Quantification of skin dose increase and photon beam attenuation for a commercial couch top and breast board using dosimetric and Monte Carlo methods

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ABSTRACT

Background*:** To study attenuation and increased skin dose for the iBEAM Standard couchtop, and attenuation of the BreastSTEP board, for an Elekta Compact 6 MV accelerator. ***Materials and Methods*:** Couchtop attenuation were measured for the range of gantry angles 125°-180° and field sizes 5×5-20×8 cm^2. H&N extension and the BreastSTEP attenuations measured in an 8×8 cm2 field. The couchtop effect on percentage depth-dose (PDD) measured by an EFD diode for field sizes 5×5-20×20 cm^2 and compared with that produced by a Co-60 beam passing through a 'tennis-racket' couch insert. A Monte Carlo (MC) model of the couchtop produced to provide more superficial PDDs. (PDDs that are more superficial) ***Results: Maximum couchtop attenuation (7.6%) measured for the 135° gantry and 5×5 cm^2 field. Couch extension attenuation was 1.5% lower. Adding BreastSTEP increased attenuation by 2.4%. MC attenuation results agreed with measurements to within 0.2%. The couchtop removed the dose buildup effect almost completely and increased the PDD at 0.4 mm depth by 60.6%-74.6%. MC-calculated PDDs at the depth range of skin basal cell layer (0.1-0.4 mm) increased by 55.3%-63.2%. The couch insert in the Co-60 beam increased the dose at 0.4 mm depth by 18.1%. For the same dose prescription at 10 cm depth, the insert in the Co-60 beam produced a skin dose 49.7% lower than the couchtop at 6 MV. ***Conclusion:*** These results provide useful practical data on attenuation and skin dose increase applicable to many centres. The accelerator-couchtop combination creates a greater skin dose increase than a tennis-racket insert on a Co-60 unit.

Keywords: *Radiotherapy, couch top, beam attenuation, skin dose.*

INTRODUCTION

Many radiotherapy (RT) techniques use photon beams passing through patient support structures (treatment couch and/or patient immobilization devices). They include traditional treatment methods as well as modern ones (e.g., rotational and non-rotational intensity modulated radiation therapy). Couchtop and patient immobilization devices attenuate a beam passing through them. If this attenuation is ignored in treatment planning, it can result in target underdosage. Moreover, the passage of a megavoltage photon beam through patient support structures reduces the dose buildup effect, thereby diminishing skin sparing and compromising one of the main advantages of using megavoltage photon beams [(1)].

The couchtop must be rigid without producing imaging artifacts. It must also be as translucent as possible to the photon beams used on the treatment unit, i.e., create minimal beam attenuation and dose buildup. In the past few decades, compact foam sandwiched between carbon fibre layers has been used due to the rigidity and higher transmission it offers compared to other materials; however, beam attenuation is still considerable and must be quantified[2].

Similarly, the need for patient immobilization structures such as head rests, baseplates for thermoplastic meshes and other fixation devices, breast boards, knee and ankle supports, etc. is well established. Information on the attenuation effects of these devices is also necessary.

Determining the dosimetric influences of couch and immobilization devices on megavoltage beams has been studied at many centres, as it is necessary to characterize the effects of each combination of patient support structures and treatment unit photon beam energy [1]. The reported magnitude and trend of the effect has been shown to be non-universal. There are differences in the attenuation for normal incidence, as well as how it varies with field size and gantry angle (GA), including the angle at which it is maximal. For example, McCormak et al. measured a 2% attenuation by a *SinMed* couch at normal incidence at ^{0} MV that reached 9% at 110° GA [3]. Poppe *et al.* measured 2.7% and 6.4% 6 MV attenuations for the *RM8* couch and the couch-combiboard combination [4]. Njeh *et al.* measured 4.9% and 2.5% (5×5 cm^2) and 3.4% and 1.6 % (10×10 cm^2) 6 MV attenuations for the *Brainlab* couch and its head rest, respectively; the highest attenuation was observed at the 110° and 120° GAs [5]. Seppala *et al.* recorded the highest 6 MV attenuation at the 110° gantry angle with the field size of 10×10 cm^2 [2].

Some papers have reported the effect on surface dose and/or percentage depth dose (PDD) near the surface. Meydanci *et al.* reported that a carbon fibre couch (Reuther Medizin Technik, Mülheim- Kärlich, Germany) increased surface dose from 7.5% to 63% in small 6 MV fields; Moreover, fivefold and twofold attenuation increases were observed at 10×10 cm^2 and 40×40 cm^2 field sizes, respectively [6]. Ghasemi *et al.* quoted 16.56% and 5.27% increases in skin dose by a non-carbon-fibre baseplate at 6 MV and 15 MV, respectively [7]. Gul et al. measured a 29% increase in Co-60 beam attenuation and 6% increase in skin dose caused by a couch nylon mesh [8].

