Radiation Safety Assessment on The Use of Portable X-Ray for General Radiography. Case Study: Portable X-Ray of X-Manufacture

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Abstract. The new development science and technology of diagnostic radiology for general radiography using portable X-ray equipment shows that the need for precise diagnostics, easy and affordable services, is increasingly taken into account. Generally, portable X-ray equipment is not considered for general radiology examinations because the resulting image is not adequate, reducing medical practitioners' accuracy in conducting medical diagnoses. It can happen because portable X-ray equipment generally has lower energy than fixed X-ray equipment. The low power of portable X-ray equipment has portable X-ray equipment limited only to specific organs. But, recently, because of the advances in science and technology, there are various types of portable X-ray equipment in the field that are much better than before and meet radiation protection and safety aspects. It can assist the needs of medical services that are fast, practical, and efficient. A comprehensive study has been carried out regarding the use of portable X-ray equipment for general radiography regarding radiation protection and safety aspects. This study shows that portable X-rays are adequate to be used in general radiography if considering radiation protection and safety, especially considering its risks.

Keywords: portable X-ray equipment, radiation protection and safety, science and technology, efficient, risk

INTRODUCTION

X-ray equipment technology in the diagnostic radiology field continues to be developed to meet the needs of good, easy, and efficient patient diagnostics services. One form of technological development is the emergence of portable X-ray equipment with a small size but can produce better quality images. Following the characteristics that are easy to carry and move, portable X-ray equipment is designed to meet the needs of patients who cannot come or move to the radiology room. However, besides its benefits, some risks must be considered from the use of portable X-ray equipment. Thus, the development of portable X-ray equipment technology must be accompanied by radiation protection actions to ensure radiation safety for patients, workers, and public members.

Nowadays, there is a kind of portable X-ray equipment that its shape and size are used for general radiography examination. One of them is portable X-ray equipment of X-Manufacture. The X-ray equipment can be operated by holding the X-ray equipment directly with hands without a tube stand. It can reduce the optimization of radiation protection safety because there is a possibility of vibration or instability when the X-ray equipment is operated. As a result, it will reduce the quality of the resulted image. Moreover, there is a possibility that the operator's hands will get unnecessary exposure. Besides, several other things should also be considered related to the risk of using this portable X-ray equipment.

The purpose of this paper is to provide a comprehensive study of the use of portable X-ray equipment of X-Manufacture for general radiography in terms of radiation protection and safety aspects.

Objective

The objective of this assessment is to provide a comprehensive study of the use of portable X-ray equipment of X-Manufacture for general radiography in terms of radiation protection and safety aspects.

MATERIAL & METHOD

This study's methodology was carried out through literature studies from national and international references and reviewed secondary data from one of the portable X-ray equipment manufacturers (X-Manufacture).
Some data used in this study is the data from portable X-ray equipment of X-manufacturer, which will be used for general radiography. The portable X-ray equipment is digital radiographs in the form of a camera equipped with a detector and notebook 17 x 17 cm, mini cradles with varying angles. The X-ray equipment tube is fitted with a collimator with one field illumination size (collimation size cannot be adjusted) with the following technical specifications.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focal spot size</td>
<td>0.4 mm</td>
</tr>
<tr>
<td>kV/mA of Tube</td>
<td>40 – 60 kV (adjustable) / 2 mA</td>
</tr>
<tr>
<td>output energy</td>
<td>120 W</td>
</tr>
<tr>
<td>energy supply</td>
<td>DC 11.1 V (Battery)</td>
</tr>
<tr>
<td>input energy</td>
<td>DC 5 – 12 V / 2.1 A (X-Ray unit)</td>
</tr>
<tr>
<td></td>
<td>AC 100 – 240 V, 50 – 60 Hz / 1 A</td>
</tr>
<tr>
<td>Weight</td>
<td>1.8 Kg</td>
</tr>
</tbody>
</table>

FIGURE 1 below explains the results of radiation exposure measurements around the portable X-ray equipment of X-manufacture in 0.5 seconds at a distance of 10 cm, 20 cm, and 30 cm from the equipment's surface.

