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# Effect of Block Tray on Build-up Dose in γ-ray Radiotherapy

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THE objective of this study is focused on teletherapy unit to investigate the effect of Polymethyl Methacrylate blocking tray on the surface and build-up doses within 0.5 cm thickness for $^{60}$Co γ-ray beams with various fields. The percentage depth dose (PDD) in build-up region for blocking tray out and in the path of the beam was measured by a Markus chamber, which was irradiated by a $^{60}$Co beam. Irradiations were performed in virtual water phantom at various depths and fields.The polarity effect and the over-response correction factor were applied for Markus chamber.The PDD of 4.5×4.5 and 35×35 cm$^2$ fields found to be 16.70%±0.14% and 67.12%±0.25% at surface for blocking tray out, and 16.86%±0.29% and 72.47%± 0.59% for blocking tray in place, respectively. Therefore, blocking tray in place was higher than the dose for tray out, but the increase was dominant for large fields. This behavior is seen in all depths in build-up region with different ratios. The maximum variations of PDD for 5×5 cm$^2$,10×10 cm$^2$, 25×25 cm$^2$ and 35×35 cm$^2$ was found at surface and were in the order of 0.15%, 0.49%, 3.23% and 5.35%, respectively, this increased with increasing field and decreased with increasing depth .The dose in the build-up region increases with increased field for blocking tray out and in place. For blocking tray in place, the dose in the build-up region was higher than that for tray out. This effect can be due to the blocking tray eliminating secondary electrons and at same time generating new electrons as photon interacts with the tray material.

**Keywords:** Build-up doses; Markus chamber; PMMA blocking tray; Cobalt-60

## Introduction

Beam modifying devices have been utilized in radiotherapy in megavoltage γ-ray and x-ray beams for cancer patients worldwide. When γ-rays interact with these devices intervened in the path of the beam, electron are generated and deposits a higher dose in skin of patients.

It is known that those electrons contaminating the photon beam is the largest source to elevate the surface and build-up doses during radiotherapy treatment. These electrons were generated from the treatment head components such as collimator jaws and flattening filter and is affected by the treatment setup parameters such as field size, source to surface distance and beam modifier. Electron contamination was reported in previous publications [1]-[14].

Various skin reactions have been observed, when cancer patients undergo radiation therapy. These reactions were classified into; early effects such as erythema with different grades of skin desquamation and late effects such as hypoxia and telangiectasia. If the dose in subcutaneous tissue is very high, fibrosis can occur [9], [16], [24], [26].

Cobalt $^{60}$Co teletherapy machines are widely use in radiotherapy for cancer treatment worldwide especially in developing countries. Therefore, the purpose of this study was to investigate the influence of PMMA blocking tray on surface and build-up region during radiation treatment of cancer patients using those machines.

## Methods and Materials

*Markus ionization chamber*

Markus ionization chamber (Model TW 23343; PTW, Freiburg, Germany) was used in the study. This is a parallel plate ion chamber (PPIC) composed of a small guard ring that has 0.02 cm wide, 0.2 cm electrode separation, and 0.057 cm$^3$

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collecting volume.The electrode diameter has a 0.53 cm, 0.6 cm wall diameter and 0.035 cm the collector side wall with a density of 1.19 g/ $cm^3$[30], [ 31].

*Experimental setup*

A Markus PPIC was connected via low noise triaxial cable to a Farmer 2570/1 electrometer from NE Technology with applied bias voltage 300 V. It was embedded in 30×30 $cm^2$ slabs of Polymethyl Methacrylate (PMMA) phantom with a 1.137 relative electron density and was used to measure ionization charge on the central axis in the build-up region. Phantom material of varying thickness was taken from below the chamber and placed above the chamber to increase the depth of measurement. Therefore, it was kept at a fixed 80 cm source to surface distance for all measurements. A minimum of 18 cm of backscatter thicknesses were used to ensure full phantom scatter equilibrium. The measurements were carried out for a Theratron 780E $^{60}$Co beam, for various field sizes in range from 4.5×4.5 $cm^2$ up to 35×35 $cm^2$ and various depth from 0 cm to 0.4 cm. A 4.5×4.5 $cm^2$ is the smallest field opening for a Theratron 780E $^{60}$Co beam. In this study we classified filed sizes into small fields as those smaller than 10×10 $cm^2$ (4.5×4.5 $cm^2$, 5×5 $cm^2$, 6×6 $cm^2$, 7×7 $cm^2$, 8×8 $cm^2$ and 9×9 $cm^2$) and large fields as those larger or equal to 10×10 $cm^2$ (10×10 $cm^2$,15×15 $cm^2$, 20×20 $cm^2$, 25×25 $cm^2$, 30×30 $cm^2$ and 35×35 $cm^2$). A PMMA blocking tray of a 0.5 cm thickness was placed in the path of the beam to determine its influence on the surface and build-up dose. The tray is generally utilized during treatments to support Cerrobend blocks. Those blocks are generally placed to shape the radiation beam to conform to the treated target and thus help in sparing normal tissues during patient treatment.

