

Experiences of in-field and remote monitoring of diagnostic radiological quality in Ghana using an equipment and patient dosimetry database.

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Abstract — A review of diagnostic radiological equipment performance and resultant patient dose values in Ghana has been undertaken. Equipment survey data was taken from 10 x-ray rooms across 7 individual hospitals in southern and central Ghana in order to establish basic equipment performance levels against IPEM standards. The x-ray kerma output data for a range of kVp values was transferred to an online relational database in order that a comprehensive dose audit could be undertaken using exposure factors emailed back to the UK using conventional data entry forms. Analysis was undertaken of the key tube performance parameters. This established a baseline level of equipment acceptability and allowed entrance surface dose values to be verified and calculated using proprietary software.

Data was collected on 1968 patients who underwent a total of 2838 radiographic projections comprising chest, pelvis, lumbar spine (AP and lateral), abdomen and skull (PA and lateral). Entrance surface doses were calculated by operators and analysts inputting the data into the database containing basic output data which then corrected for the applied kVp, mAs, focus-to-skin distance and backscatter variables. The results have been analyzed and compared with IAEA Basic Safety, European and UK quality standards in patient dosimetry. Chest PA and lumbar spine lateral results are presented.

A narrow range of performance variation between the radiographic equipment in the sample was found. The tube and generator performance is acceptable. However, the wide range of ESD values presented highlights that a prioritized approach is needed to address areas of investigation and non-compliance, especially where values exceed basic safety standards. The Chest PA results serve as an example of how standardization of technique could contribute to optimization. A program of patient dose monitoring is proposed, provided that a basic level of practical, cost-effective, ongoing routine equipment quality control can be undertaken.

Keywords— quality control, radiation protection, audit.

I. INTRODUCTION

Assessment of patient doses in diagnostic radiology is widely accepted as necessary to ensure that doses are ALARP [1]. Furthermore, in the absence of specific resources for quality control checks of the relevant parts of the imaging chain (tubes and generators, automatic exposure controls, processors), patient dosimetry offers the potential to provide ongoing quality measures. Remote monitoring of entrance surface dose (ESD) values is possible where the analyst has access to both patient exposure data for a range of examinations and efficiently acquired baseline tube output and kVp values [2]. Numerous studies with thermoluminescent dosimeters (TLDs) have demonstrated patient dosimetry outcomes with data acquired on a subject-by-subject or location-by-location basis across African nations [3, 4, 5]. Prime drivers to perform an audit using direct exposure factors rather than TLD methods were the need to minimize costs and time, to establish basic equipment performance standards, and to allow all radiographers and physics staff in the study to be able to view their results online after verification in the UK.

It was postulated that tube performance in Ghana would not be the governing factor giving rise to any deviation or unexpected results from IAEA, EU or UK reference dose standards, but rather a wider mix of training, technique and film processing resource limitations. In order to confirm this, the following specific objectives were established:

- carry out quality control test on the x-ray equipments in the selected examination rooms.
- compare the results obtained to recognized standards [6].
- measure the X ray tube outputs in μGy per mAs measured at 1 meter for the radiographic equipment in the selected examination rooms.

- estimate air kerma at different settings from the radiographic equipment in the selected examination rooms according to the clinical settings used on each site.
- measure and record patient's anatomical data and exposure parameters used for the specific examination selected for the study.
- calculate and store patient doses using the Quality Assurance Dose Data Software (QADDS) developed by IRS Ltd, Liverpool, UK.
- compare the data with internationally recommended reference values

II. MATERIALS AND METHODS

In this study, field measurements were undertaken using an Unfors Xi Platinum series semiconductor detector type field kit (Unfors Inc., Bildal, Sweden). 7 hospital sites were chosen, comprising 10 x-ray tubes and generators in total. Appropriate field measurements were undertaken of the IPEM "level B" type according to recognized UK protocols [6]. Outputs in terms of $\mu\text{Gy}/\text{mAs}$ at were ascertained at kV_p settings from 50-120 during the survey.

