Standard Electron Cone Ratio Values for Varian, Siemens and Elekta (Philips) Accelerators

David S. Followill, Ramesh C. Tailor, Nadia Hernandez and William F. Hanson
Department of Radiation Physics
The University of Texas M. D. Anderson Cancer Center
Houston, Texas 77030

INTRODUCTION

The Radiological Physics Center (RPC), through its on-site dosimetry review visits to institutions participating in NCI cooperative clinical trials, has accumulated a vast amount of dosimetry data from the institutions. These data include institution values as well as RPC measured data. An important part of the dosimetry review is the review of the institution's electron dosimetry parameters such as reference output, percent depth dose data, extended distance factors, and cone ratios. The RPC uses the Task Group 21 (TG-21) protocol[1] to perform absolute beam calibrations and the Task Group 25 (TG-25) report[2] to perform relative electron dosimetry measurements.

Upon analysis of the dosimetry data, measured during the dosimetry review visits, the RPC has been able to show that the values of some dosimetry parameters are indistinguishable for depending on the make and model of accelerator. We call these data "standard data". Standard data for a specific dosimetry parameter is an average of 5 or more measured values for a specific make and model of accelerator. Examples of standard data for depth dose data and wedge transmission values, have been previously presented [3,4,5]. Electrons are a much more difficult modality to identify standard data since their nominal incident energies vary much more than seen with photons. We decided to explore whether a standard set of cone ratio (CR) values could be identified using both the RPC measured values and the visited institutions clinical values.

Material and Methods

- Institutional clinical values and RPC measured data were compiled for various models of Varian, Siemens and Elekta (Philips) accelerators.

  1. Varian – Clinac models 1800, 2100, 2300 and 2500.
  2. Siemens – Mevatron models MD, KD, 74, 77, and 6700 series.
  3. Elekta – SL models 18, 20 and 25.

- Data from >500 electron beams from 70 institutions
  1. Energies ranged from 4 – 20 MeV
  2. Cone sizes included 5 cm circular, 6 X 6, 14 X 14, 15 X 15, 20 X 20 and 25 X 25 cm^2.
  3. RPC measured nominal incident energy (E_o) was used as a point of consistency.
  4. 100 SSD data only

- RPC measurements were performed in a water phantom with cylindrical Farmer type 0.6 cm^3 ionization chambers. At each institution, the RPC only spot checked a few cones for one or two electron energies.

- The RPC determines the cone ratio (CR) at 100 cm SSD as:

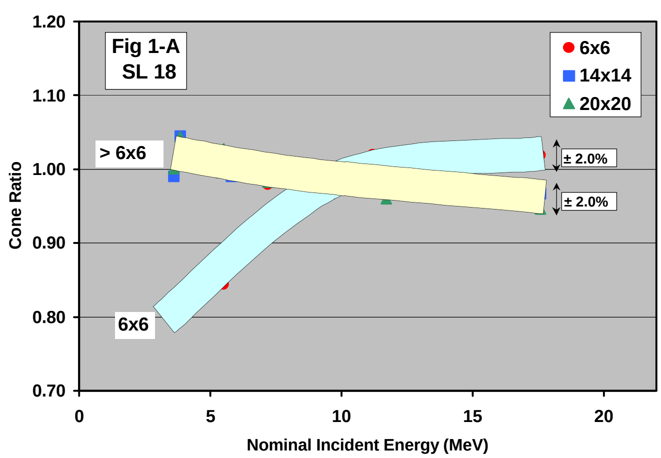
$$CR = \frac{\text{Ioniz.(cone size, } d_{max}) \bullet (P_{repl}) \bullet (L/\rho)}{\text{Ioniz.(ref cone size, } d_{max}) \bullet (P_{repl}) \bullet (L/\rho)}$$

