

Variations in Couch Transmission Factors' with Treatment Depths in Isocentric Technique at the National Radiotherapy Center, Korle-Bu Teaching Hospital, Accra. Ghana

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Abstract-Carbon fibre has become the material of choice for many radiotherapy applications, as it is lightweight, radio-translucent and rigid. However, as a result of high cost of carbon fibre, other composite materials have now become available that equally radio-translucent such as wood of 2cm². Ionization doses in the form of integral currents were measured by the electrometer at gantry angles of 180 and 0 degrees for the different radiation treatment depths systematically (non-randomly) selected for the study. A constant reference field size of 10cm x 10cm was used throughout the experiments. Treatment table top transmission factor was calculated by taking the ratio of table top (gantry angle at 180°) and open field (gantry at 0°) ionization data for the various treatment depths selected for the study. The couch top transmission factor varied from 0.975 to 0.945 with treatment depths ranging from 3cm-11cm for the 1.25Mev cobalt 60. The lowest transmission factor was observed for radiation treatment depth of 11cm (0.945) while the highest transmission factor was observed at a depth of 3cm (0.975). The couch top transmission factor decreases from the depth of 3cm to 11cm. A linear regression shows a strong inverse dependence of couch top transmission factor with treatment depth, i.e. $r = -0.995$, using r as regression constant (correlation coefficient). The coefficient of determination, i.e. $r^2 = 0.991$ calculated showed that approximately 99.1% of the variability in couch top transmission factor was linked with variability in treatment depth. Transmission factors for treatment table tops (solid radiation treatment table tops) used in dosimetry for radiotherapy procedures vary with treatment depths for isocentric set-up. Therefore, different couch factor should be used at different treatment depths for treatment time calculations of radiation beam that account for couch factor.

Keywords: Transmission factors, Treatment tabletop, Treatment depths, Isocentric set-up, Dosimetry, Target, Phantom,

Introduction

The primary aim of external beam radiotherapy is to optimize tumourcidal dose to the tumor whilst minimizing the dose to the normal tissue to reduce toxicity as much as reasonable achievable [1, 2]. In order to achieve this, important consideration should be given to factors such as patients' set-ups and the design of the treatment table or couch [3, 4]

Over the years, most radiotherapy couch tops are made of materials such as carbon fiber or glass fiber. However the portion of the couch top for the incident beam has wire mesh which is designed in the form of racket [5]. This is done to provide support for the patient's weight, preserve the skin sparing effect of the radiation and to eliminate attenuation of the radiation beam before traversing the patient [5]. After repeated and prolonged use, the wire meshes tend to lose their elasticity causing them to yield to the weight of the patient leading to intolerable sagging culminating in set-up variations. In order to address this problem the current trend is to make couch tops without the wire mesh racket of carbon

fiber material with low attenuation property. Carbon fibre has become the material of choice for many radiotherapy applications, due to its strength, rigidity, low attenuation and low density [6, 7, 8, 9]. Despite the advantages of carbon fiber, there are some disadvantages to the use of carbon fibre. It is expensive to use especially in the developing countries and also as conductor it can generate heat and thereby produce image artefacts on MRI scanners [10]

Other composite materials have now become available that are rigid and potentially are equally radio-translucent as carbon fibre and glass fiber. Some of these materials are non-conductor, so they could be used for MRI-compatible couch tops and accessories. One such material is wood which has thickness and Hounsfield value of 2cm and -409Hu respectively and this was used at the Radiotherapy Center Accra, Ghana [11]

The design of the most optimal treatment plan largely depends on freedom in beam incidences that can be realized by a combination of gantry and couch rotations [12]. With these degrees of freedom, there is a possibility for the beam to pass through the couch before entering the patient, resulting in unacceptable distortion of the intended dose distribution which is accounted for by the couch top transmission factor (couch factor) in the treatment time and monitoring units determination [13, 14]. The couch transmission factor affects treatment time or monitoring calculations and therefore the absorbed dose to the target volume [15]. This factor is usually measured at the reference field size (10cm x 10cm) and reference depth (d_{max}) [16].

