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Experimental analysis of correction factors for reference dosimetry in a magnetic field

Abstract: Today, hybrid systems of linear accelerator and MRI scanner are clinically available. Therefore it is important to investigate the feasibility of reference dosimetry with ionization chambers in the presence of a magnetic field and determine correction factors. In this work, correction factors under various conditions that influence the chamber response were experimentally investigated, using a conventional 6 MV linear accelerator together with a stand-alone magnet. We found that the correction factor for a PTW31010 ionization chamber ranges from 0.9873 to 1.009 depending on the magnetic field strength, magnetic field orientation and magnetic field size. The phantom material also does have an influence on the measured signal. Therefore, reference dosimetry with ionization chambers in the presence of a magnetic field is feasible, but requires dedicated correction factors, which depend on the experimental setup.

Keywords: ionization chamber, reference dosimetry, magnetic field, correction factor, MR-linac

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1 Introduction

Today, for magnetic resonance guided radiotherapy (MRgRT) hybrid systems of linear accelerators and MRI scanners are clinically available [1]. During radiotherapy, secondary electrons are affected by the magnetic field, so their trajectories get changed. This effects dosimetry aspects, such as the dose deposition in ionization chambers.

Hence, it is essential to determine correction factors for reference dosimetry in a magnetic field. In this work, correction factors under various parameters that may influence the chamber response were experimentally investigated.

2 Materials and methods

Measurements were performed using a PTW31010 ionization chamber in a PMMA phantom as well as in a water phantom. The PMMA phantom has a cross section of 30x30 mm² and 10 cm equivalent water depth. A permanent magnet (magnetic field size 4x4x7 cm³) with magnetic field strength of 193 mT or an electromagnet (magnetic field size 4x4x3 cm³) with magnetic field strength ranging from 0-250 mT

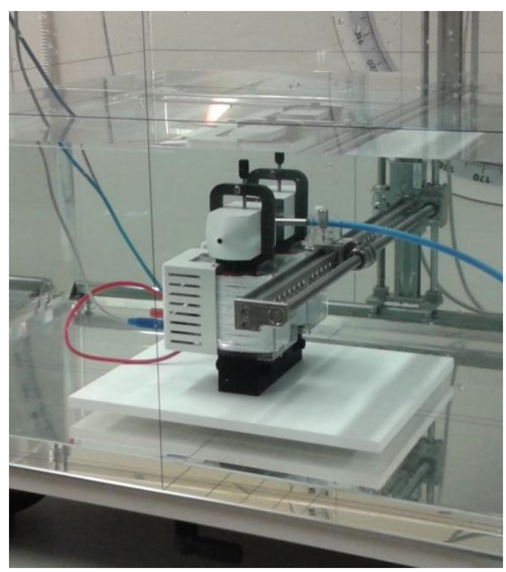

Figure 1: Experimental setup for the PTW31010 ionization chamber with electromagnet in the water phantom. Note that radiation beam direction is oriented from top to bottom, perpendicular to ionization chamber and magnetic field.

were placed inside the water phantom. The photon beam (6 MV) was applied perpendicular to ionization chamber and magnetic field. Figure 1 shows the experimental setup for the

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electromagnet in the water phantom for a PTW31010 ionization chamber.

The magnetic field strength, magnetic field orientation, chamber voltage, monitor units, radiation field size and chamber polarization were varied to study their individual effect on the measured signal. Additionally, the correction factors for a PTW31010 ionization chamber in a magnetic field ranging from 0 mT to 250 mT was determined in the water phantom as well as in the PMMA phantom to measure the influence of the phantom material.

