academicJournals

Vol. 8(46), pp. 2276-2280, 11 December, 2013
DOI: 10.5897/SRE11.2263
ISSN 1992-2248 © 2013 Academic Journals
http://www.academicjournals.org/SRE

Scientific Research and Essays

Full Length Research Paper

Environmental assessment, instrumentation-quality tests of radiological equipment and human health implications

Oluwafisoye, P. A.[1], Obed, I. R.[2], Bisi-Johnson, M. A.[3]*, Olowookere, C. J.[4], Popoola, A. O.[5] and Efunwole, H. O.[6]

[1]Department of Physics, Osun State University, Osogbo, Nigeria.
[2]Department of Physics, University of Ibadan, Ibadan, Nigeria.
[3]Department of Microbiology, Obafemi Awolowo University, Ile-Ife, Nigeria.
[4]Department of Physical Sciences, Ajayi Crowther University, Oyo, Nigeria.
[5]Department of Radiology, Oncology Unit, Lagos State University College of Medicine, Nigeria.
[6]Department of Physics, Osun State Polytechnic, Iree, Nigeria.

Accepted 15 November, 2013

The health implications of human exposures to ionizing radiation may be deleterious on the immunity mechanism, particularly when large but sub-lethal doses are applied over a period of time. Quality control tests of X-ray equipment and environmental monitoring of a private radiological center (Moroko X-ray Center, Lagos) was carried out. The results showed that radiological personnel and the facilities for safety were grossly inadequate. Dose rates of 3.0 to 3.6 µSv were recorded at the entrance door when the door is closed and opened respectively. The dose rates at the adjacent room and the waiting lobby were at least a factor of 60 higher than the background dose rate each, indicating higher risk to visitors and personnel at the center. Investigation of the equipment using a calibrated multi-purpose non-invasive X-ray test device, Victoreen model 4000M+ and radiation monitor device minirad model 1000+, showed lower values against recommended limits of the International Commission of Radiological Protection (ICRP). However, general overhauling of the facilities was recommended as the X-ray equipment is older than the recommended age by the Nigerian Nuclear Regulatory Authority (NNRA). A follow-up study indicates improved facilities and safety measures.

Key words: Quality control, diagnostic facilities, radiology, health, immunity

INTRODUCTION

Quality control (QC) in atomic radiation comprises the regular tests that must be carried out on major components of the radiation machine to ensure its optimum performance within the system as a whole (West, 1993; CRCPD, 2001; AAPM, 2002). Constant monitoring and routine Quality Control procedures and recommend tests of pieces of diagnostic Imaging equipment are a vital requirement (Cancer Care, 2004). X-rays are a form of ionizing radiation capable of traveling through materials. Since the discovery by German Physicist Wilhelm Conrad Roentgen in 1895, X-ray technology has been an invaluable tool in medicine, industry, agriculture, scientific research, security and safety. For instance, it can be used to observe broken bones and swallowed objects (Zuur, 2002), track blood flow in patients (Taber et al., 2005), and check for

*Corresponding author. E-mail: jumokade@yahoo.co.uk. Tel: +234(0)8033394407.

cavities. X-rays can also be used to diagnose cancer, kill bacteria in food (Grolichová et al., 2004), analyze the structure of crystals or distant stars (LaRouche, 2010; Martinson, 2010), and scan baggage at airports (Zhumadilov et al., 2008).

X-ray production, detection, image processing, and image viewing are some of the major systems in diagnostic radiology to which major quality control can be applied. These tests must be coupled with routine monitoring of final image quality and the environment (BIR, 1988). The purpose of a radiation monitoring programme is to identify all sources of radiation exposure within an operation area, to access the level of radiation exposure of the employee and members of the public (UNSCEAR, 2005), for the timely detection of changes in radiation parameters which may lead to increased exposures, and to produce sufficient information for optimization purpose (Zoetelief et al., 2006). Equipment quality control unit carries out evaluation of equipment performance to ensure proper image quality, as well as patient and operators' safety.

