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A STUDY ON INVESTIGATING THE EFFECT OF DOSE DISTRIBUTION IN PINEWOOD SLAB AND CARBON COUCH USING HIGH ENERGY PHOTON MV BEAM

Radiology

Sarath S Nair* Lecturer, KMC Manipal, Research scholar NICHE.*Corresponding Author
Dr V N Meena Devi Associate professor, dept. of physics NICHE Kumara coil
Dr Krishna Sharan Professor, dept. of radiotherapy KMC, Manipal

ABSTRACT

The study aims on evaluation of the isodose depths, surface and attenuation doses for pinewood slab and carbon couch table. The present study aimed to evaluate the feasibility of using pinewood slab for developing an in- house breast board in our radiotherapy. The dose distribution such as, attenuation factor, PDD, gantry angle attenuation, surface dose and depth doses measurement was done using ionization chamber. The measurement was performed for 6MV,10MV and 15MV photon of Elekta versa HD linac. The attenuation factor for pinewood slab for larger field such as 15x15, 20x20 cm2 were too close to the couch attenuation factor. For both material maximum beam attenuation was seen in gantry angle 140^0 & 130^0 (for pinewood it is 40^0 &50^0) and in small field. The depth for max dose for pinewood also shows close result with couch. It was also noted that the surface dose was increased by 38- 45% when using both couch and pinewood.

KEYWORDS

Pinewood, Carbon-couch, Attenuation, Surface Dose, Immobilization Devices

INTRODUCTION

In radiotherapy the main goal is to deliver correct and optimal dose to tumor without exceeding normal tissue dose. Immobilization devices plays an inevitable role in modern radiation therapy era. It helps in reduce the setup errors such systematic and random errors during the course of treatment, by maintaining a fixed position of tumor throughout the session. In this revolutionary era new and better immobilization devices are being introduced and equipped. The main criteria for this all devices are they must be radiolucent and must be rigid, so that they should not affect the photon beam attenuation properties. For this purpose, most of the devices such as breast board, treatment couch etc. was made off with carbon fiber whose density is equal to 1.00gm/cm^3. Thus in all radiotherapy applications, Carbon fiber has become the common ideal material of choice, due to its lightweight, radio-translucent, low density and rigidity [8]. However, in developing and under developing country due to its expensive nature, carbon fiber based immobilization devices are not widely used. Moreover, carbon may produce image artefacts on MRI scanner due to it conducting properties. Several studies are done by many researchers related with its attenuation properties [1-7]. The results all shows that the application of carbon couch will significantly increases the surface dose as well as the depth dose with reduction in the build-up dose. So it is very necessary for each center to understand the dosimetric impact of couch and each immobilization devices with each energy they are using in their department [12]. In this article we are studying the attenuation properties of pinewood (pine radiate 0.48g/cm3), and ruling out whether pinewood can be a better choice in constructing an immobilization device especially for breast board or breast wedge. Wood is a natural resource that comes from trees, and has been used for centuries in a vast amount of different applications. Woods are mainly divided into Hardwood and Softwood. Pinewood is a light weight wood with a density ranges from 0.35- 0.85g/cm3 depending on the tree [10]. Its surface is uniform and straight, with a pale yellowish or white in color. It does not bend or twist easily. The purpose of the study was to evaluate effects of dose distribution using pinewood slab (pine radiate) and carbon couch in radiation therapy department KMC hospital Manipal using Elekta versa HD linac. The main objectives of the study included

1) To study the surface dose effect of both materials
2) To determine the depth dose
3) To determine the effect of gantry angle on beam attenuation
4) To evaluate transmission factors of pinewood and carbon couch

Material and methods:

In this study we evaluate the attenuation properties of pinewood slab and carbon couch for 6MV,10MV,15MV photon energies for 5,10,15, and 20 cm2 field size. A pinewood slab of 18 mm thickness cut into a length of 600 mm and the same width that of (520 mm) a carbon couch was used. The carbon couch of Elekta consists of two thin carbon fiber plates, of 2 mm thick, sandwiching 46 mm of low density carbon foam. At first Pine wood slabs with sp34 solid water phantom were scanned on a Philips Brilliance ct-16 machine with 3 mm slice thickness. The density of pinewood, SP34 phantom, was found with the help of Hounsfield unit (HU) measured from CT images on Monaco Treatment Planning Station by HU tool.

