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Quality Assurance and Quality Control of Equipment in Diagnostic Radiology Practice - The Ghanaian Experience

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1. Introduction

The World Health Organization (WHO) defines a quality assurance (QA) programme in diagnostic radiology as an organized effort by the staff operating a facility to ensure that the diagnostic images produced are of sufficiently high quality so that they consistently provide adequate diagnostic information at the lowest possible cost and with the least possible exposure of the patient to radiation: (World Health Organization [WHO], 1982). The nature and extent of this programme will vary with the size and type of the facility, the type of examinations conducted, and other factors. The determination of what constitutes high quality in any QA programme will be made by the diagnostic radiology facility producing the images. The QA programme must cover the entire X-ray system from machine, to processor, to view box.

Quality assurance actions include both quality control (QC) techniques and quality administration procedures. QC is normally part of the QA programme and quality control techniques are those techniques used in the monitoring (or testing) and maintenance of the technical elements or components of an X-ray system. The quality control techniques thus are concerned directly with the equipment that can affect the quality of the image i.e. the part of the QA programme that deals with instrumentation and equipment. An X-ray system refers to an assemblage of components for the controlled production of diagnostic images with X-rays. It includes minimally an X-ray high voltage generator, an X-ray control device, a tube-housing assembly, a beam-limiting device and the necessary supporting structures. Other components that function with the system, such as image receptors, image processors, automatic exposure control devices, view boxes and darkrooms, are also parts of the system. The main goal of a QC programme is to ensure the accuracy of the diagnosis or the intervention (optimising the outcome) while minimising the radiation dose to achieve that objective

In a typical diagnostic radiology facility, QC procedures may include the following:

a. Acceptance test and commissioning

Acceptance test is performed on new equipment to demonstrate that it is performing within the manufacturer's specifications and criteria (and also to confirm that the equipment meets

the purchaser's specifications i.e. the requirements of the tender). Commissioning is the process of acquiring all the data from equipment that is required to make it clinically useable in a specific department. This commissioning test will give the baseline values for the QC procedures.

b. Constancy tests

Constancy tests are performed at specific intervals to check on the performance of some key parameters. The frequencies reported for the control of constancy may be with a tolerance of ± 30 days.

c. Status tests

Status tests are normally performed with full testing at longer periods, e.g. annually.

d. Performance test

Performance tests are specific tests performed on an X-ray system after a pre-determined period of time.

e. Verification of radiation protection (RP) and QC equipment and material

f. Follow up of necessary corrective actions taken in response from previous results of QC procedures. This is important because simply performing QC measurements without documentation of corrective actions and a follow ups are not sufficient.

On the other hand, quality administration procedures are those management actions intended to guarantee that monitoring techniques are properly performed and evaluated and that necessary corrective measures are taken in response to monitoring results. These procedures provide the organizational framework for the quality assurance programme. A diagnostic radiology facility as used in this sense refers to any facility in which an X-ray system(s) is used in any procedure that involves irradiation of any part of the human or animal body for the purpose of diagnosis or visualisation. Offices of individual physicians, dentists, podiatrists, chiropractors, and veterinarians as well as mobile laboratories, clinics, and hospitals are examples of diagnostic radiology facilities.

A quality assurance programme should contain the following elements listed below:

1. Responsibility.

There must be a clear assignment of responsibility and authority for the overall quality assurance programme as well as for monitoring, evaluation, and corrective measures. Responsibilities for certain quality control techniques and corrective measures may also be assigned to personnel qualified through training and experience, such as qualified experts or representatives from maintenance personnel outside the facility. These should be specified and written in a quality assurance manual.

2. Purchase specifications.

The purchasing specifications for diagnostic radiology equipment should be in writing and should include performance specifications. Staff of the diagnostic radiology facility should determine the desired performance specifications for the equipment.

3. Monitoring and maintenance.

A routine quality control monitoring and preventive maintenance system incorporating state of the art procedures should be established. This should be performed properly and according to a planned timetable.

4. Standards for image quality.

Standards of acceptable image quality which are diagnostic enough should be established. This should be comparable to International Standards such as the quality criteria established by the European Commission (European Commission 1996a, 1996b, 1999 & Bongartz et al., 2004). Ideally these should be objective as much as possible, e.g., acceptability limits for the

variations of parameter values, but they may be subjective, e.g. the opinions of professional personnel, in cases where adequate objective standards cannot be adequately defined. These standards should be routinely reviewed and redefined as and when the need arises.

