Quality assurance as a tool for optimization of radiation protection in diagnostic radiology in two tertiary hospitals in low-middle income country.

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Abstract.
Quality assurance in diagnostic radiology and its effects in the optimization of radiation protection are well known, but in practice, especially, in low- and middle-income countries, there seems to be little or no effort made towards optimization of radiation protection in diagnostic radiology, through quality assurance. This study evaluated the parameters of quality assurance in diagnostic radiology in line with Bonn-call-for-action 2012. A cross sectional study design was conducted in two Radiology Centres. Data on equipment procurement were collected using WHO recommended checklist. Quality control checks through visual inspection of the x-ray equipment and quality control measurements were collected through: Kilo Voltage peak (kVp) accuracy test using kV meter (Gammex, model RMI 245, USA) and light-beam alignment test using radio-opaque markers. Competence of equipment operators and efficiency of information and communication systems were assessed. Data on shielding goal design were collected through a Survey metre (RadEye G-10) and data on film reject were collected using adapted WHO data capture sheet.. Data were analyzed using percentages, mean and standard deviation with the aid of Statistical Package for Social sciences version 20.0. The results of the study showed that centres A and B do not adhere to WHO (2001) recommendation on equipment procurement. The visual inspection of the installed x-ray equipment were adequate while quality control test showed that equipment in centre A and B recorded kVp inaccuracy of more than ±5%, the rating of the competence of the x-ray equipment operators in the study was acceptable. The film reject analysis showed both centre A and B recorded reject rate of more than 5%. Competence of the x-ray equipment operators, visual inspection of the installed x-ray equipment and kVp accuracy test were adequate. Consequently, the optimization of radiation protection in the study centres was not in line with Bonn-call for action 2012.

Keywords: Optimization, radiation protection and quality assurance

Introduction

Optimization of radiation protection is an act of keeping doses of radiation of medical exposure for radiological purposes as low as reasonably achievable [1]. This involved obtaining the required diagnostic information at reasonably low radiation dose and taking in to account the socio-economic factors of the society. Therefore, optimization of radiation protection requires that the detriment from x-ray imaging should be reduced by quality assurance to a level such that further reductions become less significant than the additional efforts required for their implementation [2,3,4]. Quality assurance in diagnostic radiology is synonymous with the term 'check-and-balance', used in the manufacturing industry. For a diagnostic radiology facility to meet her aims and objectives there must be consistent effort to make sure that, all the components of the diagnostic facility, including human resources and equipment, are working at optimum capacity. World health organization (WHO) (2008) defines quality assurance as an organized effort by staff operating a facility to ensure that the diagnostic images produced by the facility are of high quality and at a low radiation dose to the patient. Diagnostic image can consistently be of high quality with minimum radiation dose to the patient, only if there is a planned and systematic action by the staff of the facility to ensure that the diagnostic images produced by the facility are of acceptable standard in terms of diagnostic information and optimization of radiation protection [6].

The idea behind quality assurance is to maintain or improve quality and it includes monitoring, evaluating and maintenance at required levels of performance of the x-ray equipment among others [7]. A successful quality assurance technique begins with proper equipment procurement. Due to its importance, WHO (2011) recommended a guideline for equipment procurement in the health sector, known as procurement

process resource guide: a WHO medical device technical series. It outlined seven steps of the procurement process as follows: technology assessment, device evaluation, planning and need assessment, procurement, installation, commissioning and monitoring. If technology assessment was not dully followed, there will be a tendency of a poor procurement exercise. Consequently, the procurement procedure of x-ray equipment of this study was assessed using the WHO (2011) procurement guideline. Other quality assurance parameters of interest in this study include: visual inspection of the installed x-ray equipment, tube voltage peak (kVp) accuracy test, light/x-ray beam alignment test, shielding goal assessment and film reject analysis [8].