Following the equipment surveys, radiographic staff were issued with patient dose audit forms in order that patient weight, sex, height, thickness (AP or coronal plane width), examination type, projection, focus-to-skin distance, focus to film distance, applied kV_p and mAs could be logged. The remit for each site was to obtain at least 20 patients per x-ray room per examination/projection category at each site for the most commonly employed examinations.

Patient radiation dose assessments were conducted on patients who underwent the 5 most common radiographic examinations (chest, lumbar spine, pelvis, abdomen and skull) in selected hospitals during the study period. The selection of the above examinations was based on their frequencies and contribution to the collective dose to the population. In particular, chest PA was selected because it is the most frequent x-ray examination among the hospitals [7], lumbar spine, particularly the lateral projection, because it is associated with higher ESD values than all other X-ray plain film examinations [8]. It should be noted that pelvis AP data is stored and may offer useful investigation into effective and organ dose studies owing to the critical organs irradiated.

Each patient was weighed, bare-footed and in an upright position. A specially designed caliper was used to measure the patient anatomical thickness for the body part under examination that was then used to deduce the focus-skin distances for the examination. It was therefore agreed among the radiographers in consultation with the participating radiologists that, for consistency in measurements, the

anatomical thickness of the patient for each projection in this study was to be measured at the following anatomical levels:

- (i) Chest PA projection: in the sagittal plane at the level of inferior angle of scapula.
- (ii) Lumbar spine lateral projection: in the coronal plane at the level of the lower costal margin.

A domestic tape measure was used to measure the focus-film-distances (FFD). All FFD measurements were from the center of the tube to the film or the tabletop. The data-sheets were placed near the console of the X-ray room and were completed when a patient entered requiring one of the specified examinations.

Entrance surface dose (ESD) were calculated using the formula:

$$ESD = R_{100} \cdot \left(\frac{100}{FFD - t} \right)^2 \cdot \text{mAs} \cdot \text{BSF} \quad (1)$$

Where:

ESD is the entrance surface dose in milli-Gray, R_{100} is the radiation output per mAs , at 100 centimeters from the x-ray source. Between 10 keV intervals not directly measured on the survey, R_{100} was calculated by linear interpolation between the nearest upper and lower intervals to the nearest 10 keV. mAs denotes the applied tube mAs used for the radiograph, FFD is the focus-to-film skin distance, t is the patient thickness and BSF is a backscatter factor.

III. RESULTS AND DISCUSSIONS

A summary of equipment performance values is shown in Table 1. The rooms selected show the best and worst performing tubes in terms of kV_p and timer accuracy. The selection also corresponds to sites using the same FFD and film/screen speeds, but four different kV_p ranges (Range values here) for chest examinations.

Mean Chest PA ESD values at KR2, 37M, KBUA and RR1 were 0.2, 0.2, 0.4 and 0.7 mGy respectively. The mean value across all ten locations was 0.5 mGy. Mean Lumbar Spine LAT values were 12.1, 13.2, 23.2, 6.1 mGy respectively. The mean value across all ten locations was 13.3 mGy. ESD range factors were defined as the ratio of the maximum ESD value to the minimum for each exam at each site. The intra-room values for chest examinations ranged from 2.9-10.8, and for Lumbar LAT values, from 1.9-2.8.

A wider selection of all 10 rooms surveyed and audit for dosimetry has been defined as GHANASET. The range factors across these ten rooms for chest and spine exams were 6.8 and 12.5 respectively using the ratio of the ESD means. The range factors across the whole data set for chest and spine exams increased to 38.4 and 32.0 respectively when the using the ratio of the absolute maximum and minimum ESD values.

