Measurements of output factors using different ionization chambers and build up caps

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Background: The aim of this work was to study the output factors for Linac using different ionization chambers and build up caps. *Materials and Methods:* Output factors were measured for open square fields (3 × 3 cm to 40 × 40 cm) defined by collimator jaws for 6 and 15 MV photon beams from a Varian Clinac 2100C accelerator were measured. The measurements in air were performed using Compact Cylindrical and Farmer type ionization chamber fitted with acrylic and brass build up caps. All measurements were taken with the detector set with its central axis perpendicular to the beam central axis and isocentrically positioned at the reference depth in empty water phantom. *Results and Discussion:* It was observed that out put factors increased with field size for both 6 and 15 MV photon beams. The increase in output factor is less prominent for brass build-up caps than acrylic build up caps. Up to 1.53% and 0.97 % difference were observed between 6 and 15 MV energies for acrylic and brass build up caps respectively. For acrylic build up cap, no significant difference was found for both ionization chambers. However, measurements for brass and acrylic build up caps with same ion chamber differ by up to 4.4 % for 15 MV energy. *Conclusions:* The measurement of output factors Sh with cylindrical build-up cap made of high Z material distorts Sh and should be avoided. The use of buildup caps with Z_{eff} close to that of water such as acrylic is a good choice. Ionization chamber is the best choice for Sh measurements for large field sizes. **Iran. J. Radiat. Res., 2012; 10(2): 95-98**

Keywords: Output factors, build up caps, ionization chamber.

INTRODUCTION

All of the common dosimetry systems, Tissue Air Ratio (TAR), Tissue Maximum Ratio (TMR), Tissue Phantom Ratio (TPR), and Modified Tissue Phantom Ratio (MTPR) require that dose to a point in a phantom be separated into a primary component arising from photon and electron fluence from the head of the accelerator and a secondary component arising from scatter in the phantom. The basic methods for separating these components of dose involves the measurement of the total scatter factor in a phantom (Shp) and either the head-scatter factor (Sh) or the phantom-scatter factor (Sp) individually. Direct measurements of Sp are relatively difficult. While the direct measurement of Sh is usually done as an in-air measurement with an ion chamber covered with a buildup cap.

The detector system for the measurement of Sh, composed of the ion chamber and build-up cap, is well established. The build-up cap must be totally covered by the incident beam for all field sizes to reflect the relative changes in incident fluence. The wall thickness of the build-up caps is equivalent to d_{max}, the depth of maximum dose in a water phantom for the given beam energy. But as the beam energy increases, the contamination electrons have higher energy and become more penetrating. Therefore d_{max} becomes larger that requires build-up caps of greater wall thickness. These physically larger build-up caps cannot be used to measure small field sizes of higher energy beams. In such situations, measurements have been made with build-up caps of high atomic number material or at extended distance. Build up caps made of Lead, Copper, Tungsten, Aluminum, Mylar and Graphite has been studied [1-3]. Cylindrical build-up caps constructed of high Z material have been reported to give results that differ significantly from those of low Z caps [4, 5].

The effects of build cap construction

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material on *Sh* measured with cylindrical build-up caps with two different ionization chambers will be detailed in this work. Changes in *Sh* are investigated for 6 and 15 MV photon beams for range of field sizes.

MATERIALS AND METHODS

The photon beams used in this study had energies 6 and 15 MV generated by a Varian linear accelerator (Clinac 2100C) installed at the Institute of Nuclear Medicine, Oncology and Radiotherapy (INOR) Abbottabad, Pakistan. Scanditronicx-Wellhofer Farmer type ionization chamber (FC65-G) with inner diameter of 6.2 mm and having an active volume is 0.65 cm³ had been used. The second chamber was Compact Cylindrical ionization chamber (CC 13) with inner diameter of 6 mm and active volume of 0.13 cm³. All measurements were taken with the detector set with its central axis perpendicularly to the beam central axis and isocentrically positioned at the reference depth in empty water phantom (set at 100 cm). The ionization chambers were fitted with buildup caps made of Acrylic and Brass. Four Acrylic build up caps with diameters of 30 cm and 50 cm and two Brass build up caps with diameter 1.56 cm and 2.72 cm were used for 6 and 15 MV photon beams respectively. The thickness of the build-up cap in each case was sufficiently large to provide maximum dose at the chamber. The field size was larger than the buildup cap in each case. Square fields with side length ranging from 3 cm to 40 cm were studied.

