Quality control test of fixed x-ray units at Bir hospital and National trauma center

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Abstract: One of the important goals of the use of X-rays is to diagnose a disease and its extent and minimizing the adverse effect. In diagnostic X-ray, there is an important issue concerning the quality of the image and the exposure of radiation to the patient. Regular practice of quality control in diagnostic X-ray is essential to provide good quality images, decrease hazard to patients, and enhance the appropriate diagnosis. Quality control tests were carried out at six fixed X-ray units at National Academy of Medical Sciences, Bir Hospital and National Trauma Center. Parameters like kVp accuracy, timer accuracy, Reproducibility of kV, time and dose, variable mA and radiation output Linearity with the acceptance limits were checked. Radiation leakage, spatial resolution, contrast resolution and field alignment tests were also carried out. Quality control tests of kV_p dose, dose rate, HVL, mAs, beam alignment and leakage radiation shows mixed results. The measured values were within limit in four X-ray units. Until now we do not have any regulations in Nepal on acceptance testing of x-ray units after installation. The need for quality assurance of X-ray needs to be taken to avert detrimental effects to patients and staff. Institutes must introduce a mandatory system for acceptance tests of X-ray when installed and alongside regular quality control programs.

Keywords: Acceptance test; Image; Quality control; Radiation safety.

Introduction

Nepal is one of the world's least developed countries with a population of nearly 29 million[1]. In Nepal, the use of x-ray imaging in medicine is expanding rapidly bringing significant benefits for both diagnosis and management of disease. This quantitative increment may have a positive impact on the health service system of the country. However, the quality of the service delivered cannot be overlooked since radiological procedures some health risk[2]. Due to lack of national legislation and radiation protection infrastructures in Nepal, till date no quality control test is carried out in hospitals and also there is no mandatory requirement for commissioning of X-ray machines[3]. It is essential that X-ray imaging should be performed within the established principles and framework of radiation protection[4,5]. This study was designed to determine the present status of fixed X-ray equipment at National Academy of Medical Sciences (NAMS), Bir Hospital and National Trauma Center. The main objective of this study is to investigate the status of radiation safety mechanisms, procedures and practices, to ensure proper working condition and status of radiological equipment (X-ray), to initiate steps to introduce QA programs at surveyed institutes and to minimize radiation dose for patients [6,7].

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Received: 15 Apr 2022; First Review: 03 May 2022; Second Review: 18 May 2022; Accepted: 19 May 2022.
Doi: https://doi.org/10.3126/sw.v15i15.45648

Materials and methods

IBA Primus L phantom was used to evaluate the image quality and other purposes while RADCAL Accu-Gold was used for the measurements like dose, dose rate, kV (x-ray source voltage), mA (x-ray source current), and filtration characteristics (HVL).

The following steps were applied to assess the status of quality control activities:

a. Unit assembly evaluation and technical specifications
b. Data collection: kV, mAs, Dose, HVL and time.
c. Data Analysis: kVp accuracy, Reproducibility of kV, Variable mA and radiation output Linearity, timer accuracy
d. Tube leakage and beam alignment test.

Data collection

This study was mainly focused on quality control check of fixed X-ray equipment; hence, we have collected data directly to the measuring device, Radcal Accu-Gold Touch. All data was collected by a microcontroller and transmitted to the PC via high-speed USB interface in real time which allows long-term wave recording at highest time resolution. Measurements were taken by setting SID at 100 cm and field size at 10 × 10. Measurements were taken on built-in display multifunction digitizer module X-ray analyzer Accu-Gold Touch. Accu-Gold Touch is a multi-function X-ray analyzer and uses the latest technology in solid state sensors, gold standard ion chambers, mA, and light sensors. IBA Primus L phantom was used to check spatial the alignment of light and X-ray field and image scale.

Data analysis

Data from different X-rays machines were collected by using Accu-Gold multi-meter. Measurements were exported through a USB flash drive and viewed by using Accu-Gold 2 software. Collected data were then transferred to Ms-Excel where we filtered only required data and then plotted a graph for different parameters using microsoft excel.

Result and discussion

A. Unit assembly evaluation

Out of six X-ray equipment, five X-ray tube was manufactured by Toshiba and one was manufactured by Siemens. The machines were a combination of old and new ones. The oldest machine was around 20 years old with manufacture date of 2004, while the newest one was manufactured in 2021. Visible inspection of the system and the room were carried out to ensure safety and proper use of supporting devices for the X-ray system, interlocks and Bucky assembly. At one X-ray unit, movement of table was not working properly. Two X-ray equipment's vertical as well as horizontal stand was difficult to fix. One of the machines had its collimator with limited mobility. It was found that another X-ray machine was in operation without field-light and the technicians were taking X-ray images with their guesses. Proper maintenance of that machine is recommended promptly. In one X-ray unit used extensively for chest X-rays, the chest bucky was directed to the corridor whilst at the same side on the corridor there was patient waiting area. Similar was the problem in another X-ray unit where the corridor was being used as patient waiting area making its occupancy factor higher without any added shielding. The study found that the technicians need to be re-educated in the radiation protection sector regarding the placement of the waiting room for the patients and exposures were done on the patients with more than one care givers and with wide open X-ray room door.

kVp Accuracy

At a fixed value of current and time, exposures were done for various tube voltages of different machines. Test was performed from 50 kV_p up to 120 kV_p tube voltages, at fixed tube current 200 mA and an exposure time of 0.1s. The obtained graph is shown in Figure 1.