Inspite of the fact that X-rays like other ionizing radiation have beneficial usage in various fields, improper handling and lack of monitoring system may give rise to undesirable effects, some of which have to be weighed against the benefits in application. The energy associated with electromagnetic waves upon interaction with exposed matter may generate heat which can damage cell material (Zuur, 2002). Furthermore, interactions between radiation and matter can result in the production of free radicals which can interfere with the DNA present in cells (Zuur, 2002). The damage done is sometimes reparable. However, oftentimes the damage is irreparable or an incorrect repair can occur. DNA damage due to relatively low doses may cause so called 'stochastic effects' which can be either tumour induction or genetic effects (Zuur, 2002; Berrington et al., 2004; UNSCEAR, 2006). It has been observed that following radiation injuries, the normal microbe flora of the gut, skin and respiratory tract are disconcerted (Leone, 1962). Exposure to sublethal doses of radiation caused the bacterial inhabitants of the gastrointestinal tract to invade the tissues and organs and set up bacteremia which may lead to death (Brown, 1962) of or serious morbid effect in the exposed individual. Genetic alterations due to energy deposited in irradiated cells can arise in non-irradiated cells by so-called non-targeted effects (Morgan, 2003) by receiving signals produced by irradiated cells or the descendants of irradiated cells (Coates et al., 2008; Wright, 2010). In addition, exposure to radiation may lead to resistance in terms of combating pathogenic microorganisms. The mechanism involved in such instance is that of the deleterious effect of ionizing radiations on the immune system. The immune system which is composed of lymphocytes and other accessory cells which are all over the body function to recognize antigens (foreign bodies), neutralize or quench their activities thereby preventing infections and tumours. Lymphocytes are radiosensitive and exposure to low doses and low rates of ionizing radiation might lead to immunosuppression (UNSCEAR, 2006), hence reduced defense-ability.

MATERIALS AND METHODS

In X-ray production, some of the variables investigated during quality control include; peak tube voltage (kVp), product of tube current and exposure time (mAs), beam filtration, automatic exposure devices (AEDs), machine output, X-ray beam/alignment and focal spot. These variables are initially checked to establish a baseline for Quality Assurance (QA) programme (AAPM, 2002). Thereafter, regular testing is contrived to AEDs machine output and beam alignment. Certain test is expected to be carried out on weekly basis (AAPM, 1991) on certain devices such as AED since it has the tendency to lose calibration over a period of time and this will affect both image quality and patient dose. Another variable that requires weekly measurement is the radiographic output.

There are over 4000 x-ray machines in the Nigeria with less than 5% of them under regulatory control, thereby posing serious challenges (Elegba, 2006**)** which in turn affect the quality of patient dose and image quality.

In this study we investigate the efficiency/output of X-ray machine in a private radiology centre in Nigeria. The intention is to compare the degree of conformity of current practice in the center to requirements of the International Basic Safety Standards [BSS] and hence, guide against negative consequential effects of non-compliance on human health.

Before measurements were carried out the devices to be used were standardized by calibration at the Secondary Standard dosimetry Laboratory (SSDL) of the Nigerian Institute of Radiation Protection and Research (NIRPR).

A multi-purpose measuring non-invasive X-ray test device, Victoreen model 4000M+ was used in the collection of data that bothered on the Peak Tube Voltage Kvp, Timer (Accuracy and Reproducibility), Consistency of output and Linearity of X-ray output. The tests carried out on the X-ray facility were according to the manufacturer's guideline (Victoreen, 2008). The device was employed to determine, the voltage and timer (accuracy and reproducibility), as well as the X-ray machine's current and output dose. The environmental monitoring was carried out using calibrated radiation monitor device minirad model 1000+ GM Survey Meter (Thermo scientific, 2008).

RESULTS

General observations

The observations made as shown in Table 1 is a reflection of the result of radiation dosage at the entrance lead lined door measured which is between 3.0 to 3.6 µSv/h, the dose rate at the adjacent room and the waiting lobby were a factor of 60 higher than the background dose rate. Within the cubicle a dose rate of 2.0 µSv/h was measured. Hazard warning light and signs were also not provided; Personnel Monitoring data using thermoluminescence dosemeter (TLD) badges were not available. This fall short of the expected standards required by the National and International Regulatory

Table 1. General observations.

