

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

What is IORT?

- ◎ **I**ntra**O**perative **R**adio**T**herapy (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).

[1] Vaidya JS, Baum M *et al*. The novel technique of delivering targeted intraoperative radiotherapy (Targit) for early breast cancer. *Eur J Surg Oncol*. 2002;28:447-54.

The Potential of IORT

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

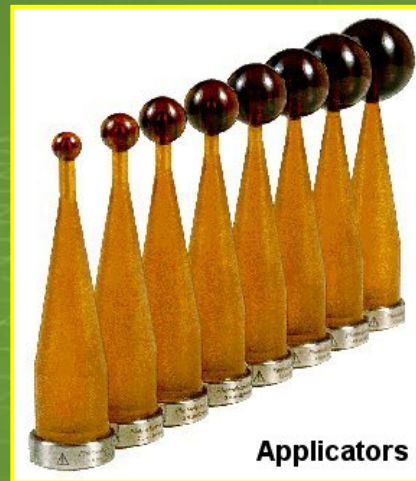
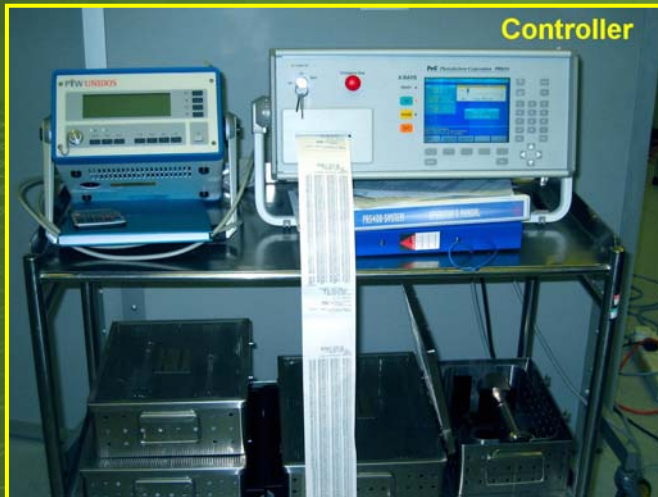
These patients represent about 33% of the projected 2011-2015 EBRT breast cancer workload (Scotland) and therefore, if IORT is proven to be clinically effective a considerable workload would be directed away from external beam services [2].

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

[2] Scottish Executive Health Department (2005) Cancer in Scotland: Radiotherapy Activity Planning for Scotland 2011 - 2015. Edinburgh: The Scottish Executive.

