Calibration Needs in Medical Radiation for Patient Safety

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Disclaimer

The presenter has no conflicts to announce.

Presentation Objectives

To discuss how calibration fits into Patient Safety.

Patient Safety Goals

- In radiotherapy:
  1. Deliver the correct dose,
  2. To the correct location,
  3. Safely
- In diagnosis:
  1. Obtain an adequate image,
  2. With the minimum required radiation dose,
  3. Safely

In Radiotherapy

1. Deliver the correct dose
   - Obviously, in external-beam therapy, calibration enters here with calibration of the treatment unit.
   - From the calibration lab's point of view, this would be calibration of the chambers and electrometers.
   - $D_{ref}=M_{raw}P_{ele}P_{ion}P_{pol}P_{atm}k_{Q}N_{D,w}^{Co}$
   - We will be covering some of the evolving calibration needs in the medical breakout session.
   - However, calibration doesn't stop there.

In Radiotherapy

1. Deliver the correct dose
   - The calibration factors only serve to guide the physicist in actually calibrating the unit to maintain the correct dose per monitor unit.
   - Delivery of the correct dose requires determination of all the other factors that go into the dose calculation, such as S_c, S_p, FDD, WF, etc.
   - All of this is calibration. Particularly modeling the beam in the treatment planning system.

In Radiotherapy

1. Deliver the correct dose
   - In brachytherapy, Calibration also plays an important role:
     - In the calibration of the strength of sources, and
     - In calibration of the chambers also used to assay brachytherapy sources.

$$\text{Dose rate}(r,\theta) = S_K \Lambda\, g(r)\, F(r,\theta)\, G(r,\theta)/G(1\text{cm},90^\circ)$$

In Radiotherapy

1. Deliver the correct dose
   - Brachytherapy source calibration plays an important part in all brachytherapy, and we could not perform treatments without it, for example, of
     - ^{125}I
     - ^{103}Pd
     - ^{131}Cs
     - ^{192}Ir low dose-rate
     - ^{192}Ir high dose-rate
     - ^{90}Y microspheres
   - Without all these calibrations, patients would die unnecessarily.

In Radiotherapy

1. Deliver the correct dose
   - Most errors in calibration that have significant effects on patients have been due to erroneous entry of calibrations into treatment planning computers.
   - Of those, many have been entry of the correct numbers but the wrong units.
   - Such errors affect many patients, and sometimes by large amounts.
   - These are quite different from worrying about calibration standards to 3%.

In Radiotherapy

2. To the correct location
   - This also is subject to calibration,
   - Of positional controls (that set position, such as gantry position, or validation of positional parameter, such as isocenter.)
   - Of imaging systems' coordinate frame.
   - There are other factors, such as that treatment planning system places the beams correctly and that the edges of the beams are modeled, all of which need to be calibrated during commissioning.
   - Not that the calibration labs have anything to do with this, but it is calibration.

In Radiotherapy

3. Safely
   - Okay, not so much calibration here.
   - This would be procedural thing to prevent errors, such as patient identification or assuring that the file downloads happen correctly.
   - This discussion would be for a different meeting.

In Diagnostic Radiology

1. Obtaining an adequate image
   - Calibration of the basic parameters (kVp, mA, time) that determine image quality.
   - Assaying radionuclide activity.
   - Using calibrated sources to in turn calibrate imaging systems' spectrometers and sensitivity/efficiency.
   - Measuring the image quality.

In Diagnostic Radiology

2. With the minimum required radiation dose
   - Assessing the typical doses from procedures.
     - ★Calibrating chambers to measure doses from CT units.
     - ★Calibrating chambers for measuring doses from conventional radiography/fluoroscopic units, including mammographic units.
     - Again, calibrating dose calibrators to assure the correct activity for studies.
   - Titrating doses.

In Diagnostic Radiology

2. With the minimum required radiation dose
   - Calibrating chambers to measure doses from CT and conventional radiography/fluoroscopic units has become a hot topic because of some bad experiences.
   - We will be hearing about this in the Medical Break-out session.

In Diagnostic Radiology

2. With the minimum required radiation dose
   - Measuring and titrating the doses used in medical imaging is much more important with digital imaging than convention radiographic systems.
   - With film, excessive doses would make the images too dark (some times, but sometimes the processors were adjusted to bring the images back to "normal.")
   - Digital systems lack this feed-back, and generally just show less noise with higher doses.

In Diagnostic Radiology

3. Safely
   - This mostly covers:
     - Mechanical safety
     - Procedural safety
     - Minimizing the dose
   - Which either do not deal with calibration (at least, not radiation calibration, or we have covered.

Safely

- Let's take one last look at the "Safely" item on both the Radiotherapy and Diagnostic Imaging lists.
- One facet that *does* involve calibration is use of radiation survey meters.
- Most practitioners in standards are not too excited about calibrating survey meters, probably because of the large variations allowed and maybe the lack of challenges, except possibly for heavier particles.

Levels at which Physicists Calibrate

- Acceptance Testing
- Commissioning
- Periodic Testing
  - Daily
  - Weekly
  - Monthly
  - Annually
- Per patient

Future Needs

What with all the calibration going on, there are still venues that need addressing.

- High dose-rate ^{192}Ir sources
- ^{90}Y microspheres
- Other new radionuclide sources (^{169}Yb, ^{131}Cs, etc.)
- For electron beams, $N_{D,w}^{Q_e}$ to replace $k_Q k_{ecal} N_{D,w}^{^{60}Co}$

- For photon beams, $N_{D,w}^{Q}$ to replace $k_Q N_{D,w}^{^{60}Co}$

Notice, However

- Problems with patient safety can produce
  1. Major errors that can compromise an individual patient's treatment outcome, or
  2. Less severe errors that can affect a large group of patients, the effect of which can only be seen statistically.
- Calibration at the user level can lead to either, and most often is a procedural error.
- Usually, errors at the calibration lab only fall into the second class. And usually that is because haste is not the hallmark of standards labs.

Summary

With respect to patient safety,

- Patient safety is mostly a procedural issue. But,
- There's a whole lot of calibration going on.
- Much of it mediated through the standards laboratories.
- But not all.
- While many calibration needs are satisfied currently, there still remains work to be done.