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RESEARCH PAPER

Synthesis and characterization of nano Bi_2O_3 for radiology shield

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ABSTRACT

Objective (s): Recently, the use of nanoparticles in medicine has increased for radiation protection purpose. Thus the aim of this study was to use nano Bi_2O_3 in prepared shield for dose reduction during medical imaging.

Materials and Methods: Nano Bi_2O_3 shield with 90% silicon and 10% nano Bi_2O_3 was prepared and dosimetry test was down in radiology by PTW DIADOS E dosimeter.

Results: The mean dose without using nano Bi_2O_3 shields were 421 µGy, 733 µGy and 1110 µGy for 60, 80 and 100 kVp, respectively. After applying 0.5 mm thickness of nano Bi_2O_3 shield, dose reduction in 60, 80 and 100 kVp was 42%, 35% and 31%, respectively. A comparison between increasing energy from 60 to 100 kVp and dose reduction showed a significant reverse effect.

Conclusion: The results indicate that the new shields containing nano Bi_2O_3 particles have a high X-rays attenuation ability but the attenuation property of the shields decreased by increasing the energy. Based on the results, this new shield can help social health and reduce the radiation risk.

Keywords: *Attenuation, Nano Bi_2O_3, Shields, Radiography*

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INTRODUCTION

Radiation devices play an important role in the diagnosis of diseases. Although ionizing radiation help to solve of patients problem but it has the possibility to damage the sensitive organs of the body [1]. Data showed that radiation can increase the risk of breast cancer which is one of the most common cancers among women [2]. Moreover, it is dangerous for eyes and thyroid gland and increases the risk of thyroid cancer and cataracts [3, 4].

One way to protect staff and patients from radiation is to use shields [5]. It seems that use of shielding to protect the thyroid, eye and breast as superficial organs could be a good suggestion. These shields are placed over the patient organs during examination [6].

Although the organ dose in radiology examinations is low but stochastic effects are important problem to be dealt with. This problem could be more serious for women as they are more prone to radation [7, 8]. Shields made of various materials such as lead, tungsten and bismuth compounds in different sizes are commonly used to protect sensitive organs against X-rays. Different atomic numbers of these materials also show different radiation attenuation behavior [9-12].

Recently, nanoparticles are used for dental applications, as antibacterial agents, in drug delivery systems, as MRI contrast agents and nano bismuth has been introduced as a contrast agent in CT [13-28]. In a study, nano bismuth composites were used to reduce the biological damage effects of X-rays and showed high ability to protect against radiation effects. According to the report by Nambiar *et al.* nano bismuth oxide as composite

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was able to attenuate most of the scattered X-rays in a 60 kVp [27]. Another study showed that nano Bi_2O_3 composite with starch matrix presented better X-ray shielding ability than its micro Bi_2O_3 composites without starch [28].

Decreasing of bismuth metal size can affect the mass attenuation coefficient for different photon energies so that it could reduce the dose of nanoparticles compared to the microparticles.

The aim of this study is to synthesize nano Bi_2O_3 for as sheilding agent to reduce the radiation damage and consequently cancer in imaging methods as well as radiology procedures such as radiography and CT scan.

MATERIALS AND METHODS

Preparation of nano Bi_2O_3

10 g of $Bi(NO_3)_3{\cdot}5H_2O$ was dissolved in 60 ml nitric acid (1 M) and 50 ml of aqueous suspension of starch was added under vigorous stirring, and heated up to 60°C for 2 h. Then the pH of the solution was adjusted to 10 by adding NaOH (3 M). Finally, the as-synthesized yellow participate was separated from the solid-liquid mixture by high-speed centrifugation, washed for several times, dried and calcined at 500°C for 4 h, and the Bi_2O_3 nanoparticles were obtained.