5. Evaluation.

The facility quality assurance programme should make provisions for results of monitoring procedures to evaluate the performance of the X-ray system(s) to determine whether corrective actions are needed to adjust the equipment so that the image quality consistently meets the standards for image quality. Additionally, the facility quality assurance programme should also include means for evaluating the effectiveness of the programme itself.

6. Records.

The programme should include provisions for the keeping of records on the results of the monitoring techniques, any difficulties detected, the corrective measures applied to these difficulties, and the effectiveness of these measures. Typically, records should contain the following:

- Results of the calibration and verification of the measurement instruments,
- Results of acceptance and quality control tests,
- Patient dosimetry results and comparison with guidance or diagnostic reference levels (DRLs),
- Inventory of X-ray systems.

7. Manual

A quality assurance manual should be written in a format which permits convenient revision as needed and should be made readily available to all personnel.

8. Education and training.

A quality assurance programme should make provisions for adequate training for all personnel with quality assurance responsibilities. The training should be specific to the facility and the equipment in use.

9. Setting up of committee.

Large facilities such as teaching or referral or specialist hospitals should consider the establishment of a quality assurance committee whose primary function would be to maintain lines of communication among all groups with quality assurance and/or image production or interpretation responsibilities.

The extent to which each of these elements of the quality assurance programme is implemented should be determined by an analysis of the facility's objectives and resources conducted by its qualified staff or by qualified outside consultants. Implementation should also be based on Regulatory requirements (Regulations, Codes or Guides), Health Service Policy as well as the Hospital's Local Rules on the application of ionising radiation. The expected benefits from any additional actions should be evaluated by comparing to the resources required for the programme.

Several studies have indicated that many diagnostic radiological facilities produce poor quality images and give unnecessary radiation exposure to patients. Inkoom et al. recommends for the institution of regular assessment of QC parameters that affect patient dose and image quality at diagnostic facilities, since patient protection is an essential element for the overall management of patient undergoing X-ray examination (Inkoom et al., 2009).

A QA programme should also address issues of radiation protection in the diagnostic radiology. This will ensure that the image quality of radiographs meet minimum quality criteria for confident diagnosis, patient doses are as low as reasonable achievable (ALARA)

and exploration of optimisation options. For instance, the International Basic Safety Standards (BSS) (BSS, 1996) requires Licensee / Registrant to;

- establish the Radiation Protection Programme (RPP),
- provide the necessary resources to properly apply the RPP,
- ensure that the RPP addresses all phases of diagnostic and interventional radiology from purchase, installation, maintenance, qualifications and training of users. etc. and
- ensure appropriate protection for patients, staff and members of the public.

This paper reviews the current QA programme and QC for diagnostic radiology practice in Ghana. The state of equipment in clinical use, QC measurements that are done, Regulatory Guidelines for QA/QC and what holds for the future are presented.

2. Equipment used in diagnostic radiology practice in Ghana

The inventory of number of items of diagnostic X-ray equipment in Ghana is compared with Health-care level III category of Zimbabwe (UNSCAER 2008 Report, 2010) as shown in Table 1.

Country	X-ray generators							
	Medical (General)	Mammo-graphy	Dental	Interven-tional	General fluoroscopy	Angio-graphy	Bone densito-metry	CT scanners
Health-care level III								
Zimbabwe*	250	2	200	2	30	15	-	8
Ghana+	230	8	17	-	9	1	2	11

* (UNSCEAR 2008 Report, 2010)
+ (Regulatory Authority Information System [RAIS], 2010).

Table 1. Comparison of number of items of diagnostic X-ray equipment between Ghana and Zimbabwe

2.1 Human resource present

As a third world country, a major challenge confronting diagnostic radiology practice is the availability of the requisite human resources. The various categories of Radiographic Staff available in Ghana is shown in Table 2.

For instance, earlier Consultant Radiologists were trained overseas until the last five years when training of Radiologists started in Ghana and the accreditation is given by either the Ghana College of Surgeons or the West African College of Physicians and Surgeons. The School of Allied Health Sciences (SAHS), College of Health Sciences (CHS) of the University of Ghana (UG) came into being in the year 2001, after an initiative from Ghana’s Ministry of Health to produce medical and dental technical graduates in physiotherapy, medical laboratory science and radiography. Since its inception, SAHS has trained more than 200 radiographers.

