Nanodot Optically Stimulated Luminescence Dosimeter for Entrance Surface Dose measurement at selected Health Clinic in Perak, Malaysia

M.T Saidin\textsuperscript{1,2}, A A Rahman\textsuperscript{1}, Y M Radzi\textsuperscript{1}, H H Harun\textsuperscript{3} and M K A Karim\textsuperscript{3}

\textsuperscript{1} School of Physics, Universiti Sains Malaysia Main Campus, 11800 Minden, Penang, Malaysia
\textsuperscript{2} Perak State Health Department, Ministry og Health Malaysia, Jalan Panglima Bukit Gantang Wahab, 30590 Ipoh, Perak, Malaysia
\textsuperscript{3} Department of Physics, Universiti Putra Malaysia 43400 Serdang, Selangor Malaysia

\textit{E-mail:} arazhar@usm.my

\textbf{Abstract.} The aimed of this study is to evaluate patient dosimetry received from Posterior Anterior Chest X-ray (PA-CXR) examination performed at community clinics in Perak using a nanodot Al\textsubscript{2}O\textsubscript{3}:C Optically Stimulated Luminescence dosimeter (OSLD). Four clinics were involved in this research namely Simpang Health Clinic, Buntong Health Clinic, Teluk Intan Health Clinic and Pengkalan Hulu Health Clinic. The ESD was measured by placing the OSLD on polymethylmethacrylate (PMMA) slabs that resembling a human body specifically lung. These clinics were selected as they were excluded from the first and second national dose survey conducted in Malaysia since 1993 - 1995 and 2005 - 2009 respectively. Previously, the recommended guidance level for PA-CXR entrance surface dose (ESD) was set at 0.9 mGy. We compare the ESD measured with OSL and guidance level set under the second national dose survey which utilize LiF:Mg,Ti thermoluminescence dosimeter (TLD). The results indicated that the 3rd quartile ESD measured using OSLD were ranged 0.271 mGy – 0.368 mGy which 30% lesser than the recommended guidance level.

\section{1. Introduction}
Patient dose measurement has always been a national concern and worldwide interest. In 2011, International Atomic Energy Agency (IAEA) has published a safety standards on Radiation Protection and Safety of Radiation Sources which eloquently stating that the government shall ensure that a set of Diagnostic Reference Levels (DRLs) is established for medical exposures incurred in medical imaging. DRLs shall be based on wide scale surveys or on published values that are appropriate for the local circumstances \cite{1,2}.

For general X-rays, the indicator for DRLs is based on the Entrance Surface Dose (ESD) value. ESD value is obtained by measuring the amount of radiation absorbed on the skin when the X-ray beam enters the patient. Over the past 20 years, TLD has been acknowledge for its reliability and commercial availability for personnel monitoring and environmental dosimetry \cite{3}. TLD has also been used for direct ESD measurements and proved to be highly sensitive except that the preparation and readout for TLD is rather a time consuming process and less practical for a large scale survey.
In recent years, research and applications have seen exponential development in nanoscience and nanotechnology. Nanotechnology, as applied to medicine, is increasingly tailored for making substantial change in the diagnosis. Nanoparticles are desirable for medical purposes due to their special characteristics, such as their surface to mass relation that is considerably greater than their particles, their quantum characteristics and their ability to adsorb and transport certain compounds. There are few studies on the efficiency of OSL dosimeters in general X-ray diagnostics compared with studies relating to radiation therapy. In view of technology advances, the emergence of OSLD has become prominent. The use of OSLD in radiation measurement and monitoring has rapidly increased in the recent years. The advent of aluminium oxide (Al$_2$O$_3$:C) based OSLD enhanced the dosimetry process in clinical procedure where the strength and wavelength of stimulation light may be controlled by optical stimulation, enabling multiple OSL measurements from the Al$_2$O$_3$ material. The substance also demonstrates good linearity and reproducibility of x-ray energy and dose range [4].