S/N	Observations	Centres abbreviation	
		MXC	
		Yes	No
1	Main door to x-ray room (Lead Lined)	X	-
2	Main door to x-ray room (Lead efficient)	-	X
3	Second Door to x-ray room (lead lined)	nil	-
4	Second door to X-ray room lead lined (efficient)	nil	-
5	Cubicle Type Lead Wood	X	-
6	Cubicle Type Lead wall	-	-
7	Cubicle Efficient	-	X
8	Cubicle window (efficient)	-	X
9	Door Interlock provided	-	X
10	Door (close Automatically)	-	X
11	Provision of lead apron	-	X
12	Lead Apron Efficient	-	X
13	Hazard warning light Provided	-	X
14	Hazard warning light functional	-	X
15	Hazard warning sign (Displayed)	-	X
16	Functional Air-Conditional Provided	-	X
17	Personnel Monitoring (TLD badges) available	-	X
18	Qualified Radiographers available	X	-
19	Darkroom and x-ray room Interconnected	-	X
20	Darkroom temperature controlled	-	X
21	Thoroughfare (Prohibited)	-	X
22	Log book available	-	X
23	X-ray machine over 10 years?	-	X
24	Space of x-ray room (adequate)	-	X
25	Collimator light functional	X	-

Y (X) = Yes, N (X) = No, nil = not available.

Table 2. Quality control tests carried out.

S/N	Radiological tests		
1	Peak Tube Voltage Kvp (Accuracy & Reproducibility).		
2	Timer Accuracy and Reproducibility.		
3	Optical-Radiation field		
4	Light/Radiation Beam Alignment		
5	Constancy of output		
6	Linearity	i	Current (mA)
		ii	Timer
7	Reproducibility of X-ray of output		

CRCPD (2001).

Bodies (IAEA, 1996; NIBIRR, 2003).

Quality control test

Table 2 shows the quality control (QC) tests performed on the equipment. The X-ray equipment was found not to measure accurately and does not reproduce set values. At the following kvp settings 65, 70, 75, 80 lower values of 57, 62, 69, 71 respectively were measured. Tube voltage should have 5% accuracy and 2.5% precision (Table 3). The AEC Optical density of the film should be between 1.10 OD and 1.50 OD **(**van den Berg et al., 1998**)**

For the time accuracy, none of the reading measured was within ±5% of the settings. The measured kvp values are not linear compared with that of the settings. For linearity test <0.5% or <0.43 µGy (0.05 mR) deviation from linearity for any exposure within the readout range of 17.4 µGy (2 mR) to 86.9 Gy (10 R), is at a given exposure rate (AAPM, 1991). The values measured could also not be reproduced.

DISCUSSION

The accuracy and reproducibility of kVp measured values

Table 3. Quality control tests on X-ray tube and generator.

Type of tests	Settings			Measured values		
	Kvp	Time (s)	mAs	Kv efficient	Exposure time (s)	Output dose (mR)
Accuracy (Kvp)	65	0.04	10	56.78	0.0313	34.78
	70	0.04	10	62.33	0.0313	37.57
	75	0.04	10	68.78	0.0313	41.32
	80	0.04	10	71.34	0.0313	44.14
Accuracy (time)	70	0.02	10	61.97	0.0415	18.82
	70	0.04	10	62.64	0.0894	38.56
	70	0.08	10	62.55	0.1409	77.22
	70	0.16	10	63.32	0.1267	119.85
Consistency (Kvp)	70	0.05	10	61.97	0.0415	18.82
	70	0.1	10	62.64	0.0894	38.56
	70	0.15	10	62.55	0.1409	77.22
	70	0.2	10	63.32	0.1267	119.85
Linearity (ma)	70	0.04	10	62.33	0.0313	37.56
	70	0.04	20	63.53	0.0313	76.13
	70	0.04	30	63.32	0.0313	151.62
	70	0.04	40	63.46	0.0313	299.89
Reproducibility (Kvp)	70	0.04	10	63.44	0.0312	37.57
	70	0.04	10	62.61	0.0323	37.57
	70	0.04	10	62.77	0.0350	37.57
Reproducibility (timer)	70	0.04	10	63.44	0.0312	37.57
	70	0.04	10	62.61	0.0323	37.57
	70	0.04	10	62.77	0.0350	37.57