To the best of knowledge, no paper has been published on the *iBEAM Standard* couchtop (Medical Intelligence (Elekta), Schwab-muenchen, Germany) regarding such effects. After an extensive search of the literature, the only reported study we found was by Wieslander et al in a conference proceedings, which included beam attenuation but not the effects of the couchtop on skin dose or the buildup region [9]. There are many RT centres worldwide equipped with this couchtop as part of an *Elekta Compact* linear accelerator unit. Although within the acceptance range, the specified penetrative quality of the 6 MV beam of this accelerator is slightly less than that stated in the *British Journal of Radiology* Supplement 25; PDD of a 10×10 cm^2 field at 10 cm depth in water being 67.0% compared to 67.5% (with probable increased effects of patient support structures). Quantifying these effects is, therefore, considered necessary. The aforementioned points constitute the novel aspects of this work.

In this study, beam attenuation as a function of GA for the combination of this accelerator's 6 MV beam and the *iBEAM* couchtop was studied to provide the necessary information for use in treatment planning. Attenuation factors of this couchtop extension and a breast board were also measured. As for skin dose, instead of measuring dose at a specific depth to estimate skin dose in the presence of couchtop at a particular depth in tissue (as reported in some studies), we measured and also Monte Carlo (MC) simulated several depths in the buildup region to provide more data and insight regarding this effect. MC simulation was a particularly useful tool in this study as it provided PDD data at very shallow depths (<0.4 mm), relevant to the various depths of the skin basal cell layer (BCL) throughout the body, where measurement was not practicable. A secondary purpose of this work was to provide a direct comparison of doses to skin and subcutaneous tissue resulting from the combination of this carbon fibre couchtop and 6 MV accelerator with those from traditional treatments on a Co-60 unit (Theratron Phoenix, Best Theratronics, Canada) equipped with a 'tennis racket' couchtop insert (nylon mesh without a Mylar sheet). This aimed to provide a link and perspective with respect to experiences of skin effects observed historically.

MATERIALS AND METHODS

Overview

Attenuation factors of the *iBEAM Standard* couchtop, its contoured *Head & Neck extension* and the *BreastSTEP* boards from the same manufacturer (Elekta, Scwabmünchen, Germany) were measured in the 6 MV accelerator beam. Then, focusing on the couchtop itself, central-axis PDD curves in the buildup depths (starting from 0.4 mm) were measured for both the accelerator and Co-60 combinations. The geometry of the accelerator and iBEAM couchtop was MC simulated and the results of the experimental measurements were used for additional validation of the model. Then, the MC model was used to provide PDD data at all buildup depths including those less than 0.4 mm. The 6 MV and Co-60 PDDs for their respective couches were then compared directly in a clinically relevant scenario.

Unless otherwise stated, accelerator beams passing through the couchtop, the extension and the breast board were measured at180° GA. For measurements without the couchtop in the accelerator beam path, measurements were made at 0° GA for practical reasons. The small differences in accelerator output (including any effects on measurements arising from gantry sag) were measured in air at 0°, 125°, 135°, 150°, 165° and 180° GAs and applied in the calculations accordingly. The 180º GA was considered as reference and the other angles were corrected relative to that. All measurements in the Co-60 beam were at 0° GA, made possible by its removable couch insert.

Attenuation measurements

Figure 1 shows the experimental setup for couchtop attenuation measurements schematically. Impact of the couchtop on beam attenuation at 125°, 135°, 150°, 165° and 180° Gas was studied for 5×5 cm^2, 8×8 cm^2, 10×10 cm^2, 15×8 cm^2, and 20×8 cm^2 field sizes.

Measurements were made with a *Semiflex* ionisation chamber (connected to a *UNIDOS* electrometer) (PTW Freiburg, Germany) placed at the isocentre at the centre of a water-equivalent plastic, cylindrical phantom of 1.03 g/cm^3 density, 25 cm diameter and 12.5 cm length. Potential variations in temperature and pressure were monitored throughout but no corrections were found to be necessary. For comparison with MC simulations, in order to have a set of measurements without the large influence of attenuation in the phantom itself, couch attenuation measurements were repeated in air with the same ion chamber and a 6 MV Perspex buildup cap (PTW Freiburg, Germany) for 5×5 cm^2 and 10×10 cm^2 field sizes.

