0 (14.3–112.6)</td>
</tr>
</tbody>
</table>

P.K. GYEKYE, et al (Ghana)
First attempt in Nepal
Analysis of radiation survey
Radiation survey at 22 X-ray/4 CT (12 hospitals)
Analysis of questionnaire-96 radiation workers
There is a great need for rules, regulation and radiation act in the field of radiation.

- Lumbar spine
  - Max 11.57 mSv
  - Ave 3.69 mSv
- Chest
  - max 1.31 mSv
  - Ave 0.68 mSv
STUDIES ON ESTIMATION OF EFFECTIVE DOSE IN COMMON X RAY DIAGNOSTIC EXAMINATIONS IN INDIA

- chest (AP, PA, LAT), lumber spine (AP, LAT), thoracic spine (AP, LAT), abdomen (AP), pelvis (AP), skull (PA, LAT) and hip joints (AP)
- 1209 number of diagnostic projections, 101 X ray machines installed in 45 hospitals in the country.
- NRPB vs. PCXMC method
- Effective dose and organ doses can also provide benchmark for comparison of X ray exposures from different hospitals, in order to reduce patient dose and maintain good image.

A.U. SONAWANE, et al (India)
STUDY OF PATIENT DOSES IN RADIOGRAPHY AND ESTABLISHMENT OF NATIONAL DIAGNOSTIC REFERENCE LEVELS IN UKRAINE

- chest fluorography (PA), chest radiography (PA and LAT), cervical, thorax, lumbar spine (AP and LAT) and pelvis (AP).
- the ESD values differed by 45-170 times
- The greatest difference of patient ESDs: film fluorography of chest.
- Thus, individual ESDs varied in the range from 0.1 mGy up to 25.1 mGy
- for chest radiography, the third quartile of ESD (0.94 mGy) distribution exceeds by 2.3 times the IAEA guidance level of 0.4 mGy

M. PYLYPENKO, et al (Ukraine)
ENTRANCE SURFACE DOSE (ESD) FOR VARIOUS RADIOGRAPHIC EXAMINATIONS IN JAKARTA, INDONESIA

- ESD (mGy); absorbed dose to air at the entrance surface of the patient in a central axis of the irradiated area, including back scattered radiation from the tissue below the surface.
- The ESD was recommended by the IAEA and ICRP
- PA thorax, AP abdomen, AP pelvis, AP and LAT lumbosacral, AP/PA and LAT skull, AP and LAT cervical spine for three hospitals
ENTRANCE SURFACE DOSE (ESD) FOR VARIOUS RADIOGRAPHIC EXAMINATIONS IN JAKARTA, INDONESIA

- ESD measurements for PA thorax exceeded the guidance levels, others were below guidance levels recommended by IAEA BSS 115

### TABLE V. COMPARISON OF ESD (mGy) GUIDANCE LEVELS IN LITERATURE AND RESULTS OF THIS STUDY [6, 7]

<table>
<thead>
<tr>
<th>Examination type</th>
<th>This study</th>
<th>IAEA BSS 115</th>
<th>UK NRPB 1999</th>
<th>US AAPM 1999</th>
<th>Europe EC 1999</th>
<th>UK IPSM 1992</th>
<th>CDR H 1992</th>
<th>Europe CEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA thorax</td>
<td>1.203</td>
<td>0.4</td>
<td>0.2</td>
<td>0.25</td>
<td>0.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AP abdomen</td>
<td>1.902</td>
<td>10</td>
<td>10</td>
<td>4.5</td>
<td>-</td>
<td>10</td>
<td>5.6</td>
<td>-</td>
</tr>
<tr>
<td>AP pelvis</td>
<td>1.696</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>AP lumbosacral</td>
<td>4.594</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>6.4</td>
<td>-</td>
</tr>
<tr>
<td>LAT lumbosacral</td>
<td>9.248</td>
<td>30</td>
<td>30</td>
<td>-</td>
<td>40</td>
<td>30</td>
<td>30</td>
<td>-</td>
</tr>
<tr>
<td>AP/PA skull</td>
<td>1.355</td>
<td>5</td>
<td>5</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LAT skull</td>
<td>0.607</td>
<td>3</td>
<td>3</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
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<tr>
<td>AP cervical spine</td>
<td>1.290</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.5</td>
<td>-</td>
</tr>
<tr>
<td>LAT cervical spine</td>
<td>1.424</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

S. HUNSTAD, et al (Indonesia)
Patient dosimetry results obtained through the DHA radiation safety initiatives and the projects conducted in cooperation with the IAEA.

