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Variations in ^{60}Co γ-ray Radiotherapy Surface Dose with Physical Wedge

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THE purpose of this study was focused on examining the influence of various physical wedge filters on the surface dose with various field sizes for ^{60}Co γ-ray beam, which have been used to treat a variety of cancer worldwide, especially in developing countries. The percentage depth dose in build-up region for open and physical wedged beams were measured by a Markus chamber, which was irradiated by a ^{60}Co beam. Irradiations were performed in a virtual water phantom at various depths for field sizes range from 4.5×4.5 up to 15×15 cm^2. The polarity effect and the over-response correction factor were applied for Markus chamber. For open and wedge beams angles 15°,30° ,45° , and 60°, the percentage surface dose found to be 25.95%±0.17%, 24.59 % ± 0.06 %,24.08%±0.01% ,23.71%±0.05% , and 24.45%±0.11%, respectively, at 10×10 cm^2 field size. So, their variations at same field were 1.36%,,2.24% 1.87% and 1.5% , respectively. The percentage surface dose decreased as the wedge angle increased for all field sizes. The percentage uncertainty for all data is 0.16%. The increase in the percentage dose at surface and build-up region with various field sizes for both open and wedged beams was due to electron contamination from the head of the treatment machine and air. However, a significant effect is seen for physical wedged beams, due to physical wedge eliminates secondary electrons at the same time generates new electrons.

Keywords: Surface and Build-up doses; Markus chamber; Physical wedge; Cobalt-60.

Introduction

Wedge filter is one of the most generally utilized beam modifying devices in conventional radiotherapy. It is used to optimize the tumor dose distributions for some of the patients. Most medical machines of megavoltage γ-ray and x-ray beams are provided with a selection of physical wedges made of metallic material that is mounted externally on treatment head of the machine. Four physical wedge degrees were designed and constructed by the vender for 15°, 30°, 45°, and 60° nominal wedge angle.

The dose at surface and build-up region may change when any material is intervened between a radiation source and the patient or phantom. The effect will depend on the material Z-number and thickness [1]. The physical wedge can produce and eliminate electrons contamination with different ratios depending on their physical characteristics. It should be known that sources of elections contamination [2-8] that contribute to the surface dose includes all components of the treatment head in addition to the beam modifying devices such as wedge filters, compensators, Multi-leaf collimators. This study will focus on one of those beam modifying devices which is the wedge filter.

Surface dose measurement is one of the most challenging issues for clinical dosimetry in radiotherapy, accordingly, accurate knowledge of surface and build-up doses is very important, so, the objective of this study was focused on investigating the effect of physical wedges on the surface and build-up doses with various field sizes for megavoltage γ-ray beams (^{60}Co), Cobalt machines have been utilized effectively for more than six decades for treating a variety of cancers worldwide, especially in developing counties.

Methods and Materials

Markus ionization chamber

Markus is a parallel plate ionization chamber (Model TW 23343). It is composed of a small guard ring that has 0.2 mm width, 2 mm electrode separation, and 0.057 cm^3 collecting volume. The

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ion collector is graphite-coated acrylic with a 5.3 mm diameter with an additional 0.35 mm thickness sidewall with a density of 1.19 g/cm^3 and with 6 mm wall diameter [9], [10].

Measurements setup

Markus chamber 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 Perspex phantom. The measurements were performed using a Theratron 780E ^{60}Co beam with field sizes of 4.5×4.5 up to 15×15 cm^2 at a fixed 80 cm source to surface distance and at different depths ranging from the surface to 0.5 cm depth for open and wedged beams with nominal wedge angles of 15°,30° ,45° and 60°. The physical wedge filters were mounted externally on the treatment head of the machine at a distance of 45 cm from the source. The wedge filter for the 15° wedge angle is made of brass and the others are made of lead. The largest possible field width with wedged beams is 15 cm ×20 cm for wedge angles (15°,30°) and 45°), and 10 cm ×15 cm for wedge angle 60°. Phantom material of varying thickness was taken from below the chamber and placed above the chamber to increase the depth of measurement. A minimum of 18 cm of backscatter thicknesses was used to ensure full phantom scatter equilibrium. 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[11], [12].

Results

Percentage depth dose for open fields

Results of the dose measurements in the build-up region for the open field are presented in **Fig. 1** for 4.5×4.5 cm^2 up to 15×15 cm^2 field size at 80 cm source to surface distance. Percentage uncertainties in measurements in terms of the standard deviation of the mean are shown on all graphs in this study. For large field sizes, the percentage depth dose was higher than that for small fields, especially at surface, as can be seen in **Fig. 1.** The higher dose for large fields can be explained by the fact that as the field size increases, there will be also an increase in the amount of electron contamination generated by the photon interactions with the machine head components as well as with the air existing between the head of the machine and the patient. This increase in dose in the build-up region with increasing field size was also reported in previous studies [1],[13-16] .