Similarly, most Medical Physicists in Ghana were trained abroad, until 2004 when the School of Allied Health Sciences began training Medical Physicists after it admitted the first batch of six students to pursue the M.Phil degree in Medical Physics. Subsequently training

of eight more Medical Physicist has been taken over from SAHS by a Post-Graduate School of Nuclear and Allied Sciences (SNAS). Currently, there are four students in training. As part of measures aimed at training the requisite human resource in nuclear science applications, a Post-Graduate School of Nuclear and Allied Sciences has been established jointly by the Ghana Atomic Energy Commission and University of Ghana, in co-operation with the International Atomic Energy Agency (IAEA). The SNAS has been designated by the IAEA as African Regional Cooperative Agreement for Research, Development and Training Related to Nuclear Science and Technology (AFRA) Centre to assist in training engineers and scientists from neighbouring countries and the sub-region.

Radiographic Staff category	Number
Population estimate, 2010 ^a	24,000,000
GDP per capita, 2010 ^b	US\$ 1,609
Radiologists ^c	25
Radiographers (B. Sc.) ^d	104
Radiographers (Diploma) ^d	97
X-ray Technicians ^e	149
Medical Physicists ^f	26

^a (Wikipaedia, 2010); ^b (International Monitory Fund [IMF], 2010); ^c (Ghana Association of Radiologist, 2011); ^d (School of Allied Health Sciences, University of Ghana, 2010); ^e (Korle-Bu Teaching Hospital, 2006); ^f (International Organisation for Medical Physicist [IOMP], 2009)

Table 2. Categories of radiographic staff in Ghana

The number of physicians and health care professionals in Ghana is also compared with that of Health-care level III category under UNSCEAR 2008 Report and WHO Health Statistics for 2010, which is shown in Table 3.

3. Advances in technology

The transition of film screen radiography to computed radiography (CR) and digital radiography (DR) is anticipated to increase in Ghana. Currently, DR and CR systems account for about 4% of conventional X-ray machines in Ghana. With the introduction of digital X-ray systems in medical imaging, QC is becoming increasingly more important. One of the reasons is that overexposed detectors, which provided a natural dose limitation for conventional image receptor systems are no longer observed in digital systems (Zoetelief et al., 2008). Also, such new technology brings with it new challenges in terms of its control and quality assurance management. In view of this, KCARE (KCARE 2005a, 2005b) have developed protocols for both CR and DR receptors; Institute of Physics and Engineers in Medicine [IPEM], (2005) have expanded their X-ray system tests to encompass digital technologies; American Association of Physicist in Medicine (AAPM) have also published a protocol for CR QA (AAPM, 2006).

The generators and X-ray tubes that are used in the radiographic systems for both CR and DR remain the same as their film screen system counterparts and QA of the X-ray tube and generators in digital systems follows the standard methods (IPEM, 2005). However, it must be noted that whenever automatic exposure control (AEC) system is selected, the X-ray output is linked (directly or indirectly) to the detector performance and this demands consideration. This can lead to an increase or decrease in patient dose when the X-ray

system becomes faulty or changes in the output consistency occurs. The detectors that are currently available in CR and DR have a wide exposure dynamic range which means there is significant potential for the initial setup of such systems not to be optimised (Medicines and Healthcare products Regulatory Agency [MHRA], 2010).

Number	Health-care level III	Country	
		Zimbabwe*	Ghana
Population (thousand)		12 000	24 000
All physicians		13	1(2587)^
Physicians conducting radiological procedures		15	25 ^c
Radiology technicians		180	350 ^{d, e}
Medical Physicists		4	26 ^f
Interventional Cardiologists		-	-
Other Physicians performing radiology		-	-
Dentists		200	0.5

* (UNSCEAR 2008 Report, 2010); ^c (Ghana Association of Radiologist, 2011); ^d (School of Allied Health Sciences, University of Ghana, 2010); ^e (Korle-Bu Teaching Hospital, 2006); ^f (International Organisation for Medical Physicist [IOMP], 2009); ^ World Health Organization, World Health Statistics, ISBN 978 92 4 156397 7, France Note: the values in the bracket represent the actual numbers.

Table 3. Comparison of physicians and health care professionals with UNSCEAR 2008 Report and WHO 2010 Health Statistics

Another part of the radiographic chain which is often neglected is the performance of monitors. Subjective evaluations of image quality assessment are made at a workstation/review monitor and as such this must be part of the QA programme. In the era of CTs, there has also been a transition from single slice to multi-slice CT and Ghana’s first 64 multi-slice CT together with other accessories like cardiac monitor and automatic contrast agent injector has been installed recently. Indications are that the transition from film screen technology to digital technology is expected to be very rapid in Ghana. This calls for re-organisation and re-alignment of current structures by all relevant stakeholders of the diagnostic imaging community so as to face the challenges that this new technology offers.