Fluoroscopy, interventional radiology (IR), computed tomography (CT) and dental radiology applications.

To establish local and national DRLs

The results of the paediatric dosimetry in radiology practices at the DHA show an acceptable level compared to the literature.

J.S ALSUWAIDI, et al (United Arab Emirates)
The dosimetry levels in this study showed an increasing trend with patients’ age.

This reflects the use of dedicated paediatric protocols reveals a good practice in view of patient radiation safety.
SURVEY FOR DETERMINATION OF DIAGNOSTIC REFERENCE LEVELS FOR COMMON
RADIOGRAPHY EXAMINATIONS OF PAEDIATRIC PATIENTS IN LITHUANIA

Data collection
- newborns, 1, 5, 10 and 15 years old children
- DRLs for chest PA/AP, skull AP/PA/LAT, abdomen AP radiography examinations were evaluated
- Collected 2600 KAP values

In 2012, it is planned to confirm DRLs for common radiography examinations for children in Lithuania.

A. CEPULIENE, et al (Lithuania)
<table>
<thead>
<tr>
<th>X ray examination</th>
<th>Age (y)</th>
<th>Lithuania KAP 3rd quartile, (Gy·cm²)</th>
<th>Germany DRLs, KAP (Gy·cm²)</th>
<th>Austria DRLs, KAP, (Gy·cm²)</th>
<th>Lithuania ESD 3rd quartile, (mGy)</th>
<th>Austria DRLs, ESD, (mGy)</th>
<th>NRPB R318, ESD, (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest PA/AP</td>
<td>0</td>
<td>0.03</td>
<td>0.008</td>
<td>0.017</td>
<td>0.042</td>
<td>0.055</td>
<td>0.05</td>
</tr>
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<td>1</td>
<td>0.04</td>
<td>0.02</td>
<td>0.023</td>
<td>0.046</td>
<td>0.069</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.05</td>
<td>0.03</td>
<td>0.026</td>
<td>0.056</td>
<td>0.082</td>
<td>0.07</td>
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<tr>
<td></td>
<td>10</td>
<td>0.05</td>
<td>0.04</td>
<td>0.037</td>
<td>0.062</td>
<td>0.108</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.09</td>
<td>–</td>
<td>0.073</td>
<td>0.064</td>
<td>0.112</td>
<td>–</td>
</tr>
<tr>
<td>Skull PA/AP</td>
<td>0</td>
<td>0.21</td>
<td>–</td>
<td>0.10</td>
<td>0.537</td>
<td>0.379</td>
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<tr>
<td></td>
<td>1</td>
<td>0.22</td>
<td>0.30</td>
<td>0.19</td>
<td>0.548</td>
<td>0.690</td>
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<td></td>
<td>5</td>
<td>0.31</td>
<td>0.40</td>
<td>0.31</td>
<td>1.031</td>
<td>0.880</td>
<td>1.1</td>
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<tr>
<td></td>
<td>10</td>
<td>0.33</td>
<td>–</td>
<td>0.37</td>
<td>1.230</td>
<td>0.998</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.39</td>
<td>–</td>
<td>–</td>
<td>1.181</td>
<td>1.123</td>
<td>1.1</td>
</tr>
<tr>
<td>Skull LAT</td>
<td>0</td>
<td>0.15</td>
<td>–</td>
<td>0.077</td>
<td>0.292</td>
<td>0.294</td>
<td>–</td>
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<tr>
<td></td>
<td>1</td>
<td>0.18</td>
<td>0.30</td>
<td>0.23</td>
<td>0.259</td>
<td>0.700</td>
<td>0.5</td>
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<tr>
<td></td>
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<td>0.34</td>
<td>0.30</td>
<td>0.20</td>
<td>0.520</td>
<td>0.506</td>
<td>0.8</td>
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<tr>
<td></td>
<td>10</td>
<td>0.31</td>
<td>–</td>
<td>0.25</td>
<td>0.556</td>
<td>0.557</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.29</td>
<td>–</td>
<td>0.33</td>
<td>0.446</td>
<td>0.676</td>
<td>0.8</td>
</tr>
<tr>
<td>Abdomen AP</td>
<td>0</td>
<td>0.15</td>
<td>–</td>
<td>–</td>
<td>0.087</td>
<td>0.100</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0.23</td>
<td>0.25</td>
<td>0.035</td>
<td>0.263</td>
<td>0.172</td>
<td>0.4</td>
</tr>
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<td></td>
<td>5</td>
<td>0.24</td>
<td>0.50</td>
<td>0.11</td>
<td>0.435</td>
<td>0.511</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.95</td>
<td>0.60</td>
<td>0.36</td>
<td>0.307</td>
<td>0.966</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.45</td>
<td>–</td>
<td>–</td>
<td>0.615</td>
<td>–</td>
<td>1.2</td>
</tr>
</tbody>
</table>
Data collection

