The role of the National Physical Laboratory in monitoring and improving dosimetry in UK radiotherapy

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Introduction

NPL as a National Measurements Institute has the role of maintaining and disseminating the UK's primary standards in various fields to the user communities. Being somewhat removed from the end user may on occasion lead to something of a detachment to the consequences if/when that dosimetry chain fails. The aim of this poster is to demonstrate how completing the circle from end user back to NPL specifically in terms of audit can assist in the correct implementation of the standards, and allow us to monitor the success or otherwise of the dissemination of the primary standards through Codes of Practice, User Guides and our calibration services. Further this also allows us to better understand users issues and requirements and build on this to develop further services and consultancies to meet their needs.

Why is audit required?

The following cases demonstrate the implications when errors are made in Radiotherapy Physics. All these cases were found to have been at least partially attributable to the lack of independent/peer audit:

Case 1: Use of an incorrect decay curve for $^{60}$Co (USA, 1974-76)

A decay curve for $^{60}$Co was incorrectly drawn with the slope steeper than intended. Based on this patient treatment times were calculated to be longer than appropriate, thus leading to overdoses. This error was compounded with time reaching up to a 50% overdose at the point at which the error was discovered.

There were no beam measurements in 22 months and a total of 426 patients affected.

Only 183 patients survived for one year of which 34% had severe complications.

Case 2: Incomplete understanding & testing of a treatment planning system (TPS) (UK, 1982-90)

When a computerised Treatment Planning System was acquired, technologists continued erroneously to apply a manual distance correction, without realising that the TPS algorithm already accounted for distance. This led to an under dosage of up to 30%.

The problem remained undiscovered during eight years affecting 1,045 patients of whom 492 patients developed local recurrence probably due to the underexposure.

Case 3: Incorrect accelerator repair & communication problems (Spain, 1990)

Accelerator fault was followed by a faulty repair. The electron beam was restored but electron energy was misadjusted meaning 36 MeV electrons were delivered, regardless of energy selected. Treatments resumed without notifying physicists for beam checks.

27 patients were affected with massive overdoses and distorted dose distributions due to wrong electron energy. At least 15 of these patients died from the accidental overexposure and two more died with overexposure as major contributor.

Case 4: Beam miscalibration of $^{60}$Co (Costa Rica, 1996)

The radioactive source of a teletherapy unit was exchanged. During beam calibration, reading of the timer was incorrect, leading to underestimation of the dose rate. Subsequent treatment times were calculated with the wrong dose rate and were approximately 60% longer than required.

115 patients were affected; two years after the event, at least 17 patients had died from the overexposure.

In the late 80’s as a response to this kind of incident the Institute of Physics and Engineering in Medicine (IPEM) set up a working party to implement a rigorous and national system of audit within the UK. This resulted in the division of the UK into 8 regions, who would conduct peer-to-peer visits on an annual basis. Between 1990 and 1994 NPL’s role

Initially, NPL’s reference dosimetry audits covered NV photon beam measurements only, but they have now been increased to include electron beam and kV x-ray measurements. The aim of these extra audits is twofold: to pick up any inter-regional differences which would be missed by the regional audits, and to check the dissemination of the UK standard of absorbed dose to the end of the calibration chain. This is achieved by measuring absorbed dose under reference conditions following the appropriate UK Code of Practice for each modality.

NPL has now conducted dosimetry audits at over 50 radiotherapy departments and has also visited the first Tomotherapy and Cyber Knife units installed in the UK to perform output measurements prior to patient treatment.

Results

The table summarises audit results in terms of the mean of the ratio of NPL to the host. The standard deviation of the mean is also given.

To date, nearly 70 audits have been performed. Consistent and similar agreement between NPL and the host department has been achieved for all modalities.

<table>
<thead>
<tr>
<th>Modality</th>
<th>Beam quality</th>
<th>Ratio NPL/Host</th>
<th>Field measurement calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron</td>
<td>0.998 ± 0.005</td>
<td>1.002 ± 0.007</td>
<td>1.001 ± 0.007</td>
</tr>
<tr>
<td>Megavoltage photons</td>
<td>0.998 ± 0.004</td>
<td>1.003 ± 0.003</td>
<td>1.002 ± 0.003</td>
</tr>
</tbody>
</table>

Conclusion

NPL’s role in audits of UK radiotherapy centres has contributed to:

- Linking the eight regional audit groups
- Expanded into kV photons and electrons
- Support for development of Alanine based services for Gamma Knife, Tomotherapy Cyber Knife, Protons and the National IMRT audit
- Enabled departments to implement confidently new codes of practice

Directly Funded Audits / Services

- Purchased by individual trusts supplementary to the NPL/IPEM
- Independent check prior to machines being made clinical

References:


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