4. Regulatory guidelines for quality assurance/quality control measurements

In Ghana, the National Competent Regulatory Authority charged with the responsibility for Authorisation and Inspection of practices using radiation sources and radioactive materials is the Radiation Protection Board (RPB) (Radiation Protection Instrument LI 1559, 1993). The Regulatory Authority was established in 1993 by the Provisional National Defence Council (PNDC) Law 308. The PNDC law 308 was an amendment of the Atomic Energy Act 204 of 1963 (Atomic Energy Act 204, 1963), which has been superseded by the Atomic Energy Act 588 of 2000 (Atomic Energy Act 588, 2000). However, before the inception of RPB, the Health Physics Department of the Ghana Atomic Energy Commission (GAEC) was providing QC and other services like environmental monitoring and film badge services in Ghana. RPB now has a memorandum of understanding with the National Health Service in order to address issues of ionizing radiation in the health delivery sector.

Just as acceptance testing and routine quality control testing of diagnostic imaging equipment are the requirements of European (Council Directive 97/43/ EURATOM, 1997) and many other national legislations, the LI 1559 of 1993 also requires Registrants and Licensees to establish a comprehensive QA programme for medical exposures with the participation of appropriate qualified experts in radiation physics taking into account the principles established by the WHO and the Pan American Health Organization (PAHO).

The operational functions of the RPB are carried out by the Radiation Protection Institute (RPI), which was established by the Ghana Atomic Energy Commission in 2000 to provide scientific and technical support for the enforcement of the legislative instrument, LI 1559. Some major activities that are undertaken by RPI include:

- conducting regulatory inspections and safety assessments for purposes of authorisation and enforcement of the requirements of the LI 1559 of 1993,
- promoting human resource development in radiation protection, safety and nuclear security by promoting training of regulatory staff and organising courses for registrants and licensees,
- carrying out radiation and waste safety services, and
- carrying out relevant research to enhance protection of workers, patients, the public and the environment from the harmful effects of ionising radiation and the safety and security of radiation sources.

In exercise of the powers conferred by regulations 8 (2) and 11 (c & e) of the Legislative Instrument LI 1559 of 1993, RPB has issued the following Guides to ensure compliance with the Regulations intended to protect patients, workers and the general public from the risks associated with exposure to ionising radiation in the course of operating a practice in Ghana. In all, it has issued ten Guides which are listed below:

1. Radiation Protection and Safety Guide No. GRPB-G1-Qualification and Certification of Radiation Protection Personnel (Schandorf et al., 1995).
2. Radiation Protection and Safety Guide No. GRPB-G2-Notification and Authorisation by Registration or Licensing, (Schandorf et al., 1995).
3. Radiation Protection and Safety Guide No. GRPB-G3-Dose Limits, (Schandorf et al., 1995).
4. Radiation Protection and Safety Guide No. GRPB-G4-Inspection, (Schandorf et al., 1995).
5. Radiation Protection and Safety Guide No. GRPB-G5-Safe Use of X-Rays, (Schandorf et al., 1998).
6. Radiation Protection and Safety Guide No. GRPB-G6-Safe Transport of Radioactive Material, (Schandorf et al., 2000).
7. Radiation Protection and Safety Guide No. GRPB-G7-Enforcement, (Schandorf et al., 2000).
8. Radiation Protection and Safety Guide No. GRPB-G8-Occupational Radiation Protection, (Schandorf et al., 2000).
9. Radiation Protection and Safety Guide No. GRPB-G9-Medical Exposure, (Schandorf et al., 2003).
10. Radiation Protection and Safety Guide No. GRPB-G10-Safe Application of Industrial Radiography, (Schandorf et al., 2003).

Currently there are Institutional reforms to establish an independent Regulatory Body to regulate the peaceful uses of nuclear energy which will be known as Ghana Nuclear Regulatory Authority (GNRA), independent from Ghana Atomic Energy Commission as it is currently. The current Regulatory functions of RPB will then be transferred to the new Regulatory Authority (GNRA).

5. Present trend of quality assurance/quality control of diagnostic radiology in Ghana

For the present trend, the Regulatory Authority is still largely in charge of QA/QC of diagnostic radiology in Ghana, which ideally is supposed to be an external audit. This practice has been so due to the non-availability of qualified personnel (medical physicists, radiation protection experts, health physicists, etc.) to man diagnostic facilities, and also this requirement not being a major one for granting of authorisation as is in radiotherapy practice in which qualified personnel availability is mandatory.