RESULTS

The X-ray beam used for the investigation of Head Output Factors *Sh* had energies of 6 and 15 MV generated by a Varian Clinac 2100C linear accelerator. The measurements were performed in air using Farmer type and Compact Cylindrical ionization chambers placed on the beam central axis at the reference depth of d_{max} in acrylic and brass build up caps. The

reference depths for 6 and 15 MV photon beams were 1.6 and 2.9 cm respectively. The *Sh* was measured at the isocenter for various square fields. The minimum field size used was 3 cm × 3 cm so that the ionization chamber along with buildup cap was within the radiation field. The measured outputs were normalized to the output of the reference field (10 cm ×10 cm).

The *Sh* for 6 and 15 MV photon beams was measured using Farmer type ionization chamber fitted with acrylic build up caps. The *Sh* was calculated by increasing the field size from 3 cm ×3 cm to 35 cm × 35 cm. Figure 1 shows the variation of *Sh* as a function of field size. The *Sh* increases with field size and slowly levels off to a limiting value for larger field sizes. The *Sh* for 6 MV photons is larger than its corresponding value for 15 MV photons by up to 1.5 % for field sizes smaller than reference field size but for field sizes larger than reference field size the *Sh* for 15 MV photons is larger than its corresponding value for 6 MV photons beam by about 1.3 %. Figures 2 and 3 presents the variations of *Sh* with field size for 6 and 15 MV photon beams for Compact Cylindrical ionization chamber fitted with acrylic and brass build up caps respectively. The *Sh* increases with field size in both cases. However the difference in *Sh* for 6 and 15 MV beams is more prominent for Compact Cylindrical ionization chamber than that for Farmer type ionization chamber (figure 1). Therefore, the *Sh* also depends on the detector used. Comparing the results of Compact Cylindrical ionization chamber fitted with brass and acrylic build up caps (figures 2 and 3), the following observation is evident. Unlike the results with acrylic build up cap, the *Sh* for 15 MV photons with brass build up cap is larger than its corresponding value for 6 MV photons for smaller field sizes. Similar controversy also exits between brass and acrylic build up caps for larger field sizes .i.e. the *Sh* for 6 MV photons is larger than its corresponding value for 15 MV photon beam. Hence the *Sh* also depends on the construction material (more

specifically, atomic number) of the buildup cap used to provide the maximum dose build up to the chamber in air. For acrylic build up cap, no significant difference was found
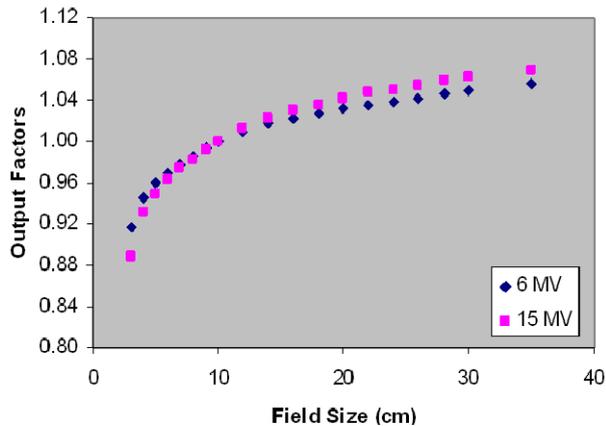

Figure1. Variations of output factors with field size measured with farmer type ionization chamber and acrylic build up cap.
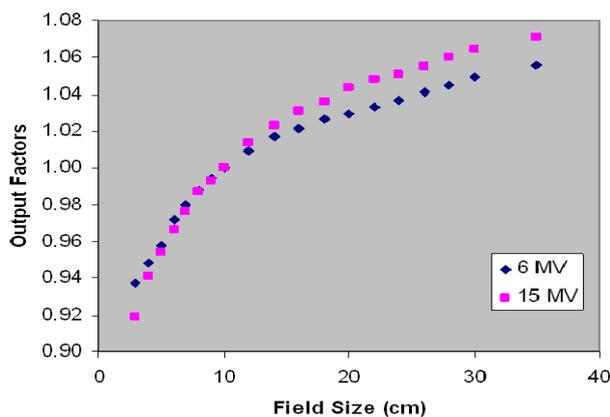

