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Exposure Rate in Mobile C-arm Fluoroscopy and Radioiodine Therapy

Dissertation submitted in partial fulfillment for the

Degree of Bachelor of Science Health in Medical Radiation

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CERTIFICATE

This is to certify that the dissertation entitled

" Exposure Rate from Mobile C-arm Fluoroscopy and Radioiodine Therapy "

is the bonafide record of research work done by

MS. NORZULAILI BINTI MD.SHALLEH

During the period from October 03, 2003 to April 04, 2004

under my supervision.

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1. Abstract

This study is done to measure the exposure rate from mobile c-arm fluoroscopy and patients undergo radioiodine therapy. The measurement of exposure rate from mobile c-arm fluoroscopy was carried out using survey meter model 451B, and also lead apron with 0.5 mm lead equivalence thickness. The exposure time, distance, shielding material and value of kVp and mAs were considered.

This study was done by varied the exposure time of mobile c-arm fluoroscopy while the value of kVp was remaining constant. This was done to see the effect of exposure time to the exposure rate. From this study, we found that the exposure rate was increased exponentially with exposure time.

This study also done by varied the distance of survey meter from mobile c-arm fluoroscopy. This was done to see the effect of distance to the exposure rate. From this study, we found that the exposure rate decreased for about 30% when the distance increased by 10 cm.

Besides that, this study was also done; by covering the survey meter with lead apron with 0.5 mm lead equivalence thickness. This was done to see the effect of shielding to the exposure rate. We found that the exposure rate decreased for more than 90% when the lead apron was used.

We also measured the exposure rate from patients undergo radioiodine therapy. This study was done after the patients had drunk the radioiodine solution for 30 minutes. This study also used survey meter model 451B to measure the exposure rate from various distance. From this study, we found that the exposure rate from radioiodine therapy patients decreased exponentially with increasing distance.

As conclusion, we can say that the exposure rate from mobile c-arm fluoroscopy and patients undergo radioiodine therapy, can be minimized by increasing distance, decreasing exposure time, and also by using shielding materials.

2. Introduction

Radiation is a general term used to describe a bundle of energy in the form of electromagnetic waves. This term applies to the emission and propagation of energy through space or material medium. Radiation sources are generally collections of matter or devices that converts other forms of energy into radiation (1).

In some cases, the energy to be converted is stored within the object. In other cases, the radiation sources are only an energy converter and other forms of energy must be applied in order to produce radiation (10).

By particle radiation, energy is propagated by traveling corpuscles that have a definite rest mass and within limits have a definite momentum and defined position at any instant. The distinction between particle radiation and electromagnetic waves, both of which represent modes of energy travel, become less sharp when, in 1925, de Broglie introduced a hypothesis concerning the dual nature of matter (1).

That is why, in theory, there are two general types of radiation, which are electromagnetic radiation and particulate radiation. Examples of electromagnetic radiation are photons and gamma rays while the examples of particulate radiation are electrons, protons and neutrons (3).

Radiation that can causes ionization is called ionizing radiation. All particulate radiation is ionizing radiation but not all electromagnetic radiation is ionizing radiation (3). Ionizing radiation can pass through materials and is also called penetrating radiation. Penetrating radiations are useful in the diagnosis and treatment of diseases and are part of backbone of modern medicine. However, because of radiation can ionize and excite molecules, it can cause damage to living tissues (3). Therefore we must take precautions when using and working around it.

The effects of ionizing radiations may be correlated with the energy deposited as ionization and excitation of atoms of the material irradiated. It can be measured in terms of exposure, absorbed dose, activity and many more. In this study, we only considered and focus on radiation exposure rate for both diagnostic and therapeutic purposes.

The latest definition of exposure given by ICRU in 1980 states that the exposure, X is quotient of dQ by dm where the value of dQ is the absolute value of the total charge of the ions of one sign produced in air when all the electrons and positrons liberated by photons in air of mass dm are completely stopped in air (1).

Therefore exposure is related to ionization in air and not to an irradiated medium such as tissue (1). The roentgen is a unit of exposure and roentgen per hour is the unit for exposure rate. The SI unit for exposure is coulombs per kilogram (C/kg) but the special unit is roentgen (R).