The wire mesh treatment couch top previously used at the National Radiotherapy Center, Accra, Ghana, has been replaced with a solid wooden treatment couch top of uniform thickness of 2cm. So far studies concerning variation of wooden couch top transmission factor with treatment depth have not been reported

The purpose of the study was to evaluate variations in the wooden couch top transmission factors as a function of treatment depth for isocentric set-up at the National Radiotherapy Center, Accra, Ghana. As this Center, treatment time on the Cobalt 60 is calculated manually for the beam that trans- verses the couch top to account for couch top transmission factor. The specific objectives of the study included the following:

- a. To quantify the transmission of the photon beams when propagating through the couch top at various treatment depths.
- b. To determine different couch top transmission factors at different treatment depths.
- c. To make appropriate recommendation to address any discrepancies in treatment time calculation for cancer treatment.

Methodology and Instrumentation

This experimental study was carried out at the Cobalt 60 Teletherapy Unit at National Radiotherapy Center, Accra, Ghana. The following materials and items were used for the study.

- a. Ionization chamber- This was a 0.125 cc volume flexi cylindrical ionization chamber type; 31002 with serial number of 0393. It is the most popular cylindrical ionization chamber designed by Farmer and originally manufactured by PTW, Freiburg, Germany, but now available from several vendors, for beam calibration in radiotherapy dosimetry. Its chamber sensitive volume resembles a thimble, and hence the Farmer type chamber is also known as a thimble chamber [17].
- b. Electrometer- PTW UNIDOS 10002 type with a serial number of 20427. The mode of dosimetry reading was in integral current with respect to time.
- c. Thermometer.
- d. Barometer
- e. 40cm x 40cm x 2cm wood sample to be used for the fabrication of custom-made Couch top.
- f. A 30cm x 30cm Perspex slabs phantom of 1cm and 0.5cm thicknesses (PTW type 2687 Perspex phantom). This is a form of Plexiglas phantom, chemically composed of (C5O2H6)n. It has mass density (g/cm^3) between $(1.16 - 1.20)\text{g}/\text{cm}^3$ with number of electrons per gram and effective atomic number of 3.24×10^{23} and 6.84 respectively.

- g. Cobalt-60 teletherapy machine.

As part of data collection for the study, perspex slab phantoms were left in the air conditioned radiation treatment room (24 hours) till the next day to be used for the experimental study. This was to allow the Perspex slab phantoms to assume the temperature of the treatment room [18].

The Perspex slabs were arranged such that the surface of the slabs were perpendicular to the beam central axis, which were then held firmly in place by gravity on the treatment couch of the cobalt-60 teletherapy unit. Among the pile of Perspex slabs was a 2 cm thick slab with hole provided on one of its sides by the manufacturer to hold a 0.125 cc farmer type ionization chamber. The distance from the ionization chamber was 15 cm towards the bottom of the Perspex phantom to provide the necessary backscatter and electronic equilibrium needed for the measurements. But the distance from the ionization chamber to the top of the perspex phantom was varied from 1.5 cm to 13.5 cm increments of 2 cm, which served as the treatment depths for the measurements.

Prior to the measurements, the ionization chamber was pre-irradiated for 5 min to liberate stray charges in order to avoid residual charges in the chamber being measured [19]. The ionization chamber was connected to the UNIDOS electrometer, which was configured to measure charges with a bias voltage of + 400 V at 60 sec interval. The readings were recorded by the electrometer in an integral current with respect to time mode ($\int \text{Idt}$).