The QA/QC is done through Regulatory inspections that are undertaken by the Radiation Protection Institute to conduct safety assessment for the issuance of authorisations. The safety assessment includes detailed inventory of X-ray equipment, availability of skilled and trained operators, adequacy of personal monitoring, health status and structural shielding adequacy with respect to actual practice, usage of personal protective devices for staff and comforters, usage of radiation protection devices for patients, etc. All these parameters which are related to radiation protection are verified and checked.

The inspections are conducted every one to three years depending upon the risk classification of practice and also, whenever there is a major maintenance or change of some key components of the X-ray system.

Some quality control measurements that are supposed to be done (because not all parameters listed under each measurement is currently carried out) to monitor the following key components of the X-ray system are:

- a. Film-processing.
- b. Basic performance characteristics of the X-ray unit.
- c. Cassettes and grids.
- d. Darkroom.
- e. For specialised equipment.
- f. View boxes.

Some parameters of the above-named components and of more specialised equipment that are supposed to be monitored are as follows:

- a. For film processing:
 - An index of speed.
 - An index of contrast.
 - Base plus fog.
 - Darkroom and solution temperatures.
 - Processor condition, film artifact identification.
 - Cassettes, intensifying screens, film, etc.
- b. For basic performance characteristics of the X-ray unit:
 1. For fluoroscopic X-ray units:
 - Tabletop exposure rates.
 - Centering alignment.
 - Collimation.
 - kVp accuracy and reproducibility.
 - mA accuracy and reproducibility.
 - Exposure time accuracy and reproducibility.
 - Reproducibility of X-ray output.
 - Focal spot size consistency.

- Half-value layer.
- Max air kerma rate and air kerma rate at the entrance of patient.
- Calibration of kerma area product (KAP) meter.
- Radiation leakage.
- Relationship between current and voltage stabilising.
- 2. For image-intensified systems, the following tests are required in addition to (1) above:
 - Focusing.
 - Distortion.
 - Glare.
 - Low contrast resolution.
 - Spatial resolution with high contrast
 - Physical alignment of camera and collimating lens.
 - Air kerma rate at the entrance of image receptor.
 - Distance from focus to Image receptor.
- 3. For radiographic X-ray units with screen-film:
 - Reproducibility of X-ray output.
 - Linearity and reproducibility of mA/mAs.
 - Reproducibility and accuracy of timer.
 - Reproducibility and accuracy of kVp.
 - Accuracy of source-to-film distance indicators.
 - Light/X-ray field congruence.
 - Half-value layer.
 - Focal spot size consistency.
 - Representative ESAK
 - X-ray tube housing leakage
- 4. For radiographic X-ray units with CR and DR:
 - In addition to the tests in (3), the following tests are needed.
 - Detector dose indicator consistency/sensitivity (for 1 plate of each size)
 - Uniformity
 - Dark noise
 - Threshold contrast detail detectability
 - Limiting spatial resolution (in one quadrant at 45° only)
 - Erasure cycle efficiency
 - Scaling errors
 - Blurring and stitching artefacts
 - Dosimetry (receptor doses)
- 5. For mammographic X-ray units with screen-film:
 - Reproducibility of X-ray output.
 - Linearity and reproducibility of mAs.
 - Reproducibility and accuracy of timer.
 - Reproducibility and accuracy of kVp.
 - Accuracy of source-to-film distance indicators.
 - Light/X-ray field congruence.
 - Half-value layer.
 - Focal spot size consistency.
 - X-ray tube housing leakage
 - Mean glandular dose.