1R = 2.58 x 10-4 C/kg air

The largest source of exposure to a person is from medical procedures, whether it is diagnostic or therapeutic exposure. Examples of diagnostic exposure are x-ray machines, CT scanner and fluoroscopy. In this study we only considered and focused on the fluoroscopy exposure rate. The examples of therapeutic exposure are linear accelerator, brachytherapy and I-131 Thyroid carcinoma treatment. But in study we only focused on I-131 Thyroid carcinoma treatment.

As been mentioned earlier, diagnostic sources include x-ray machines and radioactive materials. X-ray machines are used in radiography and fluoroscopy and they maybe permanently installed (fixed) or mobile. In radiography, the exposure time is short, usually less than one second, and x-rays are emitted from the machine only when the control switch to the unit is turn ON by the operator. Personnel are typically not in the x-ray room during the time the x-rays are being emitted.

In fluoroscopy, the exposure time may be lengthy and personnel usually work in the room while the machine is emitting radiation but sometimes, personnel or doctors need to be near to the patient especially when using c-arm mobile fluoroscopy (2). That is why in studies we are using c-arm mobile fluoroscopy to measure the exposure rate. Mobile fluoroscopy is similar in function to the fixed machines; however it is mobile and can be transported to the patients who cannot be moved. It is used especially to examine patients in the operating theater or recovery room or after or during surgery or for trauma victims.

The fluoroscope produces an instantaneous and continuous image that is especially useful for guiding a procedure, searching through a body section or observing a dynamic function (3). Fluoroscopic examination began soon after the discovery of x-radiation. Since that time, however the fluoroscopic imaging system has undergone several major changes that have improved image quality, reduced patients' exposure and provided much more flexibility and ease to use.

Modern fluoroscopy imaging systems consist of: the x-ray tube which produces x-rays; an image intensifier that captures or stops the x-rays and converts the x-ray energy into light; a closed circuit video system which ultimately producing a live image on a monitor. On some systems the light output can be also be distributed to a spot film or cinematography recording systems, though the x-ray output must be greater for these imaging modalities (3).

Fluoroscopy machines are equipped with a timer and an alarm, which sounds at the end of 5 minutes of fluoroscopy use. This system is designed alert the user when the usage is becoming significant and provides additional warning 5 minutes after each reset. Fluoroscopy systems also display the total fluoroscopy time for a procedure. There are internal requirement for fluoroscopy times (3).

Radiation exposure using fluoroscopy is directly proportional to the length of time the unit is activated by the foot switch. Human eye integration time or recognition time of fluoroscopy image is approximately 0.2 seconds. Therefore, short "looks" usually accomplish the same as continuous exposure. That is why, in this study, we had done the effect of time to the exposure rate. So, we can see how different exposure time can give different value of exposure rate and whether the exposure rate is really directly proportional to the exposure time (2).

Fluoroscopy exposure rate is also predetermined by the value of kVp, mA and filed size. High kVp, large mA and a big image field size, will produce a high exposure rate. In this study we also varies the value of kVp and automatically the value of mA also varies, so that we can see the effect of kVp and mA to the exposure rate.

Material that absorbs the radiation is a shield. The use of radiation shield is highly effective in intercepting and reducing radiation exposure from scattered radiation. Lead and concrete are the most commonly used materials for shielding x-rays and gamma ray. They are very effective in stopping or blocking the radiation beam. Lead aprons, thyroid shields and lead gloves are commonly used to shield body parts from diagnostic radiography and when portable x-ray machines are used. Shielding effect is also done in this study, to see the affect of shielding to the exposure rate. This study was done by wrapped the survey meter with the lead apron and the survey meter was placed at various distances.

Nuclear medicine is a safe, painless and cost effective way of therapeutic technique (1). A unique aspect of a nuclear medicine test is its extreme sensitivity to abnormalities in an organ structure or function. That is why nuclear medicine is always used in the treatment of hyperthyroidism, thyroid cancer, blood imbalances and pain relief from certain types of bone cancer. In this study we only measured the exposure rate for thyroid carcinoma patient that used Iodin-131 radionuclide.

Iodine 131 decays by beta emission and associated gamma emission with a physical half-life of 8.04 days (9). Beta emission from Iodine-131 can present an external exposure hazard to skin and eyes. Gamma emissions can present a penetrating external exposure hazard. Individual iodine metabolism can vary considerably. It may be assumed that 30% of an uptake of iodine is translocated to the thyroid and 70% directly excreted in urine (9).

