EVALUATION OF EXPOSURE INDEX (lgM) IN ORTHOPAEDIC RADIOGRAPHY

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Aim

- To evaluate exposure index (lgM) in orthopaedic radiography performed in a clinical routine environment

Outline

- Introduction
  - Background/rationale
  - Exposure index (lgM)
  - Problem
  - Research questions
- Materials and methods
- Results
- Discussion
- Conclusions

Background/rationale

- The purpose of radiation protection is to keep radiation exposure at the lowest levels as practicable. The radiation exposure risk should be minimized and this should be guided by the 2 triads of radiation protection: radiation protection actions and radiation protection principles(1).
- Radiation protection actions point towards the use of time, shielding and distance to **protect patients**, personnel and the public.
- Radiation protection principles deal with the concepts of **justification** or positive net benefit, **optimization** and **dose limitation**.

1. Seeram E. and Brennan P. Diagnostic Reference Levels in Radiology. Radiologic Technology. 77, 373-384 (2006).

Background/rationale

- For diagnostic purposes the optimization of exposure involves the relationship between three core aspects of the imaging process(2):

  (i) choice of radiographic technique;
  (ii) radiation dose to the patient and;
  (iii) diagnostic quality of the radiographic image.

- These three aspects are determinants for the diagnostic quality of the radiographic image and depend on the radiographer's options for a particular patient examination.

2. European Commission (EC). Optimisation of Protection in the Medical Uses of Radiation. EUR 19793. (Luxembourg: Office for Official Publications of the European Communities) (2002).

Background/rationale

- The choice of the most adequate radiographic technique involves:

  (i) management of exposure parameters;
  (ii) patient's radiation exposure;
  (iii) exposure on the imaging detector to produce the most accurate diagnosis.

- This means that a correct exposure at the detector should provide adequate image contrast concerning the clinical quality of the radiographic image.

Background/rationale

- Patient dose in digital imaging systems, due to its dynamic range, could deliver over or under-exposure[3] that influences patient's dose.
- Overexposure provides good images, but may cause unnecessary patient dose.

3. International Commission on Radiological Protection. Managing patient dose in digital radiology. ICRP Publication 93. Ann. ICRP 34(1) (Oxford: Elsevier Ltd) (2004).

Background/rationale

How to avoid the problem of overexposure?

How do we detect overexposure in a CR system?

Background/rationale

- Exposure index is in relation to the absorbed dose at the phosphor plate and is determined from the pixel values[3].
- Manufacturers provide a wide variation on different exposure index scales to measure the radiation exposure at the detector[4].
- For AGFA CR systems the exposure index is so-called lgM value and provides the dose feedback indicator[5].

4. Willis, C. E. Strategies for dose reduction in ordinary radiographic examinations using CR and DR. Pediatr Radiol. 34 (Suppl 3), S196-S200 (2004).

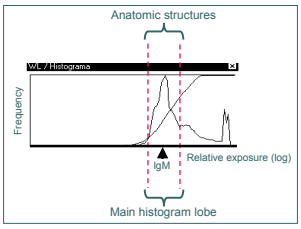
5. Schaetzing, R. Management of pediatric radiation dose using Agfa computed radiography. Pediatr Radiol. 34 (Suppl 3), S207-S214 (2004).

Exposure index (lgM)

- The exposure index obtained from a radiographic image could be a useful feedback indicator to the radiographer about the appropriate exposure level in clinical routine.
- lgM indicates how close the CR detector dose is at the expected dose.
- The lgM is related to detector exposure and it does not replace patient dose related parameters such as DAP or ESE.

Exposure index (lgM)

- The dose level at the detector is determined as the median of the logarithmic pixel values in the main histogram lobe.
- The expected lgM value for any Speed Class (SC) is about 1.96 and should be consistent to a 2.5 µGy exposure measured at the detector[5].



Exposure index (lgM)

- Exposure index lgM is related with x-ray exposure for each radiological projection that is carried out.
- Because of its logarithmic nature, each change of 0.3 (log) in lgM corresponds to reach the double or half of dose.
- For example, if the lgM value for a given image is calculated as 2.26, it indicates that the dose was about twice as that expected for the selected SC.
- This means that doubling the exposure dose at the same SC it will cause an increase of the LgM value up to 0.3 (log).
- If the SC is doubled without altering the exposure settings, then the LgM value will decrease by 0.3 (log)[6].

6. Dose monitoring software user manual. Mortsel, Belgium: Agfa Gevaert, 2003.

Problem

- Patient's exposure must be applied in order to get a constant dose on the imaging plate (IP) and this varies as a function of patient attributes (e.g. sex, weight) radiographic technique and exposure parameters.
- Exposures in CR systems may cause unnecessary patient dose due to overexposure.
- This problem should be avoided and prevented in routine clinical practice. If dose is maintained to the IP relatively constant at a value that is considered to be appropriate for the exam or patient group of interest, then dose consistency in the CR environment could be achieved[5].