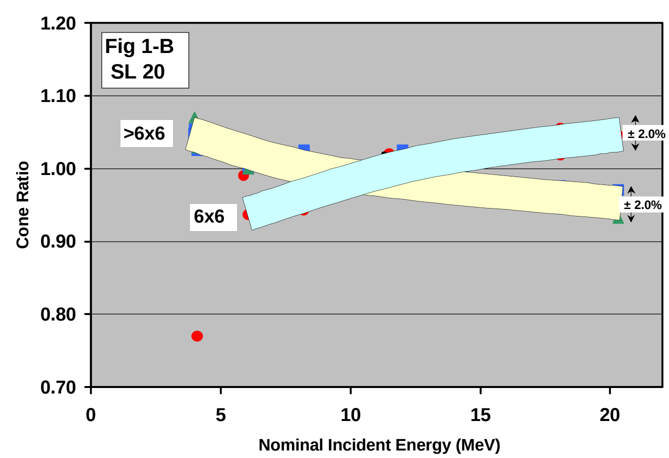
Results

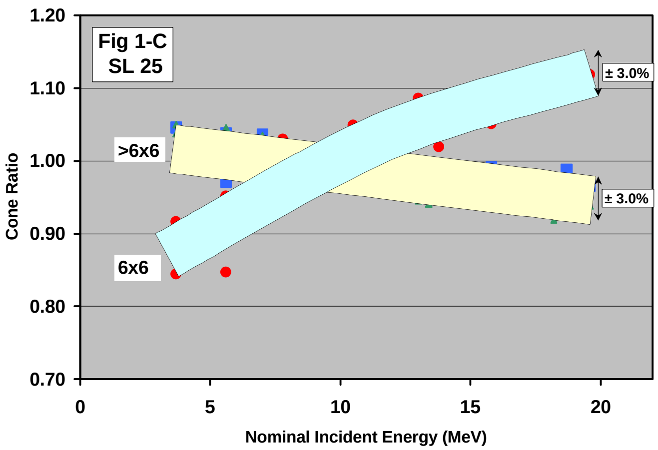
The cone ratio data for each make/model of linac are normalized to the 10 cm x 10 cm cone and analyzed as a function of nominal incident energy (E_o). For all Figures in general, the ●, ■, or ▲ symbols refer to cone sizes 6cm x 6cm (or 5cm x 5cm), 15cm x 15cm (or, 14cm x 14cm), and 20cm x 20cm, respectively. The shaded areas represent cone-size dependent trends. Since the shaded areas are drawn to include ~95% of the data pertaining to the trend, their widths represent two standard deviations (2σ) as marked in each figure. The data show that within the indicated uncertainties (2-3%), the cone ratio values, with a couple exceptions, are predictable for a given make and model of linac. These generic values, which the RPC calls “standard” data, are derived from the average of the trends represented by shaded region.

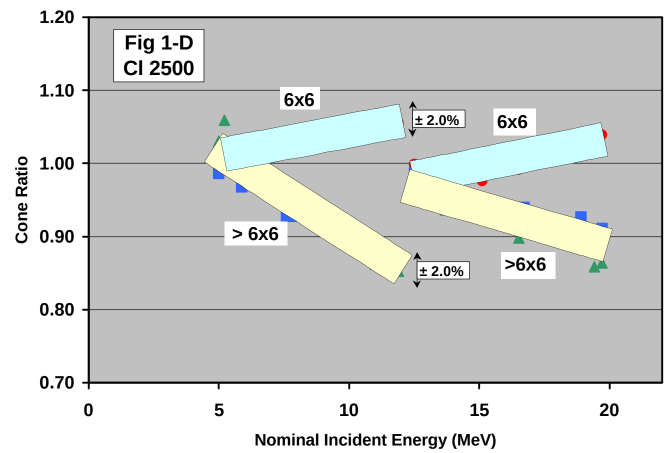
A general observation seen in figures 1-4, is that the CR values for 6cm x 6cm (or smaller size) cones increase with beam energy whereas the opposite trend is observed for cone sizes larger than 10cm x 10cm. The Clinac 2500 unlike all other makes/models of linacs, shows discontinuity in cone ratios versus E_o dependence at ~12 MeV due to changes in the primary photon jaw settings.

Figures 1-A through 1-D present data for four different linac models, the SL18, SL20, SL25, and Clinac 2500, respectively. One common finding within this group of figures is an almost complete overlap of CR values for the two larger cone sizes, i.e., 15cm x 15cm (14cm x 14cm) and 20cm x 20cm. However, there is a subtle, but consistent difference in the CR values for these two large cone sizes. The CR values for the 20cm x 20 cm consistently appear to have CR values approximately 1% less than those for the 15cm x 15cm (14cm x 14cm) size with the exception of the Clinac 2500 at low energies (<12MeV). However, this subtle difference is well within the indicated band of ±2% uncertainty. The uncommon feature of discontinuity in the trends in Figure 1-D is due to a step change in the photon collimator openings at Eo ~12 MeV. This feature is not seen with any other linac make/model presented in this work.