Iodine in the thyroid is retained with a biological half-life of 120 days in the form of organic iodine. Organic iodine is assumed to be uniformly distributed in all organs and tissues of the body except the thyroid, and retained with a biological half-life of 12 days. 10% of organic iodine is directly excreted in feces and the rest is returned to the transfer compartment as inorganic iodine. The committed dose is significantly reduced due to the short physical half-life of iodine-131 (10).

Radioactive source that was used in this study was given by drinking it (oral). During the treatment, when the radiation level in the room is high, housekeeping personnel are not permitted to enter the patients' room for normal cleaning purposes. It is only after the patient has been discharged, and the radiation safety officer has made sure that the room is free from any source of radiation.

Generally, patients will be hospitalized for a period one to five days. This is because, radioactive materials in therapeutic are highly radioactive, which means that the radioactive contamination for a period of time. They remain radioactive until the administered radioactive until the administered radioactive material decays to an acceptable level or is eliminated naturally by patients body (5).

Before the patient is given the radionuclide or before they are been treated, patient must not taken any thyroid medication for 3 weeks before the treatment. After the patients have been given the radionuclide for the treatment, most of the radioactive iodine will be in the thyroid, and smaller amounts are also present in the urine, saliva and sweat. That is why the patient will be hospitalized or will be stay in the ward until the exposure rate level can be acceptable. That is why patients are advised to drink plenty of liquids or water in order to make the radionuclide released is faster (5).

3. Objectives of the Study

3.1 To measure the exposure rate in C-arm fluoroscopy and radioiodine therapy

3.2 To see the effect of exposure time to the exposure rate in C-arm fluoroscopy

3.3 To see the effect of distance to the exposure rate in C-arm fluoroscopy

3.4 To see the effect of shielding to the exposure rate in C-arm fluoroscopy

3.5 To see the effect of distance to the exposure rate in radioiodine therapy

4. Materials and methods

4.1. Materials

4.1.1 Ionization chamber Survey Meter with Beta Slide (model 451B)

Ionization chamber survey meter model 451B was used in this study to measure the exposure rate. This survey meter is a hand-held battery operated unit designed for use in both rugged and normal environments. It can measure alpha, beta, gamma and x-ray radiation (6). It is also ideal for site surveys and also for wide range of medical and health physics applications. It is regularly used by police and fire departments, x-ray manufacturers, government agencies, state inspectors, emergency response, nuclear medicine labs, hospital radiation safety officers and nuclear power industry (7).

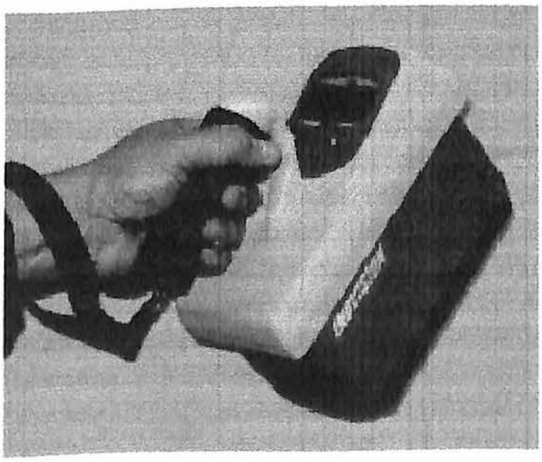

Figure 1: Survey meter model 451B

The model 451B employs microprocessor and LCD technology and features a rugged ionization chamber with Mylar window and protective steel mesh. An integral beta shield serves as an equilibrium thickness for photon measurements (6). This survey meter has several advantages which are (7) :

- High sensitivity measurements of exposure and exposure rate
- Available with dose equivalent energy response (SI units)
- Fast response to measure radiation from leakage, scatter beams and pinholes
- Ergonomic, anti-fatigue handle with replaceable grip and wrist strap
- Sliding shield for alpha and beta discrimination
- Excel added-in for windows® for data logging and selection of instrument operating parameters (optional)
- Low noise chamber bias supply for fast background settling time
- Choice of bright, highly visible colors
- Easy touch keys

This survey meter also has several important features which are (6):

- Ideal for wide rage of applications including NDT, x-ray and environmental
- Battery operated
- Auto-ranging and auto-zeroing

- RS-232 communications interface
- Measures rate and dose simultaneously
- Tripod mount for stationary, area monitor applications
- Freeze mode indicates peak reading
- Programmable flashing display and audible alarm
- Automatic, ultra-bright LCD
- Excel add-in for Windows (optional)

4.1.2 Mobile C-arm fluoroscopy (Model BV Endura (Philips))

This mobile c-arm fluoroscopy (figure 2), is an ideal x-ray system to provide fluoroscopic and radiographic imaging for a variety of clinical procedures, including applications in orthopedics, urology, general surgery and gynecology or minimally invasive procedures as well as gastrointestinal surgery or vascular intervention (11).