FIGURE 1. The radiation exposure around the portable X-ray equipment of X-manufacture [1]

FIGURE 2. Chest image resulted from the portable X-ray equipment of X-manufacture [1]

FIGURE 2. shows the chest image resulted from the portable X-ray equipment of X-manufacture. Figure 3 shows the image's comparison resulting from X-ray portable of X-manufacture with the image resulted from general X-ray radiography.

The diagnostic effectiveness of portable X-rays for patients in the intensive care unit was reported to be 84.5%. Meanwhile, patients' radiological assessment in nursing homes is sufficient, with good image quality, and favorable factors such as patient safety and comfort, no need for transportation, and no need for staff to be absent.
One in 123 patients (241 radiographs) had to undergo repeat radiographs in the hospital because the images were unclear while the rest were sufficient for diagnosis. Cellular digital chest X-ray is sensitive and specific in detecting pulmonary tuberculosis in culture-confirmed cases. For comparison, the cellular X-ray has a sensitivity of 81.8% (95% confidence interval 64.5 to 93.0) and specificity 99.2% (95% CI 99.1 to 99.3). [2]

**FIGURE 3.** The image resulted from X-ray portable of X-manufacture (left), and the image resulted from general X-ray radiography (right) [1]

**RESULTS AND DISCUSSION**

From the calculation of radiation exposure measurement that showed in Figure 1, the dose rate is at a distance of 10 cm from the focal spot surface with a time of 0.5 seconds in the position with the smallest dose (0.003 µSv) is 21.6 µSv/hour. It exceeds the limit that is required in Government Regulation No. 29 of 2008 (1 µSv/hour). Government Regulation No. 29 of 2008 Article 72 contains provisions concerning ionizing radiation generator which are exempted from the license. It states that under normal operating conditions, the equivalent dose rate in all directions does not exceed one µSv / hour at 10 cm from the equipment's surface. The maximum energy produced is less than or equal to Five keV [3].

Based on Government Regulation No. 29 of 2008 Article 72, the portable X-ray equipment of X-manufacture, is not included in the use of exempted from the license. The equivalent dose rate in all directions exceeds one µSv/hour at 10 cm from the equipment's surface. Therefore the portable X-ray equipment of X-manufacture must have a license from BAPETEN.

In terms of its physical characteristics, mobile X-ray and portable X-ray equipment are easy to move. They are designed to meet the needs of examinations of patients who cannot come or move to the radiology room: patients in the emergency unit room, patients in the intensive care unit room, patients with disabilities or patients who are difficult to move, patients in prisons, or patients in military operations [2, 4, 5].

It is necessary to make provisions or guidelines for optimizing radiation protection and safety to use portable X-ray equipment to ensure radiation protection and safety. Besides, the examinations using portable X-ray equipment cannot be carried out without medical practitioners’ proper justification [4, 5].

Portable X-ray equipment is often moved to anywhere, so it is essential to have provisions on tracking the locations of portable X-rays equipment to supervise the safety of its uses. It can be executed by restricting the location area following those stated in its license. This area may include districts, cities, or provinces. Besides that, there should be a reporting system periodically to BAPETEN on the location of portable X-ray equipment. However, supervision related to the area should be coordinated with the Ministry of Health or the local Agency of Health because portable X-ray equipment is one form of health service that must be integrated with health facilities.
In addition to area restrictions, provisions need to be made to prevent the possibility of portable X-ray equipment used by unauthorized persons. The requirements regarding the place and the method to store portable X-ray equipment appropriate and safe, and the responsible person for controlling the storage and use of portable X-ray equipment are needed. It also should be clarified and considered who justifies using portable X-ray equipment and who analyzes the image. As radiologists should interpret the image over long distances, it is necessary to ensure adequate computer and internet network specifications. The image can be read and analyzed quickly and accurately, and will not inhibit the communication between the personnel examining with the radiologists. To ensure that portable X-ray equipment is operated by qualified personnel, proof of competency or expertise of each personnel is necessary.

The things that should be considered in portable X-rays related to the radiation protection and safety aspects that include the principles of justification, dose limitation, and optimization of radiation protection and safety are as follows.

