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Patient doses in general radiography examinations

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Abstract

Purpose: To assess the level of reject films, device quality control tests performance, image quality, and patient doses, at the Elister Medical Centre, Eldoret, Kenya.

Method: The radiation doses received by adult patients undergoing general radiographic examinations were estimated using an indirect method. A standard protocol was used to record patient and exposure parameters during X-ray examinations. The radiation doses were calculated from the patient data and exposure factors: focus to skin distance, kVp, and mAs. Quality control tests, using calibrated Unfors XI equipment, were performed on the X-ray equipment prior to the study.

Results: The mean entrance surface air kerma (ESAK) to the patients was found to be: 0.13 mGy for postero-anterior (PA) chest radiograph; 2.27 mGy for antero-posterior (AP) abdomen; 2.78 mGy for AP lumbar spine; 2.60 for AP pelvis; and 1.59 mGy for AP skull.

Conclusion: For most of the procedures considered the ESAK obtained was below the corresponding international diagnostic reference level. Without compromising the diagnostic value of the radiographs, the study established the first local diagnostic reference levels in a local clinical setting. These baseline data facilitate practical quality improvement on reject films, X-ray equipment efficiency performance, patient dose and image quality.

Keywords

local diagnostic reference levels, entrance surface air kerma, film-screen radiography, quality assurance

Introduction

Somatic and possible hereditary effects of ionising radiation have been demonstrated in many prospective and retrospective studies and from the victims of nuclear fallouts.[1, 2] Such effects are assumed not to have any threshold level due to the random nature of radiation. The use of ionising radiation in the medical field accounts for the largest contribution of radiation exposure to the human population. In view of this the following are required: justification of practice, avoiding repeated exposure, optimisation of X-ray examination, and the use of diagnostic reference levels (DRLs) for effective radiation protection. Exposure factor selection is a major source of poor image quality as well as unnecessary radiation exposure to patients in developing countries, such as Kenya[3] There is a low level of implementation of quality assurance programmes (QA) in the least developed countries. Survey results indicate, however, that patient dose levels in some less developed countries are not higher than those in the developed world.[4] Brazil, for example has put in place specific radiation protection legislation, and implemented QA programmes. However, there is still room for improvement through more effective personnel training and establishment of national guidelines on good practice for the optimisation of patient doses.[5] Local DRLs form an efficient, concise and powerful standard for optimising radiation protection of a patient.

There is need for radiology departments to adopt effective QA programmes to avert considerable costly and high patient doses. Quality improvement processes within radiological facilities are enhanced through accreditation of diagnostic facilities, audits and surveillance programmes[2] with proper application of the relevant safety standards. Adherence to the as low as reasonably achievable (ALARA) principle by imaging professionals requires patient dose measurement surveillance programmes to understand exposure factors, and use of technological utilities.[6] Technical factors and patient dose are mainly influenced by the performance of the X-ray equipment, the technological level of an image receiver, and the skills of an operator.[7, 8] Exposure levels received by workers are monitored periodically. This however does not happen with patients in many countries including Kenya, for example. It is therefore equally important to measure the dose received by all patients undergoing radiological examinations, more specifically general radiography as this forms the bulk of all examination, hence larger patient radiation exposure, excluding computed tomography (CT) and interventional procedures.[9]

Patient dosimetry provides the collective effective dose from radiological procedures; an estimation of the patient risk; and a comparison with the DRLs. Optimised radiation protection measures can be maintained by using optimal performing general radiography X-ray equipment that undergoes comprehensive QA tests and is equipped with an inbuilt kerma area product (KAP) meter currently found in some fluoroscopy equipment.[10]

To achieve optimisation and patient protection in general radiography, adoption of new dose saving technologies and strategies aimed at establishing QA and quality control (QC) programmes, respectively need to be implemented.

This study was undertaken to determine the baseline data for diagnostic X-ray equipment with respect to reject films, quality assurance/control (QA/QC), and patient dose, in a medical practice in Kenya that lacked full implementation of optimisation, justification, patient dose measurements, patient dose reviews, continual dose improvement, verification of applied measures, and continuous control through monitoring measurement.

Materials and methods

The study was undertaken at a private clinic which was part of the national IAEA Technical Cooperation Project "RAF/9/033: Strengthening radiological protection of patients and medical exposure control". The project was approved by the Kenyatta National Hospital Ethics and Research Committee and did not directly involve patients.

A reject film analysis was performed on radiographs produced in one X-ray room at the study site from January to December 2012. The study aimed to include over 30% of the representative adult patient population to minimise the potential errors associated with sample size. Reject films were collected, counted and grouped according to size, type and cause of the rejection, with the aid of an experienced imaging technologist (radiographer).