The outputs of the cobalt-60 teletherapy machine were measured for a 10cm x 10cm square field, with and without the sample of wood placed on the surface of the perspex phantom for each of the selected treatment depths using isocentric irradiation technique as shown in figure 1. For each measurement, readings were repeated five times and the mean integral current (with respect to time) reading calculated for the given depth. The ambient pressure was measured with the barometer and the temperatures before and after irradiation also obtained with the thermometer to estimate for the mean temperature and pressure correction factor for the average output measured at the particular treatment depths. The ratios of the corrected mean readings with and without the wood sample in the path of the beam were calculated to determine the transmission factor of the fabricated treatment couch at a particular treatment depth [20, 21].

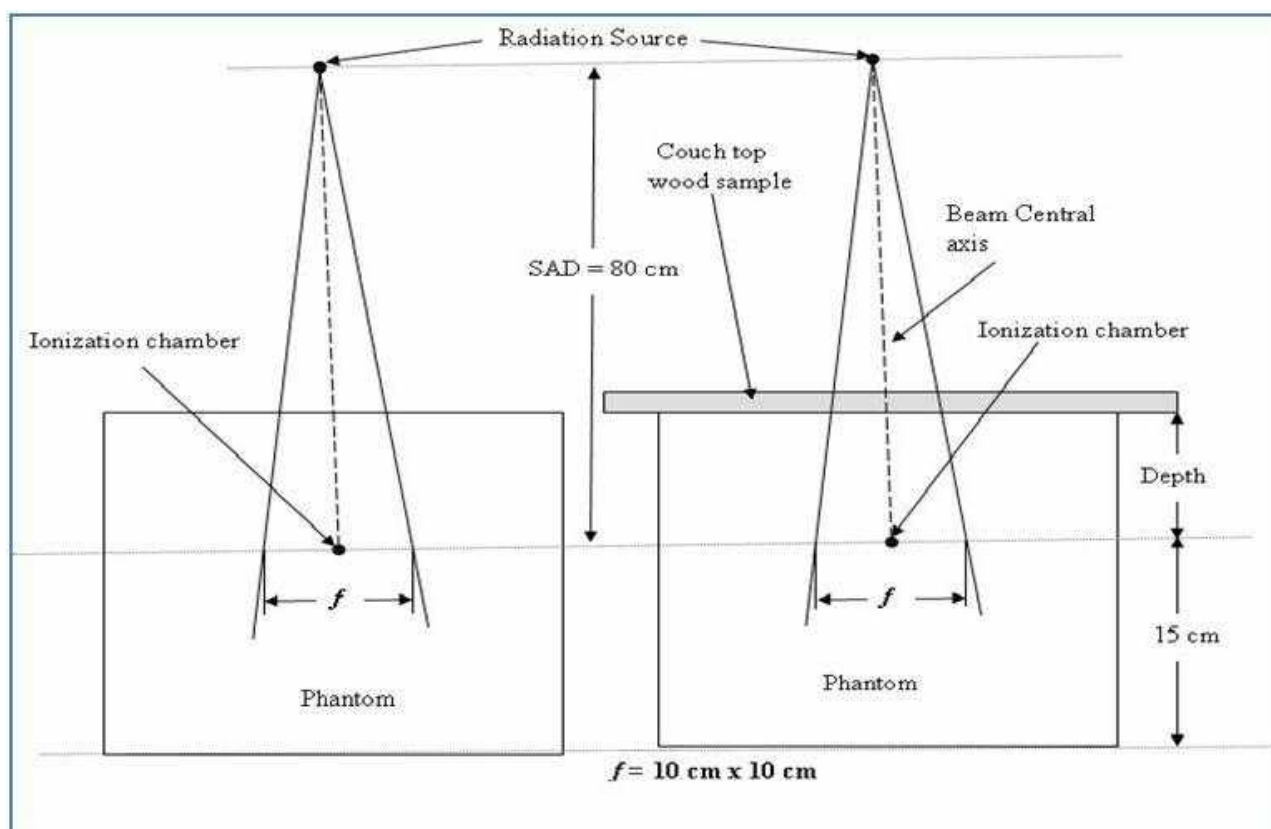


Fig 1. Schematic Diagram of the Experimental Set-up

Couch Top Transmission Factor Measurement

The couch top transmission factor at depth in Perspex slabs phantom for a field size, along the central axis of the beam was calculated with the help of the equation [7]:

$$T_f = \frac{R_c(f_s, d)}{R(f_s, d)} \quad (1)$$

Where and are the corrected mean electrometer readings along the central axis in a specified field size with and without the couch top being placed in the path of the beam at a particular treatment depth respectively.

