Monte Carlo simulations were performed using the EGSnrc system[1]. The simulated beams from Varian TrueBeam were based on the phase space files provided by Varian (Varian 2014, version 2.0)[2]. The small circular beams are obtained by add-on circular collimators cones. The details of circular beams, including the cone accessory, were simulated and the accuracy of the simulation was reported and validated against measurements[3]. The accuracy of Monte Carlo simulated beams were validated[2,3].

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Effect of Focal Spot Size on the Beam Output between Circular and Square Small Fields

George x Ding, PhD[1,2]; Kenneth L. Homann, PhD[1,2]
[1]Departmen of Radiation Oncology, Vanderbilt University School of Medicine, [2]Vanderbilt Health

ABSTRACT

Purpose: The source size (focal spot) of a photon beam from linacs is known to have effects on the output for small-field dosimetry. This study aims to determine quantitatively the sensitivity of beam field output factors (FOF) as a function of field sizes between circular and square fields.
Methods: Because experimental measurements could not separate effect between source occlusion and lack of lateral scatters on FOF for extremely small fields, we used Monte Carlo simulations to avoid experimental field size setup uncertainties and investigated FOF of circular fields defined by cones and square fields defined by jaws ranging from 4 mm to 30 mm dimensions for 6 MV-FFF, 6MV-SRS, 6 MV, and 10 MV-FFF beams.
Results: The results showed that FOF depends on focal spot size. For a small difference in FWHM of focal spot size of Gaussian distribution between 1.2 mm from Trilogy/TX and 1.7 mm from TrueBeam led to greater than 10% difference in FOF for a 5×5 mm^2 jaw opening between Trilogy/TX and TrueBeam 6 MV beams, respectively. However, these focal spot differences only led to less than 4% difference in FOF for 5 mm cone field between Trilogy/TX and TrueBeam beams, respectively. The reason is because jaws are closer to the radiation source than cones, the effect of source occlusion becomes more prevalent for jaw defined fields for very small fields.
Conclusions: This study simulated an "ideal experiment" free of machine geometric uncertainties and measurement setup uncertainties to quantitatively determine effect of focal spot size on FOF between circular and square field sizes. It is found that the focal spot size has a non-trivial effect on the FOF for jaw defined square fields and an insignificant effect on cone fields due to the source occlusion and lack of it, respectively.

CONTACT

George Ding
Vanderbilt University
2220 Pierce Ave, Nashville, TN 37032
George.Ding@VUMC.org
615-322-5256

INTRODUCTION

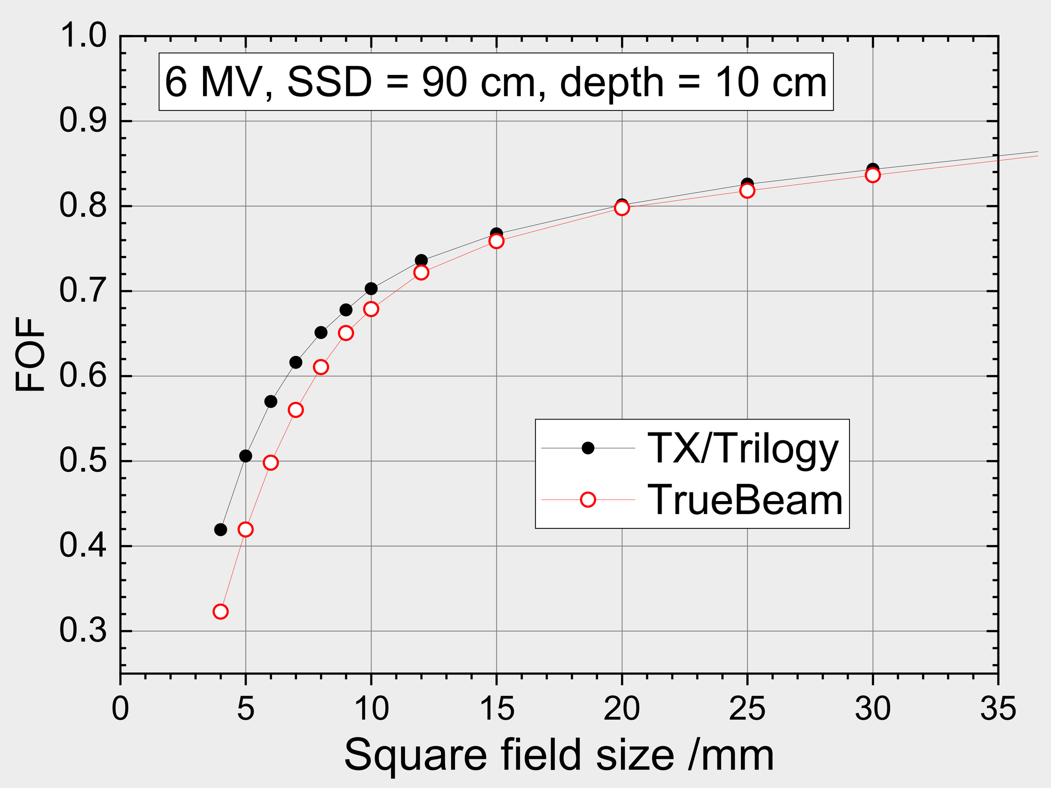
The beam field output factor (FOF) decreases rapidly as a function of field size for small fields. This rapid decrease of FOF for extremely small fields is caused by both lack of lateral charge particle equilibrium and radiation source occlusion of partial geometrical shielding of the primary photon source.