The block tray is located at a 45 cm from the source. Beam time on was 1 min for each measurement. A total of six readings by electrometer for two bias voltages were recorded and averaged for each depth and field size configuration. The polarity effect correction factor was taken into account for Markus chamber measurements. The percentage depth doses were obtained by normalizing the dose at the measured depths to the dose at depth of maximum dose ($d_{max}$=0.4 cm). The polarity effect and over-response correction factors were applied for the Markus chamber [32], [33].

**Results**

*Measurements percentage depth dose in build-up region*

The percentage depth dose and the percentage depth dose differences curves for PMMA blocking tray out and in place of 5×5 $cm^2$, 10×10 $cm^2$, 25×25 $cm^2$ and 35×35 $cm^2$ field sizes, are indicated in **Figure 1.** As can be seen from **Figure 1** the percentage depth dose for PMMA tray in place was higher than that for tray out. The maximum variations of percentage depth dose seen at surface for 5×5 $cm^2$,10×10 $cm^2$, 25×25 $cm^2$ and 35×35 $cm^2$ were 0.15%, 0.49%, 3.23%, and 5.35%, respectively, and this decreased with increasing depth. The errors were determined from repeated measurements and represent the root mean square deviation in all measurements of about ± 0.2%. Percentage uncertainties in measurements in terms of standard deviation of the mean are shown on all graphs. **Figure 2** illustrates the percentage depth dose and the percentage depth dose differences in build-up region as a function of field size. The percentage depth dose differences are the dose measured with tray subtracted from the dose measured without tray in place of the beam. The percentage depth dose at the surface for 4.5×4.5 $cm^2$ and 35×35 $cm^2$ fields were found to be 16.70%±0.14% and 67.12%±0.26%, respectively, for tray out of the beam and 16.86%±0.29% and 72.47%±0.59% for tray in place, respectively. The percentage depth dose for tray in place was higher than that for tray out, but the increase was dominant for large fields. The maximum variation of percentage depth dose is clearly seen from 15×15 up to 35×35 $cm^2$ fields and this increased with increasing fields and decreased with increasing depth.

**Discussion**

Any materials in the path of the beam can produce electrons and at the same time can absorb electrons that could be generated when photons interact with any of the components of the machine head. Some materials generate electrons more than that absorbed. When a blocking tray is irradiated by gamma-ray, the interaction between photons and the tray material will generate a huge number of electron contaminations. The amount generated will be dependent on the material type and the thickness of the tray. When the blocking tray is thick enough, low energy electron contaminations will be also absorbed in the tray material. In the case of PMMA tray with its low-Z number and 0.5 cm thickness, more electrons are generated compared to that absorbed. This cause increase in the dose at the surface and build-up region more pronounced with large field sizes.