The unit is always being used in operation theatre room to visualize patient anatomy in real time and assist in implant insertion (14). Although an indispensable tool, fluoroscopy has certain disadvantages. During procedures there is radiation exposure to the patient, the operating room personnel, and the surgeon (14). To obtain orthogonal or oblique views, it is necessary to reposition the c-arm image intensifier, adding to operative time and surgeon frustration (14).

The system consist of an undercouch x-ray tube and overcouch image intensifier with the ability of last image hold (13). But we can also exchange the position of the x-ray tube and image intensifier vise versa. The focus to image distance is 100 cm and the input field size is 23 cm (13).

In order for the system to function properly, the following steps are necessary. First, an empty c-arm image of the calibration grid is acquired and transferred to the computer for calibration. C-arm images of the patient are then transferred into the computer via a standard video or digital link (14). At the time of image acquisition, the relative position of the patient and the c-arm is measured. During this step, the position-measuring sensor at the head of the bed detects the signal from the LEDs attached to the fluoro unit and the patient (via the DRA) (14). The image is then calibrated and it allows the computer to build a mathematical description of the images that geometrically relates how a given position relative to the patient projects onto the fluoroscopic image (14).

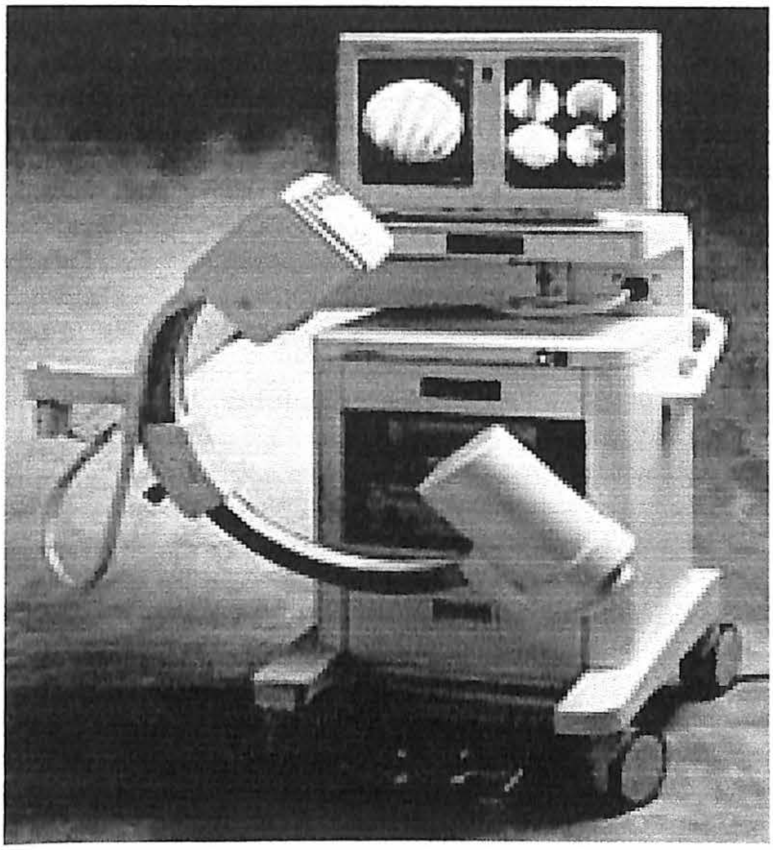

Figure 2: Mobile C-arm Fluoroscopy (Model BV Endura-Philips)

4.1.3 Sodium Iodide I-131 solution

Sodium Iodide I-131 for therapeutic use is available as a stabilized aqueous solution for oral administration (9). The solution contains the desired quantity of I-131 calibrated for the required date. The specific activity of the I-131 is designated as no-carrier-added. Each milliliter of aqueous solution contains 2 mg of sodium thiosulfate as a stabilizer. The pH has been adjusted to 7-8.5 with sodium hydroxide (12).