Table 1. Results of QC checks on x-ray equipment at four selected hospitals (maximum value of performance indicated)

Parameters	KR2	37M	KBUA	RR1
KV accuracy (%)	2.4	4.2	3.1	1.5
HVL _{80kVp} , mm Al	2.8	3.5	3.1	3.1
Total Filtration, mm Al.	2.42	3.7	2.9	2.9
Timer reproducibility (%)	9.0	1.8	N/A	0.3
Output Linearity	1.8	1.9	1.8	1.9
Radiation Output Repeatability (%)	0.1	0.3	0.6	3.1
Radiation Output Reproducibility (%)	6.6	5.0	1.5	0.5

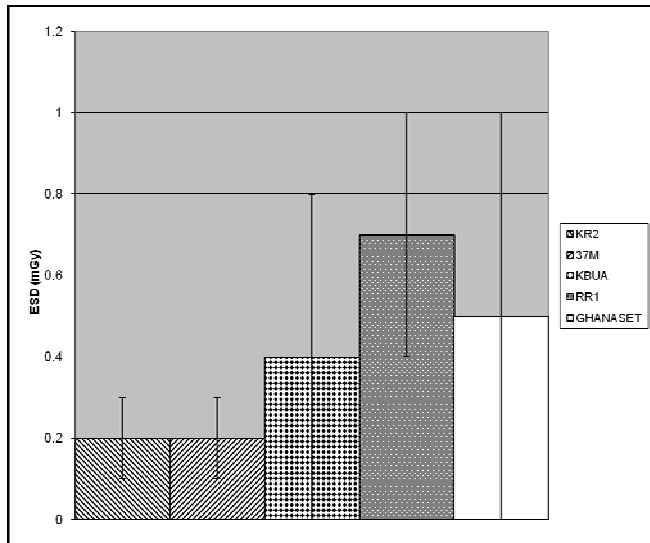


Fig. 1 Mean Chest PA Entrance Surface Doses for 4 locations in the study, together with the mean ESD values for the 10 rooms in total (GHANASET). The error bars shown represent one standard deviation in both the positive and negative direction.

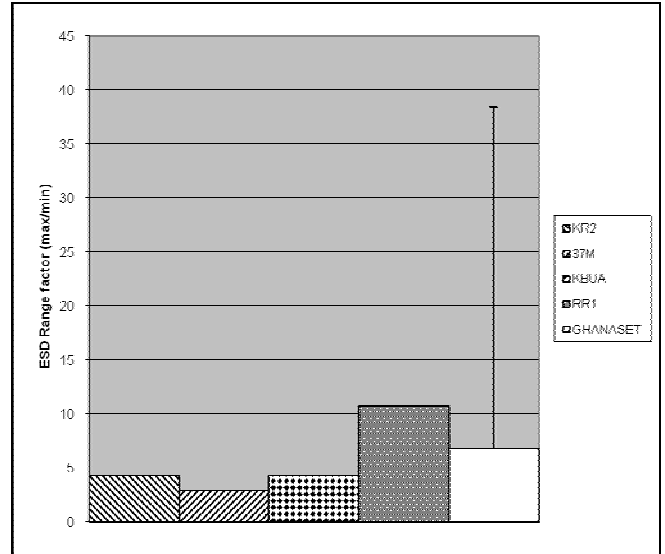


Fig. 2 Chest PA Entrance Surface Dose intra-room range factors (ESD) for 4 locations in the study, together with the mean inter-room range factor for the 10-room GHANASET. The positive error bar value represents the absolute range factor for the maximum and minimum ESD in the examination dataset.