IORT Equipment at Ninewells

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

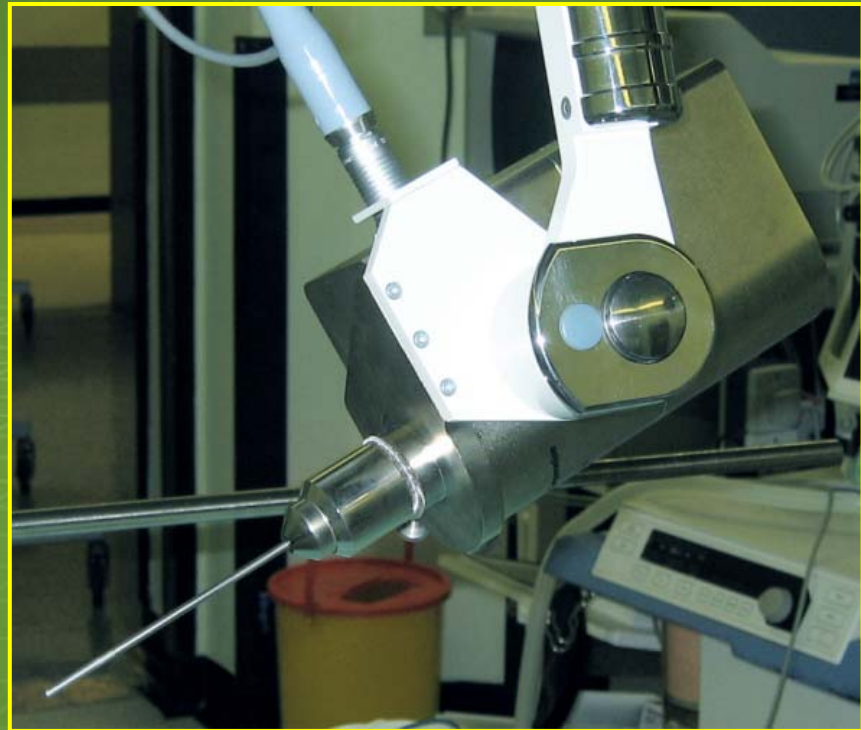


1.5 – 5.0 cm



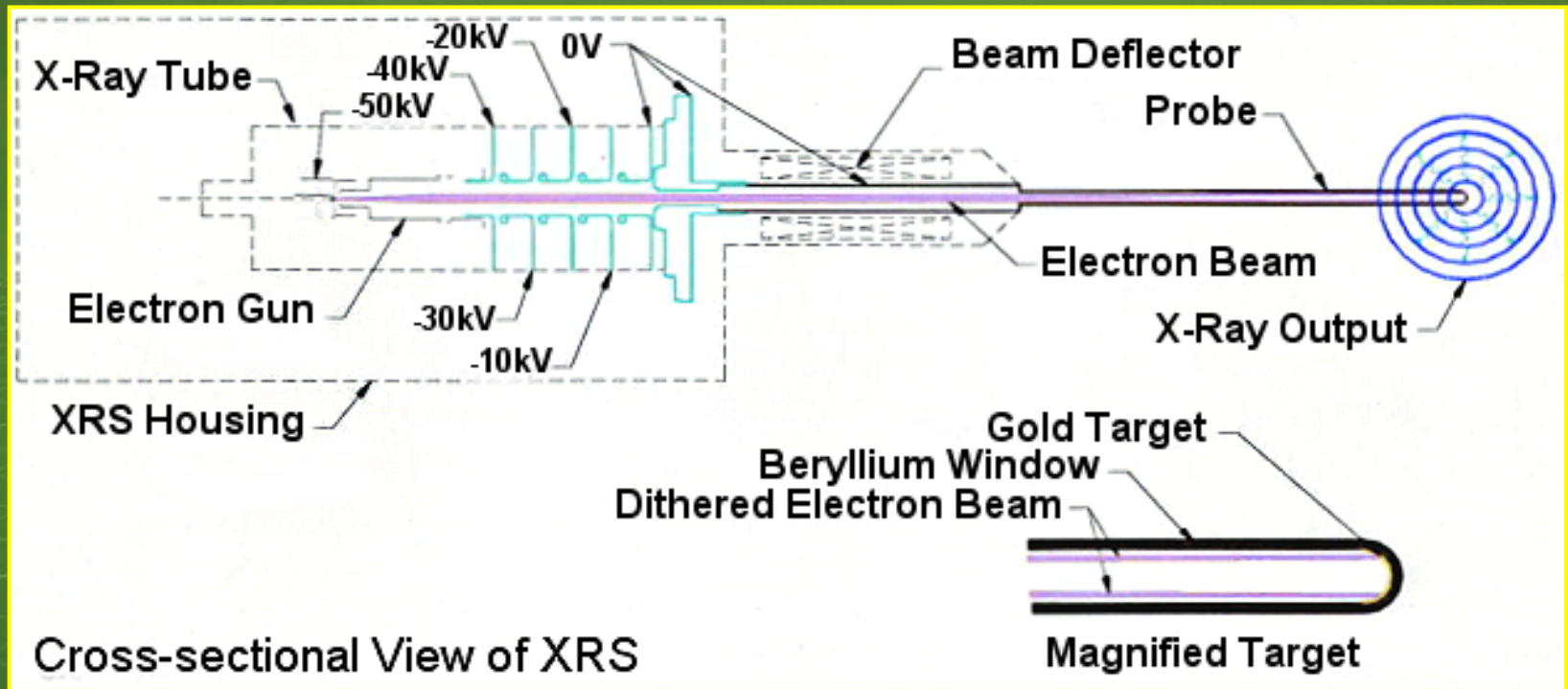
The Miniature X-Ray Source

© 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?