The data obtained were analyzed statistically using SPSS version 16.0 for Windows and Microsoft Excel 2007 spreadsheet. Using the same software (Microsoft Excel 2007 spreadsheet), the data were presented in the form of graph of couch top transmission factor (dependent variables) against treatment depth (independent variables) on a scatter diagram. By applying the method of least square regression curve fitting, a mathematical relationship was established between couch top transmission factor and treatment depth.

Results

The couch top transmission factor as function of treatment depth for isocentric irradiation is shown in figure 1, and the corrected mean electrometer readings for the various

depths for 10 cm x 10 cm field size with and without the couch top in the path of the beam, measured along the beam central axis are tabulated in Table 1. Couch top transmission factors are also presented against their corresponding treatment depths in table 1. The figure 1 shows a strong inverse relationship between couch top transmission factor and treatment depth for isocentric set-up. For the regression analysis, the quantitative goodness of fit was evaluated to ascertain how well the regression represents the set of data. This was based on the coefficient of determination R^2 for the evaluation of the correlation of the trend relative to magnitudes. The value obtained was 0.991.

The second order polynomial regression shows a strong inverse relationship between couch top transmission factor and treatment depth for isocentric set-up. The coefficient of determination, i.e. $R^2 = 0.991$ means that approximately 99.1% of the variability in couch top transmission factor was linked with variability in treatment depth [22] and the remaining percentage (0.9%) is due to other factors that affect radiation dose measurements. From the above graph, the relationship between couch top transmission factor and the treatment depth (for isocentric set-up) was linked with the equation;

$$T_f = 0.0002d^2 - 0.0058d + 0.9679 \quad ..(2)$$

where is the treatment depth. The couch top transmission factor determined at a treatment depth of 13.5 cm was 0.928 and that at 1.5 cm was 0.960, representing a 3.45 % decrease in the transmission factor for treatment depth change of 1.5 cm to 13.5 cm.

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Table 1. Corrected mean Electrometer Readings with and without couch top in the path of the beam

Depth (cm)	Corrected mean Electrometer Reading (nC)		Transmission factor (T)
	Without couch top (R)	With couch top (R _c)	
13.5	2.03996	1.89293	0.928
11.5	2.31971	2.15125	0.927
9.5	2.6107	2.43611	0.933
7.5	2.92159	2.7373	0.937
5.5	3.2427	3.05075	0.941
3.5	3.54695	3.36828	0.95
1.5	3.80833	3.65416	0.96