Therapeutic doses of iodine-131 are administered orally in liquid or capsule form. The liquid form requires greater care in handling. When considering radiation safety precautions for attending personnel, members of the general public, and patients in adjacent rooms, it is important to remember that iodine-131 emits both negative beta particles (maximum energy approximately 807 keV) and a prominent 364 keV gamma photon (5). It is the beta that delivers the major portion of the radiation dose to the remnant thyroid tissue, and it is the penetrating gamma that poses a potential radiation hazard to others outside the patients room (5). Table 1 shows the principal of radiations emitted from Iodine-131.

Radiation	Mean percent per disintegration	Energy (keV)
Beta-1	2.12	69.4 Avg
Beta-3	7.36	96.6 Avg
Beta-4	89.3	191.6 Avg
Gamma-7	6.05	284.3 Avg
Gamma-14	81.2	364.5 Avg
Gamma-17	7.26	637 Avg

Table 1: Radiation emitted from Iodine-131

Beta emission from iodine-131 can present an external exposure hazard to skin and eyes. While gamma emission can present a penetrating external exposure hazard (10). We can assume that 30% of an uptake of iodine is translocated to the thyroid and 70% is directly excreted in urine (10). Iodine retained in the thyroid with biological half-life of 120 days in the form of organic iodine (10).

Sodium iodide is rapidly absorbed in the gastrointestinal tract (9,12) and about 10-25% of the administered dose is selectively concentrated from the blood by the normal thyroid gland (12). After the absorption, the iodide is distributed primarily within the extra cellular fluid of the body (9). It is concentrated and organified by the thyroid and trapped but not organified by the stomach and salivary glands. It is also promptly excreted in the kidneys. About 90% of local irradiation is the result of beta radiation and 10% is the result of gamma radiation (9).

4.2 Methodology

4.2.1 Exposure rate measurement from mobile c-arm fluoroscopy

In the measurement of exposure rate from mobile c-arm fluoroscopy, we considered three factors, which are, exposure time, distance and shielding. Before we started the measurement, we placed the mobile c-arm fluoroscopy with the couch in the middle of it. We placed the x-ray tube undercouch and the image intensifier was placed overcouch. It was done to minimize scatter radiation from reaching the personnel and the survey meter.

In the measurement of distance effect, we chose the kVp value from 40 kVp to 100 kVp. We varied the distance of the survey meter from 0 cm to 100 cm. In this case, we fixed the exposure time at 6 seconds.