were not within acceptable range as previously stipulated (BIR, 1988; NRPB, 1988). From these results, regular evaluation of the health status of health workers who may be exposed to low radiation doses is warranted. The quality control tests of an X-ray unit are to be undertaken by a Medical Physicist with the purpose of safety and dose optimization (AAPM, 1991). The x-ray tube voltage (Kilo volt [peak]) has a significant effect in the image contrast, the optical density and the patient dose, variations between the stated kilovolt (peak) and the x-ray beam quality must be within ±5%. For the x-ray machine investigated, there is deviation of the measured kVp from the set values on the control panel. The kVp measurements from the X-ray machine as shown in Table 3 are < 5% accuracy which is in discordance to the limiting values as reported by van den Berg et al. (1998). The QC test carried out on the consistency of the machine showed non-compliance. Quality management programme needed for radiation safety policies and procedures were not put in place. Record showed that Radiation Safety Officers and Medical Physicists were not engaged in the activities of the centre. Medical Physics Experts will contribute to maintaining and improving the quality, safety and cost-effectiveness of healthcare services through patient-oriented activities requiring expert action, involvement or advice regarding the specification, selection, acceptance testing, commissioning, quality assurance/control and optimised clinical use of medical radiological devices and regarding patient risks from associated ionising radiations (AAPM, 1991; NIBIRR, 2003; MPE, 2012). The film exposed revealed light and x-ray field misalignment which should not exceed 2% (CRCPD, 2001); in this case it is above the 2% of the source-to-image distance (SID) of both the length and the width of the film. In the light beam alignment test, the film produce revealed the edges light and X ray beam to be within 1% focus–film distance (van den Berg et al., 1998). The gross deviation from acceptable standards may be an indication of exposure of personnel and visitors to radiation risks.

From the foregoing, it is generally recommended that the center be completely overhauled.

ACKNOWLEDGEMENT

The authors are grateful to the National Institute of Radiation Protection and Research (NIRPR), Physics Department, University of Ibadan, Nigeria. The authors declare that there is no conflict of interest. This study did not receive financial support from any funding agency.

REFERENCES

AAPM (1991) Staffing levels and Responsibilities of Physicists in Diagnostic Radiology. Publication of American Association of Physicists in Medicine. Report of Task Group 5 Diagnostic X-Ray Imaging Committee www.aapm.org/pubs/reports/rpt_33.pdf Accessed 13th August 2013.

AAPM (2002). Quality Control in Diagnostic Radiology. Report No. 74. Report of Task Group #12 Diagnostic X-ray Imaging Committee**.** Publication of American Association of Physicists in Medicine. by Medical Physics Publishing www.aapm.org/.../35-9918- 17465-356.pdf Accessed 13th August 2013.

Berrington de Gonzalez A, Darby S (2004). Risk of cancer from diagnostic X-rays: Estimates for the UK and 14 other countries. Lancet 363:345-351.

BIR (1988). Assurance of Quality in Diagnostic X-ray Department – London: British Institute of Radiology.

Brown MH (1962). Effect of Ionizing Radiation on Immunity. Can. Med. Ass. J. 87:1184-1186.

Cancer Care Manitoba (2004) Imaging Physics Recommendations for Routine Testing and Quality Control for Diagnostic Imaging Equipment . www.cancercare.mb.ca/ Accessed 30th July 2013.

Coates PJ, Rundle JK, Lorimore SA, Wright EG (2008). Indirect Macrophage Responses to Ionizing Radiation: Implications for Genotype-Dependent Bystander Signaling. Cancer Res. 68(2):450-456.

CRCPD (2001) Quality control recommendations for diagnostic radiography volume 2: podiatric facilities, publisher Conference of Radiation Control Program Directors, Inc. 205 Capital Avenue Frankfort, Kentucky 40601 www.crcpd.org Accessed 30th July 2013.

Elegba SB (2006). Radiation safety officer (RSO) in diagnostic and interventional radiology. Keynote Address, University of Ibadan, Nigeria. http://archive.punchontheweb.com/articl.aspx/. Last update 2006; Accessed December 2012.

Grolichová M, Dvorak P, Musilová H (2004). Employing Ionizing Radiation to Enhance Food Safety – A Review. Acta Vet (Brno) 73:143-149.

http://www.unscear.org/docs/reports/2006/07-82087_Report_2006_Web.pdf Accessed 7th July 2010.