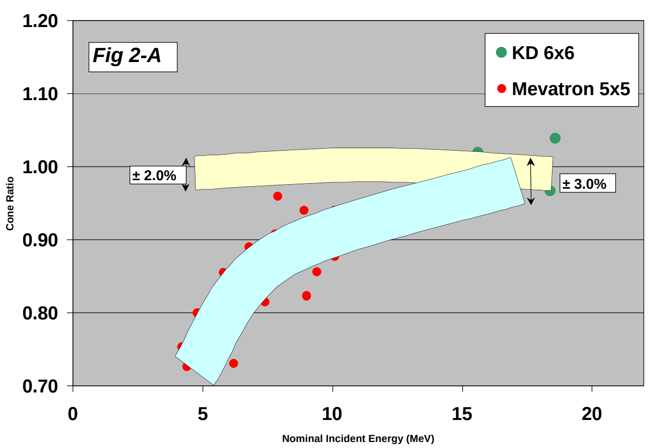


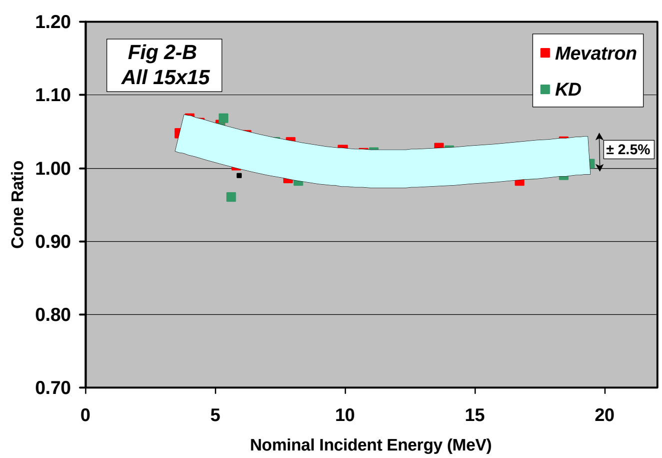


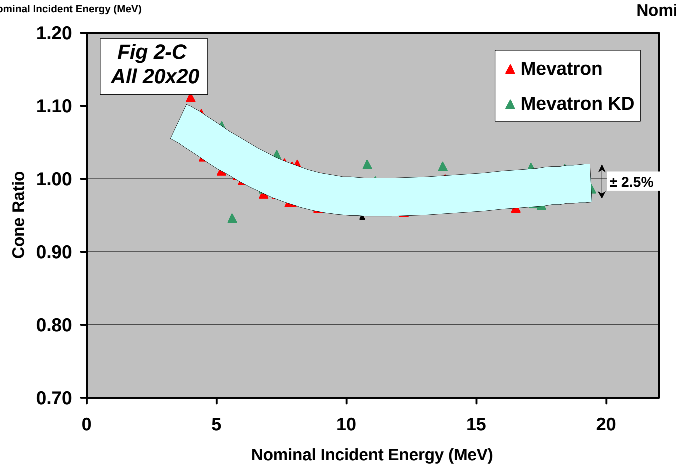




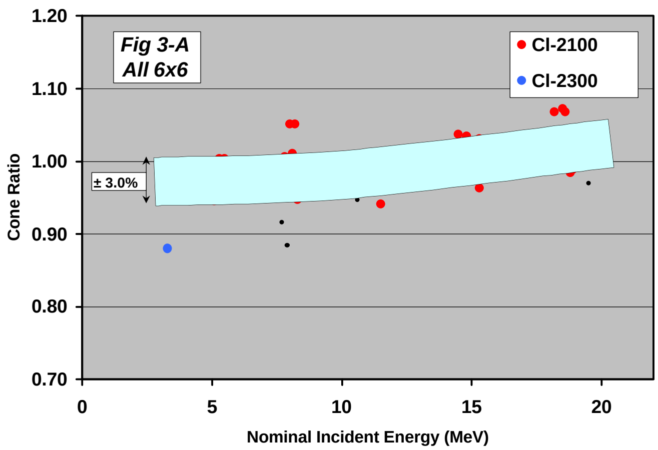
Our analyses show that CR values are the same, not only for a particular model of linac, but also between different models of linacs from the same manufacturer. The Mevatron models MD, KD, 6700, 74 and 77 series illustrate this behavior as seen in figures 2-A through 2-C. The data shown in each figure is a compilation of several linac models for a specific cone size. The two shaded areas in Figure 2-A correspond to 5cm x 5cm and 6cm x 6cm cone sizes. Figures 2-B and 2-C show data for 15cm x 15cm and 20cm x 20cm, respectively. There is a considerable overlap of the CR data corresponding to different models in figures 2-B and 2-C, implying CR values