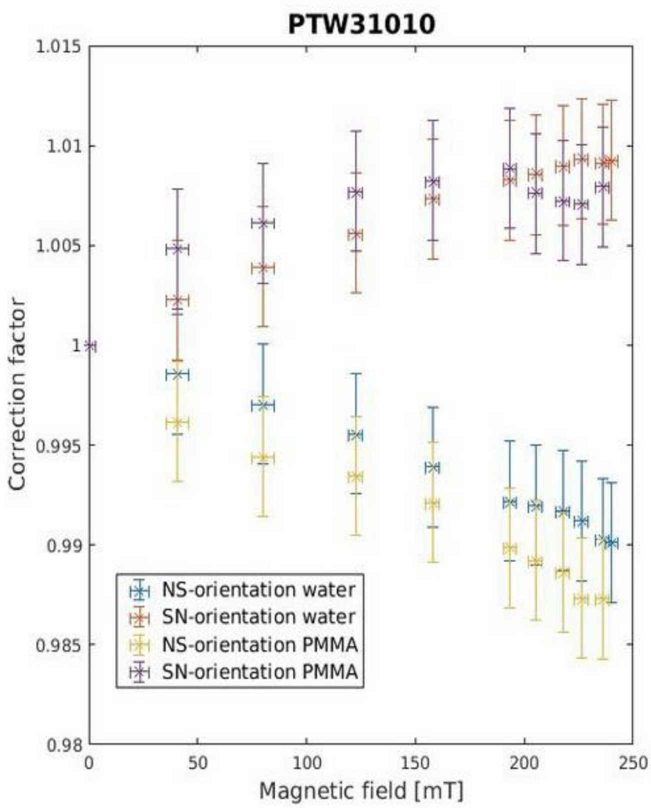

Figure 2: Correction factors for a PTW31010 ionization chamber for both magnetic field orientations, measured in PMMA and water.

3 Results and discussion

3.1 Correction factors

The results showed that magnetic field strength, magnetic field orientation and magnetic field size do have a significant influence on the correction factor.

In figure 2, the correction factors for the PTW31010 ionization chamber in PMMA and water, measured in the electromagnet, are shown for a magnetic field strength ranging from 0 mT to 250 mT for both possible chamber orientations. The correction factor (k_B) was calculated using equation 1

$$\mathbf{k}_{B} = \frac{M_0}{M_B}, \quad (1)$$

where M_0 is the measured signal without the magnetic field and M_B is the measured signal in the presence of the magnetic field [2]. The measured signal was corrected for temperature and air pressure respectively.

We differentiate between two orientations of the magnetic field. The north-south (NS) orientation means that the Lorentz force is directed to the top of the ionization chamber. The south-north (SN) orientation refers to the reverse polarity.

Figure 2 shows that for the PTW31010 ionization chamber the magnitude of the correction factor depends on the magnetic field orientation. For the NS orientation, the measured signals increase, whereas for the SN orientation, the measured signals decrease.

3.1.1 Further parameters

Results showed that further parameters such as chamber voltage, monitor units, radiation field size and chamber polarization do not influence the measured signal.

Though, in figure 2 it is possible to compare the correction factors in water with the correction factors in PMMA. For all magnetic field strengths, the correction factors in water are higher than the correction factors in PMMA for the NS orientation whereas for the SN orientation, the correction factors in water are lower than the correction factors in PMMA. Although the measured correction factors for PMMA and water are still in the error bar of each other, there is a trend that the measured effect is for both orientations less in water than in PMMA. This shows that the phantom material also does have an influence on the correction factor.

Furthermore, we compared the measured correction factors in the electromagnet with the correction factors in the permanent magnet. In Table 1, a comparison of the correction factors measured in the electromagnet and the permanent magnet, measured in PMMA are shown. The correction factors measured in the permanent magnet are always smaller than the correction factors measured in the electromagnet. This shows that the magnetic field size also does have an influence on the measured signal, because the permanent magnet has a larger magnetic field size.

Table 1: Correction factors for the PTW31010 ionization chamber in PMMA in a 193mT magnetic field. Comparison between the electromagnet and the permanent magnet.

Magnet	Orientation and phantom material	Correction factor
Electromagnet	NS-orientation; PMMA	0.9899 ± 0.0028
Permanent magnet	NS-orientation; PMMA	0.9859 ± 0.0028
Electromagnet	SN-orientation; PMMA	1.0089 ± 0.0019
Permanent magnet	SN-orientation; PMMA	1.0082 ± 0.0032

4 Conclusion

In conclusion, it is possible to determine specific correction factors, depending on magnetic field strength, orientation and size. But also the phantom material does have an influence on the correction factor. Therefore, reference dosimetry with ionization chambers in the presence of a magnetic field is feasible, by using a correction factor, depending on these parameters. Further investigation is needed to determine correction factors for other ionization chambers.

Author's Statement

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