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Modelling the impact of machine specific dosimetric variations on clinical outcomes

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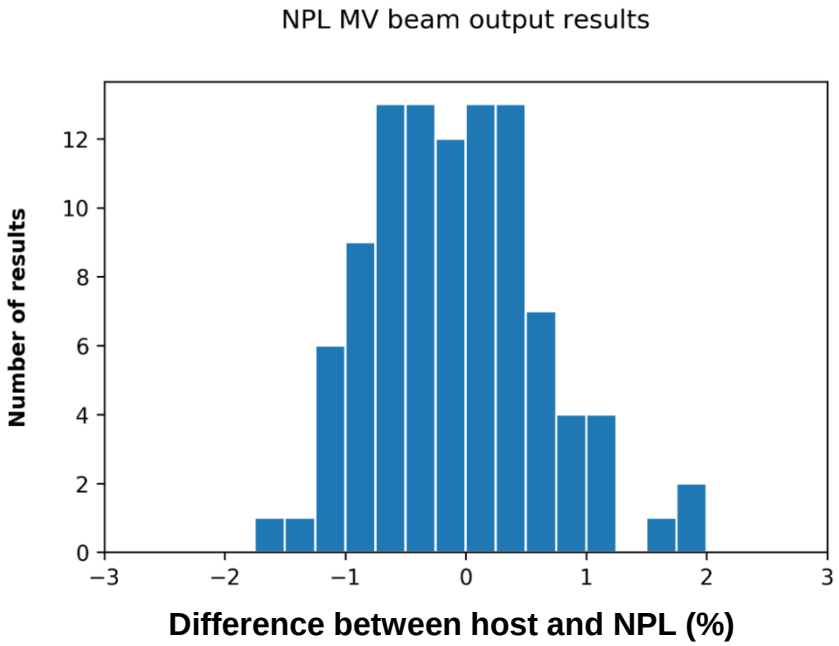
Introduction

- Assess uncertainty in dose delivery due to
    - Initial calibration uncertainty
    - Variation in beam output
- Compare with variations due to treatment planning technique
- Quantify the clinical impact of beam output variation using radiobiological models

Beam calibration uncertainty

- Quantified based on UK wide dosimetric audits conducted by the NPL over 20 years.

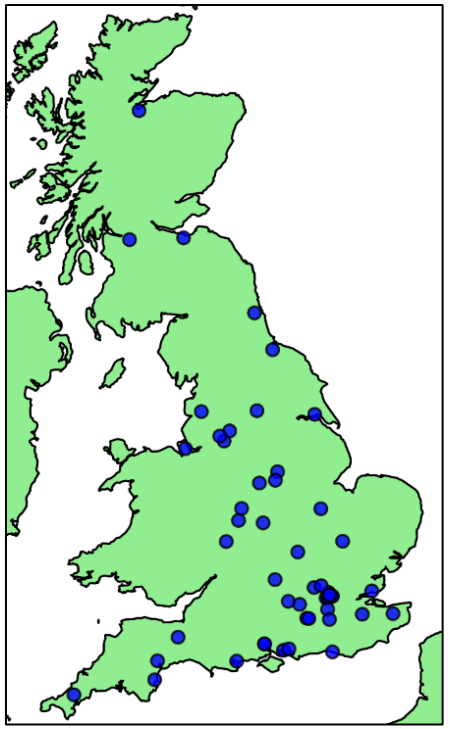
- MV photon beams
  - Normally distributed
  - Mean = -0.06%
  - Std. dev = 0.68%



Thomas, R. A. S. et al. (2017) 'Radiotherapy reference dose audit in the United Kingdom by the National Physical Laboratory: 20 years of consistency and improvements', **Physics and Imaging in Radiation Oncology, 3, pp. 21–27.**