As the cross-section of the couchtop is tapered at the two sides (figure 1), the path through the couch does not always increase with increasing beam obliquity. In order to characterize this effect with an increasing trend as a function of path length through the couchtop, beam path length for every GA was measured accurately by using the *AutoCAD* software and then, by considering the density of the materials in the couchtop, air and phantom, a total water equivalent thickness (WET) for each GA was calculated.

The attenuation factors of the extension board, and the couchtop-breast board combination, were measured in an 8×8 cm^2 field. The extension board has a similar carbon fibre foam sandwich structure to the couchtop but has thinner layers of carbon fibre and foam. The breast board has a horizontal carbon fibre baseplate and a variable-angle inclined one, which together form a wedge shape. The horizontal one is contoured such that relevant vertical and tangential beams do not pass through any solid structures. For each of the four board angles (*A, B, C* and *D*) with the horizontal baseplate of the breast board, attenuation was measured in air for a representative field size (8×8 cm^2) such that the distance between the baseplate and dosimeter was at least 20 cm, to reduce any effects of electron contamination on the readings. The results were compared with the situation that the couch and breast board were not in the beam path, at the chamber position corresponding to board angle *A*, because at that level, the influence of backscattered electrons from the baseplate was at its lowest.

Measurements in buildup region

To determine the influence of the couch on the dose in the buildup region up to a very shallow depth, depth-doses were measured using an electron field diode (*EFD*; Scanditronix/IBA, Uppsala, Sweden). The EFD is a p-type silicon diode, the effective point of measurement of which is 0.4 mm below the surface of its entrance window. This depth of detector sensitive volume was the lowest among the dosimeters available to us.

Figure 2 schematically shows the measurement setup for studying the effect of the couch on PDD. Measurements were made with and without the couch in the beam path for 5×5 cm^2, 10×10 cm^2 and 20×20 cm^2 field sizes. The diode was embedded in a purpose-made Perspex slab with its entrance window at the surface and facing the beam. A 9 cm thickness of Perspex slabs made up the rest of the phantom. The slab containing the diode was then sequentially placed at different depths until the depth of maximum dose (d_{max}) was reached. A source-to-surface distance (SSD) of 100 cm was maintained throughout. At least three readings were taken at each depth. The readings were normalized to that at d_{max}.

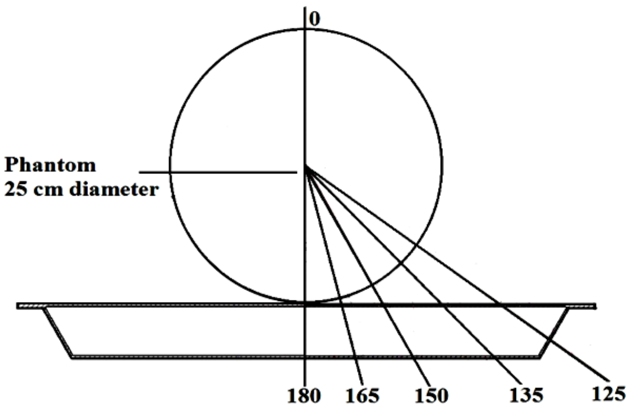

Figure 1. Schematic of the 6 MV beam attenuation measurement setup.

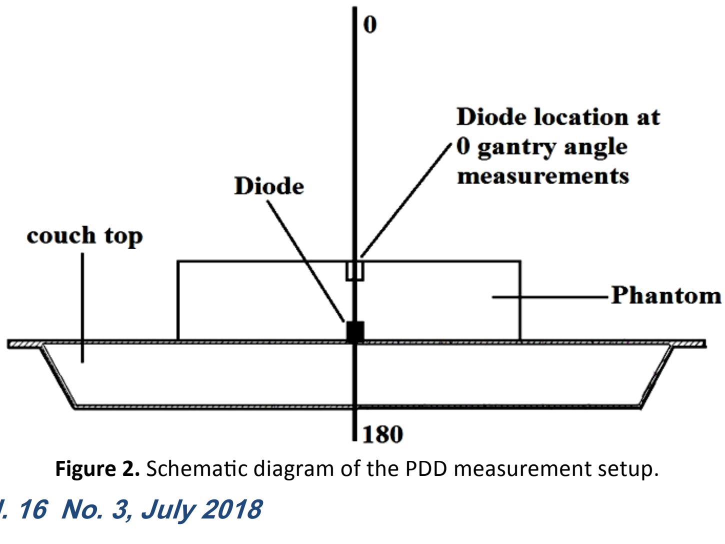

Figure 2. Schematic diagram of the PDD measurement setup.

