Performance Reproducibility of Intra Operative Radiotherapy Equipment – Photon Radiosurgery System

Kris Armoogum, J. M. Parry, C. D. Mackay, S. K. Souliman

Department of Radiotherapy and Oncology
Ninewells Hospital, Dundee, Scotland

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IORT in the UK

Two IORT centres -
- Ninewells Hospital and Medical School (Dundee)
  Treat approx. 35 patients per year.
- University College (London)
  Treat approx. 30 patients per year.
Ninewells Hospital (Dundee)

- Large teaching hospital providing care for population of approx. 0.5 million
- Oncology Service to 1400 new cancer patients annually.

3 Linear Accelerators (Varian) • HELAX Treatment Planning
IORT • LDR Brachytherapy • PLATO Brachy Planning System
Pantak DXT300 • Simulator (CT Ext.) • VISIR • Mould Room
Intraoperative Radiotherapy (IORT) is defined as the delivery of a single, large radiation dose to the bed of a resected tumour at the time of surgical intervention.

In early stage breast cancer, IORT avoids unnecessary irradiation of the whole breast [1].

We are investigating whether a single high dose imparts the same clinical benefit as external beam radiotherapy (typically 6 weeks).

The Potential of IORT

In breast cancer, IORT may potentially replace EBRT in the treatment of stage I patients undergoing wide local excision (WLE).

These patients represent about 33% of the projected 2011-2015 EBRT breast cancer workload (Scotland) and therefore, if IORT is proven to be clinically effective a considerable workload would be directed away from external beam services [2].

“... if IORT replaces EBRT for early breast cancer this would have a profound effect on the requirement for machine capacity”.

IORT Equipment at Ninewells

- Four Intrabeam™ X-ray sources (Carl Zeiss Surgical, Germany).
- Currently used to treat breast and neurological tumour sites.
The Miniature X-Ray Source

- Each XRS weighs 1.62 kg, has dimensions 17.5 x 11 x 7 cm with a 3.2 x 100 mm long chromium nitride coated probe.
How does it work?

- Beam accelerated through field (up to 50 kV).
- Beam current is selectable (up to 40 µA).
- Gold target (1 µm). Effective energy 5-20 keV.
- Spherical dose distribution ~ 2.5 Gy/min at 10 mm.
Device Intercomparison

- Performance of four x-ray sources was compared over a period of seven months.
  - Half Value Layer
  - Depth Doses in water
  - Output Trends
  - Internal Rate Monitor (IRM) reproducibility
  - Accuracy of treatment time.
The HVLs for all XRS were determined by a broad beam method; probe 20 cm from IC, Al attenuators near the midpoint.

Attenuator thickness 0.03 to 3.00 mm.

To quantify beam hardening at prescription depths, 5 and 10 mm of solid water attenuators placed ~ 2 cm from probe.
HVL Setup

10 cm  
Attenuators

20 cm  
Solid water

XRS

Soft X-ray IC

Dosemeter

Controller
HVL Results

- Unattenuated beam ~ 0.11 mm Aluminium
- 5 mm solid water ~ 0.54 mm Al.
- 10 mm solid water ~ 1.11 mm Al.
- Equivalent energies approx. 12 and 24 keV.
Comparison of Normalised HVLs

Comparison of Normalised HVLs

Normalized Reading vs. mm Al

- XRS300
- XRS313
- XRS315
- XRS345
Depth Dose in Water

- Chamber output measured at 10 to 35 mm from probe tip in water.

- Custom-built water phantom.

- Low kV x-ray parallel plate IC (PTW N23342).
Depth Dose Curves

Normalised Depth Dose Comparison

Dose Rate $\sim 1/r^3$

Normalized Dose Rate (Gy/min)

Depth (mm)

XRS300 XRS313 XRS315 XRS345
Output Trends

- Weekly calibrations on four x-ray sources.

- An internal rate monitor (IRM) test procedure used to check the response of the IRM.

- The IRM count rate obtained during this verification procedure is used in clinical treatment time calculation.
Intercomparison of Output Trend with Time
IRM Reproducibility

Reproducibility of the IRM dosimetry system was investigated for increasing exposures.

Exposure controlled using a pre-set number of IRM counts at a count rate of approx. $7 \times 10^4$ cps (at 50kV, 40µA).

Measurements made for exposures equal to counts of 4, 20, 40, 60 x $10^6$, equivalent to exposures of 1, 5, 10 and 15 minutes.
IRM Reproducibility

Difference between the preset IRM limit and IRM count obtained on beam termination was < 0.1%.

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<td>B</td>
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Mean: 0.01%

XRS 000313
IRM Count Rate = 7.269 x 10^4 Hz
50kV, 40uA. Controller S/N 000034
Clinical Treatment Times

- Clinical treatment times were recorded for 25 breast and 14 brain cancer patients.

- The mean difference between the calculated and actual treatment times for breast patients was 0.46% and for brain patients 0.37%.
Conclusions

- The four x-ray sources have proven to be stable over time.
- Measurements were found to lie within the manufacturer’s tolerances.
- Intercomparison shows that the x-ray sources have similar performance characteristics.
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www.medicalphysicist.co.uk
And finally…

Breast

Neuro