Beam Data Collection and Commissioning for Linear Accelerators: Technical Considerations and Recommendations

Indra J. Das, PhD, FAAPM, FACS, FASRO
Department of Radiation Oncology
Indiana University School of Medicine & Indiana University Health Proton Center, Indiana

Preface

Accelerator beam data commissioning equipment and procedures: Report of the TG-108 of the Therapy Physics Committee of the AAPM

Mechanical QA

- Radiation survey
- Mechanical tests
- Light radiation
- Table, Collimator, Gantry
- Jaws
- MLC
- Imaging parameters
- Other as TG-142

Planning for Commissioning Data

Exe No. 25: Incorrect depth dose data

During installation of a linear accelerator, an institution contracted the services of the manufacturer to measure depth dose data. The radiation physicist had checked the data and found an 8% discrepancy between his measurements and those of the manufacturer for some field sizes and depths. He concluded that the manufacturer’s data were correct and used them clinically. A review by an outside consultant revealed that the physicist’s measurements were correct. During a period of several months, some patients received doses that were 8% lower than prescribed.

Initiating event:
- Incorrect data for patient dose calculations; the manufacturer provided basis data that were incorrect for some field sizes and depths.
Planning for Commissioning Time

Time = \left( \frac{PDD + 5 \text{ profiles}}{\text{beam energy}} \right) \times \frac{60 \text{ points/scan}}{1 \text{ s/pts + (1s/movement and delay)}} \times 15 \text{ fields} \times 2 \text{ energies}

\approx 10^5 \text{ s}
\approx 30 \text{ h}

Rational For Commissioning Beam Data

First, it is not evident that manufacturing procedures for all linear accelerators have produced a level of reproducibility acceptable for clinical use. For example, variations in beam parameters have been noted between beams with the same nominal energies.

Second, on-site changes made during installation and acceptance of the user’s accelerator e.g., changes in beam energy and profiles from beam steering will not be modeled in the golden data.

Third, the beam characteristics of the soft wedges are made by moving jaws that depend on the speed of the jaws and a deviation at site could affect the beam profile of the soft wedge. Fourth, although acceptable agreement with the golden data set may be found in individual checks, it may be that some clinical setups will have multiple errors which combine to produce unacceptable results. Finally, the commissioned beam data also provides a thorough check of the accelerator, which may uncover problems that may not otherwise be discovered with a routine check.

Rational For Not Using Golden Data

| x_i - x^- | < \Delta_x
\Delta = \begin{cases} 
0.5, & \text{for microchamber} \\
1.0, & \text{for minichamber} \\
2.0, & \text{for standard chamber} 
\end{cases}

Definition of Detectors

- **Standard chamber 10^{-1} \text{ cm}^3**—The active volume for a standard Farmer-type ionization chamber is on average 0.6 \text{ cm}^3.
- **Minichamber 10^{-2} \text{ cm}^3**—The active volume for a mini-ionization chamber is on average 0.05 \text{ cm}^3.
- **Microchamber 10^{-3} \text{ cm}^3**—The active volume for a microionization chamber is on average 0.007 \text{ cm}^3 and ideally suited for small field dosimetry such as radiosurgery, gamma knife, CyberKnife, and IMRT.

Setting Water Tank & Detector

Air

Water

1

2

3

4

5
Know Your Connectors

- BNC connectors
- TNC connectors

Understand Detector, Connector & Cable

- Understand Detector, Connector & Cable
- Setup and Possible Errors
- Electrometer
  - Null Setting
  - Cable subtraction
  - Proper bias
    - >300 V for ion chamber
    - 100 V for diamond
    - 0 V for all diodes
  - Proper gain
  - Proper mode

Quality of Cables

- Quality of Cables
- Choose Consistent & Correct Polarity

- Choose Consistent & Correct Polarity
- Setup and Possible Errors
- Electrometer
- Quality of Cables
- Know Your Connectors
Chambers & Gain

Comparison of FID with Chamber and Gain

- 6 MV good chamber
- 6 MV bad chamber, incorrect gain
- 6 MV bad chamber, correct gain
- 15 MV good chamber

Depth (cm)

Selection of detector for beam data

Choice of Detector Orientation

Detector Orientation

6MV, 2x2 cm² field, illustration of chamber volume effects

- Diode, dmax
- PTW Pinpoint, dmax
- RK chamber, dmax

Distance Off Axis (cm)

6MV, 2x2 cm² field, illustration of chamber volume effects

- Diode, dmax
- PTW Pinpoint, dmax
- RK chamber, dmax

Distance (cm)

Surface & Baking Dose, 6 MV

- 0.6 cc
- 0.3 cc
- 0.12 cc
- Marlex
- Al
- EC-4
- Pb
- Diamond
- TFE
- SFD

Depth (mm)
Future of Beam Data Commissioning

- Standardization of linear accelerators
- Monte Carlo based commissioning
- Newer Radiation Detectors & Cables
- Newer Scanning Systems
- Smart algorithms

