Turkish Journal of Physics

http://journals.tubitak.gov.tr/physics/

Research Article

Turk J Phys
(2015) 39: 31 – 36

doi:10.3906/fiz-1401-15

The effects of plaster on radiation doses given to patients

Onur KARAMAN, Ayşe Güneş TANIR*, Mustafa Hicabi BÖLÜKDEMİR
Department of Physics, Faculty of Sciences, Gazi University, Teknikokullar, Ankara, Turkey

Received: 30.01.2014 • **Accepted:** 20.06.2014 • **Published Online:** 23.02.2015 • **Printed:** 20.03.2015

Abstract: The purpose of this investigation is to measure the total attenuation coefficients (TACs) of plaster materials using different geometries of the plaster, field sizes, and photon beam energies. The percent depth dose measurements were made using X-rays at 6 MV and 18 MV from the linear accelerator in order to plan the probable radiation dose to be given to the patient wearing a plaster cast. The TAC was experimentally determined in solid phantoms of various thicknesses both with and without plaster over areas of 5 × 5 cm^2, 10 × 10 cm^2, and 15 × 15 cm^2. The experimentally measured TAC for plaster was compared to that of the NIST program. The TAC of solid phantom with plaster was found to be larger than without plaster. This means that d_{max} is very close to the skin and that in these situations plaster has a bolus effect, increasing the skin's dose.

Key words: X-rays, total attenuation coefficient, plaster, percent depth dose

1. Introduction

The dose of ionized radiation, or more simply the dose, is determined by 1 of 2 keywords: 'absorbed' and 'equivalent'. The absorbed dose means the amount of energy deposited per gram of target matter. Dose equivalent means the damaging effect of a particular type of radiation. In order to accurately determine the dose absorbed by the target it is essential to understand the reasons for dose reduction in tissue. The amount of energy stored depends on the type of radiation, the energy, and the medium being traversed. As in the form of particles or photons, radiation ionizes or excites the target. The basic way that photons interact with the target is through the absorption and transfer of energy. The dose absorbed by the target from a beam of photons is given as follows:

$$D = \Phi \times (\pi/\rho) \times E,$$

where Φ is the flux (photons/cm^2), E is the photon energy, and π/ρ is the mass attenuation coefficient for the medium [1].

As the use of ionizing radiation sources increases, especially in fields relating to human health, the measurements and calculations of the interaction parameters for these ionizing radiations need to be more carefully highlighted. One of the most important parameters is the total attenuation coefficient (TAC) to describe the progress of photons in the medium.

The goal in radiotherapy is to ensure that the target volume receives the correct dose while the surrounding tissues remain as healthy as possible. It is for this reason that various materials are used inside the patient

*Correspondence: gunes@gazi.edu.tr

or on the patient's outer surfaces. The TAC of these materials needs to be taken into account when planning radiotherapy.

Plaster is used in radiotherapy for the following purposes:

1. To plan a 2-dimensional contour,
2. To immobilize the patient,
3. To move the dose to the surface of the skin,
4. To cover exposed areas with plaster.

In this study, the TAC of plaster used in supporting arm and leg bones was determined both theoretically and experimentally, and the effect of plaster on the dose absorbed by the tissue was investigated.

2. Experimental

Dose measurements were carried out using an electrometer (PTW Unidoes brand, model number T10008, series number 80616) and an ionization chamber with a volume of 0.6 cm^3 (parallel plate marked PTW, model number TM30010, series number 2403). The density of the solid-water phantom RW3 was 1.045 g/cm^3 and its electron density was 3.43 $\times 10^{23} e/cm^3$. It was made of white polystyrene containing 2% TiO_2 with an area of 40 $\times$ 40 cm^2. It consists of 29 plates. In measurements, sheets with thicknesses of 1 mm, 2 mm, 5 mm, and 10 mm were used. Additionally, 1 sheet with a thickness of 2 cm was prepared. The linear accelerator used to irradiate was the Oncor Impression M5395.

All of the experimental measurements were performed at a pressure of 902.4 mbar and a temperature of approximately 20.4 °C. The schematic diagram of the experimental setup is given in Figure 1.