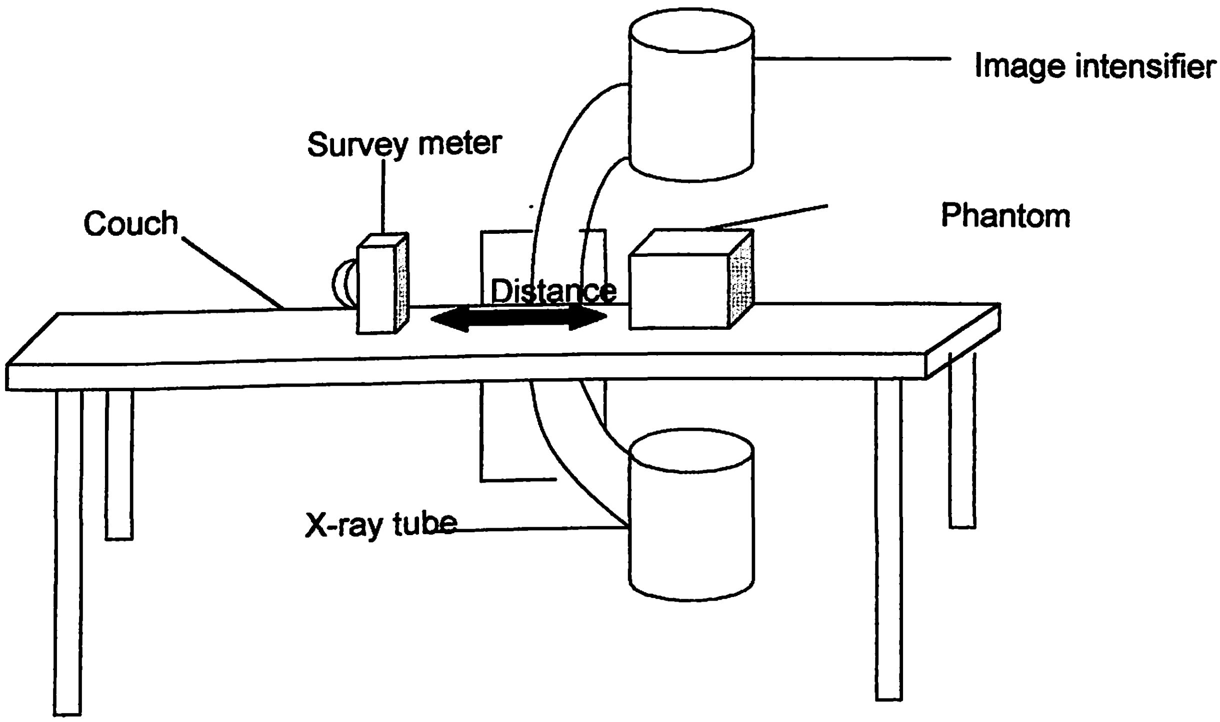

Figure 3: Measurement set up

In the measurement of shielding effect, the method was still the same as the distance effect, except we wrapped the survey meter with the lead apron 0.5mm-lead thickness equilibrium. While for exposure time effect, we fixed the kVp value at 70 kVp and 90kVp and we also fixed the distance, while the value of exposure time was varies.

4.2.2 Exposure rate measurement from radioiodine therapy patients

In this study, we measured the exposure rate for three patients with different radioactive activity, body weights and ages. We measured the exposure rate about 30 minutes after the patients drank the radioactive solution. First of all we measured the exposure rate for individual patient and then we measured the exposure rate for combined patients in the treatment room or ward. The exposure rate was measured at different angle and at different distance by using survey meter model 451B. Figure 4 shows patients position when the measurement was carried out.