Methodology

Cross-sectional survey research was carried out to evaluate quality assurance as it relates to the optimization of radiation protection in diagnostic radiology. This includes evaluation of the followings: procedure adopted for x-ray equipment procurement; quality control status of x-ray equipment; competence of x-ray equipment operators; shielding design; and the rate of film rejection. The target population for this study was radiology facility which were non-material targets that included: conventional x-ray equipment; radiographs; shielding design; and Annual Performance Evaluation Rating (APER) form of x-ray equipment operators. Two radio-diagnostic centres with 5 x-ray equipment, 5 shielded diagnostic x-ray rooms and radiographs were involved in the study. Ethical clearance was obtained from the data collection centres of the study. For ethical reasons, the participating centres for this study were designated as centre A and centre B. Document for x-ray equipment procurement at the study centres was the source was used to elicit information on the procurement documents of the study centres. The parameters of the conventional x-ray equipment tested were: kVp accuracy and light/x-ray beam alignment test. A calibrated kV meter known as RMI 245 model, produced by Gammex USA, was used for kVp accuracy. It is a handheld meter that simplifies quality assurance test of radiographic kVp using patented Quadcell detector. The meter has a calibration range of radiographic operations of 50 – 140 kVp. The radiographic kVp accuracy of the meter is ± 2% or 1 kVp, while its radiographic reproducibility is ± 0.5 kVp. The kVp is known as tube potential, it is related to the optimization of radiation protection because it is the penetrating power of the x-ray used in radiological examination. Inaccuracy in kVp or failure of its reproducibility would lead to repeat x-ray examination which would unnecessarily increase the patient dose.

Light/x-ray beam alignment test of the study was conducted using radio-opaque markers (coins) and x-ray cassette loaded with film (18 x 24 cm). The radio-opaque markers and loaded x-ray cassette were less expensive and reliable tools for light/x-ray beam alignment test. The film in the loaded x-ray cassette when exposed and processed shows the area covered by the x-ray beam while the images of the radio-opaque markers show the boundary of the light beam on the processed radiograph.

RESULT

Table 1 shows the results of the evaluation of equipment procurement procedure in the study centres. The equipment procurement procedure of both centres A and B had no technology assessment, device evaluation and monitoring as recommended (WHO 2011).

Table 2 shows the result of visual inspection of the installed x-ray equipment in centre A and B with their average score. Visual inspection of the tube and tube suspension, tube and upright bulky and control panel in the diagnostic x-ray rooms of centre A and B were found to be within the acceptable limit, except for the tube and tube suspension and control panel of x-ray room 2 of centre A that was not acceptable. The tube and tube suspension and control panel of the equipment in room 2 of centre A scored 1.3 and 1.4 respectively, while the acceptable score was 1.5 to 2.0.

Table 3 shows kVp accuracy test at centre A. Measured kVp, at various set kVp in diagnostic room 3 were within the acceptable limit, however in diagnostic room 1, measured kVp accuracy progressively increased in percentage deviation with increased in set kVp from 90 which renders it not acceptable. At the emergency diagnostic x-ray room (EXR), measured kVp were not acceptable when kVp were set at 65

and 80 but were within acceptable limit when kVp was set at 70 and 75. Table 4 shows kVp accuracy at centre B. Measured kVp were within the acceptable limit in diagnostic room 1of centre B except at 50 and 102 set kVp. In diagnostic x-ray room 2 of centre B, measured kVp was within acceptable limit except at 50, 90 and 100 set kVp, while at the diagnostic emergency x-ray room (EXR) measured kVp were not within acceptable limit except at 70 set kVp.

Table 1: Equipment procurement

Centre A & B S/N	Procurement element		Compliance
1	Technology Assessment		N
2	Device evaluation		N
3	Planning and need assessment	Y	
4	Procurement	Y	
5	Installation	Y	
6	Commissioning	Y	
7	Monitoring		N

KEY : Y = YES, N = NO

Table 2: Visual inspection of Installed x-ray Equipment

Diagnostic Centre	DR	Visual Assessment Parameters	Average Score	Remark
A	Room 1	Tube and Tube Suspension	2.0	A
		Tube and Upright Bulky	2.0	A
		Control Panel	1.8	A
	Room 3	Tube and Tube Suspension	1.3	NA
		Tube and Upright Bucky	1.6	A
		Control Panel	1.4	NA
B	Room 1	Tube and Tube Suspension	2.0	A
		Tube and Upright Bucky	2.0	A
		Control Panel	1.8	A
	Room 2	Tube and Tube Suspension	1.9	A
		Tube and Upright Bucky	2.0	A
		Control Panel	1.8	A
	Room 3	Tube and Tube Suspension	1.9	A
		Tube and Upright Bucky	1.6	A
		Control Panel	1.8	A

Key:
DR = Diagnostic Room
A = Acceptable: 1.5 – 2.0
NA = Not Acceptable: 1.0 – 1.4