Percentage depth dose for wedge field

For wedge filters, the percentage dose in build-up region over a range of field sizes ranging from 4.5×4.5 cm^2 to 15×15 cm^2, are illustrated in **Fig. 2.** The percentage depth dose for large field sizes was higher than that for small fields. For wedge 60°, the maximum field size was 10×10 cm^2. The dose in build-up region increased with increasing field size. The results of percentage depth dose for both wedge angles 15° and 60° showed a shift in the d_{max} to 0.5 cm depth instead of 0.4 cm.

Surface dose measurements

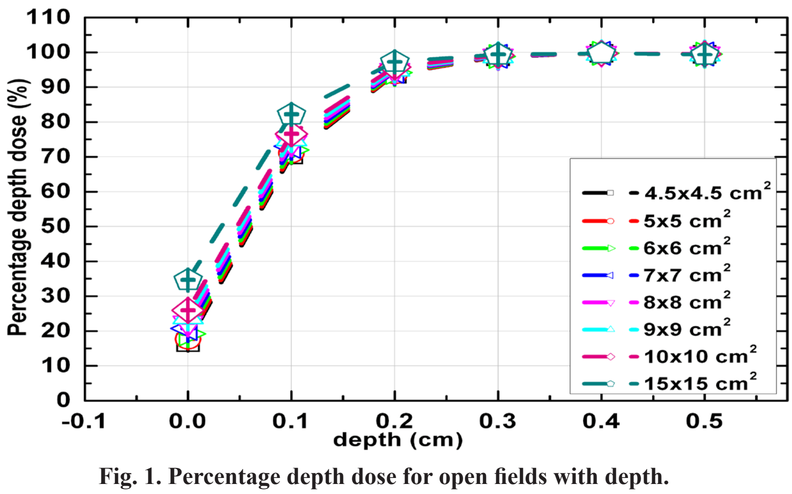

Fig. 1. Percentage depth dose for open fields with depth.

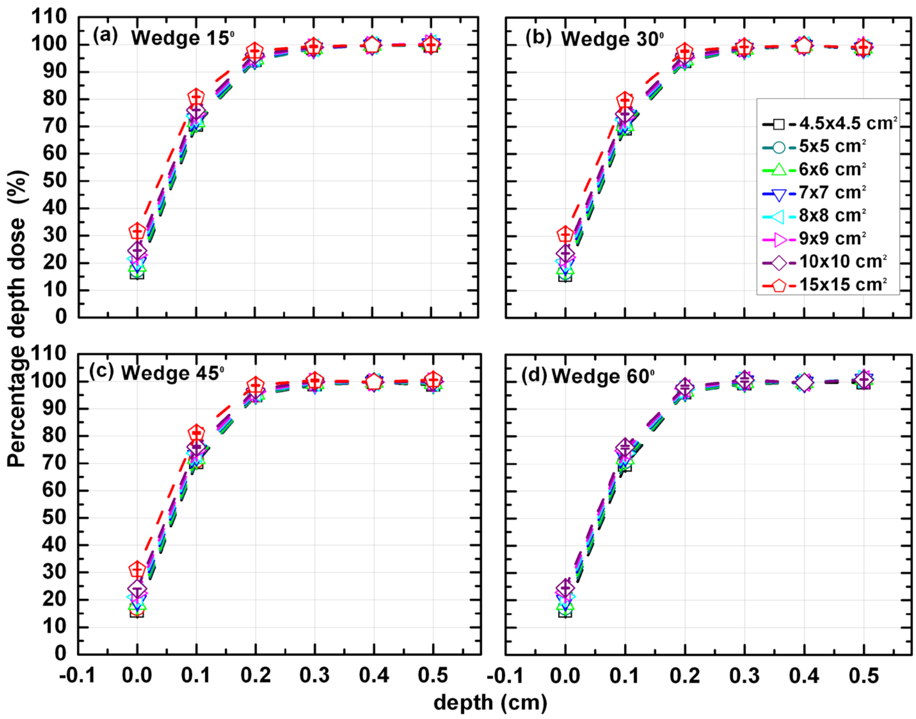

Fig. 2. Percentage depth dose for wedge angles (a) 15°, (b) 30°, (c) 45°, and (d) 60° with depth.