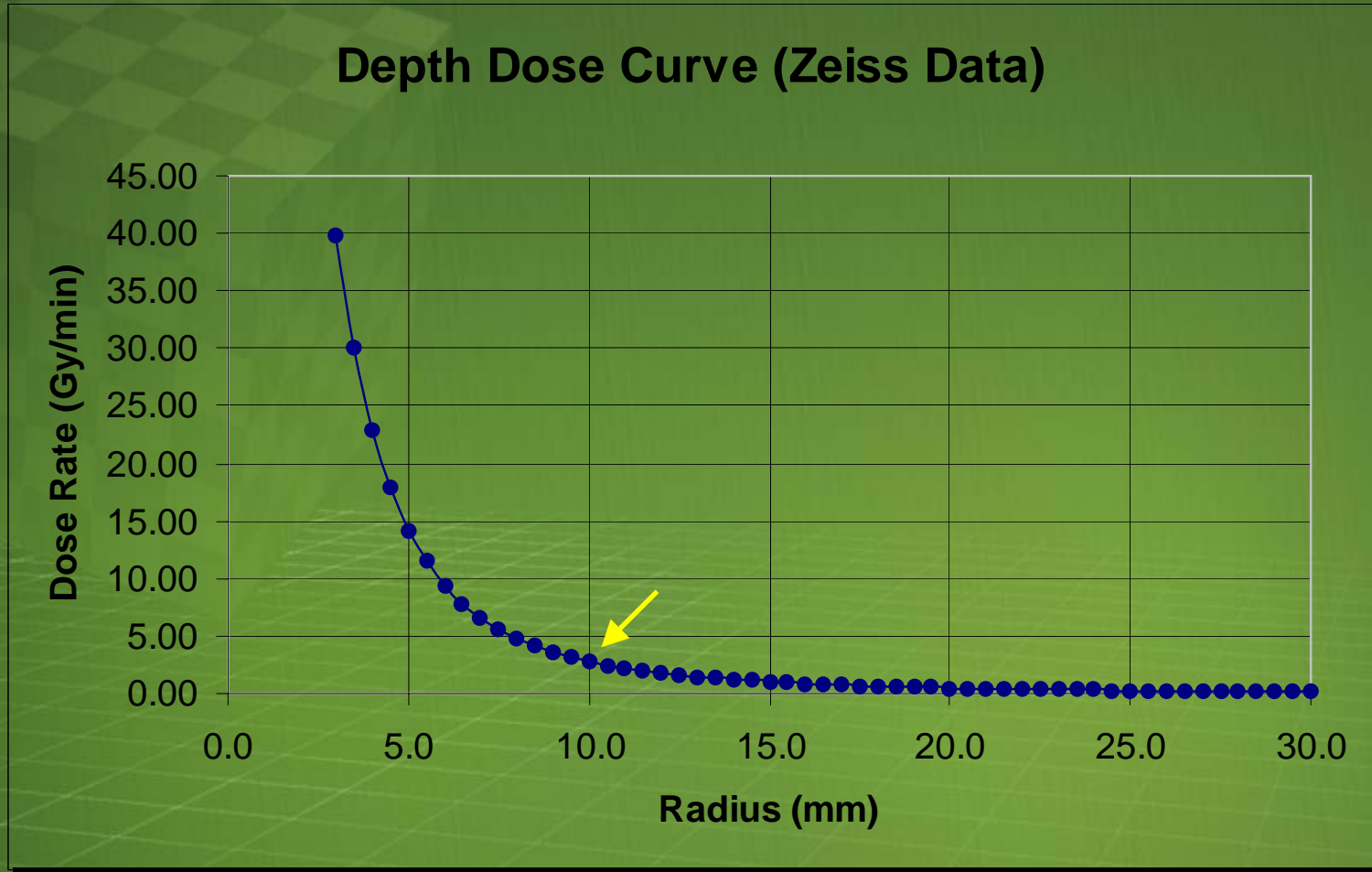
- ◎ Beam accelerated through field (up to 50 kV).
- ◎ Beam current is selectable (up to 40 μA).
- ◎ Gold target (1 μm). Effective energy 5-20 keV.
- ◎ Spherical dose distribution $\sim 2.5 \text{ Gy/min}$ at 10 mm.