6. For mammographic X-ray units with CR and DR
 - Reproducibility of X-ray output.
 - Linearity and reproducibility of mAs.
 - Reproducibility and accuracy of timer.
 - Reproducibility and accuracy of kVp.
 - Accuracy of source-to-film distance indicators.
 - Half-value layer.
 - Light/X-ray field congruence.
 - Focal spot size consistency.
 - X-ray tube housing leakage
 - Mean glandular dose.
7. For dental X-ray units
 - Reproducibility of X-ray output.
 - Linearity and reproducibility of mAs.
 - Reproducibility and accuracy of kVp.
 - Accuracy of source-to-film distance indicators.
 - Half-value layer.
 - Focal spot size consistency.
 - Representative ESAK.
8. For automatic exposure control devices:
 - Reproducibility.
 - kVp compensation.
 - Field sensitivity matching.
 - Minimum response time.
 - Backup timer verification.
- c. For cassettes and grids:
 1. For cassettes:
 - Film/screen contact.
 - Screen condition.
 - Light leaks.
 - Artefact identification.
 2. For grids:
 - Alignment and focal distance.
 - Artefact identification.
- d. For darkroom:
 - Darkroom integrity.
 - Safe light conditions.
- e. For specialised equipment:
 1. For tomographic systems:
 - Accuracy of depth and cut indication.
 - Thickness of cut plane.
 - Exposure angle.
 - Completeness of tomographic motion.
 - Flatness of tomographic field.
 - Resolution.
 - Continuity of exposure.
 - Flatness of cassette.
 - Computed tomography dose index.

2. For computerised tomography:
 - Precision (noise).
 - Linearity and contrast scale.
 - Spatial resolution with high contrast.
 - Low contrast resolution.
 - Alignment light/slice congruence.
 - Mean CT Number.
 - Slice thickness.
 - Computed tomography dose index.
 - Positioning the patient support.
 - Sensitivity profile of slices.
 - Coronal and Saggital resolution.
- f. View boxes
 - Consistency of light output with time.
 - Consistency of light output from one box to another.
 - View box surface conditions.

5.1 Ghana's participation in IAEA project

Ghana is involved in several IAEA Technical Cooperation Projects, but one of significant importance to the subject matter under discussion is on Strengthening Radiological Protection of the Patient and Medical Exposure Control. The main objectives of this Project are to upgrade / strengthen radiological protection of the patient in medical exposures due to:

- i. Diagnostic Radiology and Interventional Radiological procedures,
- ii. Nuclear Medicine procedures and
- iii. Radiotherapy practice.

Ghana is participating in four tasks of the Project which are:

1. Surveys of image quality and patient doses in simple radiographic examinations; establishing guidance levels and comparison with international standards.
2. Survey of mammography practice from the optimisation of radiation protection view point.
3. Patient dose management in computed tomography with special emphasis to paediatric patients.
4. Taking steps to avoiding accidental exposure in radiotherapy.

For task (1) above, the entrance surface air kerma (ESAK) in some selected X-ray rooms were estimated from output data of the X-ray machine. A calibrated Ionisation chamber was used to measure air kerma (in mGy) at 1 m focus-detector-distance for different kVp settings. The values of X-ray tube output (in mGy/mAs) were plotted against tube potential (kVp) and the resulting output-kVp curve fitted to a square function. Then at the indicted kVp, the analytical equation (1) was used to evaluate the ESAK.

$$ESAK = Y(kVp, FFD) * mAs * \left[\frac{100}{FSD} \right] * BSF \quad (\text{mGy}) \quad (19)$$

where

$Y(kVp, FFD)$ is tube output for actual kVp used during examination (derived from mGy/mAs-kVp curve) at 1 m, mAs is actual tube current-time product used during

examination, FSD is the difference between the focus-to-film distance (FFD) and patient thickness (in m) in the anatomic region of interest, BSF is the backscatter factor. The mean entrance surface air kerma estimates from six X-ray rooms from Ghana and other African countries that participated in the IAEA project is shown in Table 4 (Muhogora et al., 2008).

Radiographic Projection	Entrance surface air kerma (mGy)							Diagnostic Reference Level (Rehani, 2001)	
	Congo	Ghana	Madagascar	Sudan	Tanzania	Zimbabwe		400 Film-Screen	200 Film-Screen
Chest, posteroanterior	0.3	0.1	0.29	0.21	0.3	0.2		0.2	0.4
Lumbar spine, anteroposterior	0.4	8.3	3.92	1.63	2.1	0.7		5.0	10.0
Lumbar spine, lateral	-	14.4	6.61	3.29	4.7	2.0		15.0	30.0
Abdomen, anteroposterior	0.3	10.3	3.92	1.5	0.9	0.6		5.0	10.0
Pelvis, anteroposterior	0.1	7.0	3.92	0.9	1.5	1.1		5.0	10.0
Skull, anteroposterior	-	-	2.95	1.02	-	0.8		2.5	5.0

Dash (-) indicates that data not available.

Table 4. Mean entrance surface air kerma to adult patients before implementing a quality control program in participating centers in Africa (Muhogora et al., 2008)

Data on technique factors used for most computed tomography (CT) examinations (head, chest & abdomen) and the frequency of examinations / year for both adult and paediatric patients were collected from four hospitals, which is shown in Table 5.