Figure 3 shows the percentage surface dose with open (angle zero) and wedge angles for different field sizes. It can be seen that the percentage surface dose was slightly higher with the open field as compared to that with wedge filters for all field sizes. As the wedge angle increase, the surface dose decreases until reaching 30° wedge angle, after this angle the surface dose increases slightly as the wedge angle increases.

The percentage surface dose curves as a function of field size are presented in **Fig. 4**. The percentage surface dose increased almost linearly with field size (~2.97%/cm), (~2.87%/cm), (~2.76%/cm), (~2.80%/cm), and (~2.94%/cm) for open, wedge 15°, wedge 30°, wedge 45°and wedge 60°, respectively. The largest difference in the plots of the surface dose with respect to the used wedge angle is seen at the largest measured field size. It should be noted from **Fig.4** that surface dose was highest with the open field and lowest with the wedge 30° as most obviously seen with the largest field size.

Discussion

The measured dose with the wedge and that without the wedge was subtracted and the percentage difference was calculated for the different measured depths in the build-up region. Then results were plotted in **Fig. 5** for the different used field sizes for each of the wedges. The effect seen in the **Fig.** will be dependent on the process of elimination of electron contamination and the process of production of electrons by the photons interacting with the wedge as they traverse its material during patient or phantom irradiation. If these differences are positive, then this could mean that the electron contamination eliminated is larger than the electrons generated within the wedge filter. It is clear from the figures that this effect is dependent on field size and wedge angles. The largest percentage difference was seen at the phantom surface indicating the predominance of the electron contamination elimination process. The percentage difference then decreases to zero difference at 0.1cm depth. If these differences are negative, then this could mean that the electron contamination eliminated is less than the electrons generated within the wedge filter. Plots in **Fig. 5** indicated that larger percentage differences appear in the first 0.2 cm depth. Beyond this 0.2 cm depth, the differences were small. At last, as can be deduced from **Fig. 5,** the number of electrons eliminated by the wedge is higher than the number of electrons produced in the wedge. According to that, it may be concluded that a significant effect is seen for the physical wedge on the surface dose region.

The surface dose was the subject of many research work [18-22]. Because the physical wedge, which is a medium atomic number absorber, can reduce the secondary electron scattering in the forward direction, it can reduce the surface dose. Zhu and Palta calculated the electron contamination in 8 and18 MV photon beams. Due to the attenuation of contaminating electrons from the treatment head by the external wedge, the electron contamination dose for an open field is higher than that for wedged field [6]. Many other investigations utilizing various energies also agreed with this conclusion and stated that the surface dose values for wedged fields were lower than that for an open field. [18-22]. However, it should be mentioned that Ochran et al. investigated a unique wedge configuration, where the wedge position was relocated beyond the blocking tray. They studied the possible increase in the surface dose due to the proximity of the wedge to the skin surface with their new design and they found that the surface dose for an open field is lower than that for wedged field [17].

Conclusion

The increase in the percentage dose at

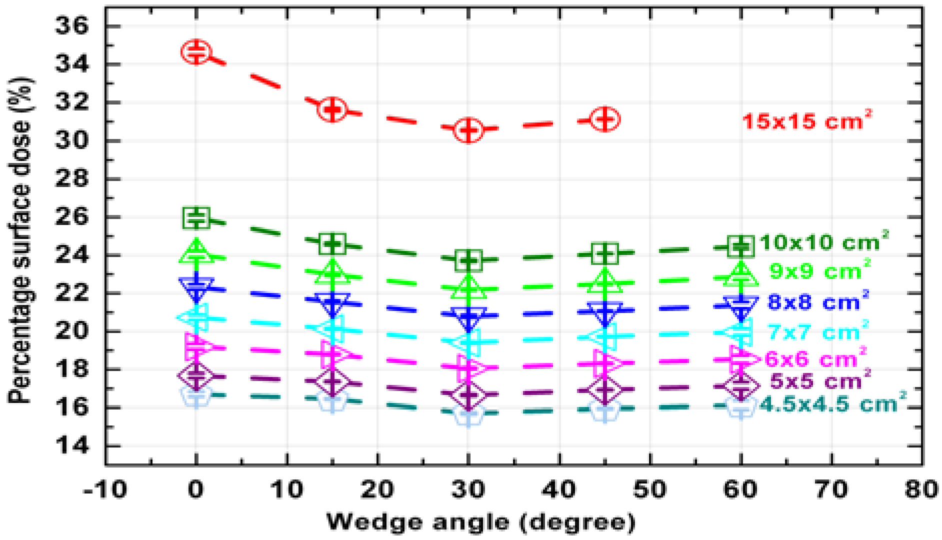

Fig. 3. Percentage surface dose curves as a function of wedge angles for field sizes.