IAEA, International Atomic Energy Agency (1996). FAO, International Atomic Energy, International Labour Organization, OECD Nuclear Energy Agency, PAN American Health Organization, WHO, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No.115, IAEA, Vienna.

LaRouche L (2010). "The Escape from Hilbert's 'Zeta' 'X': Mapping the Cosmos." Executive Intelligence Rev. EIR 37(11):4-24.

Leone CA (1962). Ionizing radiations and immune processes. Leone, C.A. Editor: Gordon and Breach, New York.

Martinson P (2010). Towards a New Periodic Table of Cosmic Radiation. EIR 37(16):30-37.

Morgan WF (2003). Non-targeted and delayed effects of exposure to ionizing radiation: II. Radiation-induced genomic instability and bystander effects *in vivo*, clastogenic factors and transgenerational effects. Radiat. Res. 159:581-596.

MPE, Medical Physics Expert (2012), Radiation Protection**,** European Commission Guidelines on Medical Physics Expert Directorate - General for Energy Directorate D – Nuclear Energy Unit D.4 - Radiation Protection 30 April 2012 http://lacomplutense.ucm.es/web/medical-physics-expert-project Accessed July 2013.

NIBIRR (2003). "Nigeria Basic Ionizing Radiation Regulations". *B 166-B247. Nigeria Supplement to Official Gazette* No.13 Vol. 92, 3rd March, (2005) – Part B (B45).

National Radiological Protection Board (NRPB) (1988). Guidance Notes for the Protection of Persons against Ionizing Radiation arising from Medical and Dental use. London: HMSO.

Taber KH, Black KJ, Hurley RB (2005). Blood Flow Imaging of the Brain: 50 Years' Experience. J. Neuropsychiatr. Clin. Neurosci. 17:441-446.

Thermo scientific (2008). Minirad 1000 gm survey meter manual, thermo fisher scientific inc. www.thermoscientific.de

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (2005). General Assembly Official Records Sixtieth session Supplement No. 46 (A/60/46). Report on the fifty-third session. http://www.undemocracy.com/A-60-46.pdf. Accessed 7th July 2010.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (2006). Effects of Ionizing Radiation. Reports to the General Assembly, with Scientific Annexes. Volume 1. United Nations, New York, 2008, p. 48.

van den Berg L, Aarts JCNM, Beentjes LB, van Dalen A, Elsakkers P, Julius HW, Kicken PJH, van der Meer F, Teeuwisse W, Thijssen MAO, Zoetelief J (1998). Guidelines for Quality Control of Equipment used in Diagnostic Radiology in the Netherlands Radiation Protection Dosimetry 80(1–3):95–97. Nuclear Technology Publishing.

Victoreen (2008). X-ray test device model 4000M+ Operators manual, No, 4000M+-1-1 Rev.7 Fluke corporation Victoreen Inc, USA. www.flukebiomedical.com Accessed 30th July, 2013.

West M (1993). The principle of quality assurance and quality control applied to both equipment and techniques. In Postgraduate medical science, radiation protection of patient. Wootton, R (edit) Cambridge University press, pp. 49-57.

Wright EG (2010). Manifestations and mechanisms of non-targeted effects of ionizing radiation. Mutat. Res/Fundam. Mol. Mech. Mutagen. 687(1-2):28-33.

Zhumadilov K, Stepanenko V, Ivannikov A, Zhumadilov Z, Zharlyganova D, Toyoda S, Tanaka K, Endo S, Hoshi M (2008). Measurement of absorbed doses from X-ray baggage examinations to tooth enamel by means of ESR and glass dosimetry. Radiat. Environ. Biophys. 47(4):551-545.

Zoetelief J, van Soldt RTM, Siliman II, Jansen JTM, Bosmans H (2006).Quality Control of Equipment used in Digital and Interventional Radiology. Radiat. Prot. Dosim. 117(1-3):277-282.

Zuur C (2002). Ionising Radiation and Radiobiological effects. Proceedings of the International Symposium Dublin, 30:8-14 http://ec.europa.eu/energy/nuclear/radiation_protection/doc/publication/130.pdf Accessed 7th July 2010.