are the same for these particular models. The data follow the trends shown by the shaded areas for each cone size independently. The tightness or the spread (2σ) of the data within each shaded area is within 2.5-3%.

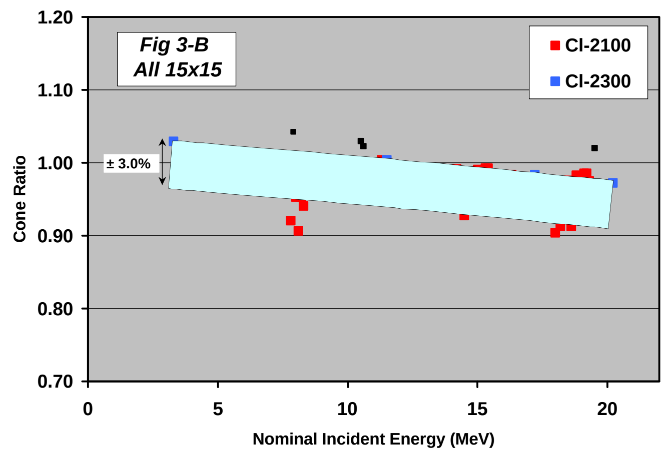


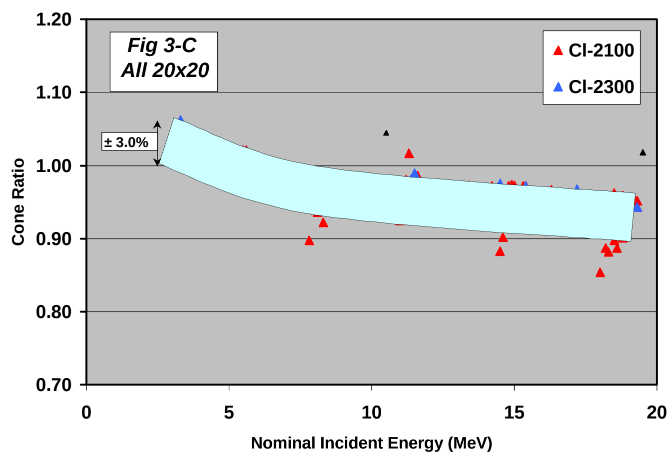




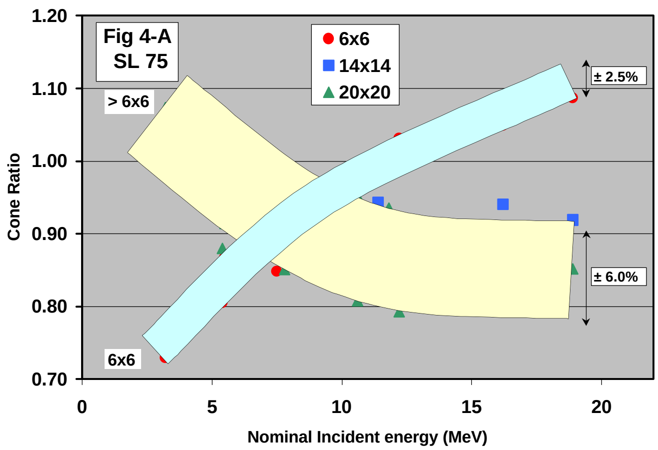
Figures 3-A through 3-C present data for two Varian models, Clinac 2100C (or 2100 CD) and Clinac 2300CD. Similar to the data shown in figure 2, these Varian models also have the same CR value irrespective of these model types. The cone ratio values are practically the same for these two models with some additional spread due to the introduction of a new cone design in the early 90's. For each cone size, the trend indicated by shaded area shows data tightness (2σ) to within 3%.