**Justification**

Government Regulation No. 33 of 2007 Article 22 states that justification must be based on the benefits that are greater than the risks [6]. The advantages of using portable X-rays are providing health services to patients more efficiently, practically, and quickly, especially for patients who can not move to a fixed X-ray equipment room. For example, patients in emergency units, intensive care units, patients with disabilities, or critical patients who have difficulty or are significantly at risk when moving, patients in prison, or patients in military operations [3,4]. However, despite its benefits, its risks should be considered in the use of portable X-ray equipment. These risks that should be regarded as include [2, 4, 5]:

- The use of portable X-ray equipment can be done in an outdoor area, or in a room that does not have adequate shielding, or in a place where there are other patients or the public who are near portable X-ray equipment during exposure.
- Portable X-ray equipment is often moved, assembled, and stored anywhere, so it may be affected by mechanical stability that may disturb the generator's output.
- Portable X-ray equipment is small and easy to carry to be used or operated by unauthorized persons.
- Portable X-ray equipment uses batteries more often, so there is limited energy availability, which will affect the exposure process and image quality.
- The limited current (mA) used in portable X-rays can affect image quality. To get the expected image quality, it takes more prolonged exposure, and the radiation will be more significant.
- The limited kV used in portable X-rays also limits the examination types because some examinations require quite large kV parameters.
- The use of X-ray equipment meets the needs of patients who can not come to the hospital, so it takes time, place, and personnel to go to the site. It is necessary to consider the issue of resources related to personnel, funding for transportation, personnel, and quality control of the equipment that may be greater from the routine examination.
- In addition to the justification by BAPETEN, it should be considered the suggestions from radiologist professional organizations and the Ministry of Health. It relates to the readiness and improvement of human resource competencies, increased legal awareness, and justification for new technologies and procedural techniques. Request for consideration of justification of new technology to the protection organization and the ministry of health is a mandate of the General Safety Requirements Part 3 (GSR Part 3) of IAEA [7].

Because of its risks, the portable x-ray equipment should only be used for examinations where it is impractical or not medically acceptable to transfer patients to a fixed unit. The medical practitioners should justify the use.

**Dose Limit**

The radiation exposure around the portable X-ray equipment of X Manufacture, when operated, should be considered to estimate whether the dose value received by radiation workers exceeds the dose limit for radiation workers determined by the Bapeten Chairman Regulation No.4 of 2013 or not. The dose limit for workers is the effective dose of 20 mSv (twenty millisieverts) per year, on average, for 5 (five) years in a row [8].

From **FIGURE 1**, we get the dose calculation received by the radiation worker for a year. The dose is the highest dose behind or next to the X-ray equipment, where the operator is likely to stand, dose value is 0.085 µSv at a distance of 10 cm for a single exposure. If it is assumed that one worker operates the portable X-ray equipment 20 times per day, then the dose to be received by the worker for one year (250 workdays) is:

$$0.085 \, \mu \text{Sv} \times 20 \times 250 = 425 \, \mu \text{Sv} = 0.425 \, \text{mSv per year}$$
From the calculation, it is obtained the most massive dose at a position 10 cm behind the equipment by assuming there are 20 operations in a day, which is 0.425 mSv per year, which is still much lower than the dose limit for radiation workers (20 mSv / year). However, it is highly dependent on information about how many operations are usually done by workers. Therefore, the information regarding the workload analysis of radiation workers is needed. It is advisable to verify the measurement of radiation exposure during radiation using portable X-ray equipment using a phantom so that the radiation exposure measurement results also take into account the patient's scattering radiation.

Besides, another thing that must be considered is work area restriction, namely the control area and supervision area. Access to work areas where radiation is being used should be controlled to ensure doses to visitors are below the dose limits for the public. In a diagnostic radiology facility, the control area is the locations where the X-ray equipment is operated. Therefore, where portable X-ray equipment is placed can also be categorized as controlled areas during radiological procedures are being carried out. The site should be shielded and should be restricted, and there should be radiation warning signs indicate that X-ray equipment is being operated [9]. Following BAPETEN Chairman Regulation No. 4 of 2013, personnel in the control area should use individual dose monitor and radiation protective equipment [8]. The supervised area may involve areas surrounding the control area. The supervised site is not primarily based on the radiation exposure level, which in radiology diagnostic can be kept very low, but instead as a 'buffer zone' due to other individuals' potential to enter the X-ray area inadvertently and be exposed. Thus, this supervision area should also be marked [3].