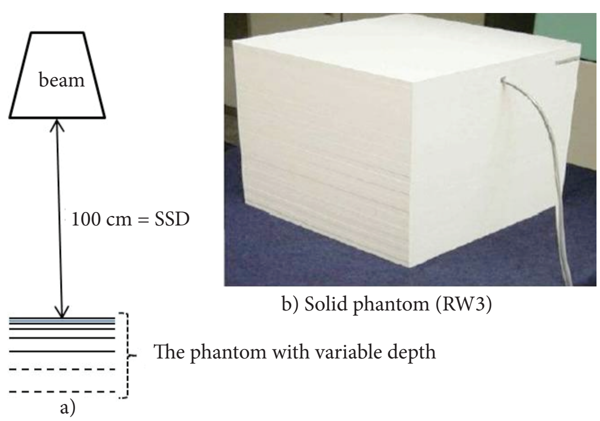

Figure 1. a) Schematic diagram of experimental setup. b) Solid phantom with variable thickness.

The plaster used in the study was commercially available and it was subjected to 2 processes before being used: it was first prepared by cutting it into patches measuring 0.5 $\times$ 1.0 $\times$ 1.5 cm and immersed in water for 10 min. Later it was inserted into the mold and subjected to heat to dry it out. The content of the plaster was measured using an X-ray fluorescence (XRF) device (Table 1).

3. Results and discussion

3.1. The measurements using a solid phantom without plaster

The percent depth dose (DD %) values were measured using the electrometer and the ionization chamber placed in the solid phantom over 5 $\times$ 5, 10 $\times$ 10, and 15 $\times$ 15 cm^2 areas with a source-to-surface distance of 100 cm for 100 monitor units. The measurements were repeated by increasing the thickness of the solid phantom from 0.5 cm to 5.0 cm. As is known, DD % is defined as the quotient of the absorbed dose at any depth to the absorbed dose at fixed reference depth d_{max}. As shown in Figures 2 and 3, the maximum dose for 6 MV is at 1.5 ± 0.1 cm, and it is at 3.0 ± 0.1 cm for 18 MV.

Table 1. Contents of plaster used in this study.

Component	Weight fraction %
B_2O_3	8.8500
CO_2	4.0400
Na_2O	0.0069
MgO	0.3120
Al_2O_3	0.0571
SiO_2	0.3730
SO_3	48.900
Cl	0.0079
K_2O	0.0084
CaO	36.700
Fe_2O_3	0.0231
SrO	0.7310

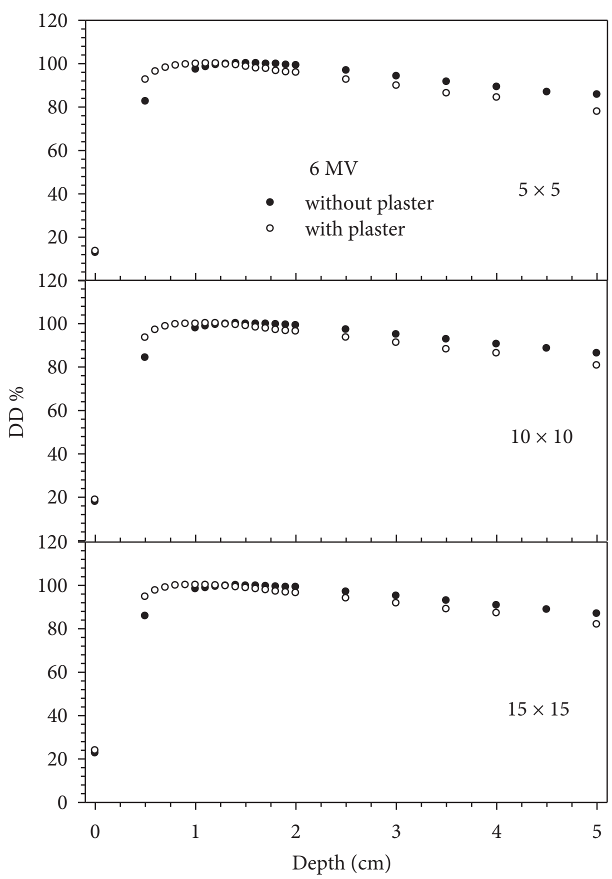

Figure 2. Percent depth dose versus thickness of solid phantom for 6 MV.