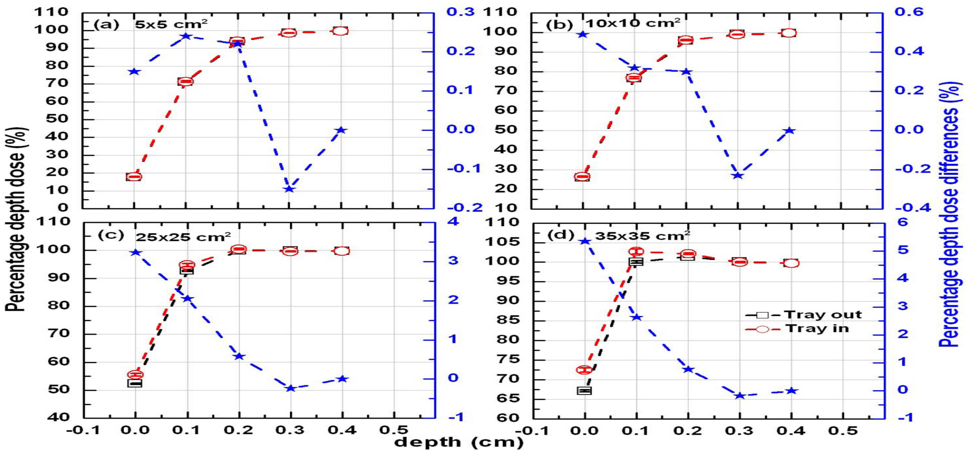


**Fig. 1. Percentage depth dose for tray out and in place for (a) 5×5 cm², (b) 10×10 cm², (c) 25×25 cm²and (d) 35×35 cm² fields.**

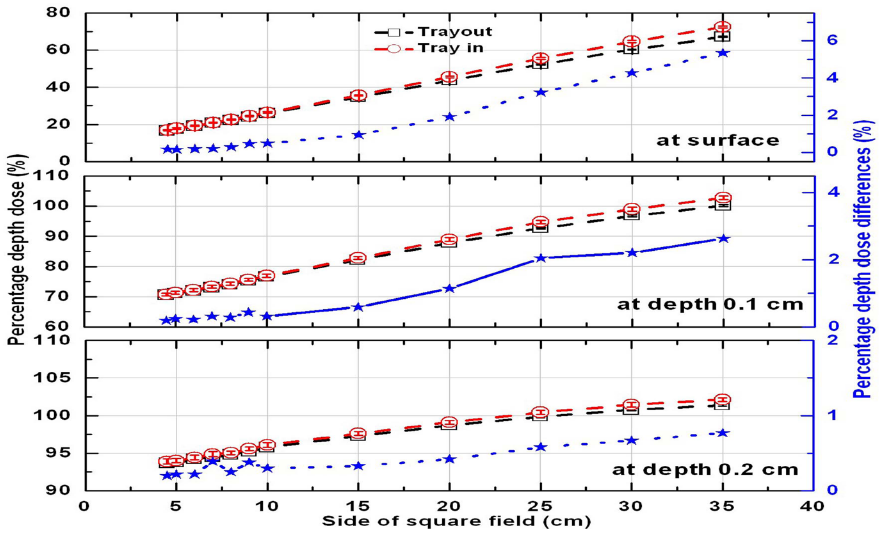


**Fig. 2. The variation of percentage depth dose in build-up region as a function of depth.**

When a 0.5 cm PMMA tray was introduced into the beam, the surface and build-up doses were increased. These data were plotted in **Fig. 3** as a ratio of the percentage depth dose with tray in place to the percentage depth dose with tray out versus depth for 4.5×4.5 cm² up to35×35 cm² field sizes. This ratio indicates that, in the presence of the tray, dose can increase by a factor of about 1.01 up to 1.08 at the surface and 1.00 up to 1.03 at 0.1 cm beyond the surface, respectively**.** This ratio was highest with large field sizes at the surface and decreased with increasing depth.

Several authors [14]-[28] studied the effect of blocking tray on surface and build-up doses by different materials and thicknesses of blocking tray using various dosimeters and energies. Our measured results agree with data published in the literature in Table1. Their results found that the percentage depth dose at the surface in the presence of the tray were higher than that with the tray out (see Table 1) with larger difference seen at larger field sizes. The is caused by the increase in the electron contamination emitted from the blocking tray as the field size increases.

Build-up regions are not only dependent on the energy, but also varies between different machines. Thus, the specific characteristics for each clinical teletherapy unit and blocking tray system must be independently verified [7].