During the study, seven quality control tests were performed at one meter focus to detector distance on the X-ray machine (Model XG200C, Shanghai, China) using a calibrated Unfors Xi Instrument (Unfors AB, Billdal, Sweden). The QC tests performed included: kVp accuracy, kVp reproducibility, radiation output reproducibility, timer accuracy, exposure time linearity, and total filtration (mm Al). An Unfors DXR+ direct X-ray ruler was used to assess the X-ray/light field alignment. Green sensitive fast speed film was used for the QC tests and processed in an automatic film processor. The QC results were considered to have either 'passed' or 'failed' in accordance with the New South Wales Environment Protection Authority Methods and Standards.[11]

Assessment of radiation exposure to patients was indirectly estimated from the X-ray tube output and the technique parameters following the International Atomic Energy Agency (IAEA) protocol and guidelines.[12] The ESAK for each patient was calculated indirectly using equation 1.

$$\text{ESAK} = M \times mAs \times \left(\frac{FFD}{FSD}\right)^2 \times BSF \,........1$$

where M is the reading from the plotted x-ray tube output factor graph (mGy per mAs) at a specified voltage (kVp), mAs is the tube loading used for each patient, FFD is the focus-film distance, FSD is the focus-skin distance and BSF is the backscatter factor.

The ESAK mean values were considered the local diagnostic reference levels (LDRLs) and the baseline for optimisation. The third quartile values were derived and compared with the DRLs values in the literature. For each case, the following parameters were recorded: patient age, gender, mass, exposure factors (kVp, mAs), FFD, focal spot size, filtration, use of grid, examination projection, field of view, patient thickness at the centre of the incident X-ray beam, patient mass and height. To anticipate future research on the effect of patient size on radiation dose from the use of mass-equivalent cylindrical phantoms this study derived equivalent cylinder diameter (ECD) from the patient data. The ECD was derived using equation 2.

$$ECD = \sqrt[2]{W/\pi H} \,.................................2$$

where W is the mass in grams and H is height in cm.

Useful radiographs were assessed for image quality conformity at the study site according to the European Commission (EC) quality criteria.[13] An image grade of A, B or C was assigned to each radiograph independently by two radiologists. The grading system criteria were: A= features detected and fully reproduced, details visible and clearly defined; B= features just visible, details just visible but not clearly defined; C= features invisible, details invisible and undefined.

Results

The results in Figure 1 indicate a distribution of causes of the reject films. At the radiographer level there was an 11% annual film reject rate. Human error (1%), too dark (3%) and too light (3%) radiographs accounted for most of the reject films. The other causes of reject films referred to in Figure 1 include loose cassette clips, processor failures, missing name, image blur, fogging, dirt stains and artefacts. The relative distribution of the X-ray examinations performed during the study period is indicated in Figure 2.

The results of the QC assessment of the X-ray equipment are presented in Table 1. The QC tests performed were within the New South Wales Standards [11] used in the study.

Tables 2 and 3 contain the exposure parameters and radiation exposure involved

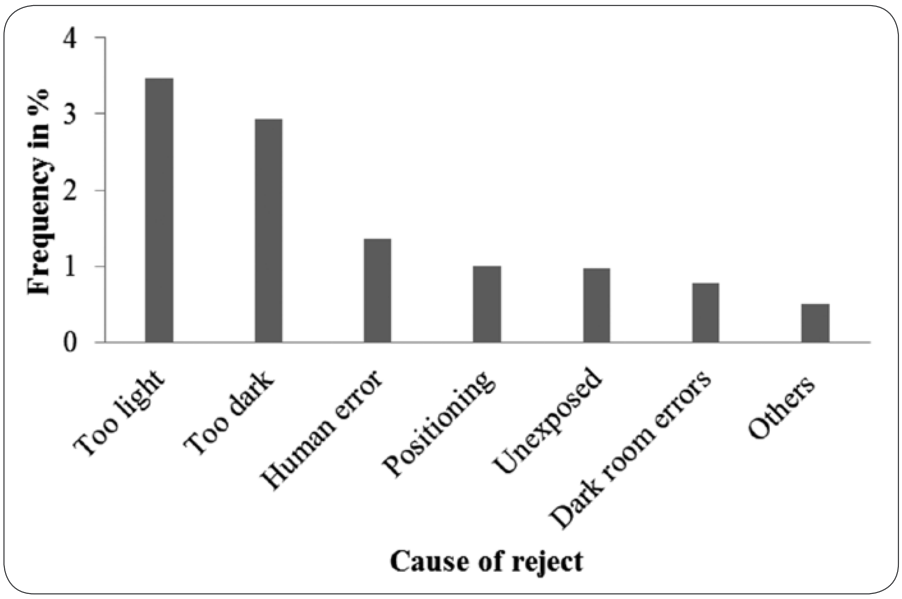

Figure 1. The distribution of the film rejects analysis for the study site.

