UNIVERSITI TEKNOLOGI MARA

ESTABLISHMENT OF AND END-TO-END 3D DOSIMETRY SYSTEM FOR RADIOTHERAPY OF THE BRAIN USING COMPLEMENTARY METAL OXIDE SEMICONDUCTOR-OPTICAL COMPUTED TOMOGRAPHY (CMOS-OCT) AND PRESAGE RADIOCHROMIC POLYMER DOSIMETER

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ABSTRACT

Advanced radiotherapy techniques require a three-dimensional (3D) dosimetry system that is capable of measuring the complex dose delivery accurately. Available dosimeters are mostly in one-dimensional (1D) and two-dimensional (2D), which have limitations to evaluate the volumetric dose distribution from the advanced radiotherapy techniques. This study attempts to establish an end-to-end 3D dosimetry system for radiotherapy of the brain using a PRESAGE dosimeter and an anthropomorphic phantom that is readout using a complementary metal oxide semiconductor-optical computed tomography (CMOS-OCT) system. The characterisation of the CMOS-OCT/PRESAGE system was performed by investigating the dose uniformity, linearity, dose-rate dependency and percentage depth dose (PDD). The dosimetric properties of PRESAGE measured by the CMOS-OCT system were investigated and compared with the external beam therapy (EBT) film. Ultraviolet-Visible (UV-Vis) spectroscopy was used to verify the optical density (OD) change measured by the CMOS-OCT system. It was found that the OD of PRESAGE measured by the CMOS-OCT system demonstrated a linear dose response with the R^2 better than 0.984. The system shows dose rate independency from 100 to 800 cGy/min with a less than 3% variation. The system illustrated an excellent agreement of the PDD profile with the ionisation chamber. These characterisation results demonstrated that the CMOS-OCT/PRESAGE system has potential for radiotherapy dosimetry. The CMOS-OCT/PRESAGE system also illustrates good agreement with standard dosimeter (EBT films) and with standard measurement system (UV-Vis spectroscopy).The performance of the PRESAGE dosimeter was evaluated by investigating the dose response under room temperature (27° C), control temperature (3°C to 5°C), exposure to visible light, fading response, reusability and reproducibility for the complex radiotherapy dose delivery. The irradiation was performed using a linear accelerator at 6 MV and 10 MV photon beam energy. The dose was delivered at 600 cGy/min for a dose range of 0.5 to 10 Gy at 100 cm SSD and 10 cm × 10 cm field size. The OD of PRESAGE decreased by 0.1% per hour at the control temperature compared to 2.06% per hour at room temperature. The PRESAGE returns to its original state within 48 hours (2 days) when kept at room temperature. PRESAGE is also very sensitive to the visible-light with 21.13% change of OD for each hour of exposure. PRESAGE can be reused and has 85% reproducibility when irradiated at the 2nd time. The radiotherapy treatment plan of three-dimensional conformal radiation therapy (3D-CRT), intensity modulated radiotherapy (IMRT) and stereotactic radiosurgery (SRS) to PRESAGE dosimeter inside an MAX-HD anthropomorphic phantom. The accuracy of 3D dose distribution from the 3D-CRT, IMRT and SRS was assessed using the isodose-line profile and gamma analysis between PRESAGE, EBT film and Monaco treatment planning system (TPS). The measured dose distribution of PRESAGE from 3D-CRT, IMRT and SRS treatment is agreed with the measured dose distribution of EBT film and Monaco TPS with a less than 3% variation. The PRESAGE shows high gamma passing rates of more than 95% based on 3%/3mm criteria. The dosimetric properties, dose distribution and gamma analysis results demonstrated the capability of CMOS-OCT/PRESAGE to establish an end-to-end 3D dosimetry system for radiotherapy.

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CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Cancer is one of the world's critical health challenges. Globally, cancer is the second leading cause of death. According to the World Health Organization (WHO), one in every six of human's death is caused by cancer. Approximately, 10 million deaths are due to cancer in 2020. In 2018, there are 26,395 deaths were reported due to cancer among the 32 million of Malaysian populations (Manan et al., 2019). Head and neck cancer (HNC) is the seventh most common cancer globally, accounting for more than 660,000 new cases and 325,000 deaths annually (Gormley, Creaney, Schache, Ingarfield, & Conway, 2022). Approximately 75% of patients with HNC will benefit from radiotherapy as part of their primary treatment or as adjuvant treatment modality after surgery (Grégoire, Langendijk, & Nuyts, 2015). The cancer treatment modalities involve surgery, radiotherapy, immunotherapy, chemotherapy and hormonal therapy (Esfahani et al., 2020; Student, Hejmo, Poterała-Hejmo, Leśniak, & Bułdak, 2020; Wei, Wang, Yang, Wang, & Ju, 2021). Radiotherapy stands as crucial cancer treatment with estimation of more than 50% of all cancer patients receiving it during their journey of illness (Bourhis et al., 2019).

The goal of radiotherapy is to use prescribed dose of ionising radiation to kill cancer cells at the same time limiting the exposure to the normal surrounding tissues. Radiotherapy has advantage for being able to control tumour effectively (Yao, Chu, Xu, Hu, & Song, 2019). In addition, radiotherapy also has been alternative treatment for a patient that unbefitting for surgery which might be due to the major co-morbidities or inoperable disease (Evans & Staffurth, 2018). Furthermore, the survival rates of radiotherapy has improved from 30% to 80% in two decades in head and neck cancer (Chen & Kuo, 2017). Despite its benefit and success, radiotherapy remains a challenge due to it has become more advance and sophisticated (Clark et al., 2015). Besides, the radiotherapy also has many sources of error include modelling of various components of linear accelerator. There is also potential uncertainties in the treatment such as errors in patient setup, changes of anatomy and limited machine precision (Yock et al., 2019).