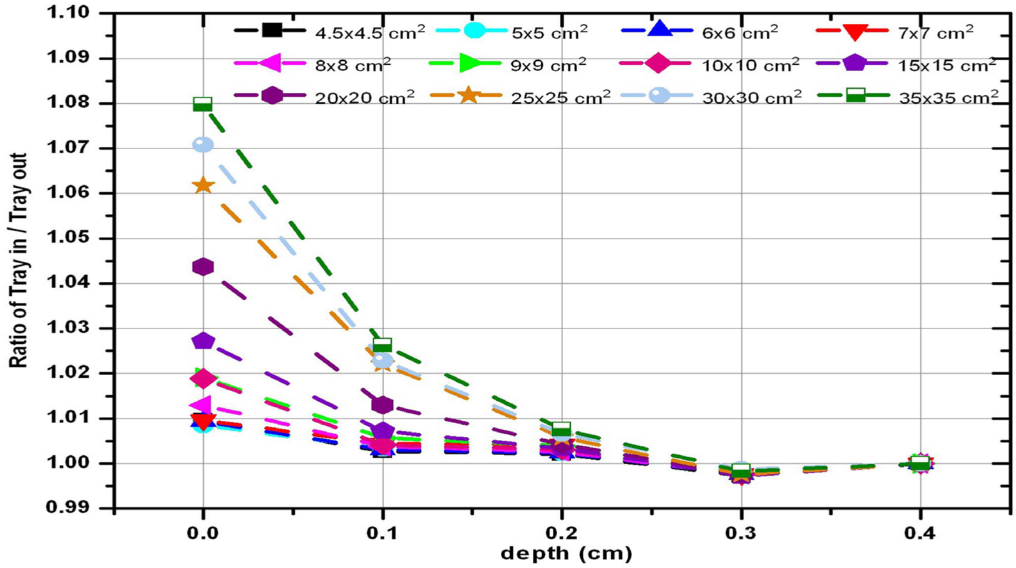


**Fig.3. The ratio of Tray in/ Tray out curves as a function of depth for 4.5×4.5 up to 35×35 cm² fields.**

**TABLE 1: The comparing results of percentage dose at surface phantom for present and previous studied.**

| Authors | Energy of Machines | dosimetry | Source to tray distance | Blocking tray | Field size | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 5×5 cm² | | 10×10 cm² | | 20×20 cm² | |
| | | | | | open | tray | open | tray | open | tray |
| *This study* | Theratron-780E $^{60}Co$ | Markus chamber[a] | 45 cm | 0.5 cm PMMA | 17.67 | 17.82 | 25.95 | 26.44 | 43.68 | 45.59 |
| *Tannous et al.* [14] | Therac 6 MV | Extrapolation chamber | 70 cm | 0.5 cm Lucite | | | 13 | 16 | | |
| *Velkely et al.* [16] | Theratron-80 $^{60}Co$ | Extrapolation chamber | | 0.6 cm Lucite | | | 18 | 22.5 | | |
| *Nilsson and Montelius*[18] | $^{60}Co$ | Extrapolation chamber | | 0.5 cm Perspex | | | 16 | 35 | 25 | 61 |
| *Purdy* [19] | Clinac 6/100 6 MV | Capintec chamber | 57.8 cm | 0.6 cm polycarbonate | 8 | 8.4 | | | | |
| *Kim et al.* [20] | Clinac2100C 8 and 18 MV | Markus chamber | | 0.55 cm acrylic | 6<br>5 | 7<br>5 | | | | |
| *Fiorino et al.* [21] | Clinac 6/100 6 MV | Markus chamber[b] | | | 9.2 | 9.7 | 14.6 | 15.7 | | |
| *Korn et al.* [22] | Clinac2100C 6 MV | TLD extrapolation | | 0.6 cm Perspex | 10.0 | 10.7 | 16.3 | 17.7 | 26.9 | 34.2 |
| | | Normal TLD | | | 32.3 | 32.1 | 38.9 | 40.6 | 49.9 | 56.6 |
| | | Thin TLD | | | 21.4 | 22.1 | 28.4 | 30.7 | 40.8 | 47.4 |
| | | Extra thin TLD | | | 14.2 | 14.9 | 20.8 | 23.0 | 32.4 | 41.8 |
| | | Black TLD | | | 11.6 | 11.6 | 19.3 | 21.9 | 29.9 | 36.8 |
| | | Markus chamber | | | 19,4 | 20.5 | 25.4 | 27.8 | 36.6 | 43.4 |
| | | Markus chamber[a] | | | 8.7 | 9.7 | 14.7 | 17.1 | 25.9 | 32.7 |
| *Nadir et al.* [23] | Mevatron-MD2 6 MV | Markus chamber | 56.5 cm | 0.6 cm acrylic | | | 13 | 14.2 | | |
| *Yu et al.* [24] | Clinac2100C 6 and 18 MV | Attix chamber | | 0.6 cm Perspex | | | 16<br>13 | 20<br>18 | | |
| *Yadav et al.* [27] | Elekta precise 15 MV | Markus chamber[a] | 64.7 cm | 1 cm acrylic | | | 11.71 | 14.01 | | |