Table3: KVp Accuracy at centre A

DR	**Set kVp**	**Measured kVp**	**% Deviation**	**Remark**
Room 1	60	61.90	3.20	A
	70	72.50	3.60	A
	80	85.30	6.60	NA
	90	97.90	8.80	NA
	100	111.40	11.40	NA
Room 2	60	61.00	1.70	A
	70	65.60	3.70	A
	81	81.20	0.20	A
	90	89.40	1.60	A
	102	101.20	1.20	A
Room 3	65	70.50	8.50	NA
	70	71.50	2.20	A
	75	75.90	1.20	A
	80	71.80	10.30	NA

Key:
DR = Diagnostic Room
A = Acceptable: ≤ 5%
NA = Not acceptable: > 5%

Table 4: **KVp Accuracy at centre B**

DR	Set KVp	Measured KVp	% Deviation	Remark
Room 1	50	56.90	13.8	NA
	60	60.40	0.70	A
	70	71.40	2.40	A
	81	83.40	3.40	A
	90	93.80	4.20	A
	102	108.00	5.90	NA
Room 2	50	57.90	15.80	NA
	60	61.60	2.70	A
	70	72.90	4.10	A
	80	83.80	4.80	A
	90	95.20	5.80	NA
	100	107.70	7.70	NA
EXR	50	59.90	19.00	NA
	60	63.10	5.20	NA
	70	68.00	2.90	A
	80	85.80	7.30	NA
	90	97.70	8.60	NA
	100	112.30	12.30	NA

Key:
DR = Diagnostic Room
A = Acceptable: ≤ 5%
NA = Not acceptable: > 5%

Table 5: Light beam alignment test for centre A and centre B

Centre	DR	Direction	Measurement (cm)	Total measurement (cm)	Percentage misalignment
A	1	AL_1	0.5	AL = 0.7	AL = 0.7
		AL_2	0.2		
		AC_1	0.5		
		AC_2	0.5	AC = 1.0	AC = 1.0
	2	AL_1	3.8	AL = 7.7	AL = 7.7
		AL_2	3.9		
		AC_1	1.6		
		AC_2	2.3	AC = 3.9	AC = 3.9
B	1	AL_1	0.0	AL = 0.1	AL = 0.1
		AL_2	0.1		
		AC_1	0.3		
		AC_2	0.5	AC = 0.8	AC = 0.8
	2	AL_1	0.5	AL = 1.1	AL = 1.1
		AL_2	0.6		
		AC_1	0.5		
		AC_2	1.0	AC = 1.5	AC = 1.5

Tolerance limit = 1% misalignment
Key:
DR = Diagnostic Room

AL = Along the couch
AC = Across the couch

Table 6: Competence of x-ray equipment operators at Centre A

Indicators for competence	Radiographer (n = 2) Degree holders	X-ray Technician (n = 8) Diploma holders
Job Assessment		
Min-Max	5.20– 5.20	4.10 – 5.00
Mean	5.20 ± .0000	4.59 ± .2949
Character Trait		
Min-Max	5.30 – 5.90	4.30 – 5.00
Mean	5.60 ± .4243	4.7500 ± .2204
Work Habit		
Min-Max	5.00– 5.80	4.30 – 5.40
Mean	5.40 ± .5657	4.83 ± .3454
Leadership attainment		
Min-Max	5.00 – 6.00	4.00– 4.50
Mean	5.50 ± .7071	4.24 ± .2134
Overall Competence		
Min-Max	5.13 – 5.73	4.12 – 4.98
Mean	5.43 ± 0.4243	4.60 ± 0.27

Competence acceptability range:
Acceptable = 3.0 to 6.9
Not acceptable = 1.0 to 2.9

Table 7: Competence of x-ray equipment operators at Centre B

Indicators for competence	Radiographer (n = 8) Degree holders	X-ray Technician (n = 9) Diploma holders
Job Assessment		
Min-Max	4.70– 5.40	4.30 – 5.10
Mean	5.09 ± .2100	4.67 ± .2500
Character Trait		
Min-Max	4.80 – 5.20	4.10 – 5.30
Mean	4.93 ± .1282	4.64 ± .3678
Work Habit		
Min-Max	4.40– 5.40	4.40 – 5.30
Mean	4.90 ± .3295	4.72 ± .3193
Leadership attainment		
Min-Max	4.70 – 5.10	4.20– 5.50

	Mean	4.90 ± .1309	4.73 ± .3841
Overall Competence			
	Min-Max	4.65 – 5.3	4.25 – 5.30
	Mean	4.95 ± 0.1997	4.69 ± 0.3303

Competence acceptability range:
Acceptable = 3.0 to 6.9
Not acceptable = 1.0 to 2.9

Table 8 and 9 show the results of shielding design assessment at centre A and B respectively. The mean value ± SD of shielding design assessment in diagnostic x-ray room 1 and 3 at centre A were within the acceptable limit of 0.1 mSv/wk at control console and 0.02 mSv/wk at other areas, except for the cubicle of x-ray room 1 at centre A that recorded 0.0283 mSv/wk, which was higher than recommended. Table 9 shows the result of shielding design assessment at centre B. The mean value ± SD of shielding design assessment in diagnostic x-ray room 1 and 2 of centre B were all acceptable as shown in Table 9.