Cross-sectional View of XRS

Magnified Target

Depth Dose Curve



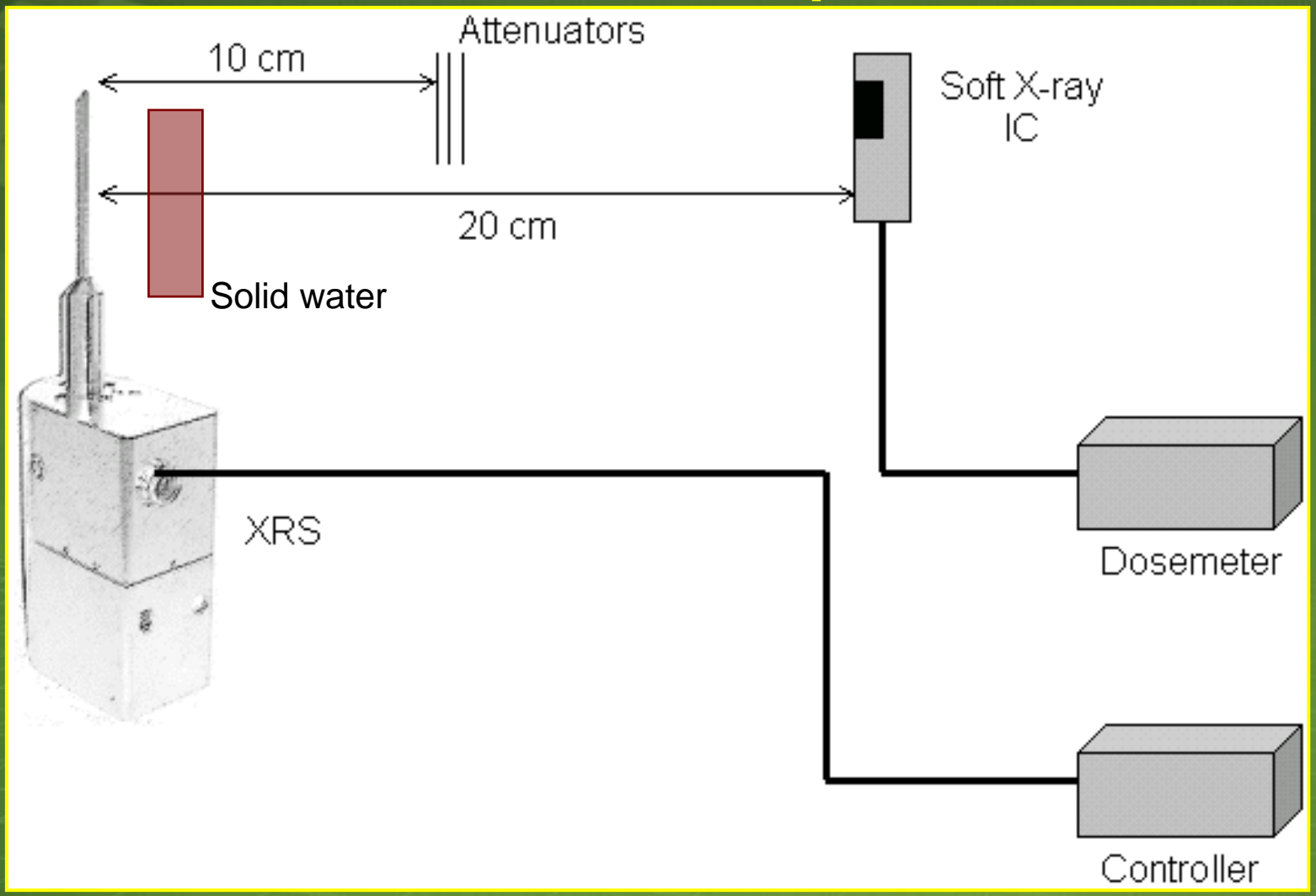
Device Intercomparison

- ◎ 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.

Half Value Layer

- 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.