The fundamental principle of a OSLD is based on the luminescence emitted from an irradiated crystalline insulator or semiconductor during exposure to light. The OSLD intensity is a function of the dose of radiation absorbed by the sample and thus can be used as the basis method for radiation dosimetry. Crystal of Al$_2$O$_3$:C contains trace amounts of contaminants that form crystal-lattice imperfections or defects. These imperfections of the lattice causing trapping of electrons or holes or recombination of both in the luminescence centres. Luminescence centres is a recombination centre where electron and hole recombine and produce luminescence light. The principle of radiation detection for OSLDs and TLDs are comparable. However, the distinction between both dosimeters were OSLD uses light stimulation to free trapped electron and emit luminescence while TLD uses heat stimulation. OSLD is independent of temperature, irradiation angle and energy but dependent on minimal dose rate and could be readout repeatedly with very little loss in signal (0.05% per reading) [5].

Generally, there are little research especially on the reliability of OSLD in diagnostic imaging. We sought to introduce OSLD for low level of radiation and compare the performance against the TLD. The relationship between spectral of X-ray with the ESD value also were evaluated. Hence, this study aimed to evaluate ESD of CXR examination and compare with the previous guideline by Ministry of Health of Malaysia.

2. Materials and Methods

This study utilized OSLD (Landauer, Inc., Glenwood, IL) for ESD evaluation. The OSLD are 7 mm in diameter and has 0.3 mm-thick plastic disks infused with aluminium oxide doped with carbon powder (Al$_2$O$_3$:C, synthetic sapphire). The disks are encased in a 10 mm x 10 mm x 2 mm light-tight plastic holder. The Nanodot has a water-equivalent buildup of 0.04 gm/cm$^2$. Nanodot OSL dosimeters are read with an InLight microStar reader.

Four health clinics in Perak; Simpang Health Clinic, Buntong Health Clinic, Teluk Intan Health Clinic and Pengkalan Hulu Health Clinic were selected in this study. These clinics were chosen as they was excluded from the first and second national dose survey conducted in 1993 to 1995 and from 2005 to 2009, respectively. Both surveys utilized TLD-100 for dosimetry measurement. There are a number of diagnostic imaging procedures performed at these health clinics. Exposure parameters were varied for the measurements based on the commonly used techniques and parameters by radiographer with kVp ranging from 50 – 90 kV and tube currents of 5, 16 and 25 mAs. For each examination, three OSLD were placed on the centre of PMMA slabs representing patient’s thickness (Figure 1).
3. Results and Discussion

Table 1 tabulates the ESD values of PA chest X-ray examinations using OSLD. As observed, the ESD values were ranged from 0.027 - 0.533 mGy, 0.037 - 0.607 mGy, 0.033 - 0.650 mGy and 0.029 - 0.481 mGy at Simpang Health Clinic, Buntong Health Clinic, Teluk Intan Health Clinic and Pengkalan Hulu Health Clinic, respectively.

Table 1. Exposure parameters and mean ESD values measured for PA Chest X-Ray examinations using Nanodot OSL dosimeter.

| Clinics        | mAs | 50kV (mGy) | 60kV (mGy) | 70kV (mGy) | 80kV (mGy) | 90kV (mGy) | 3rd Quartile (mGy) |
|----------------|-----|------------|------------|------------|------------|------------|--------------------|
| Simpang        | 5   | 0.027      | 0.042      | 0.057      | 0.078      | 0.105      | 0.298              |
|                | 16  | 0.090      | 0.135      | 0.195      | 0.267      | 0.353      |                    |
|                | 25  | 0.141      | 0.221      | 0.329      | 0.444      | 0.553      |                    |
| Buntong        | 5   | 0.037      | 0.059      | 0.077      | 0.105      | 0.121      | 0.354              |
|                | 16  | 0.111      | 0.178      | 0.239      | 0.323      | 0.391      |                    |
|                | 25  | 0.175      | 0.268      | 0.386      | 0.510      | 0.607      |                    |
| Teluk Intan    | 5   | 0.033      | 0.060      | 0.078      | 0.109      | 0.133      | 0.368              |
|                | 16  | 0.105      | 0.180      | 0.245      | 0.325      | 0.415      |                    |
|                | 25  | 0.163      | 0.274      | 0.410      | 0.529      | 0.650      |                    |
| Pengkalan Hulu | 5   | 0.029      | 0.042      | 0.057      | 0.081      | 0.096      | 0.271              |
|                | 16  | 0.081      | 0.131      | 0.184      | 0.250      | 0.313      |                    |
|                | 25  | 0.124      | 0.201      | 0.292      | 0.392      | 0.481      |                    |