Table 8: Shielding design assessment at Centre A

Diagnostic Room	Measurement Point	Minimum mSv/wk	Maximum mSv/wk	Mean ± SD mSv/wk	Remark
Room 1	Control Console	0.00032	0.00060	0.0005 ± 0.0002	A
	Cubicle	0.02772	0.02936	0.0283 ± .00090	NA
	Single Door	0.00062	0.00115	0.0009 ± 0.0003	A
	Double Door	0.00050	0.00056	0.0005 ± 0.0001	A
	Behind ECS	0.00011	0.00030	0.0002 ± 0.0001	A
Room 3	Control Console	0.00016	0.00444	0.0016 ± 0.0025	A
	Cubicle 1	0.00884	0.01032	0.0097 ± 0.0079	A
	Cubicle 2	0.00740	0.01099	0.0097 ± 0.0020	A

	Single Door	0.00001	0.00002	0.0000 ± 0.0000	A
	Double Door	0.00004	0.00038	0.0002 ± 0.0002	A
	Behind ECS	0.00572	0.00788	0.0068 ± 0.0011	A

Key: A = acceptable = 0.1 mSv/wk at control console and 0.02 mSv/wk at other areas
NA = not aceptable

Table 9: Shielding design assessment at Centre B

Key: A = acceptable = 0.1 mSv/wk at control console and 0.02 mSv/wk at other areas

Diagnostic Room	Measurement Point	Minimum mSv/wk	Maximum mSv/wk	Mean ± SD mSv/wk	Remark
Room 1	Control Console	0.00075	0.00285	0.0015 ± 0.00121	A
	Cubicle	0.00001	0.00001	0.0000061 ± 0.00000	A
	Single Door	0.00001	0.00001	0.0000079 ± 0.00000	A
	Double Door	0.00001	0.00001	0.0000061 ± 0.00000	A
	Behind ECS	0.00001	0.00001	0.0000053 ± 0.00000	A
Room 2	Control Console	0.00146	0.01256	0.0015 ± 0.00023	A
	Cubicle	0.00001	0.00002	0.0000153 ± 0.00001	A
	Single Door	0.00001	0.00001	0.0000053 ± 0.00000	A
	Double Door	0.00001	0.00001	0.0000048 ± 0.00000	A
	Behind ECS	0.00002	0.00001	0.0000268 ± 0.00001	A

NA = not aceptable

Table 10: Film Reject Analysis by Examination

Centre	Skull	Chest	Abdomen	Pelvis	Spine	Extremities	Contrast	FNCI`	Total
A	78 (6.52%)	228 (19.07%)	91 (7.61%)	65 (5.43%)	159 (13.03%)	152 (12.71%)	79 (6.61%)	343 (28.70%)	1195 (6.63 %)
B	171 (9.01%)	579 (30.53%)	105 (5.53%)	72 (3.79%)	378 (19.93%)	315 (16.61%)	33 (1.74%)	243 (12.81%)	1896 (8.38 %)

Table 11: Film Reject Analysis by Reason

Centre	Over Exposure	Under Exposure	Positioning Error	Cut-off	Fog	Informant Fault	Processing Fault	Miscellaneous	Total
A	234 (19.58%)	285 (23.84%)	116 (9.70%)	48 (4.01%)	83 (6.94%)	73 (6.10%)	104 (8.70%)	252 (21.08%)	1195 (6.63 %)
B	333 (17.56%)	882 (46.51%)	168 (8.86%)	21 (1.10%)	57 (3.00%)	0 (0.00%)	195 (10.28%)	240 (12.65%)	1896 (8.38 %)

Conclusión

Quality assurance as a tool for optimization of radiation protection have been assessed in this study. Competence of the x-ray equipment operators, visual inspection of the installed x-ray equipment, kVp accuracy test and shielding design were adequate. While equipment procurement procedure and film reject rate were inadequate.

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