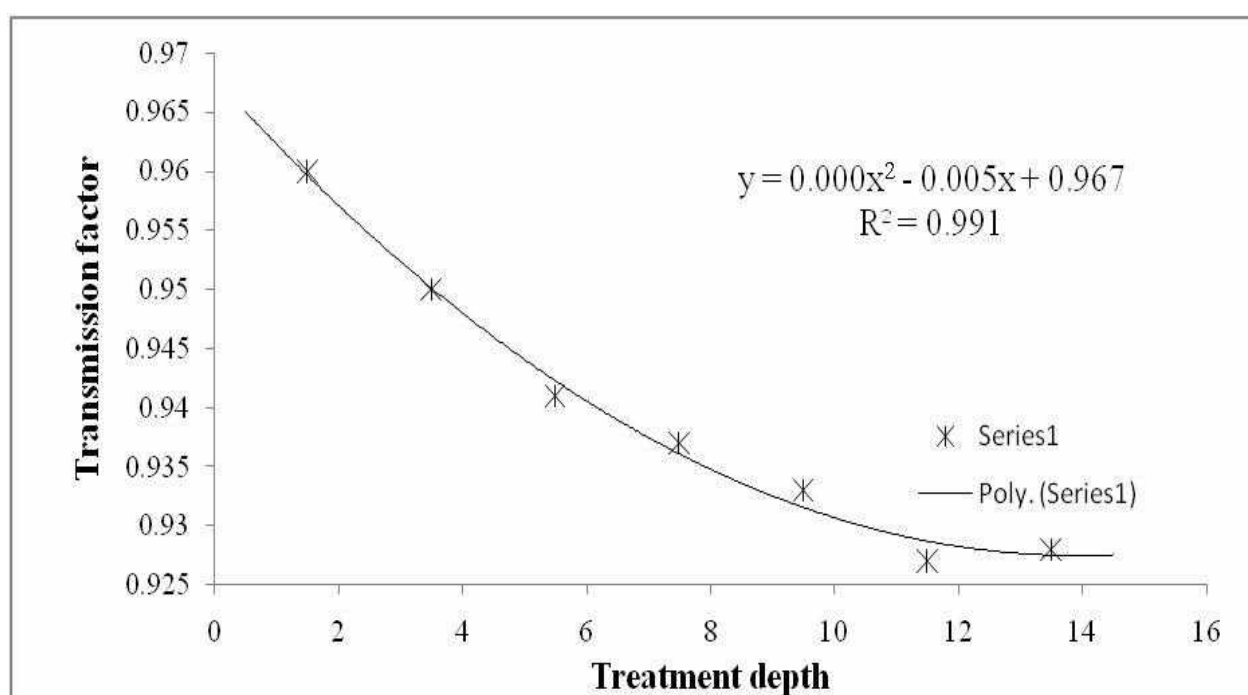


Fig 1 Couch Top Transmission Factors as a Function Treatment Depth

Discussion

The above trend exhibited by the curve of couch top transmission factor as a function of treatment depth may be attributed to the decrease in divergence of the beam with increasing treatment depth associated with the isocentric set-up. As beam divergence increases, the volume of the couch top material traversed by the radiation also increases resulting in a commensurate or corresponding increase in scattered radiation from the couch top to the effective point of measurement in the phantom, which adds up to the dose at the point. This phenomenon had also been envisaged with carbon fibre couch tops of linear accelerators, which were attributed to beam hardening and variation in beam divergence with treatment depth [23, 24]. But for a mono-energetic photon beam like cobalt-60, the sole contributing factor to the above is due to variation in beam divergence with treatment depth. The limited number of Perspex slab phantom did

not allow the number of the treatment depths systematically (non-randomly) selected for the study to be increased. The significant variation of the couch top transmission factor with treatment depth, calls for its inclusion in the treatment planning process [25]. For independent manual treatment time calculation involve the couch top, couch top transmission factors need to be determined for a wide range of treatment depths or equation (2) could be used to estimate the transmission.

A single treatment table top transmission factor (for radiation beam that transverse through the couch top) measured at a reference treatment depth (d_{max}) for manual radiation treatment time calculation irrespective of the various treatment depths 0.927

associated with target volume localization may not be valid for all radiation treatment depths for isocentric irradiation

technique. Also the effect of variation in field size on the transmission factor of the intended material for the fabrication of the couch top needs to be investigated, so that the cumulative effect on the transmission factors by the two treatment parameters determine for possible incorporation into the treatment time calculation or the dose calculation algorithm of the treatment planning system. Since the radiological properties of the intended material for the fabrication of the couch top was not comparable to that carbon fibre, and the material was not radio-translucence to cobalt 60 beam, surface dose analysis must be made prior to the use of the couch top for clinical treatment [26].

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