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Skin dosimetry of thyroid radioiodine with MOSkin detector: A phantom study

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Abstract

Radioiodine treatment is administered radioactive iodine to treat the thyroid cancer or to ablate a thyroid remnant. However, due to the risk of radiation, there is a possibility that the patient will experience side effects. Skin dose is an important parameter for quantifying patient dose. The aim of this study is to use a MOSFET detector for real time skin dosimetry. At the Centre for Medical Radiation Physics (CMRP), University of Wollongong, a new type of MOSFET detector called MOSkin is being developed to measure the skin dose, with real-time read out. This paper discusses the pre-clinical characterization the MOSkin and phantom study with radioiodine. In this study, the MOSkin is operated in active mode during irradiation, with +5 V gate bias supplied by a Lithium battery. The Electrical characterization, temperature response, dose linearity response, energy response, and sensitivity versus gate bias for MOSkin were investigated. For the detector characterization, the MOSkin had temperature instability Vth of 0.2 mV/°C under used readout current. The MOSkin energy response was like any MOSFET detector, the dose depending on photon energy. However for a photon energy of more than 250 keV the MOSkin had a flat response that allowed calibration of the MOSkin on a 6 MV LINAC. The sensitivity of the MOSkin was 1.72 mV/cGy and 2.54 mV/cGy under gate biases of +5 V and +15 V respectively. Sensitivity was constant and within 1% when MOSkin irradiated up to 10 Gy. A phantom study was performed with radioiodine 1-131 of activity 80 MBq. The absorbed skin doses for anterior neck and posterior neck were 63.95 and 2.92 cGy respectively. In conclusion, the unique design of the MOSkin appears to show great promise as a skin dosimetry device, with the added advantage of being small in size and having real-time dosimetry capabilities for radionuclide treatment in nuclear medicine.

Keywords

detector, radioiodine, study, skin, moskin, dosimetry, thyroid, phantom

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Skin Dosimetry of Thyroid Radioiodine with MO*Skin* detector: A Phantom Study

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Abstract– **Radioiodine treatment is administered radioactive iodine to treat the thyroid cancer or to ablate a thyroid remnant. However, due to the risk of radiation, there is a possibility that the patient will experience side effects. Skin dose is an important parameter for quantifying patient dose. The aim of this study is to use a MOSFET detector for real time skin dosimetry. At the Centre for Medical Radiation Physics (CMRP), University of Wollongong, a new type of MOSFET detector called MO*Skin* is being developed to measure the skin dose, with real-time read out. This paper discusses the pre-clinical characterization the MO*Skin* and phantom study with radioiodine. In this study, the MO*Skin* is operated in active mode during irradiation, with + 5V gate bias supplied by a Lithium battery.**

The Electrical characterization, temperature response, dose linearity response, energy response, and sensitivity versus gate bias for MO*Skin* were investigated. For the detector characterization, the MO*Skin* had temperature instability V_{th} of 0.2mV/^{0}C under used readout current. The MO*Skin* energy response was like any MOSFET detector, the dose depending on photon energy. However for a photon energy of more than 250 keV the MOSkin had a flat response that allowed calibration of the MOSkin on a 6MV LINAC. The sensitivity of the MO*Skin* was 1.72 mV/cGy and 2.54 mV/cGy under gate biases of +5V and +15V respectively. Sensitivity was constant and within 1% when MO*Skin* irradiated up to 10Gy. A phantom study was performed with radioiodine I-131 of activity 80 MBq. The absorbed skin doses for anterior neck and posterior neck were 63.95 and 2.92 cGy respectively.

In conclusion, the unique design of the MO*Skin* appears to show great promise as a skin dosimetry device, with the added advantage of being small in size and having real-time dosimetry capabilities for radionuclide treatment in nuclear medicine.

I. Introduction

Radioiodine treatment is a nuclear medicine treatment technique that uses a high dose of radioactive radioiodine (I-131). This treatment is the standard methodology to treat the primary thyroid cancer/metastasis, or to ablate a thyroid remnant after thyrodectomy. However, due to the risk of radiation from radioiodine, there is a possibility that the patient will experience side effects during treatment, post treatment or risks of secondary cancer. I-131 has a half life of 8.02 days and decays by emission of gamma photons primarily of energy 364 keV, and via beta radiation with maximum energy of 606 keV. Dose to the patient since administration of the isotope depends on activity of the isotope, half life and the rate of natural excretion of isotope from the body. In nuclear medicine there exists a methodology of estimation of internal dose from administered isotope to different organs based on Monte Carlo simulations [1]. However, very little has been published on the direct measurements of doses due, to difficulties in acquiring such measurements.

Skin dose is an important parameter for quantifying patient internal dose and is useful for monitoring the side effects. By definition from ICRP 59, the skin dose is the dose equivalent at a depth of 0.07 mm, typical for the basal layer [2]. Currently, there is no real-time dosimeter suitable for verifying the skin dose from radioiodine treatment. The TLD dosimeter and radiochromic film can be used but they do not provide the dose at an appropriate depth. They are also complicated in usage and are not real time dosimeters. A MOSFET detector is attractive option.