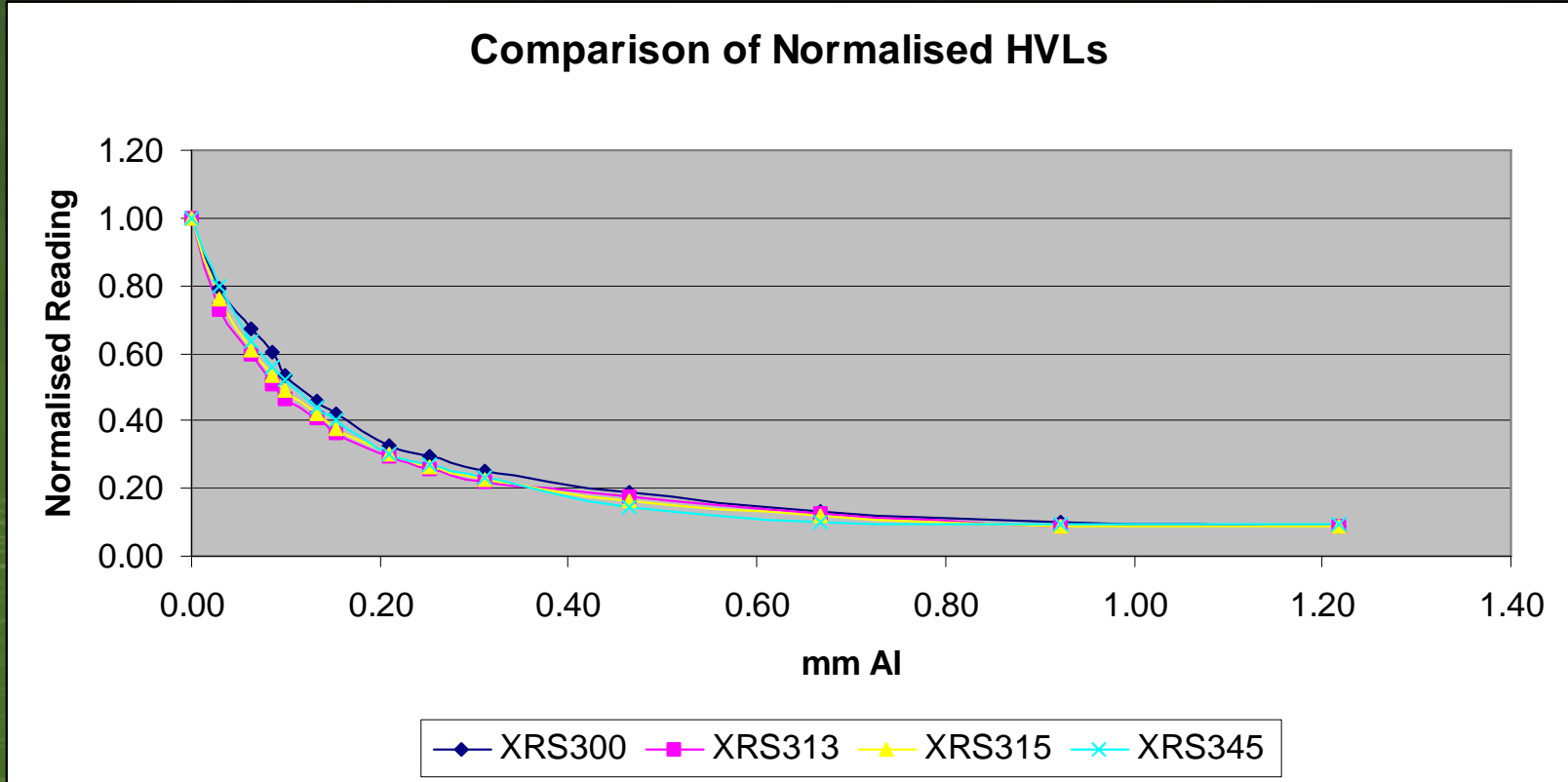
HVL Setup



HVL Results

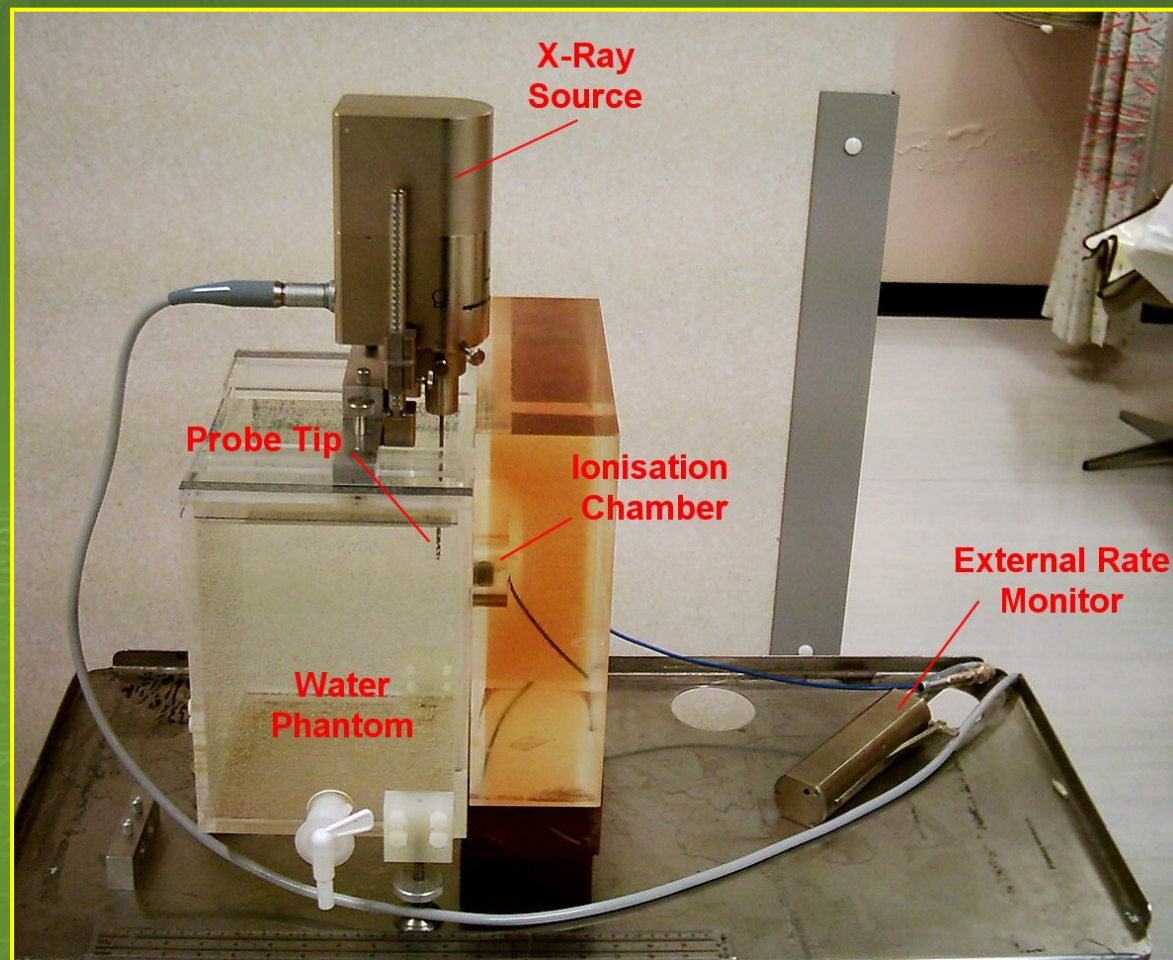
- Unattenuated beam ~ 0.11 mm Aluminium
- 5 mm solid water ~ 0.54 mmAl.
- 10 mm solid water ~ 1.11 mmAl.
- Equivalent energies approx. 12 and 24 keV.