- a part of the activities under the IAEA Regional Projects RLA/9/057 and RLA 9/067

- Group 1- newborn ~1year old, and group II -4 ~ 6 years old

- 25 patients per exam for each group

- Preliminary value for reference dose for pediatric chest examination in Cuba

A.O. FERNÁNDEZ HERRERA, et al (Cuba)
Pediatric imaging may require dedicated equipment as well as specialized personnel training.

Necessitate the hospital to introduce urgent intervention measures for the optimization of imaging technique through the establishment of quality control and retraining of the imaging technologists in pediatric radiography.

J.S. WAMBANI, et al (Kenya)
Patients Dose Tracking

**POTENTIAL APPLICATIONS OF DOSE-TRACKING AND ACTIVE DOSIMETRY SYSTEMS TO ENCOURAGE X RAY IMAGE OPTIMIZATION AND MINIMIZE STAFF DOSE**

- Radiation dose structured reports (RDSR) in DICOM encapsulate patient dose information associated with X-ray images in a standardized format.
- Linked to this the Integrated Health Enterprise (IHE) Radiation Exposure Monitoring (REM) profile provides a standard format for imaging modalities to export radiation exposure details.
- Manual transforming patient’s dose data: time consuming and subject to transcription errors.
- Recent approach is via automated collection and analysis of dose data directly from the imaging system modalities.

WILKINS et al (United Kingdom)
Patients Dose Tracking

POTENTIAL APPLICATIONS OF DOSE-TRACKING AND ACTIVE DOSIMETRY SYSTEMS TO ENCOURAGE X RAY IMAGE OPTIMIZATION AND MINIMIZE STAFF DOSE

- Facilitating production of detailed national diagnostic reference levels and international comparisons
- At hospital or institution level: For individual X-ray rooms and operators, this could be a powerful tool to discourage dose creep and encourage optimization.

WILKINS et al (United Kingdom)
Patients Dose Tracking

POTENTIAL APPLICATIONS OF DOSE-TRACKING AND ACTIVE DOSIMETRY SYSTEMS TO ENCOURAGE X RAY IMAGE OPTIMIZATION AND MINIMIZE STAFF DOSE

- Real-time personal dose-rate data displaying system
- Interventional radiology and cardiology labs
- Instant feedback to operators of the radiation fields directly after the operation (in contrast to the delays inherent in TLD and other conventional monitoring).
- By raising awareness of high dose-rates at the time of exposure, such information may prove beneficial in encouraging operators to take immediate steps to reduce doses to themselves and colleagues.

WILKINS et al (United Kingdom)
Summary

- Quality control
  - For optimization
- Evaluation of patient doses
  - Optimization
  - Diagnostic reference level