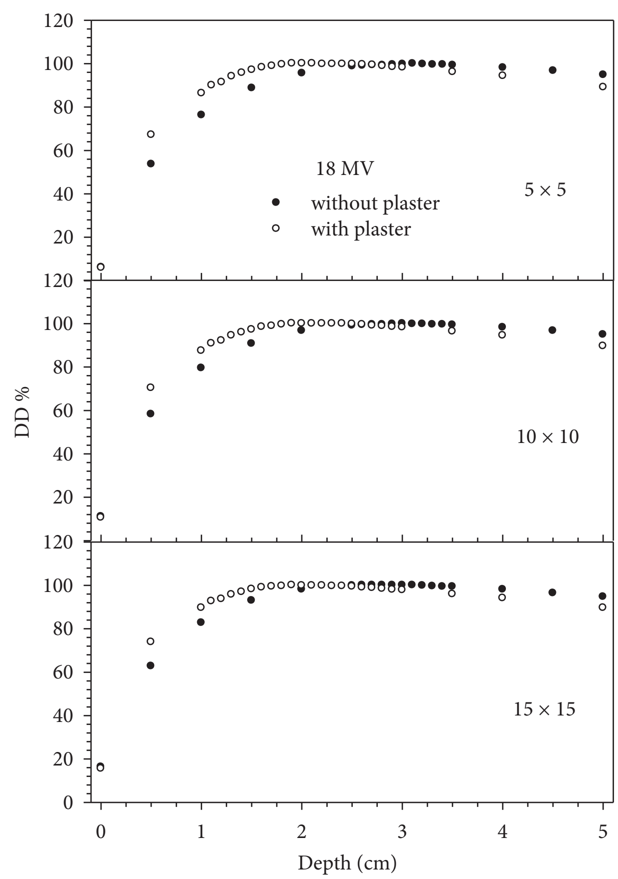

Figure 3. Percent depth dose versus thickness of solid phantom for 18 MV.

The logarithmic DD % values that were measured from d_{max} to the end point were plotted versus thickness and the TAC values were calculated from the slope of the straight line (for example, see Figure 4). The TAC values are listed in Table 2. It can be seen that the TAC values are inversely proportional to the size of area at the same photon energy. Additionally, the TAC value at 18 MV is smaller than that at 6 MV for the same size of area. For example, while the TAC value was 0.0276 ± 0.0018 cm^{-1} for 5 × 5 cm^2 at 18 MV, it was 0.0491 ± 0.005 cm^{-1} at 6 MV. These results are consistent with the values in the NIST tables [2] for water.

Table 2. The experimental and theoretical total attenuation coefficients (1/cm).

	6 MV		18 MV	
Area (cm^2)	Without plaster	With plaster	Without plaster	With plaster
(5 × 5)	0.0491 ± 0.005	0.0655 ± 0.003	0.0276 ± 0.018	0.0439 ± 0.002
(10 × 10)	0.044 ± 0.003	0.056 ± 0.003	0.0275 ± 0.01	0.0425 ± 0.002
(15 × 15)	0.042 ± 0.004	0.051 ± 0.003	0.0286 ± 0.015	0.0404 ± 0.002
Theo. (5 × 5)	0.0494	0.0715	0.0271	0.0438

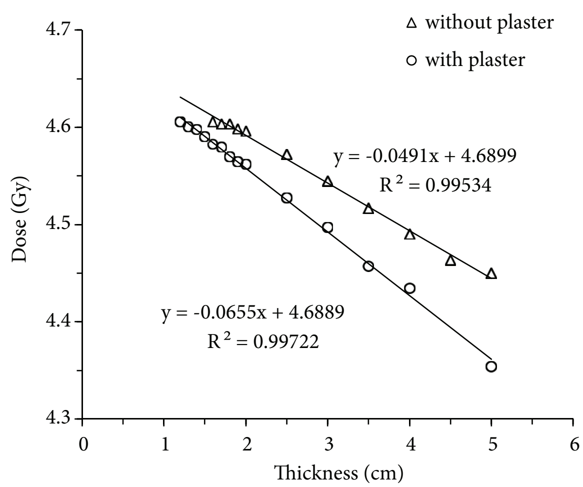

Figure 4. The experimental TAC values using the DD % graphs.

3.2. The measurements using a solid phantom with plaster

The experimental processes applied to the solid phantom without plaster were repeated for a solid phantom with plaster. The data are also displayed in Figures 2 and 3. The maximum doses found were at 1.1 ± 0.1 cm for 6 MV and at 2.0 ± 0.1 cm for 18 MV. The difference between the maximum dose values with and without plaster was about 7.3%; this is a significant difference that should be considered in radiotherapy planning. The TAC values are inversely proportional to the size of area for the same photon energy. For example, the TAC value at 18 MV was 0.0439 ± 0.002 cm^{-1} and at 6 MV was 0.0655 ± 0.003 cm^{-1} for 5 × 5 cm^2. The TAC value of the solid phantom with plaster was found to be greater than that without plaster, meaning that d_{max} is closer to the skin. Plaster creates a bolus effect and this situation stops the ‘skin-sparing’ effect of photons and leads to unintended consequences like erythema or desquamation. Thus, the plaster increases the dose absorbed by the skin. The plaster may have air bubbles because of its nonhomogeneous distribution. For patients with plaster, the thickness of plaster and the effect of air between the skin and the plaster should be taken into account in the treatment planning system.