Comparison of HVLS



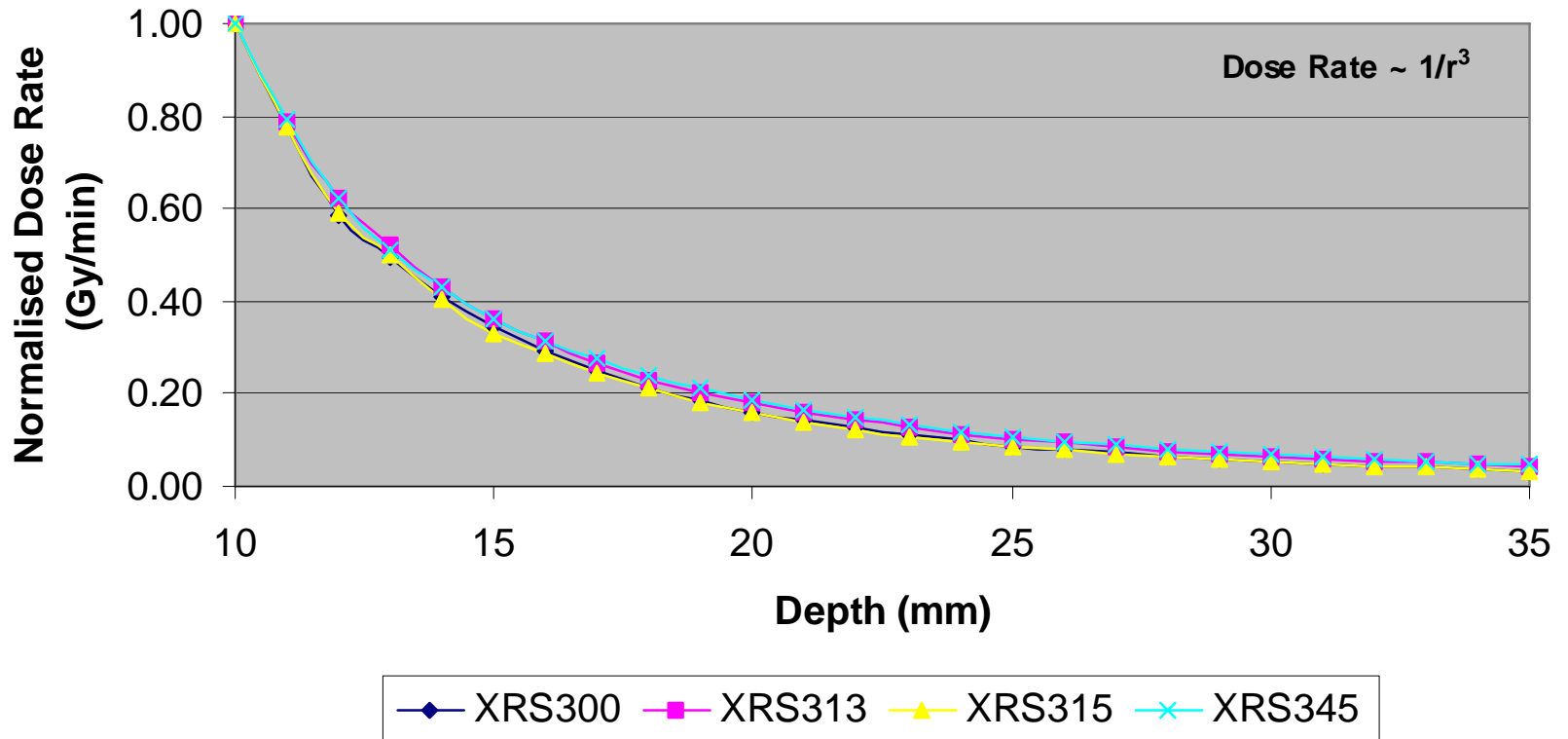
Depth Dose in Water

- ◎ 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

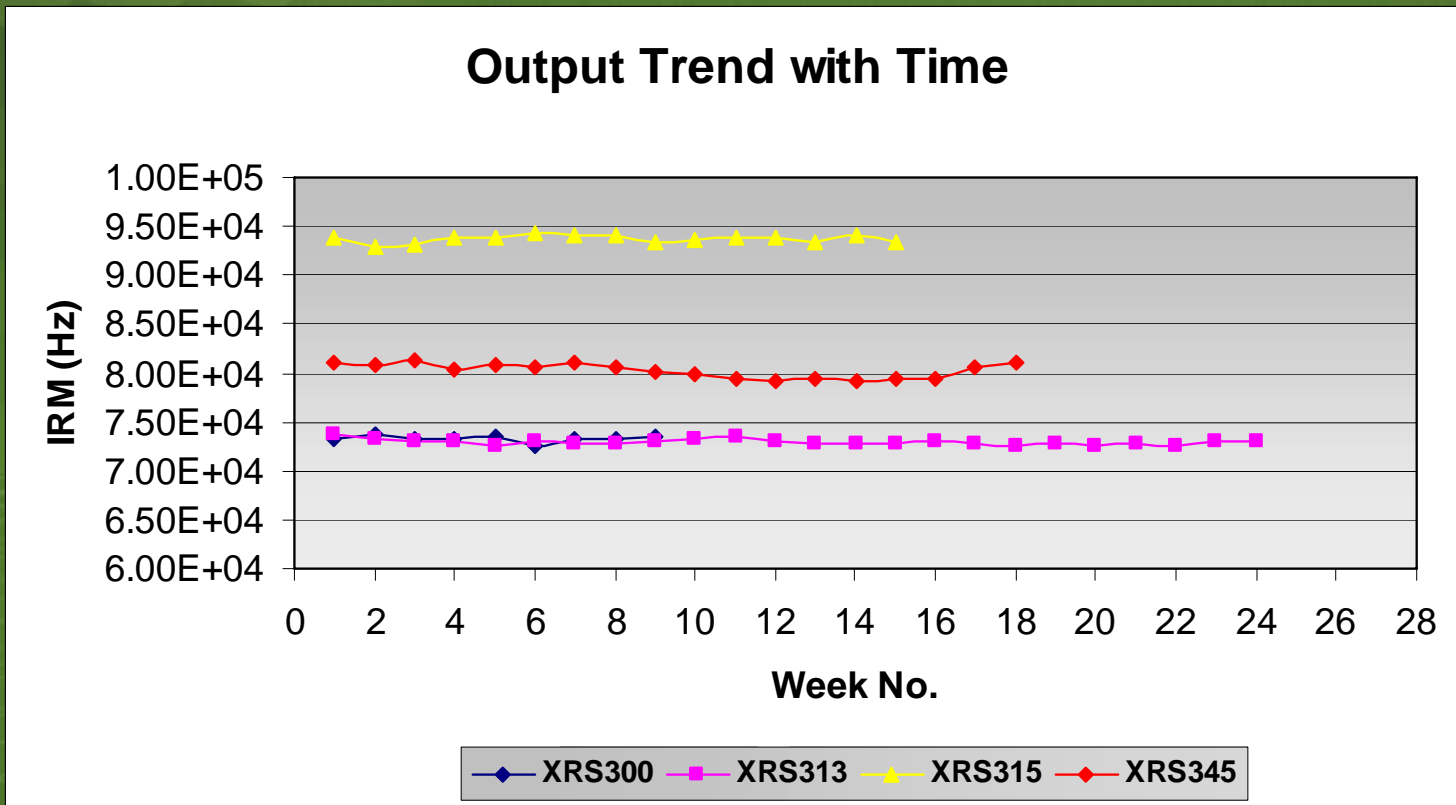
Normalised Depth Dose Comparison



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. 7×10^4 cps (at 50kV, 40 μ A).
- ◎ Measurements made for exposures equal to counts of 4, 20, 40, 60 $\times 10^6$, 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 $< 0.1\%$.