**Optimization of Radiation Protection and Safety**

The principle of optimization of radiation protection and safety, as explained in Government Regulation No.33 of 2007, is The optimization of radiation protection and safety is an effort to achieve radiation exposures are as low as reasonably achievable, with economic, societal, and environmental factors taken into account [6]. Optimization also is a prospective and iterative process that requires qualitative and quantitative information. It means that the level of optimization would be the best possible under the prevailing circumstances. To achieve optimization of radiation protection and safety, among other things, the appropriate features of X-ray equipment and radiation protection and safety procedures. [9]

**Portable X-Ray Equipment Features**

Portable X-ray equipment should have the following features [9,10, 11,12]:
- high-frequency microprocessor generator systems
- Operating parameters for radiation generators that are clearly and accurately shown
- X-ray tubes with adequate filtration
- equipment that indicates clearly (visually and audibly) when the beam is on
- adjustable beam collimating equipment
- battery energy indicators
- adequate internet network
- tube stand which is relatively stable to vibrations
- means to detect immediately any malfunction of a single component of the system
- means to minimize the likelihood of unintended or unnecessary exposures
- X-ray equipment radiation leakage does not exceed one mGy (one milligray) per hour at 1 (one) meter from focus.

Following the characteristics of portable X-ray equipment that are often installed, stored, and carried, there will be a possibility of changes in mechanical stability that are likely to affect the output's stability. Therefore, the portable X-ray equipment's internal quality control should be carried out more frequently than fixed X-rays equipment. External quality control should be done to ensure the tube's compatibility with the generator output and to ensure the reliability of the X-ray equipment. External quality control should be done through the compliance test mechanism based on the regulation on the compliance test of X-ray equipment interventional and radiology diagnostic.

**Radiation Protection and Safety Procedure**

Proper procedures will increase the optimization of radiation protection and safety. These procedures should be specified in the radiation protection and safety program document. The following are the radiation and protection safety procedures that should be carried out in portable X-ray equipment use [9].
before portable x-ray equipment is used, it is necessary to determine and give boundaries the controlled and supervised areas to ensure that there are no unauthorized persons to enter the site around portable x-ray equipment. these boundaries should be marked.
- the operators should wear lead aprons.
- the operators' position should be behind the tube of portable x-ray. they should maintain as much distance as possible between themselves and the patient while still maintaining adequate visual supervision of the patient and communicating verbally with the patient (approximately at a distance of two meters).
- verbal warning of an imminent exposure should be given.
- in an area where other patients are adjacent to the examined patient, such in the emergency unit, mobile shields should be used. the primary beam should be directed away from staff and other patients whenever possible.
- other staff should be as far away from the patient as possible during the exposure (typically at least three meters) or are behind appropriate barriers.
- with a combination of distance, placement of mobile shielding, and careful control of the x-ray beam direction should ensure that appropriate public radiation protection is being afforded.
- for patient safety, it should be considered the diagnostic reference level, keep the distance between the x-ray tube and patient at least 1 m (one meter), and the collimator should be adjusted to patient examination needs.
- the operator's workload should be considered such that the dose limit is not exceeded, and the optimization of radiation protection and safety can be achieved.

CONCLUSION

This study provides some conclusions that the development of science and technology makes portable X-rays equipment adequate to be used in general radiography. The portable X-ray equipment should only be used for examinations where it is impractical or not medically acceptable to transfer patients to a fixed unit. Medical practitioners should justify their use. The use of portable X-ray equipment should consider the aspects of radiation protection and safety that cover the justification, dose limitation, and optimization principle. The risks that should be considered in using portable X-rays are the inadequate shielding of the working area, the mechanical instability, the limited availability of energy, the possible misuse by unauthorized or incompetent persons, and difficulties for the Regulatory Body in monitoring.

REFERENCES

[1] Seoul National University, Bundang Hospital, 2018, Portable X-Ray Mine.
[8] Nuclear Energy Regulatory Agency (BAPETEN), 2014, BAPETEN Chairman Regulation No. 4 of 2013 on Radiation Protection and Safety in Utilization of Nuclear Energy.