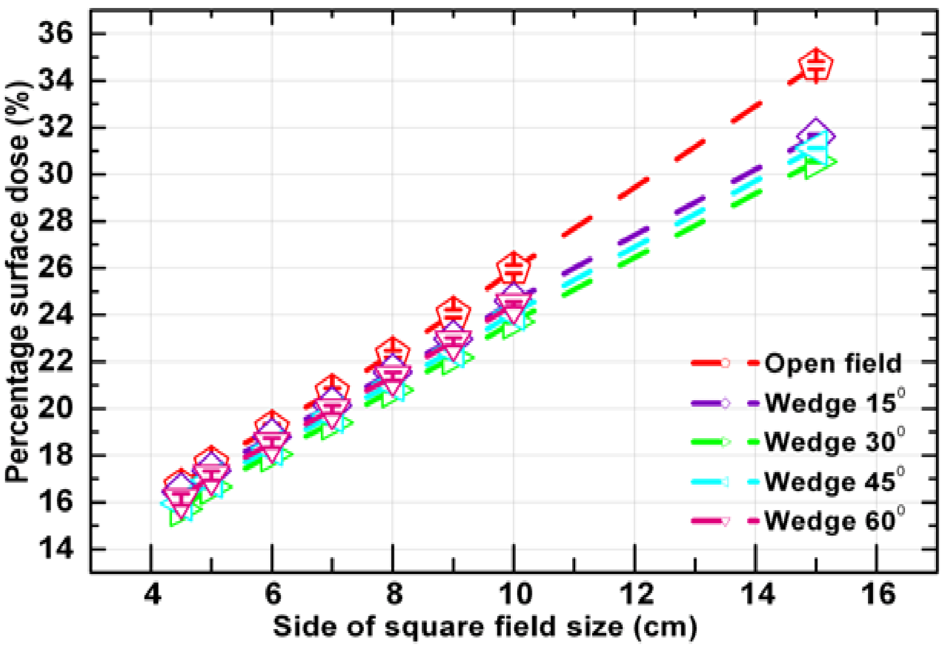

Fig. 4. Percentage surface dose as a function of field sizes.