The as-synthesized nano Bi_2O_3 and silicon rubber were used to fabricate nano bismuth shields. For preparing shields, first nano Bi_2O_3 (10 wt. %) and silicon (90 wt. %) were mixed gently for 30 min. Then in order to remove the air bubbles, the obtained mixture was placed in vacuum for 10 min. Shields were made in 20*20 cm dimensions with 0.5 or 1.5 mm thickness. To test validity of the nano Bi_2O_3 shields, a conventional radiography device (VARIAN tube type) and a PTW DIADOS E (T11035-0206) were used. Shields were placed at a distance of one meter from the X-ray tube and the dosimeter was placed below the shield (Fig 1). To calculate the attenuation quantity of the shields, the tests were performed once in the absence of the shields and once in the presence of the shields and through the following formula (1), the attenuation was measured.

$$\text{attenuation\%} = \frac{\text{dose measured in without shield} - \text{dose measured in presented shield}}{\text{dose measured in without shield}} \times 100$$

Morphology of shield and physical dosimetric map were used to present new shield quality in relation to nanoparticles distribution within the matrix. To test the uniformity of the nanoparticles, the attenuation amount was obtained in different parts of the shield with a dosimeter in 5 locations and for 3 times and the results were compared between 5 parts (Fig 1**)**.

All tests for measuring dose were taken at three different energies of 60, 80, 100 kVp and 16 mAs and three time for each energy.

Fig 1. The photo of X-ray tube, setup of dosimeter and nano Bi_2O_3 shield to measure dose reduction ability and uniformity. A: Radiography device with probe of dosimeter, B: Physical dosimetric map for 5 recording placements of dose in air, C: Similar physical dosimetric map for 5 recording placements with shield, D: Dosimetric device called DIADOS E (PTW) that measure the dose (μGy) for showing dose reduction uniformity

RESULTS

Fig 2 shows the powder X-ray diffraction (XRD) of the as-prepared sample in the diffraction angle (2θ) range from 4° to 70°, the spectra are indexed to the crystal planes of the monoclinic system of the Bi_2O_3 (JCPDS Card No. 41-1449).

As shown in SEM micrograph (Figure 3), the obtained Bi_2O_3 sample has almost spherical polycrystalline structure with mean size of 30 nm.

The results indicate that there was not any difference in attenuation between different parts of the shield that represents the uniformity of the nanoparticles in different parts of the shield matrix for three different energies measured separately in this study.

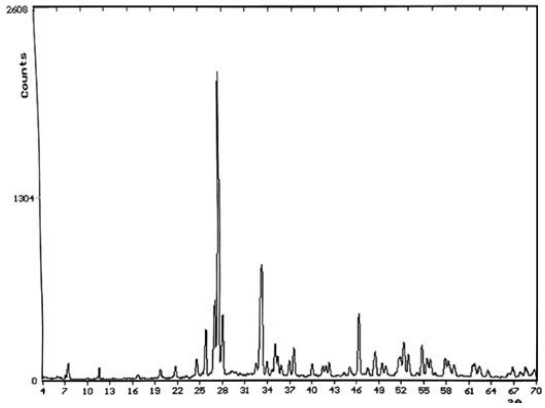

Fig 2.XRD analysis of the nano Bi_2O_3

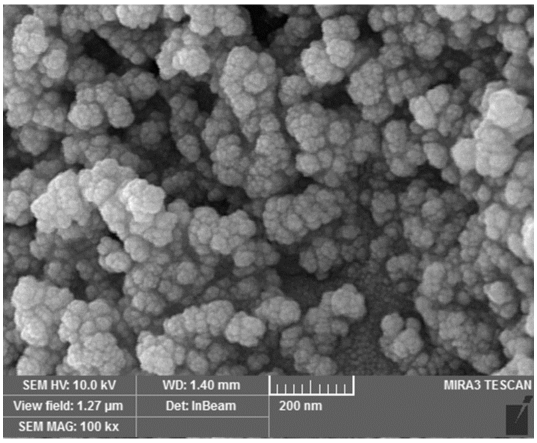

Fig 3. SEM image of the Bi_2O_3 nanoparticles

The mean dose without using nano Bi_2O_3 shields were 421 µGy, 733 µGy and 1110 µGy for 60, 80 and 100 kVp, respectively. Results showed that by using nano Bi_2O_3 shield with 0.5 mm thickness, the average dose in 60, 80, and 100 kVp were 240.3±7.0, 475.66±6.0 µGy and 763.66±13.0 µGy, respectively.