At first the attenuation factors for couch and pinewood were measured using sp34 water equivalent phantom and pinpoint detector at 5x5,10x10,15x15,20x20 cm^2.All measurement was done at SAD with isocentre at the chamber center for 6,10, and 15 MV photons with 100 MU. Prior to the measurement chambers were given a radiation bath to remove the residual charges from the measurement. For measuring the attenuation reading without couch a direct anterior posterior beam was used**.** The pinewood attenuation, was measured by placing the pinewood slab on the phantom surface and meter reading was noted from PTW unidose electrometer. Exposure was done with the same setup but at gantry 180° with couch for the couch attenuation**.**

Gantry angle also affect the amount of attenuation when couch was introduced in the beam path. The effect of gantry angle on 6MV,10MV,15MV photon beam attenuation was studied with a field size of 5x5 ,10×10 ,15x15, 20x20 cm^2. The measurements were performed with a pin point ionization chamber at a depth of 16 cm in an Octavius cylindrical phantom made of PMMA.The meter reading produced by the ion chamber was measured with a unidose Dosimeter. The phantom was aligned longitudinally on the treatment table and the isocenter was set to the center of the chamber. A reference value was measured with gantry angle 0°,45° & 90° for without couch and pinewood. The beam attenuations of carbon couch were measured every 10° at gantry angles starting between 90° and 180°. Couch rails rod, were not present in the beam path, during all measurement, the attenuation measurements were performed in the thicker part of the table couch only. The effect of gantry angle on Pinewood attenuation is measured by placing the pinewood on the top of Octavius phantom with gantry starting from 0° to 90°.

Fig 1: measurement setup for gantry angle attenuation

To evaluate the influence of the pinewood and couch on the surface dose and depth-doses, measurement was done for 6,10,15 MV photons and 10x10 cm2 and 20x20 cm2 field size in the build-up region and depth using a Markus parallel plate chamber and sp34 water-

equivalent phantom

Another problem which we have to face was the overresponse of the chamber in the build-up region due to the scattered electron from the chamber itself. To solve this, we can use the Gerbi's overresponse correction factor for the chamber[9].

$F(d, E) = P(d, E) - (0, E)\, Ie - \alpha(d/dmax)$

Measurements for surface dose was performed for pinewood with a direct anterior beam, while for couch it was done with a gantry angle of 180○ as shown in fig 2(a) & 2(b). The phantom was aligned such that the chamber surface was always facing the central axis of beam, All the measurements were performed at source to skin distance (SSD) 100 cm to the surface of the chamber (14). The dose at dmax of each photon energy was taken as the reference one

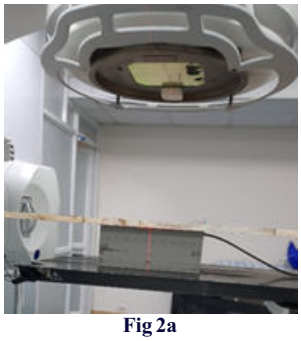

Fig 2a

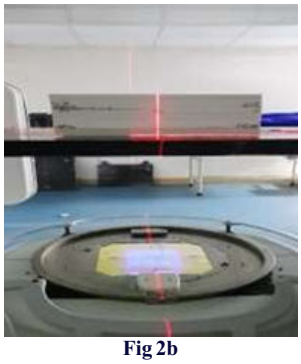

Fig 2b

Fig 2:surface measurement setup using pinewood and couch using parallel plate chamber and sp34 phantom

RESULTS:

The couch beam attenuation factor for 6MV,10MV,15MV range from 0.9703 to 0.9875, whereas for pinewood it was 0.9638 to 0. 9825.