Questions…

- Is the lgM exposure index next the recommended target of 1.96?
- How does SC influences lgM?
- What are lgM values for patient's sex and weight groups?

Materials and methods

- In this study we analysed the lgM of 267 exposures performed during a period of one month.
- Radiographs were obtained in clinical routine environment by 3 experienced radiographers.
- 265 exposures (125 female and 140 male) obtained at 200 and 400SC were considered.
- 2 exposures obtained at a SC100 were excluded.
- All the radiological projections were acquired using an AGFA CR system (MD plate).

Materials and methods

- Exposure information such as patient-related data, examination data, radiographic technique, exposure parameters and post-processing information was recorded in a spreadsheet.
- Two group of patients (female; male) and three weight group (overweight; normal weight; underweight) were considered.

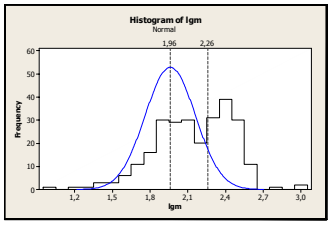
Materials and methods

- Data were submitted to statistical analysis and comparisons between means were tested.
- Anderson-Darling (AD) statistic test was used to measure how well lgM data follow a normal distribution and if values fit the reference data.
- The lgM reference value considered for this study is 1.96[5] and a reference standard deviation of 0.2[6] is considered as upper and lower limits for statistical analysis.
- A significance of $p \leq 0{,}05$ was used for statistic tests.

Results

- The mean value of lgM in our sample is 2.14.
- One sample *t*-test at a significance level of 5% shows a significant difference (p=0,000 ≤0,05) from 1.96 lgM reference.

IgM histogram



- Histogram shows majority of exposures above the reference values: 72% are above the 1.96 IgM and 42% are above the value of 2.26.
- Above this value an IgM value ranging from 2.35 to 2.45 is evidenced at a frequency of 39%.

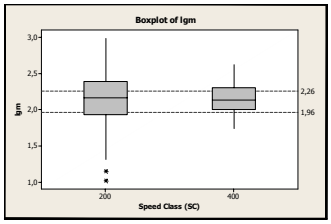
IgM in orthopaedic radiological examinations considered

- In 5 most requested examinations (knee; foot; pelvis; shoulder; and lumbar vertebrae) IgM mean value is higher than 2.04. As an example, knee is the most requested examination (73) where IgM mean is higher (2.35) ranging from 1.77 to 2.62 (range 0.85).
- Wide range of IgM for most of the examinations can be found. This is an evidence that IgM varies a lot among the same examination (e.g. knee: 0.85; pelvis: 0.95; shoulder: 1.11).

Examination	Count	Mean (Max-Min)	SD	Range
wrist (with cast)	3	2,69 (2,76-2,62)	0,10	0,14
leg	3	2,39 (2,46-2,33)	0,07	0,13
knee	73	2,35 (2,62-1,77)	0,17	0,85
foot	19	2,25 (2,59-1,87)	0,21	0,72
elbow	2	2,24 (2,26-2,23)	0,02	0,03
wrist	12	2,21 (2,53-1,84)	0,25	0,69
pelvis	17	2,13 (2,56-1,61)	0,23	0,95
shoulder	28	2,09 (2,49-1,38)	0,28	1,11
pelvis orthostatic	6	2,07 (2,36-1,90)	0,16	0,46
calcaneus	3	2,05 (2,30-1,87)	0,22	0,43
lumbosacral junction[1]	4	2,04 (2,30-1,67)	0,31	0,63
lumbar vertebrae[1]	24	2,04 (2,62-1,44)	0,29	1,18
ankle	8	2,03 (2,43-1,77)	0,20	0,66
hip	6	2,02 (2,30-1,51)	0,32	0,79
hand	4	2,00 (2,10-1,87)	0,12	0,23
cervical vertebrae	14	1,93 (2,33-1,67)	0,19	0,66
hand digits	8	1,86 (2,20-1,38)	0,28	0,82
patella	25	1,86 (2,98-1,02)	0,43	1,96
foot digits	6	1,76 (1,87-1,61)	0,12	0,26

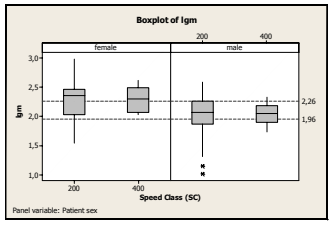
[1]Includes AP and lateral projections

IgM and SC



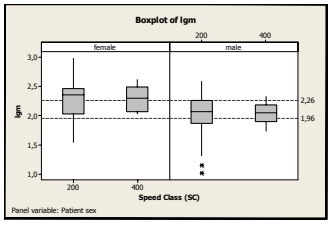
- Boxplot of IgM shows that median values are above 1.96 and below 2.26 for SC200 (2.16) and SC400 (2.13). The interquartile range is lower in SC400 (0.30) than in SC200 (0.46). The range between upper and lower quartiles is smaller in SC400.