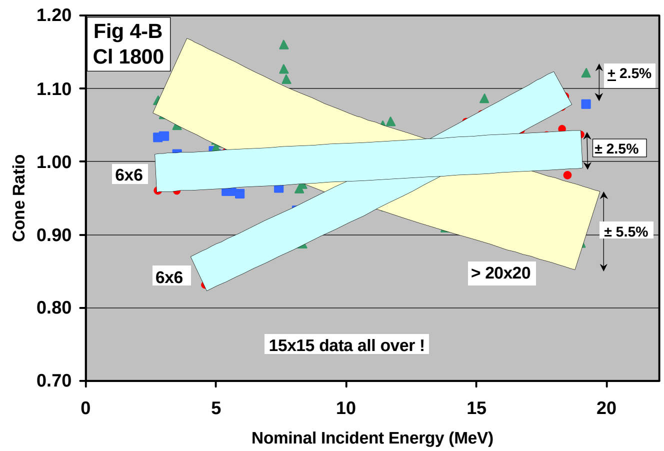






Figures 4-A and 4-B present CR data for SL75 and Clinac 1800, respectively, for which the spread in CR values is not as tight as presented in the preceding figures. Within figure 4-A, if one focuses on the SL75 data for cone sizes larger than 6 cm x 6 cm, the data for both of the larger cone sizes overlap nicely however with a large scatter ($2\sigma \sim 6\%$). We do not have an explanation for the large spread in the CR values for this particular linac model. In addition, the Clinac 1800 CR data, shown in figure 4-B, appear to have a great deal of scatter. The manufacturer "Varian" indicates that this machine has always been provided with a single cone design "Type-2 accessory" (cones with solid closed walls in contrast to the open wall design "Type-3 accessory"). A possible explanation for the increased spread in the data is that they represent a mixture of both cone designs. In addition, since this particular linac model has been in existence for a long time, some of these units may have had alterations such as replacement of the flattening filter or photon jaws with different designs thereby resulting in a large scatter in the data.





CONCLUSIONS

1) CR values, for a specific cone design, are predictable within the stated uncertainty for a given make and model of linac.

2) For Mevatron machines, CR values are indistinguishable among its five different models MD, KD, 6700, 74 and 77 series.

3) Among Varian models, CR values are indistinguishable between Clinac 2100C (or 2100CD) and Clinac 2300C (or 2300CD).

4) Among all Varian machines, the Clinac 2500 is unusual in terms of exhibiting a discontinuity in CR versus E_o trend at ~12 MeV.

5) In general, irrespective of linac make/model, 6 cm x 6 cm or smaller cones, CR values increase as a function E_o while an opposite behavior is observed for larger cone sizes.

6) The “standard” CR values, based on an average from the shaded regions, will serve as a remote-audit tool for the RPC to identify potential discrepancies with the clinical values in use at the participating institutions.

7) The “standard” CR values may serve the physics community as redundant check for machine commissioning data, clinical data in use, and the annual quality assurance measurements.

REFERENCES

1) American Association of Physicists in Medicine, Radiation Therapy Committee Task Group 21, “A protocol for determination of absorbed dose from high-energy photon and electron beams.” *Medical Physics* 10:741-771 (1983).

2) American Association of Physicists in Medicine, “Clinical electron-beam dosimetry: Report of AAPM Radiation Therapy Committee Task Group 25.” *Medical Physics* 18, 73-109 (1991).

3) Followill, D.S., Davis, D.S., and Hanson, W.F. Standard Wedge Transmission Values for Varian, Siemens, Phillips and AECL Accelerators. *Medical Physics* 24:1076, 1997.

4) Davis, M.S., Followill, D.F., Kennedy, P., and Hanson, W.F., Electron percent depth dose and cone ratio from various machines. *Medical Physics* 22:1007, 1995.

5) Kennedy, P.M., and Hanson, W.F. A review of high-energy photon beam characteristics measured by the Radiological Physics Center. *Medical Physics* 19:838, 1992.

This investigation was supported by PHS grant CA10953 awarded by the NCI, DHHS.