A Novel Adjustable Anthropomorphic Head Phantom for Verifying the Dose of Radiation Therapy

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ABSTRACT

This study aims to make a phantom to verify dose distribution and compare two techniques of radiation therapy, including 3D conventional radiotherapy (3D-CRT) and modulated photon radiotherapy (IMRT). For treatment of brain cancer, physicians have to prescribe radiation therapy to involved patients so that organs at risk receive unwanted dose causing them to be damaged. To know precise dose delivered into them and evaluate treatment-planning system (TPs), it is necessary to do dosimetry in the phantom owing to difficulties of dosimetry in human.

It is important to make a phantom with characteristics similar to humans and ability to compute dose and dose distribution in desired organs and tissue. Thus, there is possibility to compute dose in different parts, including doses delivered in ears, eyes, stem brain and optic nerve. Furthermore, this phantom has to provide this opportunity to investigate whether some techniques of radiation therapy such as 3D-CRT or IMRT depend on the size or location of tumors.

To this end, a low workload, easy-to-set-up, lightweight, and transportable phantom was designed, and made from Polylactic acid (PLA) in dimensions 23×24×32 cm^3. The phantom consists of brain, tumors in different dimeters, including 2, 4, 6 cm and also parts for eyes and ears to locate TLDs. Head, brain and tumors are able to open so that they can be filled with polymer gel dosimetry making possible record dose distribution in three-dimensions (3D) and sharp dose gradients.

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Keywords

Phantom; Radiation Dosimeters; Radiation; Radiotherapy

Introduction

Radiation deposits energy in human tissue during radiation therapy. It is vital to evaluate the distribution of radiation energy delivered into tissue of human body throughout the treatment process. Due to limitation of dosimetry in human bodies, radiation scientists use phantoms to compute precisely doses delivered into different organs. Since phantoms should have the shape as same as a part or all of the human body, materials used in phantom should change easily into different shapes and maintain characteristics of the mechanical integrity for a while [1]. Additionally, it is required to use some type of radiation dosimeters in order to determine dose distribution in phantoms. To verify radiotherapy treatment quality, the International Atomic Energy Agency (IAEA) is in cooperation with the World Health Organization (WHO) that it makes the IAEA/WHO thermoluminescent dosimeter

(TLD) postal program be implemented. Quality assurance networks of worldwide TLD confirm the advantages of this research [2-5].

Gel dosimetry involves accurate dosimetry in a different of circumstances and benefits over conventional dosimeters that the most important one is to measure a complicated dose distribution within a volume while there is a single radiation exposure. In addition, there are other advantages, including reasonable convenience, good dose precision, tissue-equivalence, high spatial accuracy [6]. Furthermore, polymer gel dosimetry can be used for situation in which there is sharp dose gradients such as IMRT, stereotactic radiosurgery and brachytherapy dosimetry [7].

There is a progress in some anthropomorphic dosimetry phantoms so as to be used in various radiotherapy methods such as head and neck intensity modulated radiation therapy (IMRT), prostate IMRT, stereotactic body radiotherapy for thorax and the liver as well as stereotaxic radiosurgery [8]. Moreover, it is given criteria to be met in acceptable and suitable compliance like the absorbed dose of brachytherapy, external beams and the mechanical parameters of linear accelerators (LINACs). The crucial criterion met in dose delivered to tumor is about 5% of the target dose [9, 10].

Moreover, material used in phantoms should have densities as same as tissue with the same electrons number per gram. For the first material, water can be a good idea to be used as a tissue substitute in measuring radiation [11]. In more studies, in 1923, wax was introduced. Moreover, some materials, including rubbers and plastics have been used to increase application phantoms for tissue simulation [12]. In addition, there is another material called Poly (lactic acid) or polylactide (PLA) used in making phantoms; it has some properties near to human tissue. Furthermore, its electron density ratio compared to water is 1.14, and Zs effective of water, PLA and PMMA are 7.42, 4.22 and 6.47, respectively. However, the density of it is about 1.2 gr per cm^3 and its electron density is 0.4 more than water, based on the thickness used in phantoms, attenuation coefficient can be less and near to real tissue [13, 14].

Material and Methods

As mentioned above, it is possible to use different materials to make phantoms. However, we prefer to use PLA due to oxygen. This kind of material has more oxygen in comparison with others. PLA is the most widely studied and biodegradable and new aliphatic polyester is used in making it. PLA has been tested to replace regular petrochemical-based polymers for applications, which are not only industrial but also medical. In addition, owing to 2 mm thickness with 15 percent density, there has not been any attenuation by PLA; thus, it has been near the real tissue. When high-energy radiation is irritated, the attenuation will be the less, especially higher than 10 Mev for brain tumors.

To compare with other biopolymers, PLA has the major advantages [3], as following: 1) Eco-friendly which being not only stemmed from renewable resources such as wheat and corn or rice but also recyclable, biodegradable and compostable [15, 16]. Its production also consumes carbon dioxide [17]. 2) Biocompatibility which being the most interesting feature of PLA owing to biomedical applications. Besides, as products of PLA degradation are not toxic, at a lower composition, it is a usual and natural choice for biomedical applications [18].