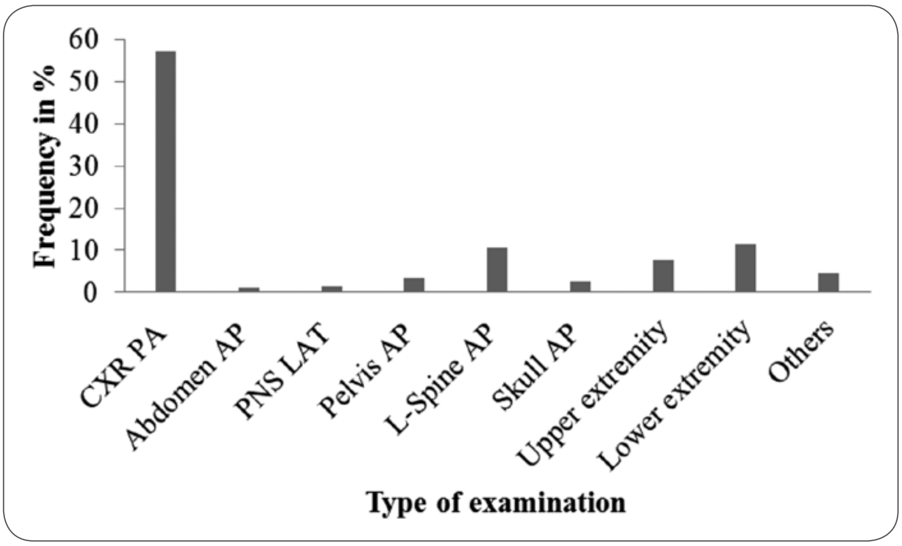

Figure 2. Relative frequency distribution of radiological examinations during the study.

Table 1. X-ray equipment performance tests results

QUALITY CONTROL TEST	RESULTS	COMMENTS
kVp accuracy (± 5%)	-2.5	Pass
kVp of reproducibility (± 2%)	1	Pass
Radiation output reproducibility (± 5%)	2	Pass
Timer accuracy (± 5%)	1	Pass
mA and exposure time linearity (± 10%)	7	Pass
HVL (> 2.3 mm Al @ 80 KVp)	2.7	Pass
Light/radiation beam alignment (1% FFD)		
Anode side	0.3	Pass
Cathode side	0.1	Pass
Inside	0.2	Pass
Outside	0.1	Pass

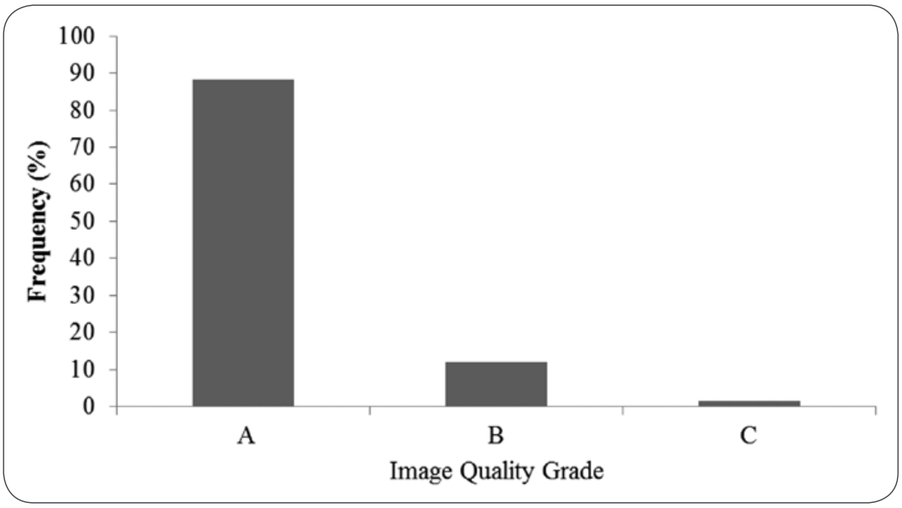

Figure 3. Radiologists' level image quality assessment at the study site.

during general adult radiography examinations. Use of low kVp technique, high mAs values on small body thickness was generally prevalent. Overall the mean ESAK values, as well as the LDRLs, were below the guidance levels indicated in the Tables.

Optimisation of radiation protection of patients requires radiologist participation in order to maintain quality clinical images. Figure 3 indicates the relative distribution of the radiologists' image quality assessment results during the study.

Discussion

The 11% reject film during the study period was above the 5% to 7% recommended film reject rate.[14] Measures implemented after the reject films audit include: in-house QA training, regular participation in continuous medical education (CME), and continuous professional development (CPD) meetings, use of previous optimal exposure parameters for similar body mass index (BMI) patients, regular equipment QC inspection and servicing.