Figure2. Variations of output factors with field size measured with compact cylindricalionization chamber and acrylic build up cap.
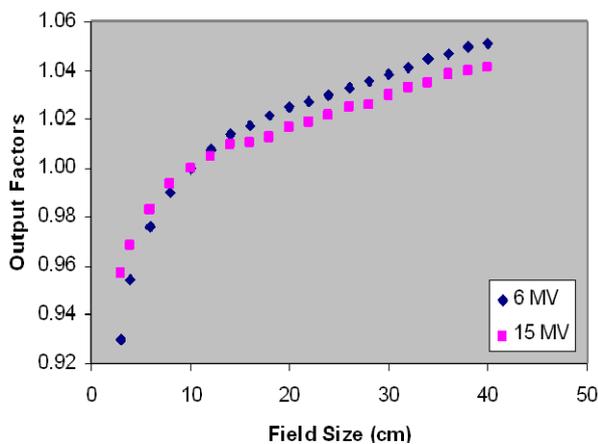

Figure 3. Variations of output factors with field size measured with compact cylindrical ionization chamber and brass build up cap.

for both ionization chambers. For former type ionization chamber, the difference in *Sh* for acrylic and brass build up caps decreases with increasing field size for 6 MV. However, for 15 MV energy, this difference decreases till the reference field size and then again increases till the maximum field size.

DISCUSSION

The increase in *Sh* with field size may be attributed to the radiation scattered from the primary collimator and flattening filter in the treatment head. As the collimator jaws are opened to increase the field size, more scattered radiation is allowed to leave the treatment head. Also increasing the jaw opening decreases the number of photons backscattered from the jaw to the monitor chamber by a small amount [6].

This causes the feedback circuit to increase the accelerator current. Both of these effects are reflected as an increase in the *Sh* with field size. By comparing Figures 2 and 3, it is clear that the curve for *Sh* rises less rapidly with increased field size for brass (higher atomic number material, Z = 29) than acrylic build up cap (lower a tomic number material, $Z_{eff}= 6.56$). Predominantly this is due to an increase in contamination electrons with larger field sizes. The build-up caps of high atomic number material cause much greater scatter of electrons [1]. This will cause a net scattering of electrons away from the ion chamber, which is observed as a lower signal at larger field sizes for high Z materials.

The atomic number of the material used in cylindrical buildup caps had been shown previouslyto have an effect on the measurement of $Sh^{[1, 5, 7]}$. For graphite versus brass and lead cylindrical buildup caps, the difference in output factors has been reported to become larger with energy[5]. This is consistent with the published results that *Sc* decreases with increasing Z values for graphite, copper and lead build up caps. The ratio of the difference in *Sc*for lead to Mylar

build up caps was reported for 18 MV X-rays to be 0.794[7]. However, some measurements of the output factor for buildup caps of different Z materials reported contradictory results. No differences in output factors were found in the lead and acrylic build up caps with ionization chamber [8].

As the field size increases, the outer regions of the flattening filter became exposed to the detector and build up cap. The outer edge of the flattening filter gives rise to X-ray energy-fluence spectra that are lower in energy [6,9,10]. Consequently a decrease in the effective energy of the beam at larger field sizes will occur. This change of the energy-fluence spectrum with field size will change the transmission, scatter, and buildup in the buildup caps. It is these combined changes that cause *Sc* to differ for buildup caps fabricated from different Z-materials.

With acrylic build up caps, both types of ionization chambers resulted in identical output factors suggesting that the measurement is independent of the detector used. This is consistent with other published studies. It has been reported that semiconductor detectors and ion chambers in same type of buildup caps give identical measurement of *Sh* versus field size for photon beam qualities of Co-60 to 50 MVX-rays [11].However, plastic scintillation detectors produce significantly higher output factors than the ionization chamber at the smallest fields[12]. Therefore, ionization chamber is the best choice for output factor measurements in extended water phantoms for large field sizes while diodes and plastic scintillation detectors are an alternative in small fields.

CONCLUSION

The measurement of *Sh* with cylindrical build-up cap made of high *Z* material distorts *Sh* and should be avoided. The use of buildup caps with Z_{eff} close to that of water such as acrylic is a good choice. Ionization chamber is the best choice for output factor measurements for large field sizes while diodes and/or plastic scintillation detectors are an alternative in small fields.

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