3.3. Measurements using a solid phantom with cotton gauze (with and without plaster)

In order to determine the effect of cotton gauze on the absorbed dose, DD % values and attenuation coefficients were measured using solid phantoms with cotton gauze (with and without plaster) placed between plaster and solid phantom over areas of 5 × 5, 10 × 10, and 15 × 15 cm^2. The maximum DD % values for the solid phantom with cotton gauze without plaster were at 3.1 ± 0.1 cm and 1.5 ± 0.1 cm at 18 MV and 6 MV, respectively. These values were at 1.2 ± 0.1 cm for 6 MV and 2.1 ± 0.2 cm for 18 MV using the solid phantom with cotton gauze with plaster. Furthermore, the TACs for the solid phantom with cotton gauze without plaster were found to be 0.0502 ± 0.0056 cm^{-1}, 0.046 ± 0.0028 cm^{-1}, and 0.0433 ± 0.0031 cm^{-1} at 6 MV for 5 × 5 cm^2, 10 × 10 cm^2, and 15 × 15 cm^2, respectively. These values were respectively 0.0276 ± 0.018, 0.0279 ± 0.0122, and 0.0291 ± 0.0149 cm^{-1} at 18 MV. Cotton gauze was not observed to have a significant effect on the dose, so no graph was plotted.

3.4. The measurements for imitation arm and leg with plaster

The measurements were repeated using an imitation adult-sized arm and leg in plaster. The total thickness of the plaster and the imitation system were adjusted to 5 cm for the arm and 10 cm for the leg. The thickness of the plaster was changed from 0.5 cm to 1.5 cm. The measurements were made over 5 × 5 cm^2, 10 × 10 cm^2, and 15 × 15 cm^2 areas. No significant differences were observed among the DD % values for the imitation arm and leg with plaster. Their TAC values both with and without plaster were found to be the same as for the solid phantom.

3.5. Determining TAC for plaster

The TAC value for the plaster used in the study was determined using the NIST X-ray programmer and compared with the results of experimentally measured values. The plaster was analyzed using an XRF device at the central laboratory of Middle East Technical University in Ankara, Turkey. The results of this analysis are given in Table 1. The TAC values for each of the elements in plaster were found using the NIST programmer [2,3] and the total TAC value of the plaster was calculated according to $\mu/\rho = \sum_i w_i \ (\mu/\rho)_i$, where μ/ρ is mass attenuation coefficient and w_i is the fraction of weight.

The TAC of the solid water phantom was found to be 0.0491 cm^{-1} for 6 MV and 0.0276 cm^{-1} for 18 MV for an area of 5 × 5 cm^2. TAC values from the NIST X-ray programmers are 0.0494 cm^{-1} at 6 MV and 0.0271 cm^{-1} at 18 MV.

For the solid phantom with plaster, the experimental TAC was found to be 0.0655 ± 0.003 cm^{-1} at 6 MV for an area of 5 × 5 cm^2, while the value found using the NIST programmer was 0.0715 cm^{-1}.

4. Conclusions

TAC depends on the spectrum of the photon energies used, the size of the fields, and the thickness of the plasters. The TAC for mono-energy beams is larger only by 1.03% and 1.27% at 6 MV and 18 MV, respectively.

The measured DD % values increased as the size of the target area increased. This indicates that the attenuation coefficients decrease and the scattering increases as the area expands. According to the results, the plaster does affect the absorbed dose at different photon energies, different sizes, and different target thicknesses. It can be concluded that the effects of plaster on dose should be experimentally measured before radiotherapy is given to the patient.

References

[1] Martin, J. E. *Physics for Radiation Protection*, 2nd ed.; Wiley-VCH: Weinheim, Germany, 2011.

[2] Hubbell, J. H.; Seltzer, S. M. *NISTIR 5632*; National Institute of Standards and Technology: Gaithersburg, MD, USA, 1995.

[3] Gerward, L.; Guilbert, N.; Jensen, K. B.; Levring, H. *Radiat. Phys. Chem.* **2001**, *60*, 23–24.