For a fixed applied tube current average of observed voltage was calculated. Percentage deviation between applied and observed voltage is calculated and found to have fairly good kV accuracy. However, inconsistent kV_p accuracy was found in two X-ray units with highest deviation at -6.9% greater than 5% tolerance limit. This meant that these machines need calibration and to be adjusted to be within 5% kV_p accuracy. Besides that, in one equipment all the measured kV were less than the set kV.

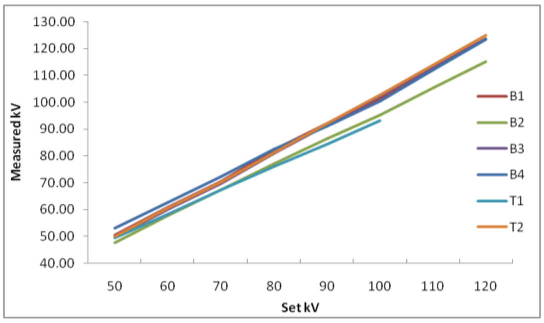

Figure 1: Relationship between applied and observed voltage

Reproducibility of kV, time and dose

For the reproducibility test, the machine was set at a fixed tube voltage at around 80 kV, considering its availability to tune to 80 kV, tube current 200 mA and time 0.1s. Readings were taken with the same repeated procedure for 5 times. In most of the X-ray equipment, excellent reproducibility were observed with coefficient of variance for kV_p - 0.00061, for time - 0.00662 and dose - 0.00044 which is much less than tolerance of 0.02 for kV_p and 0.05 for the others.

Variable mA and radiation output Linearity

mA linearity test was done for both small focal spot and big focal spot sizes. The linearity tests were done with kV value fixed at 80 kV and time set at 0.1 sec while applying variable mA values from 10 to 400 mA where applicable. However with higher mA values errors were introduced hampering the data acquisition.

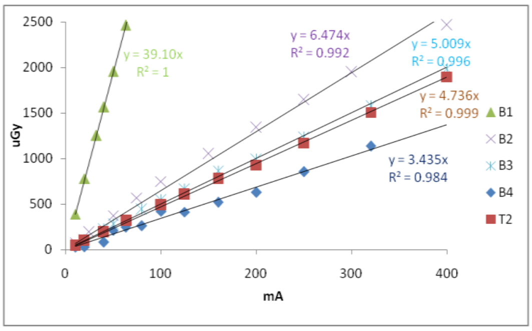

Figure 2: mA linearity

In the graph above, lesser data acquisition, up to 71 mA only, was done for the equipment B1. The linearity graph shows that all of the equipment has excellent linearity close to one R^2 values except for the equipment B4 which has the least R^2 value. The probable reason for this mediocre performance might be that this machine has not been used routinely for a long period of time of around 4 years in its life time of about eight years.

Timer *accuracy*

At fixed voltage and current, measurements were carried out for varying time. The observed graph of different applied values of mAs is shown in Figure 3.

It was observed that at three X-ray unit, the deviation of the measured time and set time were within the tolerance limit of 5% whereas for other equipment the deviation was as high as -65.9% for one unit and respectively 30.3% and -87.8% for other two X-ray equipment. Similarly, it is also observed that three X-ray equipment have consistent μGy/mAs with coefficient of linearity less than the tolerance value of 0.1 while the other machines with large deviating timer value, the coefficient of linearity were greater than the tolerance value.

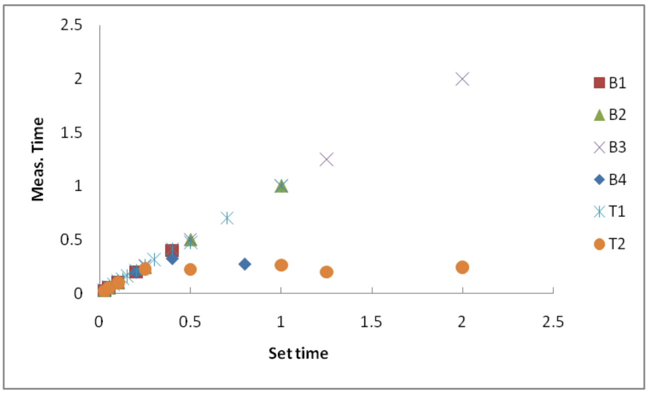

Figure 3: Relationship between applied and measured time

It is also observed that equipment B4 has irregular response for the measured and applied time, the probable reason being it an old machine without any maintenance and was also not used for a long period.