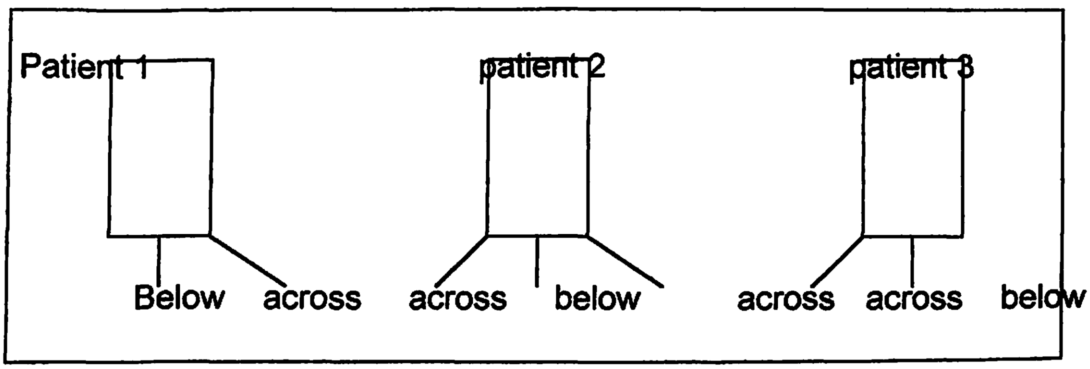

Figure 4: Patient position in radioiodine therapy ward

Patient 1: LATIFAH AHMAD, 32 YEARS AND 65 KG = 150 mCi

Patient 2: RAKIAH HUSIN, 40 YEARS AND 70 KG = 175 mCi

Patient 3: NURUL AFZAN, 15 YEARS AND 35 KG = 100 mCi

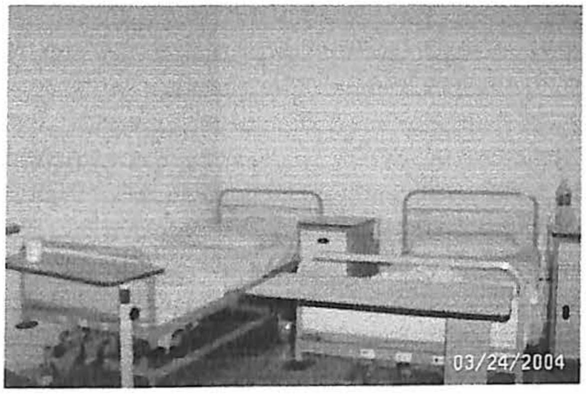

Figure 5: Patient 1 and 2 position

Figure 6: Patient 2 and 3 position

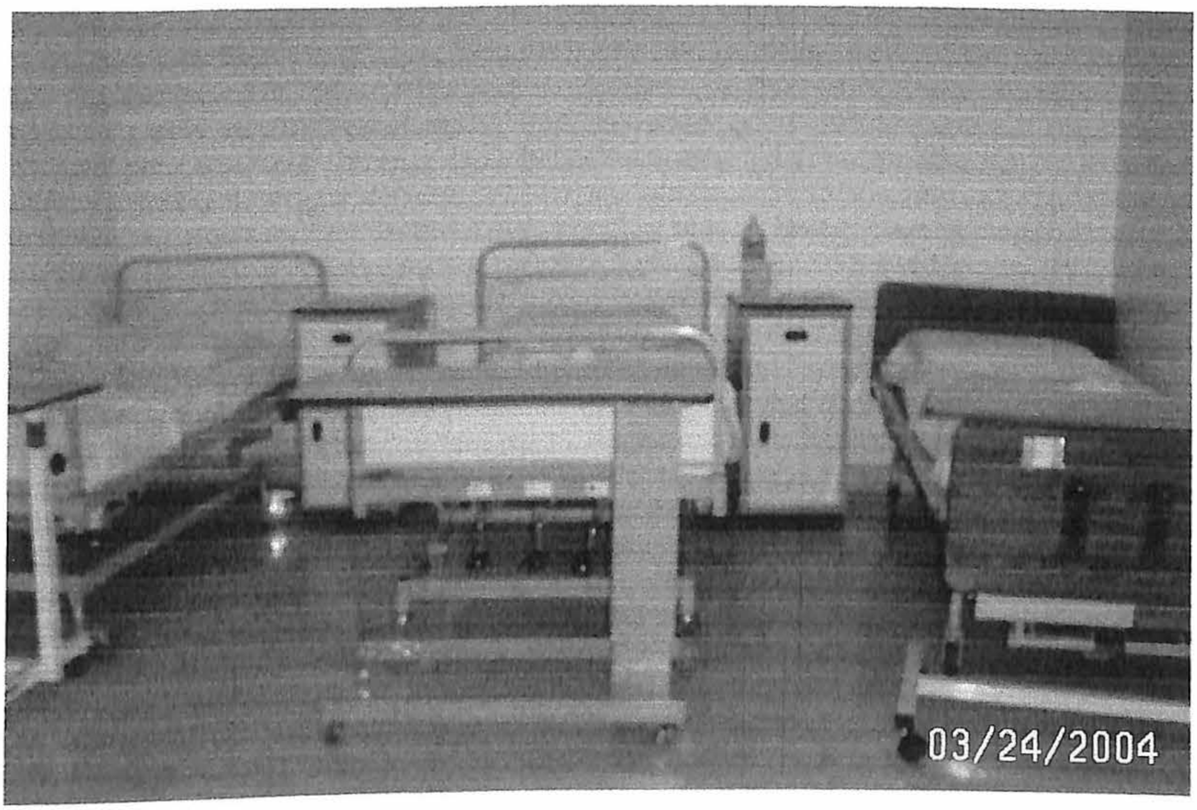

Figure 7: All patients position in radioiodine therapy ward

5. Result

5.1 Exposure Rate from Mobile C-arm Fluoroscopy

Table 2, figures 8 and figures 9 below show that the exposure rate was affected by the exposure time. From the table 2, we can see that the exposure rate increase with increasing exposure time at the beginning but it become constant after certain time. From graph 1 and 2 we can see that the exposure rate increased exponentially with exposure time.

kVp	Distance From the x-ray tube	Time 1sec	Time 2sec	Time 3sec	Time 4sec	Time 5sec	Time 6sec	Time 7sec	Time 8sec	Time 9sec	Time 10sec
70	0 cm	24.5 mR/h	100	150	190	200	200	200	200	200	200
90	25 cm	125mR/h	205	225	225	225	225	225	225	225	225