PDD normalized at 10 cm depth

PDD curves of the 10×10 cm^2 fields of the accelerator and Co-60 units were compared directly by considering a typical patient treatment. The prescription (normalization) point was assumed to be at 10 cm depth in water. Each PDD was therefore normalized at 10 cm depth. Since the PDD curves for beams with and without a couch in the beam path only differ negligibly after d_{max}, we used our previously measured clinical beam data for the two machines for depths beyond d_{max} and merged them with our measured values in the buildup region.

Monte Carlo simulations

The iBEAM couchtop was simulated using the MCNP4c code based on the information supplied by the manufacturer on the densities and dimensions of the carbon fibre sheets and inner-core foam sandwiched between them [10]. The couchtop MC model was then added to a previously validated, detailed model of the treatment head of the Elekta Compact accelerator [11]. The simulated geometries for couchtop attenuation were two field sizes (5×5 cm^2 and 10×10 cm^2) at GAs 125°, 135°, 150°, 165° and 180°, for the in-air measurement setup with a Perspex buildup cap (density 1.18 g/cm^3). The number of simulated histories in each case was 2×10^9. For variance reduction, geometry splitting (as a method of population control) was applied [10].The cut-off energies used for electrons and photons were 0.512 MeV and 0.01 MeV, respectively. The results were compared with in-air measurements for further validation of the MC model. Then, MC-computed PDD distributions in Perspex were obtained for the beam passing through the confirmed model of the couchtop for field sizes 5×5 cm^2, 10×10 cm^2 and 20×20 cm^2 by simulating 7×10^9 histories in each case. Scoring regions of 0.1 mm thickness were used in the depth range 0.0-0.4 mm and 0.4 mm for further depths.

Statistical analysis

In all experimental measurements, three readings were taken for each measurement and the average and standard deviation values for each set of three measurements were calculated. In Monte Carlo simulations, sufficiently large numbers of photon and electron histories were followed such that the relative error *(R)* value (calculated by MCNP as SD/mean) for the result in each tally cell became ≤0.01. Calculated results with R <0.05 are deemed generally reliable for point detector data [10]. As with other studies of this type, no further statistical analysis was carried out.

RESULTS

Beam attenuation

The smallest GA output correction factor was required at 0˚ (0.999) and the highest at 125° (0.993).

The results of the couchtop 6 MV beam attenuation measurements in the cylindrical water-equivalent phantom are presented in figure 3. The percentage standard deviation (SD) among the readings for each set of measurements ranged from 0.0% to 0.1%. The highest attenuation (7.6%) was observed at 135° GA and 5×5 cm^2 field. There were typically 0.2% (maximum 0.4%) differences between the results obtained in air and phantom.

Figure 4 shows the trends of beam attenuation at different filed sizes as a function of the total WET (including the couchtop, cylindrical phantom, and air). The minimum WET for the path length was 13.98 cm (180º) and the maximum 14.44 cm (135°). WET then decreased to 14.32 cm at GA 125°.

The results of the attenuation simulations are compared with the measurements in figure 5. There were typically 0.2% (maximum 0.4%) differences between the measurements and simulations. The range of quoted R values for the MC results was 0.007-0.01 (well within the reliability threshold value of 0.05).

Attenuation of the couch extension was measured to be 2.7%. The total attenuation of the breast board-couchtop combination was 6.7% to 6.8%. The attenuation at the four board angles only differed by 0.05%. The percentage SD among the readings for each set of the above measurements ranged from 0.04% to 0.07%.

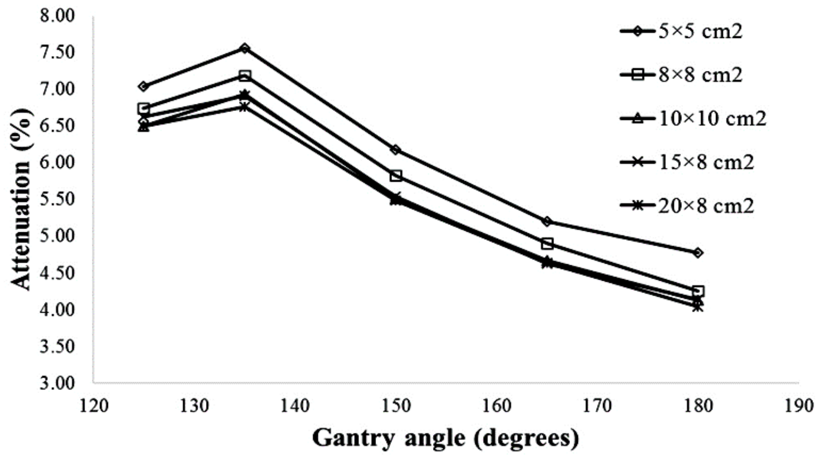

Figure 3. Measured 6 MV beam attenuation of the couchtop at different gantry angles and field sizes.