Therefore, we made a phantom from PLA in dimensions $23\times24\times32$ cm^3, as shown Figure 1. Firstly, we made it using the general design, which was on the internet.

Secondly, the small parts of head were designed and made from PLA by 3D printer; then, they were held by glue together. Finally, its inside was emptied out so that brain shape was maintained within it, as shown in Figure 2.

Thickness of head is about 1 cm. It has also

Figure 1: The general design of phantom.

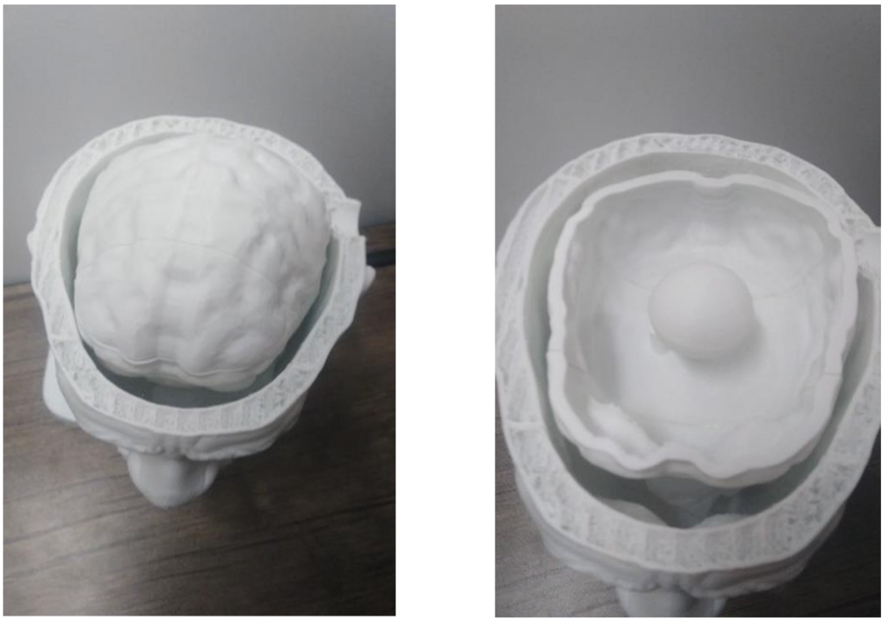

Figure 2: Inside emptied of phantom.

anthropomorphic shape on both inside and outside; besides, its wall density is 15 percent, while it passes resolution 100 micrometer. There are some parts in it, including brain with walnut shape filling with materials near to white matter such as brain sheep and the part around it fills with water as its density is near to gray matter.

Moreover, there are three places in brain in the middle and 1 cm towards the right ear for tumors with different diameters, including 2, 4 and 6 cm. Since the phantom is made for multiple purposes such as doing dosimetry organs at risk like eyes and ears and investigating if whether treatment planning techniques are dependent on location and size of tumors, there are places in the phantom for locating TLDs for dosimetry such as ovals shapes for eyes or ears and also tumors with different size and place. In addition, head, brain and tumors are able to open so that they can be filled with polymer gel to record dose distribution in three-dimensions (3D) and sharp dose gradients.

As discussed and seen in Figure 3, there are two ovals as eyes, filling with equivalent materials, with diameters, including 3 and 2 cm, that are available from inside of head for locating TLD. Besides, it can be seen that for other organs at risk, middle ears, two spheres are designed with diameter 1.5 cm filling with air and are proper places for TLD and they can be filled by polymer gel to compute dose in volume.

Brain tumor is one the common and important cancer owing to normal tissue around the tumors like brain stem, optic nerve and hippocampus as well as organs at risk such as eyes and ears; thus, we are to simulate situation for different tumors in order to compute dose delivered to normal tissue and organ at risks. Compensating for every damage to all parts of brain is irrecoverable. Therefore, it is important to simulate the situation to compute the precise dose delivered to prevent from damage. In addition, owing to the characteristics of this phantom, it is suitable to compare or investigate different treatment planning techniques such as 3DCRT, IMRT.

Discussion

Although IMRT method was to be used for treatment with advantage of low dose delivered into organ at risks in different tumors, as seen here, delivered dose was lower into organs at risks such as eyes using 3D-CRT method in this phantom study. Based on the results, we cannot be sure which method is better; however, IMRT has been the most popular methods since it causes delivered dose to be manipulated in accordance to intensity. Here, we could measure dose directly using TLD and check the delivered dose.

Conclusion

Based on the characteristics mentioned

Figure 3: Places for eyes and ears to locate thermoluminescent dosimeter (TLD) .

above, the use of this phantom is appropriate for dosimetry testes to verify the dose computed by TPS. Since the parts inside of it are relocatable, it is possible to do different tests for different organs or normal tissue. Furthermore, this phantom provides this opportunity to investigate whether treatment-planning techniques depend on the size or location of tumors. It is not only inexpensive, but also able to do many tests of dosimetry to verify doses computed by TPS, including doses delivered in ears, eyes, stem brain and optic nerve.

Conflict of Interest

None

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