Table 2: The effect of exposure time to the exposure rate for 70 kVp and 90kVp

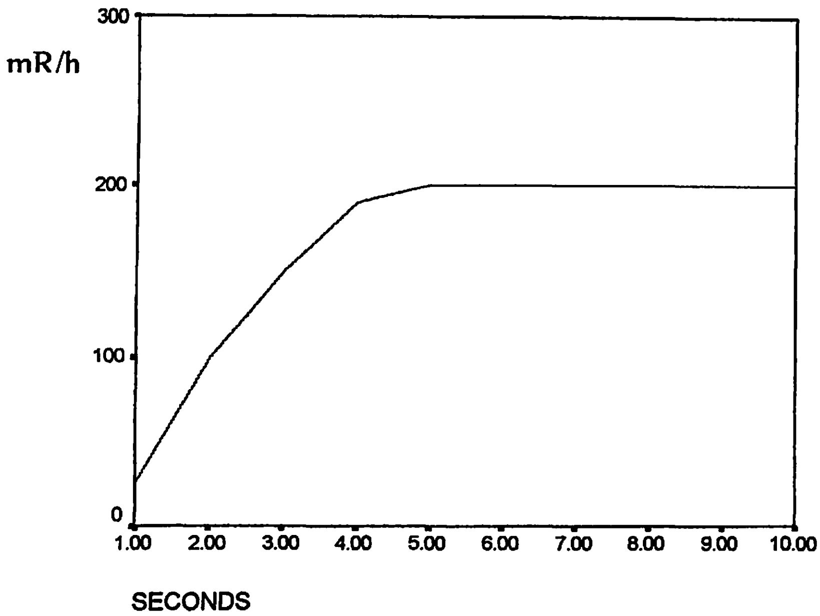

Figure 8: Graph of exposure rate (mR/h) vs. time (second) for 70 kVp

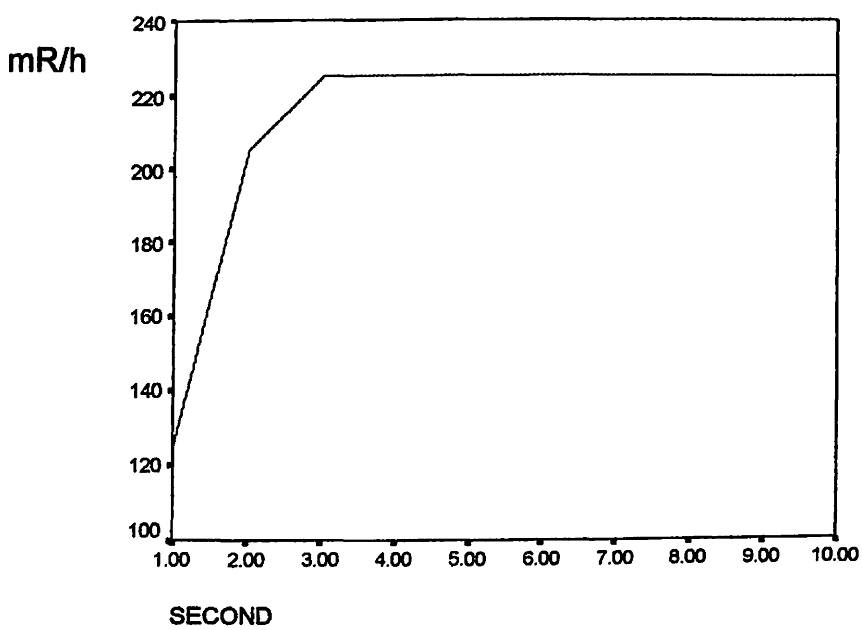

Figure 9: Graph of exposure rate (mR/h) vs. exposure time (second) for 90 kVp

From table 2, we can see that the exposure rate for 70 kVp, remain constant after reaching 5 seconds but for 90 kVp, it remain constant after reaching 3 seconds. This is because; higher energy scattered less compare to lower energy radiation.

Table 3, shows the effect of distance in exposure rate measurement. We can see that the exposure rate decreased when the distance is increased. We can also see that when we increased the value of kVp, the exposure rate is also increased. The reason of this condition was, when kVp increased more radiation was produced.

The distance effect is shown in the figure 10. Figure 10, shows the exposure rate decreased exponentially when we increased the distance. So, in order to decrease the effect of radiation in human body, it is important for the personnel to be as far as possible from the radiation exposure source.