While experimental methods could not separate these two effects accurately, the Monte Carlo simulation can quantitatively study the contribution of lack of lateral scatter and radiation source occlusion separately.

Using Monte Carlo simulations, this study obtained information on the sensitivity of FOF for small fields that are not currently available. The information that decrease of FOF is caused only be source focal size is useful for beam commissioning and beam configuration of a commercial treatment planning system to improve the beam modelling.

METHODS AND MATERIALS

Monte Carlo simulations were performed using the BEAMnrc/DOSXYZnrc codes[1]. The simulated beams from Varian TrueBeam were based on the phase space files provided by Varian (Varian 2014, version 2.0)[2] while the beams from Varian Trilogy/TX were simulated based on the linac head information provided by Varian. The small circular beams are obtained by add-on circular collimators. The details of circular beams, including the cone accessory, were simulated and the accuracy of the simulation was reported and validated against measurements[3]. The accuracy of Monte Carlo simulated beams were validated[2,3].
All FOFs are calculated relative to a 10×10 cm^2 open field at the same SSD and depth.



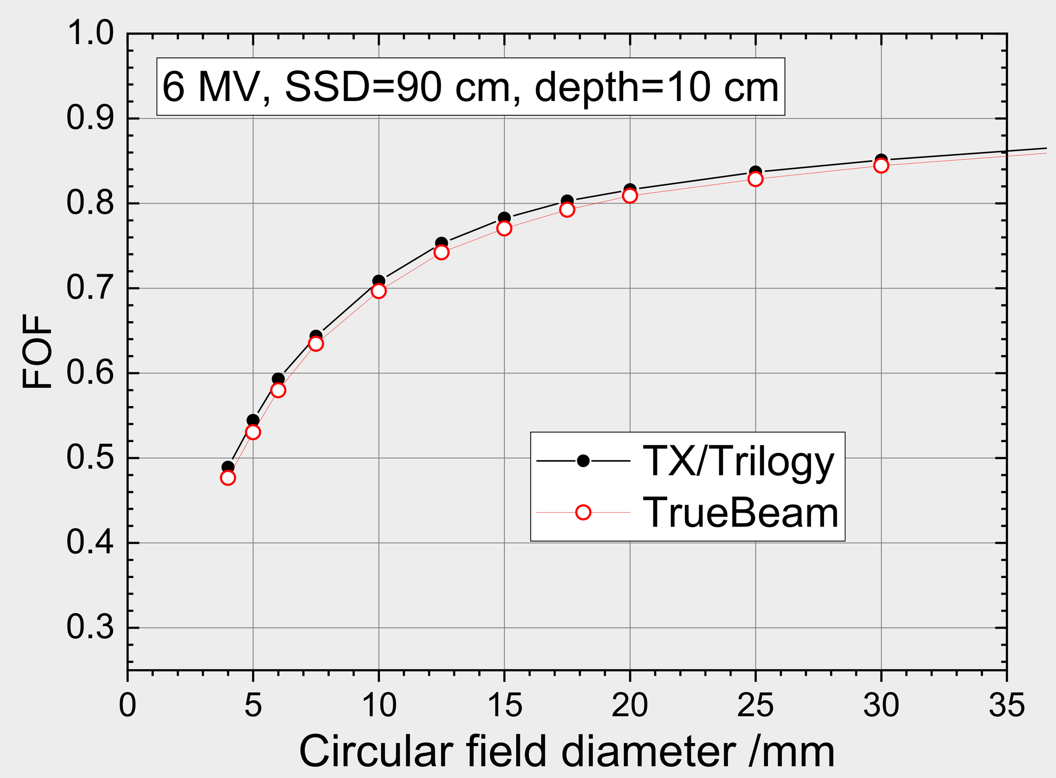


Figure 1. FOF as a function of small square and circular fields.

RESULTS

Figure 1 shows the Monte Carlo generated FOF as a function of square and circular field sizes for 6 MV beams from, respectively.

For square field defined by jaws, it is seen that the difference in FOF increases rapidly between beams from TX/Trilogy and TrueBeam when field size decreases at small fields starting from 15×15 mm^2. However, there are only insignificant differences in FOF circular fields defined by cones independent of field sizes.

The large differences for square fields are mainly caused by variations in the radiation focal spot. The FWHM of the incident electron's radial intensity Gaussian distribution is 1.2 mm and 1.7 mm for 6 MV beams from the Trilogy/TX and TrueBeam linacs, respectively. Because jaws are closer to the radiation source than cones, the effect of source occlusion becomes more prevalent for jaw defined fields for very small fields. In this case, the difference in FWHM of the beam focal spot between 1.2 mm and 1.7 mm led to >10% difference in FOF for a 5×5 mm^2 jaw opening. The effect of beam focal spot size on FOF diminishes at field size > 15 x 15 mm^2.