MOSFET dosimetry is based on the built in charge in the gate oxide due to ionizing radiation, leading to threshold voltage shift of the MOSFET detector that is easily measurable in real time. MOSFET dosimetry has found application in space, HEP and radiation therapy [3], [4]. At the Centre for Medical Radiation Physics (CMRP), University of Wollongong, a new design of MOSFET detector called MO*Skin* is being developed to measure the dose delivered at the basal layer point, with real-time capability. This study discusses the pre-clinical characterization the MO*Skin* and phantom study for use in thyroid radioiodine. Figure 1 show a MO*Skin* chip built into a kapton strip, providing a layer of reproducible Water Equivalent Depth (WED) of 0.07mm. This device can be easy attached to the patient's body [5]-[7].

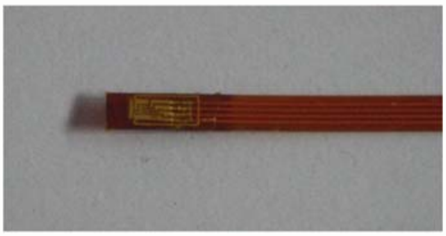

Fig. 1. MO*Skin* detector with "Kapton" pigtail, this allows the build-up layer of detector has reproducible thickness capable of presenting a WED of 0.07 mm. for skin dose measurement

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The aim of this work is to acquire real time skin dosimetry on the neck of the patient after being administered with a dose of radioiodine.

II. Material and Method

In this study, the MO*Skin* is operated in active mode with a +5V gate bias during irradiation, supplied from a miniature Lithium battery mounted on the end of the Kapton pigtail.

Fig. 2. The 5V Lithium battery with the package

Electrical characterization, temperature response, dose linearity response, photon energy response, and sensitivity versus gate bias for MO*Skin* were investigated. Radiation tests were carried out using a 6MV medical LINAC and X-ray machine in the energy range 50-250 KVp.

The phantom used in this study is a Capintex® thyroid neck phantom which is neck tissue equivalent. The phantom has a slot to insert the radioiodine which corresponds to the anatomical position of the thyroid gland. The phantom is cylindrical in shape and made from PMMA (poly methyl methacrylates) with a physical density of 1.18 g/cm3. The diameter of the phantom is 13 cm and has a height of 12.5 cm.

Fig. 2. The Capintex® thyroid neck phantom made from PMMA provide tissue neck equivalent with 13 cm diameter

III. Results

For the characterization, the MO*Skin* had temperature instability V_{th} of 0.2mV/^{0}C under used readout current. The MO*Skin* energy response was like any MOSFET detector, the dose depending on photon energy. However for a photon energy of more than 250 keV the MOSkin had a flat response that allowed its calibration on a 6MV LINAC. The sensitivity of the MO*Skin* was 1.72 mV/cGy and 2.54 mV/cGy under gate biases +5V and +15V respectively. Sensitivity was constant within 1% when the MO*Skin* irradiated up to 10 Gy. For this experiment MO*Skin* were used with a gate bias +5 Volts during irradiation.

A phantom study was performed with I-131 radioiodine of representative activity 80 MBq. Three MO*Skin* were calibrated and placed on the surface of the neck phantom. Two MO*Skin* detectors (one with a gate oxide facing the phantom surface labeled "Anterior Neck Faced Down" and another with the gate oxide away from the surface labeled "Anterior Neck Faced Up") were placed on the anterior side of the phantom. Another detector was placed on the posterior neck surface and labelled "Posterior Neck". . The data were collected after administration of the activity over a period of one week. Readout of the MO*Skin* was carried out using a reader developed at CMRP. Results are shown in Figure 3.

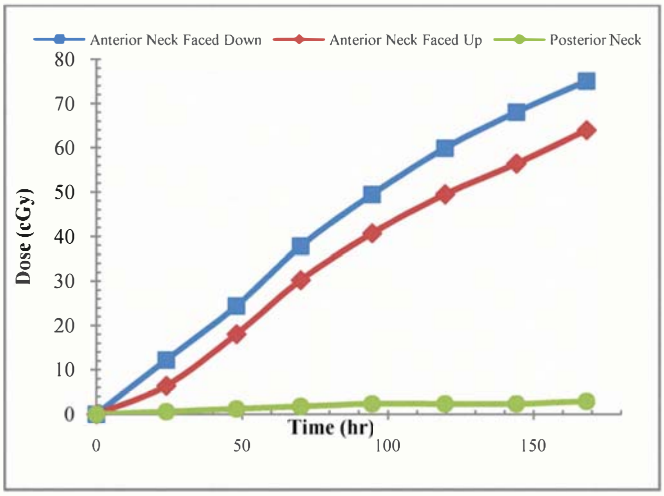

Fig. 3. shows surface dose due to gamma photon accumulation in time over a period of one week as measured by 3 MO*Skin* detectors after I-131 radioisotope administration

All beta particles were assumed to be stopped by the phantom material. The MO*Skin* detector ("Anterior Neck Facing Down") measured dose at WED about 0.7 mm due to 0.375 mm Si substrate above the gate, while "Anterior Neck Facing Up" MO*Skin* measured the exit dose at depth 0.07 mm with a result that was less than expected. The dose on posterior surface of the neck phantom was essentially less than expected

IV. Conclusion

The absorbed skin doses for anterior neck and posterior neck for a typical I-131 administration for this procedure were 63.95 and 2.91 cGy respectively, one week after administration.

These doses do not take into account natural excretion of the isotope. The unique design of MO*Skin* appears to be very promising as a skin dosimetry device with the advantage of being small in size and possessing a real-time dosimetry capability for radionuclide treatment in nuclear medicine. Results of preclinical studies on patients will be presented which in due course.

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