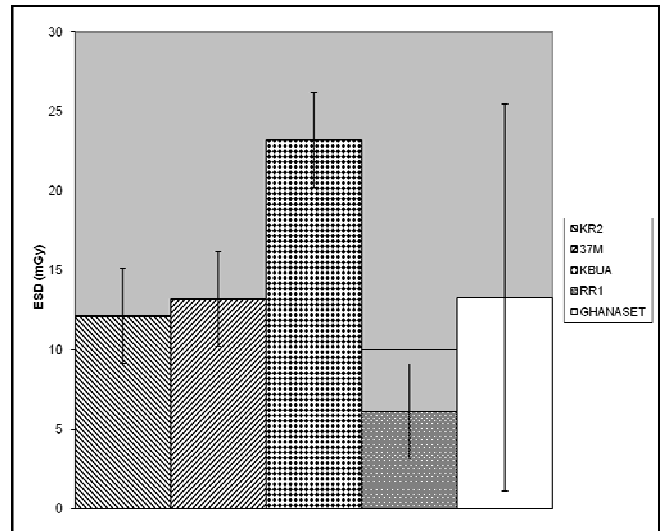


Fig. 3 Mean Lumbar Spine LAT Entrance Surface Doses for 4 locations in the study, together with the mean ESD values for the GHANASET. The error bars shown represent one standard deviation in both the positive and negative direction.

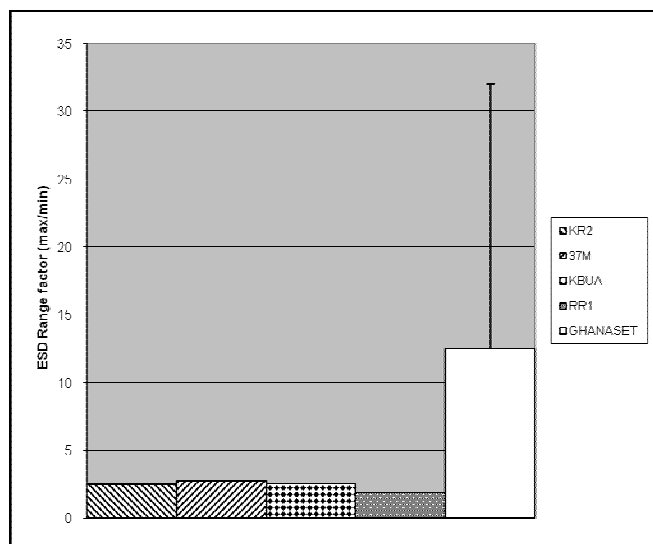


Fig. 4 Lumbar Spine LAT Entrance Surface Dose range factors (ESD) for 4 locations in the study, together with the mean range factor for all GHANASET sites, based on the mean ESD obtained in each room. The positive error bar value represents the absolute range factor for the maximum and minimum ESD in the examination dataset.

The four centers sampled for this audit submitted the same FFD and speed class parameters. They all used AEC and grid techniques. The third quartile ESD value for Chest PA is 0.8 mGy, 0.2 mGy lower than a published value [3]. Mean ESD values for Lumbar Spine LAT exams are available from Nigeria [5], in a reported range of approximately 5-24 mGy, with an overall range factor of approximately 17. The GHANASET lumbar LAT mean ESD in this study is 13.3 mGy. Individual intra-room Ghana range factors are lower than those published in [5], but the overall inter-room range is approximately twice that of Nigeria. It is observed that different audit methods and total patient numbers are employed in each study.

IV. CONCLUSIONS

The results contained herein suggest that improvements have been made in the past ten years in terms of dose reduction in chest radiography. However, the spread of dose values remains similar to or greater than that encountered in Ghana and other African nations [3, 4, 5]. Review and prioritized areas for action in terms of patient dose are still needed.

The methodology contained in this study suggests that a basic local QC program could serve to show consistent x-

ray tube compliance and thus allow for more users to update and review performance via the web or other database technologies with little or no requirement for TLDs. It has already been shown that QC programs serve to improve reject analysis figures and reduce patient dose. [3, 8]

It should be considered through review of training and exposure protocols whether the use of appropriate kV_p ranges and grids and other technique factors in are employed optimally according to specific examinations. The results from this study support this. X-ray tube performance is satisfactory.

The large amount of data stored from this study should allow more sensitive analysis than may have been possible previously. In particular, analyses with respect to demographic parameters, or moving-average studies over time as has been demonstrated elsewhere [2] are possible.

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