Hospital	Examination	Number / year	
		Adult	Paediatric
A	Head	2080	780
	Chest	520	520
	Abdomen	520	520
B	Head	1820	520
	Chest	520	-
	Abdomen	1040	-
C	Head	1300	260
	Chest	520	520
	Abdomen	780	260
D	Head	5200	520
	Chest	780	260
	Abdomen	1300	260

Dash (-) indicates that no data was available at the time of the survey

Table 5. Frequency of CT examinations surveyed in each hospital

For Task (3) above, the CT dose descriptors that were used were weighted and volume computed tomography dose index ($CTDI_w$, $CTDI_{vol}$) and dose length product (DLP). Computed Tomography Dose Index (CTDI) is the patient CT dose defined as the integrated dose profile (in z-direction) for a single slice, normalised to the nominal slice thickness and the DLP for a complete examination. The DLP takes into account the scan length and number of sequences. Standard methods were used to determine the CT dose descriptors [European Commission 1999, McNitt-Gray 2002, Wall 2004].

The summary of the mean $CTDI_w$ values for adults from four participating hospitals in Ghana for each CT procedure is shown in Table 6 together with other countries that participated in the project (Muhogora et al., 2009).

By country	Method	Mean $CTDI_w$ (mGy) ^a					
			Chest	Chest HR	Lumbar spine	Abdomen	Pelvis
		DRL	(30)	(35)	(35)	(35)	(35)
Algeria	P		9.2	6.8	16.2	15.4	19.1
Ghana	P or I		17.1	17.2	20.4	20.4	20.4
Kenya	P		20	-	-	13	20
Morocco	P		10	25.8	11.9	11.9	10.6
Sudan	P, I or C		19.2	14.1	-	20.5	7.3
Tanzania	I		16.8	13.9	38.8	22.7	26
Tunisia	C		24.3	-	-	-	25.4
Japan	C		14	15	19.3	19.3	19.3
Kuwait	C		12	18.2	-	11.7	-
Syria	P		18.6	24.3	-	21.6	28.4
Thailand	C or P		15.3	14.4	19.5	18.5	16.8
Bulgaria	P		16.7	14.7	20.7	16.3	18.2
Czech Republic	P, I or C		21.3	16.9	23.9	18.4	20.3
Bosnia & Herz.	P		13.5	20.6	21.2	21.2	20.1
Srpska B & H	C		6.9	-	22.8	10.2	8.3
Estonia	C		15.7	-	-	19	14.5
FYROM	I		11.4	-	-	13	11.4
Malta	C		11.5	10	15.4	14.8	21.8
Serbia	C		20.1	-	12.3	12.3	14.1

Dash (-) indicates that data not available.
The Federation of Bosnia and Herzegovina is stated as Bosnia & Herz, Republic of Srpska as Srpska B&H and the former Yugoslav Republic of Macedonia as FYROM.
^aFor examinations of the trunk, calculated values of $CTDI_w$ relate to the 32 cm diameter CT dosimetry phantom (Shrimpton et al. 2006).

Table 6. Mean $CTDI_w$ values for adult patients in different countries. The determination method is indicated as based on phantom measurements (P), calculation by Internet data (I) or display of console (C). The DRL (European Commission, 1999) is shown in brackets (Muhogora et al., 2009)

The summary of the mean DLP values for adults from four participating hospitals in Ghana for each CT procedure is shown in Table 7 together with other countries that participated in the project (Muhogora et al., 2009).

By country	Mean DLP (mGy.cm) ^a					
	DRL	Chest	Chest HR	Lumbar spine	Abdomen	Pelvis
		(650)	(280)	(780)	(780)	(570)
Algeria		347	194	646	554	604
Ghana		396	348	523	496	415
Kenya		933	-	-	1314	837
Morocco		256	121	341	341	271
Sudan		423	171	-	725	163
Tanzania		382	366	363	602	494
Tunisia		874	-	-	-	599
Japan		564	404	513	513	513
Kuwait		223	561	-	552	-
Syria		416	103	-	638	545
Thailand		301	99	720	574	390
Bulgaria		512	-	-	435	322
Czech Republic		341	-	507	444	466
Bosnia & Herz.		437	330	460	460	323
Srpska B & H		246	-	541	448	231
Estonia		833	-	-	910	698
FYROM		342	-	-	526	416
Malta		296	117	289	480	268
Serbia		148	-	512	512	305