Table 2 indicates ESD values for PA CXR examination from this study and it is remarkably lower than the guidance value from the second national dose survey conducted in 2009. It also demonstrates the fact that variations in ESD of x-ray machines can be associated with exposure parameters. These variations in ESD may be due to the different technical characteristics of a
radiographic equipment and the technical parameters used. The variance in measurements can also be attributed from the used of different filtration and thickness of HVL for each machine.

Primarily, beam energy is depending on selection of tube voltage (kV) and tube current (mAs) as well as the amount of beam filtration. The energy of the X-ray photon varies substantially to these parameters. The selection of a higher kV and mAs increases the number of electrons flowing to anode, X-rays energy imparted on the phantoms and beam penetrability. As X-ray becomes penetrative, more energy will reach the dosimeter and consequently contribute to the increased of ESD. In brief, ESD in diagnostic examination is proportional to the tube current, tube voltage and exposure duration [6]. Thus, it should be emphasized to the radiographers that the use of a higher kV technique, lower mAs or a shorter exposure during PA chest X-ray examination may reduce the dose to the patient. By modifying the physical parameters and with the improvement of X-ray exposure techniques used, it allows ESD reduction to patients without significant loss of image quality. It is important to keep the patient’s dose as low as possible in order to avoid any potential damaging effect and eventually minimize the probability of stochastic effects.

**Table 2.** 3rd Quartile of ESD (mGy) for PA Chest x-ray examination from the present study compared to the second national dose survey (MOH, 2009).

| Health Clinic | 3rd Quartile of ESD (mGy) | Second National Dose Survey MOH, 2009 (mGy) |
|---------------|---------------------------|------------------------------------------|
| Simpang       | 0.298                     | 0.90                                     |
| Buntong       | 0.354                     |                                          |
| Teluk Intan   | 0.368                     |                                          |
| Pengkalan Hulu | 0.271                     |                                          |

Permanent filtration of the x-ray tube has to be capable of reducing beam penetration by 50%. Sufficient filtration of the x-ray beam enabled low energy radiation to be eliminated. Table 3 compares the filtration measured for each machine during the last performance test in 4 health clinics with the established standard from Malaysian Standard (MS 838). In compliance with the MS 838 standard, filtration of the useful beams for all machines operating at 70 kV to 100 kV shall not be less than 2.0 mm Al equivalent. Radiation intensity is one of the essential properties in radiography that can be reduced by filtration. Low energy X-rays are preferentially absorbed through filtration. Without filtration, it is likely that this low energy X-rays absorbed by patient without contributing to the image formation. Generally, additional filtration from the minimum value can reduce dose however outstanding increase of filters are susceptible to affect image quality and leads to higher dose as greater mAs applied to compensate radiation intensity.

**Table 3.** Comparison of filtration measured from the last performance test for each machine in the 4 Health Clinics with established standard from MS 838

| Health Clinic | Filtration measured from the last performance test | MS 838 Standard |
|---------------|-----------------------------------------------|-----------------|
| Simpang       | 3.2 mm Al at 70kV                             | Shall not be less than 2.0 mm Al equivalent for machine operated in the range 70 kV – 100 kV |
| Buntong       | 2.8 mm Al at 70kV                             |                 |
| Teluk Intan   | 3.1 mm Al at 70kV                             |                 |
| Pengkalan Hulu | 3.1 mm Al at 70kV                             |                 |
4. Conclusions

In this study, the ESD value measured by OSLD was found to be within the guidance values recommended from the second national dose survey by Ministry of Health Malaysia. This served as a preliminary study to establish dose assessment for patients undergoing PA Chest X-ray examination at Perak Health Clinic using OSLD perhaps in future it can be further extend to include other x-ray examinations for a wider scale of surveys in Perak and it should also be periodically reviewed to ensure that they remain appropriate. Special consideration has to be given to adequate training for all radiographers to update patient’s dose consideration and implementation of a regular performance test audit to optimize radiological practice.

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