Monte Carlo Codes

Simulation of intensity at target

Simulated Profiles

Profiles for different fields
**Depth Dose Simulation**

**Detectors**

<table>
<thead>
<tr>
<th>Detector</th>
<th>Manufacturer</th>
<th>Type</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFD</td>
<td>Scanditronix</td>
<td>Photon diode</td>
<td>$1.7 \times 10^{-5} \text{cm}^3$</td>
</tr>
<tr>
<td>PFD</td>
<td>Scanditronix</td>
<td>Photon diode</td>
<td>$1.9 \times 10^{-4} \text{cm}^3$</td>
</tr>
<tr>
<td>Exradin A-16</td>
<td>Standard Imaging</td>
<td>Ion chamber</td>
<td>$0.007 \text{cm}^3$</td>
</tr>
<tr>
<td>Wellhofer-IC4</td>
<td>Scanditronix</td>
<td>Ion chamber</td>
<td>$0.40 \text{cm}^3$</td>
</tr>
<tr>
<td>Pinpoint</td>
<td>PTW</td>
<td>Ion chamber</td>
<td>$0.015 \text{cm}^3$</td>
</tr>
<tr>
<td>0.125cc</td>
<td>PTW</td>
<td>Ion chamber</td>
<td>$0.125 \text{cm}^3$</td>
</tr>
<tr>
<td>0.3cc</td>
<td>PTW</td>
<td>Ion chamber</td>
<td>$0.3 \text{cm}^3$</td>
</tr>
<tr>
<td>0.6cc</td>
<td>PTW</td>
<td>Ion chamber</td>
<td>$0.6 \text{cm}^3$</td>
</tr>
<tr>
<td>Diamond</td>
<td>PTW</td>
<td>Diamond</td>
<td>$0.005 \text{cm}^3$</td>
</tr>
<tr>
<td>Markus</td>
<td>PTW</td>
<td>Parallel plate</td>
<td>$0.035 \text{cm}^3$</td>
</tr>
<tr>
<td>Edge Detector</td>
<td>Sun Nuclear</td>
<td>Diode</td>
<td>$10^{-5} \text{cm}^3$</td>
</tr>
</tbody>
</table>

**Treatment Fields**

- **Magna-Fields**
  - 200x200 cm$^2$
  - 40x40 cm$^2$
  - 4x4 cm$^2$

- **Traditional Fields**
  - 40x40 cm$^2$
  - 4x4 cm$^2$

- **Advance Therapy Fields**
  - SRS/SRT
  - Gamma Knife
  - Cyber-Knife
  - Tomotherapy
  - IMRT

**What is a Small Field?**

- Lack of charged particle
  - Dependent on the range of secondary electrons
  - Photon energy
- Collimator setting that obstructs the source size
- Detector is comparable to the field size

**Views of Source Sizes**

Definition of Small Fields

Calculation of Fluence Map Elements

Dosimetry

- Absolute Dose
- Relative
  - Depth Dose \([D(r,d)/D(r,dm)]\)
  - TMR
  - Profiles
- Output, \(S_{\text{ref}}\) (total scatter factor), \([D(r)/D(\text{ref})]\)

Dosimetry™

Absolute

Relative

Depth Dose \([D(r,d)/D(r,dm)]\)

TMR

Profiles

Output, \(S_{\text{ref}}\) (total scatter factor), \([D(r)/D(\text{ref})]\)

New Data on Correction Factor

Pantelis et al, Med Phys, 37(6), 2369-2378, 2010
New Data on Correction Factor

$k_Q$ is not Constant in Small Field

Depth Dose & Source Size

Profile & Source Size

Comparison of Large Tank and Small SRS Cylinder Tank for SRS, TMR & Profiles

Moving Tank System for TMR

Sham et al, Med Phys, 35, 3317-3330, 2008

Chung et al, Med Phys, 37(6), 2404-2413, 2010


ARM Inc., Port Saint Lucie, FL 34983
Direct TMR Data Acquisition

No SSD to SAD calculations required. No cubic spline fit of a limited number of fixed data points needed.

Calculated TPR ~2% less at depth. Cubic spline fit of 12 data points.

Nikesch et al, CyberKnife Center, Palm Beach, FL.

3D Scanner (Sun Nuclear)

- Setup Subjectivity
  - Automatic leveling, water surface detection and beam center detection
  - No tank shifts

- Detector orientation/resolution
  - 3D Scanner design always using the short dimension of chamber to scan

- Time
  - Setup is faster and more accurate
  - No tank shifts
  - Smaller tank fills and drains faster

Scanner Orientation Advantage

1. Ring drive maintains consistent scanning direction
2. Diameter drive has maximum scanning range of 640mm
3. Vertical drive has maximum travel of 400mm

Conclusions

- Golden Data should be taken as a reference only
- Understand time and amount of data to be taken
- View each parameters properly, double check by another individual
- Use proper detector for each type of data collection
- Set optimum speed for scanning, do not rush

Future technology & resources could help commissioning simpler.

Understand the limits and measuring condition
Question every unusual data set
Do not smooth data too much
Write report for future reference
Thanks