Dash (-) indicates that data not available.
The Federation of Bosnia and Herzegovina is stated as Bosnia & Herz, Republic of Srpska as Srpska B&H and the former Yugoslav Republic of Macedonia as FYROM.
^a For examinations of the trunk, calculated values of DLP relate to the 32 cm diameter CT dosimetry phantom (Shrimpton et al. 2006)

Table 7. Mean DLP values for adult patients in different countries. The DRL (European Commission, 1999) is shown in brackets (Muhogora et al., 2009)

The results of the CTDI_w and DLP show some wide variations, with some CT centres recording values greater than diagnostic refrence levels. This calls for some optimisation studies in order to reduce patient dose without a compromise in image quality.

6. Future of quality assurance/quality control

Optimisation of patient dose and image quality is of primary concern in the field of diagnostic imaging. It is recognised that comprehensive quality assurance programmes are a vital component of the optimisation process. Due to the importance of quality control in diagnostic imaging, it is recommended that the appropriate facility personnel review the control tests, data and images periodically (eg. quarterly reviews).

With the availability of training institutions like the School of Allied Health Sciences and the Post-Graduate School of Nuclear and Allied Sciences, more radiologic staff are expected to be churned out to meet the manpower needs of the diagnostic imaging community. For instance, the next 10-15 years, it is projected that about 100 Medical Physicists / Engineers are expected to be trained.

There are also plans for the registration of Ghana Society for Medical Physics (GSMP) association. GSMP will draw out necessary modalities to streamline the Education and Training of Medical Physicists and other professionals since Medical Physics experts are identified as one of the professional groups for whom training is mandatory. GSMP will also work on the accreditation and recognition of Medical Physics Profession in Ghana and job placement of Medical Physicists in Hospitals in Ghana, starting with the Teaching Hospitals. It is expected that the human resources trained locally will be employed to establish Physics Units or Departments in the hospitals for the establishment of quality assurance programmes and quality control services that meets regulatory requirements and international best practices. The Medical Physicists will take charge of the routine QC procedures at their departments, undertake periodic dose audits and assist in the establishment of local reference levels and national guidance levels. These levels are to be compared with diagnostic reference levels and other international recommendations which are internationally recognised as a practical tool in the optimisation of radiological protection.

The independent GNRA when it becomes operational will put in place regulatory control system including authorisation, inspection and enforcement for the beneficial and peaceful uses of nuclear energy for all practices in Ghana. The GRNA is expected to revise/update the protocols that are currently being used to conduct safety assessment to authorise diagnostic radiology departments in order to keep pace with the emergence of modern medical equipment, and also due to the transition from screen-film technology to digital technology in the country. Additional equipment and test protocols will be needed in this regard. When the country attains the necessary critical mass of expertises, the RA may have to consider licensing some Technical Support Organizations (TSO) including Radiation Protection Institute, which will undertake some of the regulatory inspections of facilities on behalf of the Authority, and submit reports to the RA to issue the necessary authorisation.

A comprehensive review of all the RPB Guides that have been issued since 1995 to 2003 is necessary. This will address current challenges of diagnostic radiology practice due to rapid advances in technology. For instance current regulatory guidelines do not cover the application of non-ionising radiation such as ultrasound and magnetic resonance imaging (MRI).

Quality control for view boxes conditions must be incorporated in the QA programme as this is also part of the radiographic chain. Parameters such as consistency of light output with time, consistency of light output from one box to another and view box surface conditions can be incorporated in the QC measurements.

When all appropriate QA programmes are put in place, these will enable the facility to recognise when parameters are out of limits, which could result in poor quality images and

can increase the radiation exposure to patients (Compliance Guidance of Radiographic Quality Control, 2003).

7. Conclusion

It has been increasingly recognised that quality assurance programmes directed at equipment and operator performance can be of great value in improving the diagnostic information content, reducing radiation exposure, reducing medical costs, and improving departmental management. Quality assurance programmes thus contribute to the provision of high quality health care.

There are strong indications that access to diagnostic radiological services will increase in Ghana in the near future. This comes with complex challenges of QA, QC, radiation protection and patient dose management. In all this, the ultimate goal should aim at achieving a diagnostic image that meets clinical requirements with doses to patients as low as possible. Now is the time for all stakeholders (Regulatory Authority, Health Authorities, Universities and other Training Institutions, Physicists, Hospital or Biomedical Engineers, Radiologists, General Physicians, etc.) to work together to improve the quality of patient protection and management.

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