When the thickness of the sheild increased to 1.5 mm, the average dose decreased to 192.6±4.0, 402±8.54 and 676.66±4.58 µGy in 60, 80 and 100 kVp, respectively.

By using formula (1), the attenuation percent for all three energies and two thicknesses were calculated. The effect of different tube energies and shield thickness on the attenuation was shown in Figure 4.

The results revealed that dose reductions in 60 kVp for both thicknesses of nano Bi_2O_3 shields are higher than those at 100 kVp. The dose reduction percentages for 1.5 mm thickness of nano Bi_2O_3 shield were 54% and 39% using 60 kVp and 100 kVp, respectively.

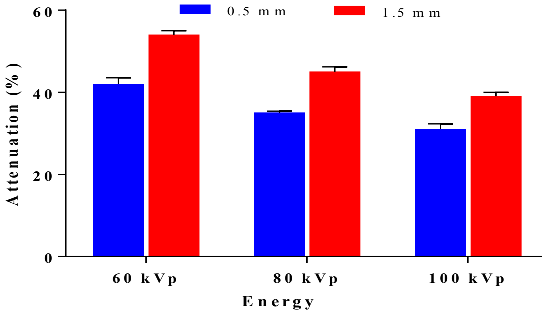

Fig 4. Dose reduction of shields with different thicknesses (0.5 and 1.5 mm) at different energy

DISCUSSION

This study showed that nano Bi_2O_3 has the potential to be employed for dose reduction in radiology. Dose measurement for three energies of X-ray tube showed that this shield has the ability of dose attenuation depending on the energy (kVp) and shield thickness.

Today, there is an increasing need for nanoparticles in medicine especially in diagnosis imaging [22, 29]. In the field of radiation protection, some studies have been done on the effects of different materials such as micro bismuth and tungsten on the attenuation of X-rays in radiography.

One such study presented the use of nanoparticles instead of micro-particles of CuO which could increase the ability of shield to attenuate the X-rays by up to 14% at low energies [30].

In the present study, by increasing the energy of the X-ray tube from 60 to 100 kV, the efficiency of the shield to attenuation beams was reduced. However, by increasing the shield thickness, the ability of shield for dose reduction increased. The study by Nambiar *et al.* showed that nanobismuth (BO) shield could decrease the attenuation from 73 % to 50 % by increasing tube voltage from 70 to 150 kVp while by increasing the thickness from 1.29 mm to 4.92 mm, the attenuation increased from 60% to 87% at 100 kVp [28].

In this study, silicon materials were used as a base material in manufacturing of shields due to their low atomic number.

The main factors in absorbing X-rays within the shield and its attenuation is existence of nano Bi_2O_3 particles and the particle size of the Bi_2O_3. Studies have shown that at low-energy X-rays, shields containing nanoparticles exhibited a more pronounced effect on the attenuation of X-rays than microparticle containg shields. However, this property was reduced by increasing the voltage [29, 31]. The use of nano Bi_2O_3 in powder form allows nanoparticles to be well distributed within the silicon matrix and provides a better uniformity. The uniform distribution of nano Bi_2O_3 powder at any point of the shield makes it possible to increase the efficiency and attenuation when X-rays pass through different place of the shield.

CONCLUSION

The results indicated that the new shield made of nano Bi_2O_3 particles has a high ability to attenuate the X-rays and thus it can be a good candidate as sheild to better protect the petients from the radiation risk. It was also shown that by increasing the energy from 60 to 100 kVp, the attenuation property of shields decreased.

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