A		B		
IRM Limit	Time (min)	IRM Limit	Beam ON	% Diff.
Calculated		Beam Termination	Average	(A:B)
$\times 10^7$ Cnts		$\times 10^7$ Cnts	mins	
0.4361	1.00	0.4361	1.001	0.00%
2.1807	5.00	2.1810	4.978	0.01%
4.3614	10.00	4.3610	9.967	0.01%
6.5421	15.00	6.5420	14.916	0.00%
			Mean:	0.01%

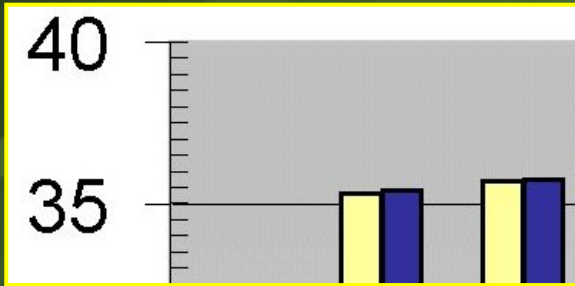
XRS 000313

IRM Count Rate = 7.269×10^4 Hz
50kV, 40uA. Controller S/N 000034

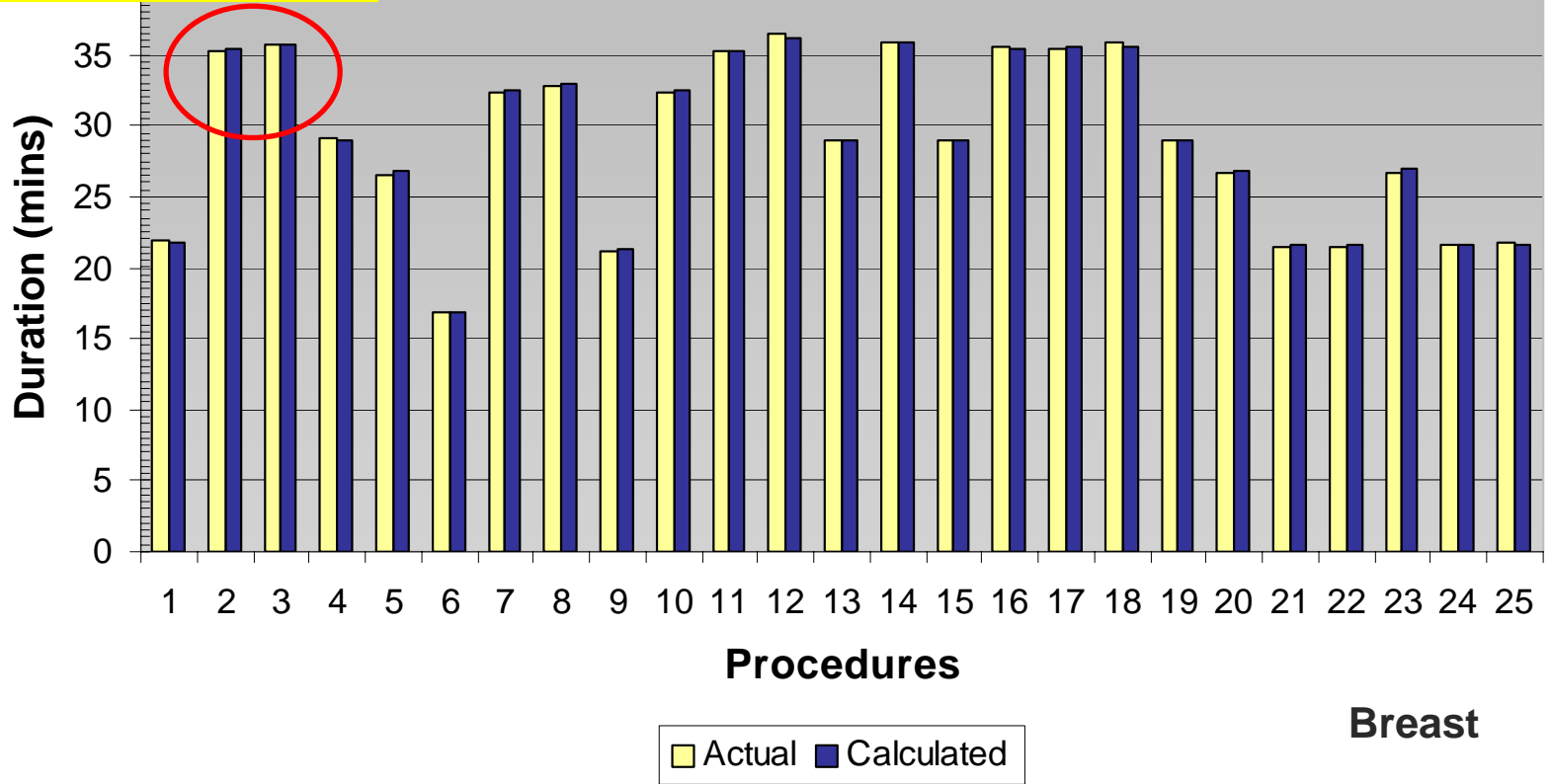
Clinical Treatment Times

- 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%.

Clinical Treatment Times



Calculated v Actual Clinical Treatment Time



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...