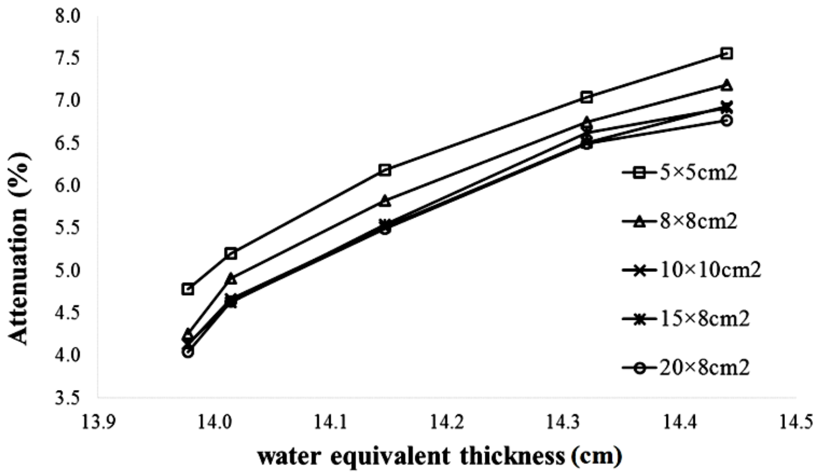

Figure 4 Couchtop attenuation for different field sizes as a function of total WET traversed along the 6 MV beam axis.

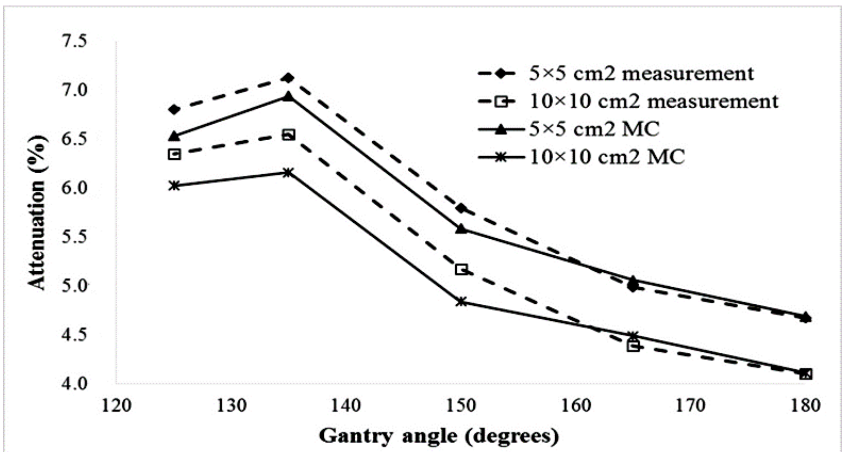

Figure 5. Comparison between couchtop 6 MV beam attenuation results of MC simulations and in-air measurements.

Percentage depth dose

Figure 6 shows the PDD curves in Perspex for the two treatment units for three field sizes with and without the couch in the beam path. The lowest depth of measurement was 0.4 mm. At that depth, we measured 24.6%, 29.7% and

39.4% doses without the couchtop at 5×5 cm², 10×10 cm² and 20×20 cm² fields, respectively. With the couchtop, those respective values increased to 99.2%, 99.4% and 100%. The maximum percentage SD for the readings at each measured depth was 0.08%.

Figure 7 compares the PDD curves in Perspex obtained by measurement and MC. The PDDs with and without couchtop were normalised at depths 0.4 mm and 13.4 mm, respectively. With the couchtop, differences between the measurement and simulation values were mostly within 1.5%. Without the couchtop,, at the PDD of 40% (typical of the high gradient region), there was 0.7 mm, 0.5 mm and 0.15 mm differences between the measured and simulated PDD curves, at field sizes of 5×5 cm², 10×10 cm² and 20×20 cm², respectively.

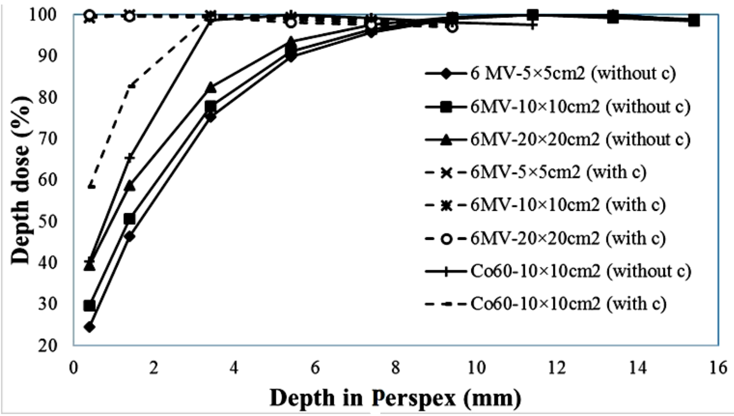

Figure 6. PDD curves in Perspex for the accelerator and Co-60 treatment units in three field sizes with and without the couch. (c = couch).