Meanwhile the response for the T2 machine is troublesome as it is being used routinely and excessively. Proper maintenance of that machine is recommended promptly.

Tube leakage test

Tube radiation leakage test were done by using calibrated radiation survey meter (collimator closed) and readings were taken at 100 cm distance at the anode, cathode and front and back of the X-ray tube. There is leakage in almost all units and average reading was 0.095mSv/hour.

Beam alignment tests:

The X-ray beam alignment was checked by using perpendicularity of reference axis with table/Bucky with field size of 20 × 20 cm^2, 100 cm SID. The acceptable limit was set between 1.5° to 3.0° at the perpendicularity (alignment) of the X-Ray beam. Beam alignment test shows that four X-ray units were within limit and in two X-ray units were not within the acceptable limit.

X-ray to field light alignment was also carried out for the x-ray units. Area was collimated at 10 cm × 10 cm or more but within the cassette/detector. In three X-ray equipment +2 mm deviation was observed and in two unit +1.5 mm and in one equipment the deviation was +1 mm.

Conclusions

The quality control tests were carried out at six fixed X-ray units. Different parameters like kVp accuracy, timer accuracy, reproducibility of kV, time and dose, variable mA agrees with the acceptance limits [9]. Radiation leakage test, the alignment of light and X-ray field, geometry symmetry tests were also carried out. It was found that leakage exists in almost all units but the average reading was 0.095 mSv/hr which is within the acceptable limit. It was also found that in one X-ray unit, collimators were not working properly. One X-ray unit needed urgent maintenance as field light was out of the order and the X-ray exposure was being done on the intuition of the technician. One X-ray unit does not have a scale and manufacturer's manual. The alignment of X-ray unit ranged from 0.3 to 1.0 cm which is within the tolerance level. X-ray system should be tested periodically and record should be monitored through testing.

The study shows that there is a serious need for quality assurance of diagnostic X-ray to be implemented to avert detrimental effects to patients and staff. Radiographers should be provided with sufficient training to ensure proper condition of X-ray machines. Radiation regulation and national standards are also essential for such programs to be introduced. Any program managing patient dose in radiology should be given high priority in a country like Nepal. Institutions must introduce a mandatory system for acceptance tests of X-ray machines when installed and adopt regular quality control program [10, 11]. Similarly the study found that the concerned authorities need to be made aware in the radiation protection sector regarding the placement of the waiting room for the patients. The interlock system in X-ray room is not mandatory by law but from this study it was found that with no mandatory law, it is completely neglected.

Acknowledgements

The authors are very thankful to the radiological staff at NAMS, Bir Hospital and National Trauma Center for their support throughout the entire period of study. Authors are also thankful to the IAEA/RCA project RAS6087: "Enhancing Medical Physics Services in Developing Standards, Education and Training" program for providing measuring equipment without which this study could not have been possible.

References

1. Census 2021, Central bureau of statistics, Nepal.
2. Hall, E. J. and Brenner, D. J. 2008. Cancer risks from diagnostic radiology Br. *J. Radiol*. **81**: 362–78.
3. Hart, D. Hillier, M. and Shrimpton, P. 2012. Doses to patients from radiographic and fluoroscopic x-ray imaging procedures in the UK-2010. Review HPA-CRCE-034.
4. Adhikari, et al. 2012. Status of radiation protection at different hospitals in Nepal. *Journal of Medical Physics*. **37(4)**: 240-244.
5. IAEA (International Atomic Energy Agency) 2011. Radiation protection and safety of radiation sources: International basic safety standards interim (Vienna: IAEA) General safety requirements part 3.
6. ICRP (International Commission on Radiological Protection) 2007a. The 2007 recommendations of the ICRP Publication 103; Ann. ICRP 37 (2–3) (Oxford: Elsevier)
7. Adhikari, K. P. 2012. Radiation regulation in Nepal: a challenging journey. *Radiation Regulator*. **1(1)**: 6-10.
8. Valentine, J. The 2007 Recommendations of the international commission on radiological protection. ICRP Publication 103. Ann. ICRP 37.
9. Williams, M. B., Krupinski, E. A., Strauss, K. J., Breeden, W. K., Rzeszotarski, M. S., Applegate, K., Wyatt, M., Bjork, S. and Seibert,

J. A. 2007. Digital radiography image quality: image acquisition. *J Am Coll Radiol*. **4(6)**: 371-88.

10. General x-ray QC guideline. 2013. Version 1. The Royal Australian & New Zealand college of radiologist.
11. Radiological protection and safety in medicine.1996. ICRP Publication 73. Ann. ICRP. **26 (2)**.
12. Servomaa, A. Current level of radiation dose to patients in. 2001. *Proceedings of an International Conference on Atomic Energy.* 26-30