The more rapid falloff in FOF for square fields as a function of decreasing field sizes for TrueBeam was mainly caused by slightly larger beam focal spot size for TrueBeam. This falloff at extreme small square fields was enhanced by radiation source occlusion when focal spot is larger and jaws are closer to the radiation source than the cones as discussed in the context of small field dosimetry[4-6].

Although the designs of the linac head differ between TrueBeam and Trilogy/TX, if we used the TrueBeam focal spot size in generating Trilogy/TX beams, the very similar FOFs for square fields are obtained as shown in Figure 2.

These results provide knowledge that separates effect of focal spot size and field size on the output factors at extreme small fields.

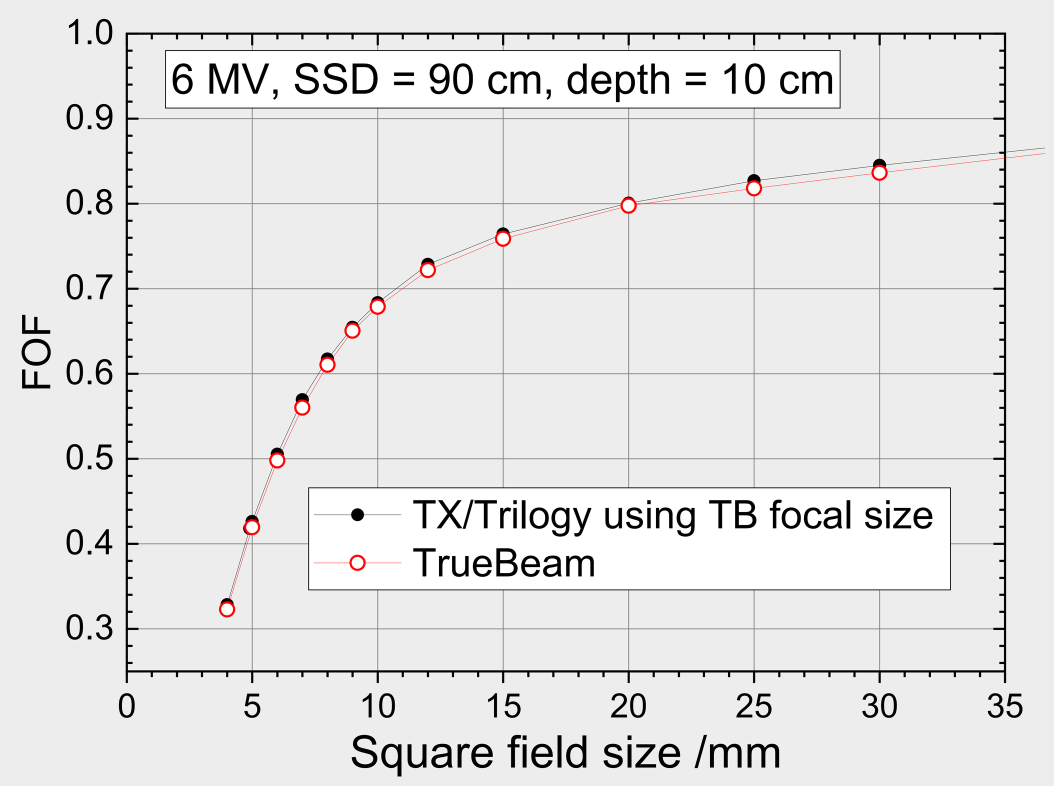


Figure 1. FOF as a function of small square fields defined by jaws when focal spot sizes are the same while the linac head designs are not the same .

DISCUSSION

FOF decreases rapidly as a function of field size for small fields. Although it is known that the fall of FOFs for small fields are contributed by lack of lateral charge particle equilibrium and radiation source occlusion, to separate the two contributions is difficult using experimental measurements. Because the Linac specification for jaw opening accuracy is at 1 mm and not at submillimeter it is difficult to know the actual field size when fields is defined by jaws. This study demonstrates that the Monte Carlo method not only can quantitatively separate two effects, but also show the sensitivity of FOFs on the focal spot size.
This study also indicates that the small field FOFs can differ significantly for fields defined by jaws, even for the beams from the same model, if their focal spot sizes differ slightly. On the other hand, the FOFs for small circular fields defined by cones are almost independent of focal spot size. The information obtained in this study is useful for beam commissioning and beam configuration of a commercial treatment planning system to improve the accuracy of SRS/SBRT treatments.

CONCLUSIONS

Using Monte Carlo simulation, we performed an "ideal experiment" free of machine geometric uncertainties and measurement setup uncertainties to quantitatively determine effect of focal spot size on FOF of circular and square field sizes.

We found that FOFs for jaw defined square fields are extremely sensitive to the focal spot size for fields < 15 mm^2 while for FOFs for circular cone defined fields are almost independent of the focal spot size.

For the same nominal 6 MV beams, the FOF as a function of square fields defined by jaws mainly depends on the focal spot size for small fields. If the jaw openings can be precisely set in the experimental measurements the FOF can be related to the focal spot size.

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