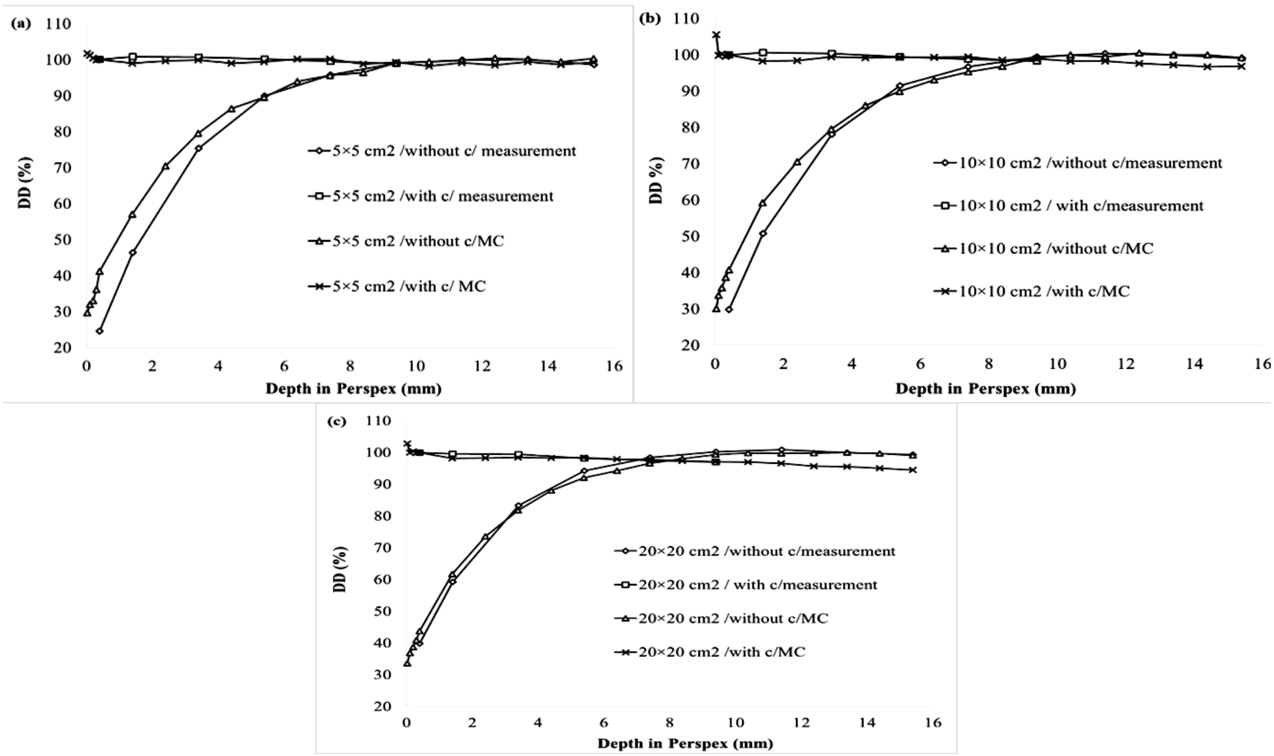

Figure 7. (a, b, c) Comparison between PDD distributions in Perspex obtained by measurement and MC simulation for three different field sizes. The PDDs with and without couchtop were normalised at depths 0.4 mm and 13.4 m, respectively. (c = couch).

Measured PDD curves with the couch for the accelerator and Co-60 units, normalized to the depth of 10 cm in water, are compared in figure 8. This comparison shows that 49.7% and 7.8% higher doses were measured in the case of the accelerator at depths of 0.4 mm and 1.7 mm (6 MV d_{max}), respectively. In contrast, at 4.0 mm depth (Co-60 d_{max}), the accelerator unit delivered a 23.4% lower dose. Also, the depth of d_{max} in the Co-60 unit decreased only slightly to 2.9 mm in water (from 5 mm), while in the accelerator unit, it decreased to 1.2 mm (from 13.5 mm).