MV	Couch attenuation factor				Pine wood attenuation factor			
	5x5	10x10	15x15	20x20	5x5	10x10	15x15	20x20
6	0.970	0.976	0.977	0.981	0.963	0.967	0.971	0.975
10	0.976	0.983	0.981	0.984	0.967	0.975	0.976	0.972
15	0.982	0.986	0.989	0.987	0.974	0.978	0.982	0.982

Fig 3: couch and pinewood slab beam attenuation factor for different energy with different field size

While measuring the surface dose using parallel plate chamber it was found that the value for the depth of maximum dose for both pinewood and carbon couch are coming close, mainly for 6 mv and 10x10 field size. It was found that the surface dose was increased by 38-45% when using couch and pinewood. The results also show that surface dose don't have too much deviation in both materials. Surface dose was increased when large field size was used. The results of surface dose measurement for 10x10 & 20x20 cm2 and fractional depth dose were shown in fig 4(a) & 4(b) below

Depth (mm)	Pinewood PDD			Couch PDD		
	6 mv	10 mv	15 mv	6 mv	10 mv	15 mv
0	92.7	85.0	79.0	92.0	83.1	76.0
2	95.9	88.9	82.7	95.2	86.9	79.8
4	98.7	93.5	87.9	98.3	92.1	85.8
6	99.8	96.3	91.9	99.6	95.6	90.4
8	**100**	98.1	94.8	**100**	97.7	93.6
10	99.6	99.2	96.8	99.8	99.0	96.0
12	99.3	99.8	98.2	99.2	99.7	97.6
14		100	99.2		99.9	98.8
15		**100**	99.5		**100**	99.1
16		99.9	99.8		99.9	99.5
18		99.6	**100**		99.7	99.8
20		99.2	100		99.3	**100**
22			99.9			99.8

Fig 4(a): comparing build-up region of couch and pinewood slab at 6,10, and 15 MV photon energy and 10x10 cm2 field size

Depth (mm)	Pinewood PDD			Couch PDD		
	6 mv	10 mv	15 mv	6 mv	10 mv	15 mv
0	97.0	92.6	88.5	97.1	91.3	86.0
2	98.8	94.7	90.7	98.8	93.7	88.8
4	99.6	97.2	94.0	99.8	96.4	92.5
6	**100**	98.7	96.3	**100**	98.3	95.3
8	99.7	99.6	98.0	99.8	99.3	97.2
10	99.2	99.9	99.0	99.4	99.7	98.5
12		**100**	99.6		**100**	99.3
14		99.7	99.8		99.8	99.7
15		99.5	**100**		99.7	99.9
16		99.3	99.9		99.5	**100**
18			99.9			99.8

Fig 4(b): comparing build-up region of couch and pinewood slab at 6,10, and 15 MV photon energy and 20x20 cm2 field size

With couch, beam also shows some dependence with gantry angulation. The dependence of gantry angle attenuation on different photon energy with different field size (5x5 cm2,10x10 cm2, 15x15 cm2, and 20x 20 cm2) for pinewood and carbon couch was given below in fig 5(a),5(b),5(c). For both materials large attenuation was observed on gantry angle 130○ and 140○ for small energy and with small field size. The reading was given in fractional dose, taking maximum dose as reference one

Gantry angle	Pinewood				Couch			
	5x5	10x10	15x15	20x20	5x5	10x10	15x15	20x20
90	1	1	1	1	1	1	1	1
100	1	1	1	1	1	1	1	1
110	1	1	1	1	1	1	1	0.997
120	1	1	1	1	0.996	1	0.997	0.997
130	0.938	0.943	0.946	0.947	0.967	0.964	0.969	0.972
140	0.950	0.954	0.957	0.958	0.966	0.966	0.968	0.969
150	0.950	0.952	0.957	0.956	0.973	0.972	0.974	0.975
160	0.968	0.967	0.969	0.970	1	0.996	0.993	1
170	0.946	0.949	0.955	0.957	0.979	0.974	0.976	0.980
180	0.945	0.956	0.962	0.960	0.967	0.974	0.979	0.976

Fig 5(a): Measured 6 MV beam attenuation of the couch and pinewood at different gantry angles with different field sizes

Gantry angle	Pinewood				Couch			
	5x5	10x10	15x15	20x20	5x5	10x10	15x15	20x20
90	1	1	1	1	1	1	1	1
100	1	1	1	1	1	1	1	1
110	1	1	1	0.997	1	1	1	1
120	1	1	1	1	1	1	0.980	1
130	0.951	0.952	0.959	0.957	0.975	0.974	0.985	0.985
140	0.963	0.963	0.965	0.966	0.977	0.974	0.990	0.992
150	0.961	0.964	0.963	0.967	0.979	0.978	0.984	0.987
160	0.969	0.971	0.976	0.976	0.996	0.996	1	1
170	0.961	0.962	0.963	0.964	0.982	0.980	0.984	0.976
180	0.961	0.965	0.963	0.964	0.978	0.984	0.984	0.985

fig 5(b): Measured 10 MV beam attenuation of the couch and pinewood at different gantry angles with different field sizes.