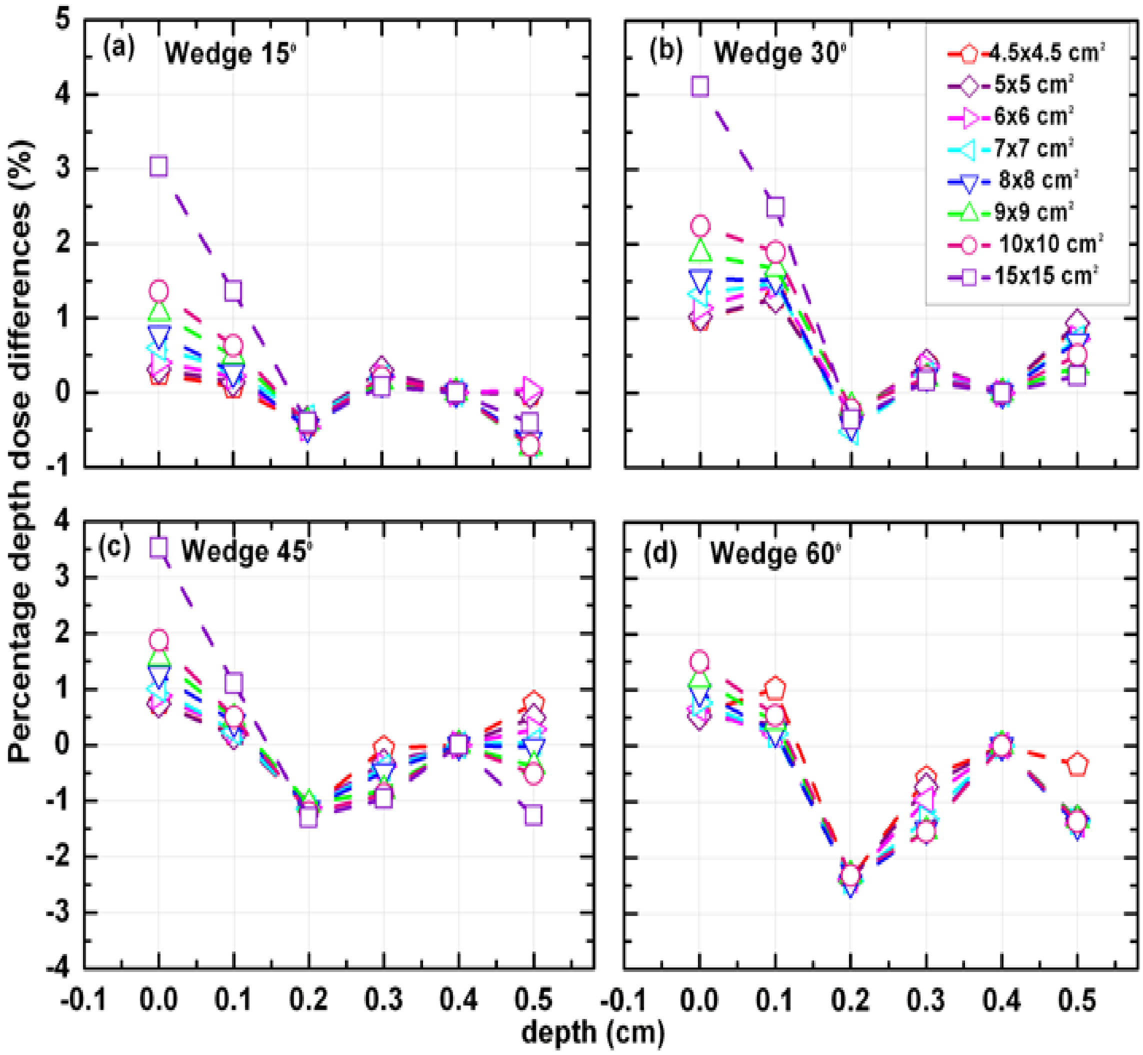

Fig. 5. Percentage depth dose differences with depth for wedge angles(a) 15°, (b) 30°, (c) 45°, and (d) 60°.

surface and build-up region with various field sizes for both open and wedged beams was due to electron contamination from the head of the treatment machine and air. For physical wedge (upper wedge) fields, the dose in the build-up region was lower than that for open field sizes, however, a significant effect is seen for physical wedged beams, due to physical wedge eliminates secondary electrons at the same time generates new electrons.

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التباينات في الجرعة السطحية مع الوتد الفيزيائي لأشعة جاما ^{60}Co في العلاج الإشعاعي

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الغرض من هذه الدراسة هو التركيز على اختبار التأثير المختلف لمرشح الوتد الفيزيائي على الجرعة السطحية باختلاف المجالات العلاجية لأشعة جاما كوبالت ٦٠، و الذي يستخدم لعلاج مجموعة متنوعة من السرطان في جميع أنحاء العالم، وخاصة في البلدان النامية. تم قياس جرعة العمق المئوية في منطقة النمو للأشعة المفتوحة (عدم وجود وتد) و في حالة وجود الوتد الفيزيائي بواسطة غرفة التأين ماركوس، التي تم تشعيعها بواسطة شعاع الكوبالت ٦٠. وأجريت عمليات التشعيع في فانتوم المياه الافتراضية علي أعماق مختلفة لحقول علاجية تتراوح بين ٤,٥×٤,٥ إلى ١٥×١٥سم٢. تم تطبيق تأثير القطبية وعامل التصحيح المفرط للاستجابة لغرفة ماركوس. بالنسبة للأشعة المفتوحة و في حالة وجود الوتد ذات الزوايا ١٥°، ٣٠°، ٤٥° و٦٠°، وجدت الجرعة السطحية المئوية بأنها ٢٥,٩٥٪±٠,١٧٪، ٢٤,٥٩٪±٠,٠٦٪، ٢٣,٧١٪±٠,٠٥٪، ٢٤,٠٨٪±٠,٠١٪ و ٢٤,٤٥٪±٠,١١٪ ،على التوالي، للحقل العلاجي١٠×١٠سم٢. لهذا، كانت اختلافاتهم لنفس الحقل ١,٣٦٪، ٢,٢٤٪، ١,٨٧٪ و ١,٥٪ على التوالي. انخفضت الجرعة السطحية المئوية مع زيادة زاوية الوتد لجميع الحقول. علماً بان نسبة عدم اليقين لجميع البيانات هي ٠,١٦٪. وقد أثبتت النتائج أن الزيادة في الجرعة المئوية السطحية ومنطقة النمو للحقول العلاجية المتنوعة في حالة عدم وجود الوتد الفيزيائي ووجوده كانت بسبب تلوث الإلكترون من رأس جهاز المعالجة والهواء. ومع ذلك، شوهد تأثير هام للأشعة في حالة وجود الوتد الفيزيائي، بسبب أن الوتد الفيزيائي يزيل الإلكترونات الثانوية و في نفس الوقت يولد إلكترونات جديدة.