IgM and SC (patient sex)



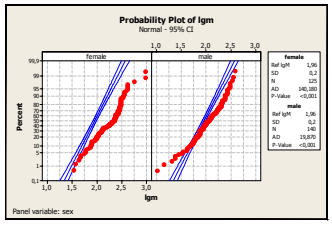
- IgM values are compared in two groups of patients (female; male).
- The IgM median is highest for females both at 200 (2.36) and 400 SC (2.30). However, in this group of patients there is no important variability, with an interquartile range of 0.43 and 0.42 respectively.
- In addition, the distribution in SC200 is wider than in SC400 between lower and upper boundaries (1.54 to 2.98).

IgM and SC (patient sex)



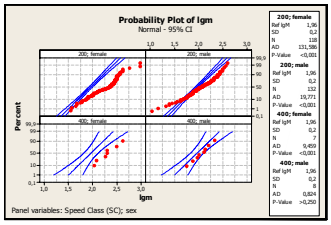
- Male patients have similar median IgM both for SC200 and SC400 (2.07 and 2.05, respectively).
- SC400 also exhibits the least variability, with an interquartile range of 0.28 and the least difference between lower and upper boundaries (1.74 to 2.33).
- SC200 shows wider interquartile range distribution (0.39) and wider IgM values for lower and upper boundaries (1.31 and 2.59).

IgM probability plot (patient sex)



- Anderson-Darling (AD) statistic test shows that both for female and male patients the data do not follow the specified distribution.
- Female group of patients shows an AD value of 140,180 (p<0,001) and male patients show an AD value of 19,870 (p<0,001).
- Despite the fact that results from both groups show a significant difference from the normal distribution, male group of patients has a smaller AD value which indicates that the results from this group are closer to the normal distribution.

IgM probability plot (patient sex & SC)



- SC200 show a significant difference (p<0,001) from the normal distribution for both groups of patients.
- Lower AD value is found on male patients (19,771) when compared to female group (131,586). This means that for SC200 male patient's lgM is closer to the reference values than female group.
- SC400 shows that the data plotted points follow the fitted distribution line fairly closely for male patients. AD statistics value is 0,824 and should be considered as normal (p>0,250).
- Female patients in SC400 don't fit the reference line fairly well. AD statistic test (9,459) is not normal (p=<0,001) showing significant statistical difference from the reference value.

lgM probability (patient sex & weight)

- Concerning patient's weight significant statistical difference is found on
  - normal weight group
    (female: AD=127,496 p<0,001; male: AD=13,499 p<0,001).
  - Overweight group
    (females: AD=20,295 p<0,001).
- Although other groups' results don't fit very well in lgM reference value, no statistical significant differences are found on underweight groups (both female and male) and on overweight males.

Discussion (I)

- The analysis of results shows that lgM is far above the recommended target of 1.96[5].
- At least 42% of evaluated exposures were above the limit of 2.26 which indicates that the imaging plate receives at least the double of exposure that is necessary to produce an adequate image.
- Findings shows that lgM is higher in female than in male patients.

Discussion (II)

- This could be a problem because an lgM far above from manufacturer's recommendation could configure a practice of overexposure.
- Considering lgM as a result of exposure, technique chart seems to be inadequate in particular for female patients.
- Exposure parameters and the choice of the most adequate SC for each examination, patient sex and weight should be carefully studied in order to obtain the desired image quality at the lowest exposure dose.

Discussion (III)

- Studies performed in a different CR system shows that it is possible to obtain lower exposure indices than those recommended by manufacturer[7].
- The establishment by manufacturers of recommended exposure indices remains unclear and the exposure indices using the exposure in current practice could be significantly higher than the optimum level.

7. Peters, S. and Brennan, P. Digital radiography: are the manufacturers' settings too high? Optimisation of the Kodak digital radiography system with aid of the computed radiography dose index. Eur Radiol. 12, 2381–2387 (2002).

Discussion (IV)

- In addition to exposure parameters, lgM is sensitive to a number of other factors. The most critical one is segmentation. Any errors in the segmentation algorithm (e.g., including background that does not belong to the body part, or excluding portions of the body part) can cause variations in lgM. In a related effect, collimation can also affect lgM[5].
- Reliable lgM feedback occurs only when the system has been calibrated properly. This study was performed in clinical routine environment and data was collected from a CR system that holds a normal maintenance program.
- Finally, lgM is related to detector exposure and it does not replace patient dose related parameters such as DAP or ESE. Patient ESD or DAP was not measured in this study due to the fact that in the x-ray facility where the study was carried out there is no DAP meter.

Conclusions

- Results found in this study seem to indicate that IgM values are far above the manufacturer's reference of 1.96.
- Exposure technique chart should be optimized in order to provide a significant reduction of dose in the detector.
- This action accomplished with further studies for exposure optimization that should result in a substantial reduction in patient and detector exposure.

Thank you…

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