Gantry angle	Pinewood				Couch			
	5x5	10x10	15x15	20x20	5x5	10x10	15x15	20x20
90	1	1	1	1	1	1	1	1
100	1	1	1	0.998	1	1	1	1
110	1	1	0.998	1	1	1	1	1
120	0.997	0.994	1	1	1	1	1	1
130	0.955	0.955	0.959	0.962	0.978	0.985	0.983	0.983
140	0.964	0.967	0.968	0.971	0.975	0.982	0.982	0.985
150	0.962	0.968	0.969	0.970	0.977	0.986	0.989	0.985
160	0.970	0.973	0.977	0.977	0.986	1	1	1

170	0.960	0.963	0.968	0.968	0.976	0.987	0.988	0.985
180	0.960	0.966	0.976	0.974	0.976	0.984	0.985	0.988

Fig 5(c): Measured 15 MV beam attenuation of the couch and pinewood at different gantry angles with different field sizes.

DISCUSSION & CONCLUSION:

There will be always an attenuation when beam passing through the carbon couch, which was inevitable. Therefore, it is necessary to collect the beam attenuation data dosimetry for couch and each immobilizations devices which we are using in our radiotherapy. A study done by Taylan Tugrul states that the couch influence in 6mv photon may result in surface dose up to 70% and for 15mv it is up to 53%(16). This study focus on the feasibility of using pinewood slab for the construction of breast board in a low cost mode. The electron density of pinewood when compared with carbon fiber is less, but more when compared with the carbon foam. It is mainly the carbon foam whose density is nearly 0.04g/cm3 which present in the couch help in reduce the attenuation of the beam passing through it. Most of the breast boards, breast wedges, wing boards etc., presence of any carbon foam is less or nil and only have carbon fiber whose density is nearly 1.0g/cm3. The results in this study shows that the attenuation properties pinewood was matching with the carbon couch especially for large photon energy and large field size.If we analysis the attenuation factor for 10x10 cm2 to 20x20 cm2 we can see that for 6mv,10mv, and 15 mv it will range from 0.970 to 0.981,0.976 to 0.984,0.982 to 0.987 for pinewood slab and for couch it is 0.963 to 0.975,0.967 to 0.977,0.974 to 0.982 respectively. For larger field the values are coming similar for both materials.

The results show that the beam attenuation happens significantly at a gantry angle 130○-140○ with smaller photon energy and smaller field size for both materials. The study for the surface dose measurement for couch clearly shows that the dmax for all energies were shifted to the surface with a hype in surface dose.it is clearly seen that skin sparing effects of photon beams were compromised (15,17,18). The dmax for 6mv,10mv, and 15 mv shifted from 15mm to 8mm, 21mm to 15mm and 27mm to 20mm for 10 x10 cm2 and for 20 x 20 cm3 field size it is further shifted to 6mm,12mm and 15 mm respectively. In other way we can say that carbon couch and pinewood slab are acting as a bolus by shifting the dose distribution to the surface. This dosimetric effects must be considered during the planning and treatment aspects, otherwise it leads to miscalculation and mistreatment of patient. The fractional depth dose also shows similar results for both. Since the aim of study was just focused on the beam attenuation of pinewood slab and carbon couch, comparing with attenuation beam data of more immobilization devices will help to give us more relevant output. Moreover, here study is done on 18 mm thickness pinewood slab only.

As we know that attenuation also depend on depth, keep in mind that in this study all attenuation measurement was done at a particular point depth only. In this present study the beam attenuation properties of both pinewood and carbon couch was analyzed. The result clearly shows that the attenuation effects and depth dose distribution of both pinewood and couch were more or less similar. The beam attenuation, as we expected mainly depends on energy and the field size for both the materials.

By analyzing this result, we can come to this conclusion that pinewood can be consider as one of the material for making breast board in ca breast radiotherapy. It was always advisable that, to avoid any devices or couch in the radiation beam path during the course of planning, imaging, or treatment.

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