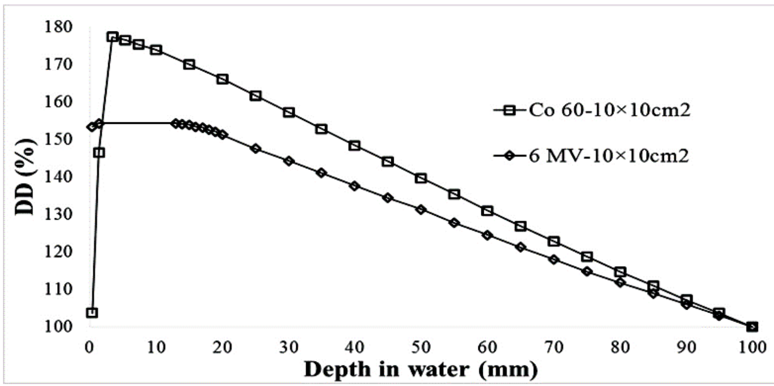

Figure 8. Relative depth-dose for a 10×10 cm2 beam passing through the couch when the same dose was prescribed at the 10 cm depth in water in both treatment units.

DISCUSSION

Beam attenuation data for the couchtop and breast board on the Compact accelerator are necessary for accurate treatment planning of patients. The detailed PDD data in the buildup region provides clinically relevant information for the various depths of the BCL at different body regions. The current study is the first paper on this combination of accelerator and couchtop (and accessories). The *iBEAM* couchtop was studied in terms of both attenuation and skin dose by both experimental and MC methods. A direct comparison of the depth-doses created by each of the accelerator and a historically well-established Co-60 equipment combination showed that higher doses are delivered to subcutaneous tissues in the Co-60 unit, but the reverse is true for the BCL. Data provided in this study can help decide on the maximum ‘safe’ beam weights for beams passing through the couchtop and extension and breast boards.

Measured couchtop attenuation for the accelerator unit was 4% to 7.6% for the range of GAs and beam sizes studied (figure 3). As expected due to the buildup factor effect in cone-beam attenuation, beam attenuation increased with field size. At 180°, we measured a 4.1% attenuation at 6 MV, which compares reasonably with the 3.3% attenuation at 8 MV quoted in the *iBEAM* user manual [12].

With all field sizes, maximum couchtop attenuation occurred at the 135° GA and minimum at 180°. At 125°, despite the greater beam obliquity, attenuation was less than 135°. As shown in figure 1, the central axis of the 125° beam passes through the oblique edge of the couchtop. We demonstrated the magnitude of this effect in terms of WET, where a reasonable trend of increasing attenuation was observed as a function of WET. Moreover, with fields of large transverse dimension and highly oblique incidence angles, some areas of the field do not pass through the couchtop at all, thereby increasing transmission. At 125° GA, this happens for any rays in the upper 0.6 cm and 3.3 cm along the transverse direction in symmetric 15 cm and 20 cm wide fields, respectively. The GA that creates maximum attenuation depends on the couchtop dimensions and shape and varies in different types [2-6].

The extension board beam attenuation was measured to be 1.5% lower than the couchtop itself. By placing the breast board on the couchtop, the attenuation increased by 2.4%-2.5%, its angles making negligible differences.

In-air attenuation measurements were up to 0.4% lower than the corresponding in-phantom ones. These small disagreements probably stem from differences in absorption and scatter, a detailed evaluation of which requires further investigation. In order to remove the confounding effects of the larger attenuation in the phantom compared to the couchtop (and any resulting uncertainties in modelling the phantom), we simulated attenuation in air with a buildup cap instead.

MC attenuation results agreed with the measurements to within 0.2% and showed the same trends, suggesting the suitability of the MC model for attenuation simulations regarding this couchtop and accelerator (figure 5).

Wieslander et al. studied the attenuation of a 6 MV photon beam of another accelerator by the *iBEAM* couchtop [9]. Our attenuation results agree with theirs to within 0.4%. Smith et al. reported 2.7% 6 MV attenuation by the *iBEAM evo* couchtop (from the same manufacturer) reaching 4.6% at 130°[13]. Their lower attenuation values compared to ours further suggests that the *iBEAM evo* is more radiotranslucent than the *iBEAM Standard* couchtop studied here. The *Connexion* couchtop (the manufacturer's next generation couchtop after *iBEAM evo*) has reportedly shown 2.4%-3.6% attenuation at 6 MV [14].