[a]using; Rawlinson formula and [b]Gerbi and Khan formula Polymethyl Methacrylate calls Perspex or acrylic or Lucite

## Conclusions

In general, the surface and build-up doses increase with increasing field sizes. The effects of the blocking tray on the surface and build-up doses were quite significant and increased with increasing field size, due to the influence of electron contamination produced by the PMMA blocking tray.

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**تأثير صينية البلوك علي جرعة منطقة النمو في العلاج الإشعاعي بأشعة جاما**

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الهدف من هذه الدراسة هو التركز على وحدة المعالجة بالكوبالت للبحث في تأثير لوح من بولي مثيل ميثااكرلك على جرعات السطح ومنطقة النمو بسمك ٠,٥ سم وذلك بأخذ أحجام مختلفة للحقول العلاجية التي يتم تشعيعها بأشعة جاما المنبعثة من جهاز الكوبالت ٦٠ . تم قياس جرعة العمق المئوية (PDD) في منطقة النمو في حالتين هما وجود و عدم وجود لوح بولي مثيل ميثااكرلك في مسار الأشعة العلاجية بواسطة غرفة التأين ذات اللوحين المتوازيين ألمسماه ب ماركوس، والتي تم تشعيعها بواسطة أشعة الكوبالت ٦٠. وأجريت عمليات التشعيع في فانتوم المياه الافتراضية على أعماق و حقول علاجية متنوعة. تم تطبيق تأثير القطبية وعامل التصحيح المفرط للاستجابة لغرفة ماركوس. أظهرت النتائج أن جرعة العمق المئوية (PDD) للحقول العلاجية ٤,٥×٤,٥ و٣٥×٣٥ سم$^{٢}$ هي ١٦,٧٠٪±٠,١٤٪ و٦٧,١٢٪±٠,٢٥٪ على سطح الفانتوم في حالة عدم وجود لوح البولي مثيل ميثااكرلك، و ١٦,٨٦٪±٠,٢٩٪ و٧٢,٤٧٪±٠,٥٩ في حالة وجوده، على التوالي. وعليه، كانت الجرعة السطحية المئوية في وجود لوح بولي مثيل ميثااكرلك أعلى منها عند عدم وجوده، لكن الزيادة كانت سائدة في الحقول العلاجية الكبيرة. و يظهر هذا السلوك في جميع الأعماق في منطقة النمو بنسب مختلفة. حيث وجد أن الاختلافات القصوى لجرعة العمق المئوية لـ ٥×٥ سم$^{٢}$ ,١٠×١٠سم$^{٢}$، ٢٥×٢٥سم$^{٢}$ و٣٥×٣٥سم$^{٢}$ على السطح كانت في حدود ٠,١٥٪، ٠,٤٩٪، ٣,٢٣٪ و٥,٣٥٪، على التوالي، وبناءاً عليه فان الجرعة السطحية المئوية تزيد مع زيادة المجال وتقل مع زيادة العمق. أثبتت النتائج أن الجرعة في منطقة النمو تزداد مع زيادة حجم الحقل في حالة وجود اللوح أو عدم وجوده. غير انه في حالة وجود اللوح، كانت الجرعة في المنطقة النمو أعلى منها في حالة عدم وجوده. نستطيع القول ان هذا التأثير ناتجًا عن قيام اللوح بإزالة الإلكترونات الثانوية وفي نفس الوقت توليد إلكترونات جديدة حيث يتفاعل الفوتون مع مادة اللوح.