The use of estimated patient exposure parameters according to body size by the imaging technologist was the major cause of the reject films reported in this study. If automatic exposure controls were available it could have mitigated such a practice. In general radiography there are technical limitations associated with approximating exposure factors from the observed patient body size. Therefore there is a need for development of adequate skills, posting of optimal radiographic techniques including exposure charts, regular professional training programmes and an adequate development of practical optimisation strategy.

The second phase of the study will involve optimisation and corrective measures that focus on QA strategies not limited to the identification of dose optimisation need, patient dose measurements, review of QA results, establishing interventions, verification and continuous monitoring of quality improvement.[6] The same portion of reject films results in an equivalent waste of radiology resources, loss of work hours, unnecessary delays leading to inefficiency and loss of earnings. The relative examination frequency in Table 2 shows that chest radiography was the most prevalent of all the examinations performed. The ob-

Table 2. Patient parameters and exposure factors used in the adult radiographic examinations

	MEAN VALUES OF RADIOGRAPHIC TECHNIQUE				EC RECOMMENDED RADIOGRAPHIC TECHNIQUE PARAMETERS[12]		
EXAMINATION	KVp	mA	TIME (ms)	FFD (cm)	KVp	TIME (ms)	FFD (cm)
Chest PA	74	100	40	180	100-150	<20	140-200
Abdomen AP	78	100	80	90	75-90	<400	100-150
Lumbar spine AP	75	100	200	90	70-90	<400	100-150
Pelvis AP	77	100	100	90	70-90	<400	100-150
Skull LAT	73	100	100	90	70-85	<100	100-150

Table 3. Recorded adult patient mean parameters and ESAK values compared with IAEA guidance levels

EXAMINATION TYPE	AGE (yrs)	HEIGHT (cm)	Weight (Kg)	ECD	MEAN ESAK (mGy)	ESAK RANGE (mGy)	3rd QUARTILE (mGy)	DRL[7] (mGy)
Chest PA	42	168	70	23	0.13	0.05-0.52	0.14	0.2
Abdomen AP	38	168	80	25	2.27	1.60-3.22	2.60	5
Lumbar spine AP	44	168	72	24	2.78	1.60-14.59	2.94	5
Pelvis AP	58	168	72	23	2.6	0.80-6.90	2.68	5
Skull LAT	40	168	75	24	1.59	1.20-1.79	1.73	1.5, 3*

* EC[13]

served frequency of 57% was higher than the values reported in literature.[2, 6]

The increase in chest radiography could be attributed to high lung infections, HIV/Aids, road accidents and assault victims resulting in a spillover from the nearby national referral hospital. In general, the increased examinations show the important role of radiological examinations in patient healthcare management. There is therefore a crucial need for optimal x-ray equipment performance especially those with generators whose workload exceed 50 mA-min per week. X-ray equipment under this typical workload condition requires that QC checks should be performed every six months.[15] All x-ray equipment in clinical use should be subjected to regular QC tests. This includes the X-ray equipment used in the study with an estimated nominal workload of 5 mA-min per week.

Regular QC means that the performances of the machines are tested. The use of optimised radiographic techniques is important in patient dose reduction. Previous studies have shown that breast and thyroid radiation doses are directly proportional to ESAK.[16] A good chest radiographic technique was achieved by the use of a high kVp technique and high speed screen/film combination. Good imaging technique was found to be essential for the examinations (in brackets) involving radiosensitive organs such as thyroid (PNS), thymus (chest), stomach, ovaries, bladder (abdomen), cervix, and gonads (pelvis). Reduction of patient dose in chest radiography can be achieved by employing a high kVp technique with low mAs usage. Radiation exposure to the eyes in AP skull examinations will be reduced by performing PA projections. Most FFD parameters used during the study were not consistent with the good radiographic technique given by the EC; the X-ray machine had limitations in the FFD that could be selected on AP or PA procedures done on the X-ray couch (table).[13] Similar studies have been conducted in Greece, Lithuania, and Sudan. Discrepancies in the patient doses and techniques used for the examinations studied were found among the examinations and hospitals, denoting the importance of establishing a national QA programme and localised optimal examination protocols to ensure enhanced patient safety.[17-19]

Conclusion

Management of patient doses and determination of institutional/local diagnostic reference levels are important parts of a QC programme. Optimization and justification of all the radiology processes must be included in a radiology QA programme to achieve effective, excellent general radiography practice. Developing countries, such as Kenya, require radiology standards and regulations to ensure convenient integrated dosimetry instrumentation: kerma area product (KAP) meters being integrated within X-ray equipment, for example. High reject film rates are unacceptable and result in unnecessary patient radiation exposures, and extra operational cost. Regular technical staff training programmes, the implementation of QA/QC tests, regular film-reject analysis, and patient dose assessment, should boost quality improvement in radiological services.

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