For PDD measurements in the buildup region, the EFD dosimeter was chosen mainly due to its superficial effective point of measurement. This set the minimum depth limit for our measurements. The depth of the BCL of skin typically varies in the range 0.05-0.4 mm depending on the anatomical region [1]. Therefore, our shallowest measurement depth (which we call '*measured* skin dose') refers to the greatest depth of the BCL.{Olch, 2014 #6;Olch, 2014 #6} Placing the couch in the beam path increases the skin dose 74.6%, 69.7% and 60.6% at 5×5 cm^2, 10×10 cm^2 and 20×20 cm^2 fields, respectively (figure 6).

Smith *et al.* measured a 17.9% surface dose without a couch at 6 MV and the *iBEAM evo* couchtop increased that to 91.8% [13]. In a study by Butson et al., the *Varian* carbon fibre and tennis string inserts increased the 6 MV BCL dose from 16% to 67% and 43%, respectively [15].

We, therefore, used MC simulation to investigate the relative dose received where the BCL is more superficial (figure 7). The simulation results showed that the couchtop increased the dose at 0.1-0.5 mm depths in water by about 55%-63%.

Both the measurement and MC results showed that the depth of d_{max} decreases greatly by placing the couchtop in the beam path. In fact, the buildup region PDD becomes so flat that quoting a d_{max} is clinically meaningless. In this sense, the couchtop acts as a bolus layer.

Comparing the dose buildup effect that occurs with this accelerator and couchtop combination to that of a Co-60 beam and 'tennis-racket' couch insert provided an informative link and perspective with respect to historical experiences of patients' skin effects. As shown in figure 8, the Co-60 unit produced a measured skin dose that was about 50% lower than that produced by the accelerator unit. Also, the depth of d_{max} in the Co-60 unit decreased only 2.1 mm in water, while in the accelerator unit, it decreased 12.3 mm. These results suggest that the higher attenuation of the carbon fibre couchtop relative to the tennis racket, negates the advantage of the higher mean energy of the 6 MV beam compared to Co-60.

It is well known that, when comparing single 6 MV and Co-60 beams of the same size for treatment of a deep target, PDDs of skin and almost all of the underlying tissues are greater with the Co-60 beam. This, of course, means that if we aim to deliver the same dose to a deep point, then the skin and almost all other depths along the central axis up to the prescription (normalization) point receive a higher dose with the Co-60 beam[16]. In this study, we tested the same situation for the two above-mentioned machines when the beams pass through their corresponding couches and quantified the differences for the case of a 10×10 cm^2 field and 10 cm deep prescription point. The trend was as expected, but at the range of depths relevant to the BCL, the reverse was true and the PDD for the accelerator combination was greater, the measured PDD at 0.4 mm depth being almost 50% higher. The increase is even greater nearer the surface.

One of the strengths of this study is its choice of dosimeter. In addition to its near-surface measurement depth, the choice of the EFD was due to its small volume averaging and low perturbation. The use of unshielded electron diodes in megavoltage photon beams can produce satisfactory results in selected situations [17]. They suffer less from the over-response problems stemming from electron scatter shown by shielded photon diodes[18, 19]. Some studies, (e.g., Refs .[4 , 2]), have used ionisation chambers to measure the effect of couchtops on skin dose. In the buildup region, ionisation chambers can cause non-negligible perturbation that requires correction [20]. Silicon diodes have much smaller sensitive volumes than air-filled chambers resulting in less volume averaging and, therefore, a higher measurement spatial resolution. This makes diodes satisfactory candidates for measurements in high dose gradients such as the buildup region. The use of an extrapolation chamber for this type of study is also of interest [21].

MC simulation was another beneficial tool used here. The model gave sufficiently accurate attenuation results to merit its use in the PDD part of the study. Nevertheless, further work may be needed to improve the model's consideration of low-energy photon and electron contaminations that deposit dose in superficial regions. It should, however, be re-emphasized that dose measurements at or near the surface are carried out in conditions lacking electronic equilibrium and are prone to inaccuracies themselves [10]. The least amount of agreement between our MC and measured PDDs at and near the surface was observed with the smallest field size, which may be due to the fact that non-equilibrium worsens in smaller field sizes [10]. This motivates the use of MC modelling for this type of investigation.

CONCLUSION

These results provide accurate quantitative data on the attenuation and skin dose increase of the couchtop, extension and breast boards when used on the *Compact* accelerator, which can be used in treatment planning calculations. The combination of the 6 MV beam and the *iBEAM* Standard couchtop creates a greater PDD increase in the BCL depth range than the traditionally used tennis racket couch on a Co-60 unit. It is, therefore, worthwhile to optimize dose distributions in patient treatment plans with the added consideration of keeping the contribution of any beam(s) passing through the couch sufficiently low to avoid unnecessary skin reactions.

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Conflicts of interest: *Declared none.*

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