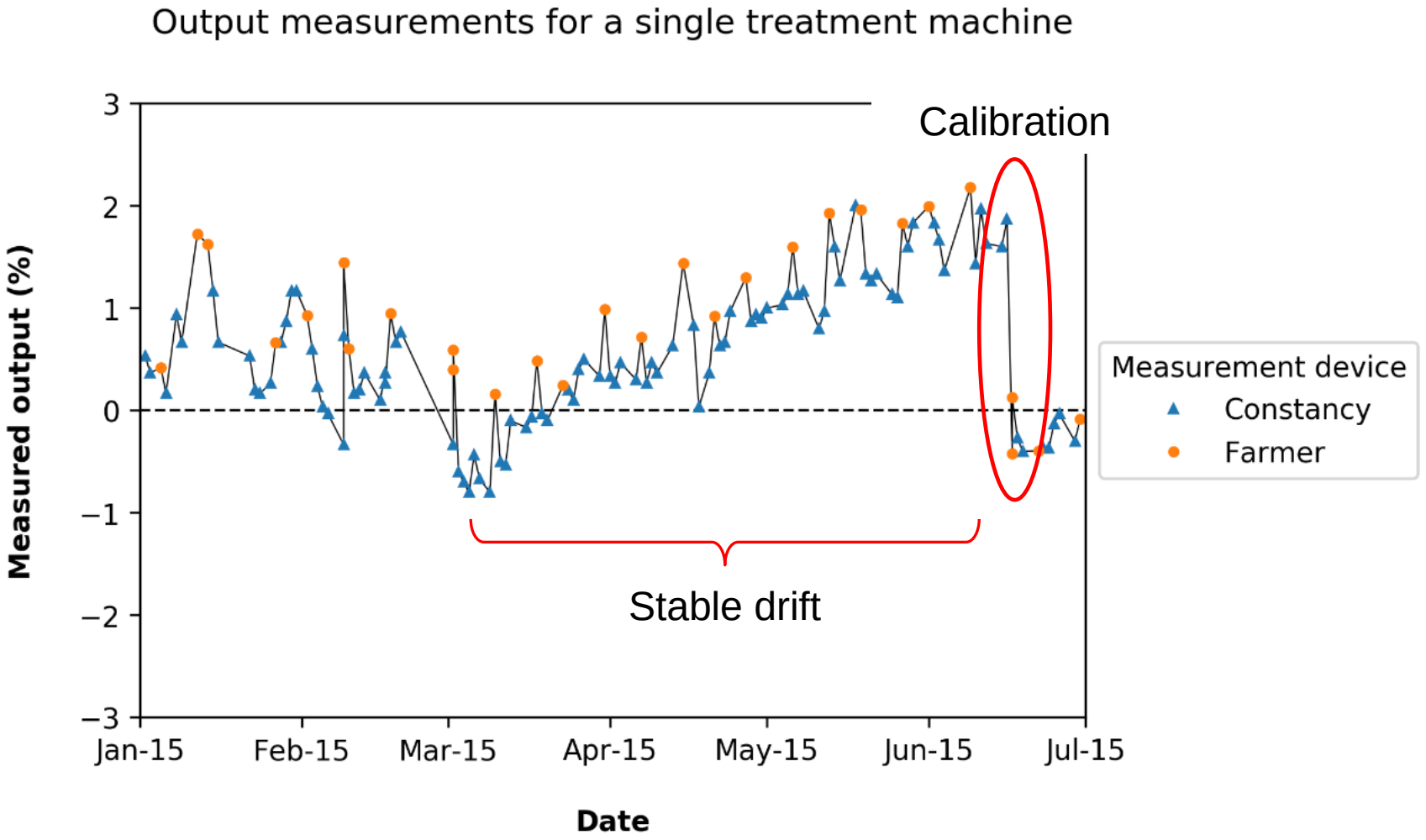
Beam output uncertainty

- Data collated from 52 UK centres, 204 machines
  - 96 Varian linacs,
  - 92 Elekta linacs
  - 12 Seimens linacs
  - 3 Tomotherapy
  - 1 Cyberknife
- 25,000 measurement sets
  - 6MV Jan – June 2015



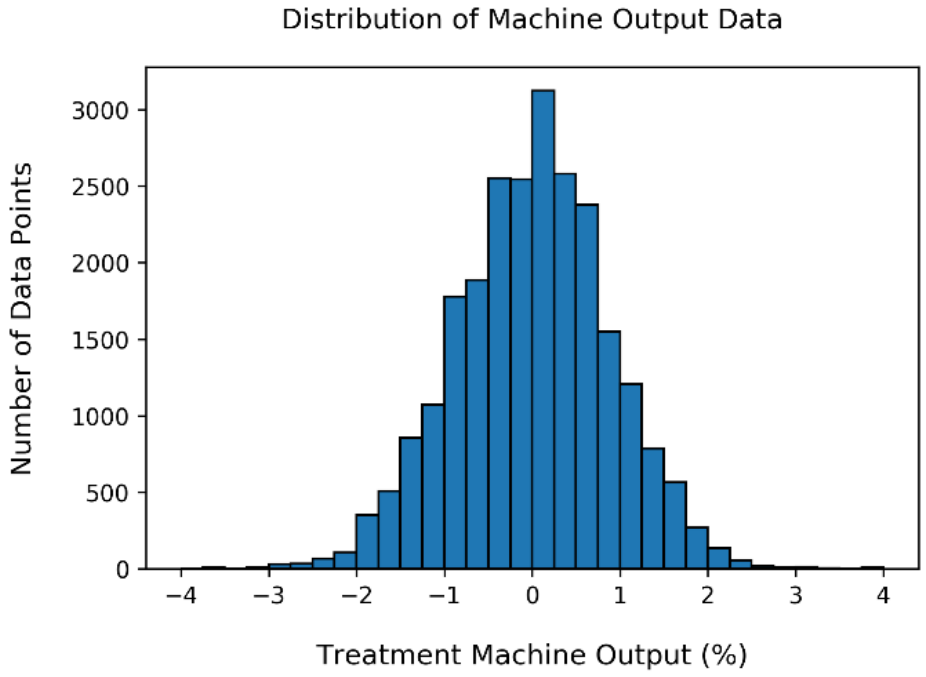
Bolt, M. A. *et al.* (2017) 'A multi-centre analysis of radiotherapy beam output measurement', ***Physics and Imaging in Radiation Oncology***. Elsevier, 4(October), pp. 39–43.

Typical beam output data



Distribution of delivered doses

- Dose delivered varies dependant upon machine patient is treated on.
    - Mean beam output 0%
    - Standard deviation 0.7%



Dose variation summary

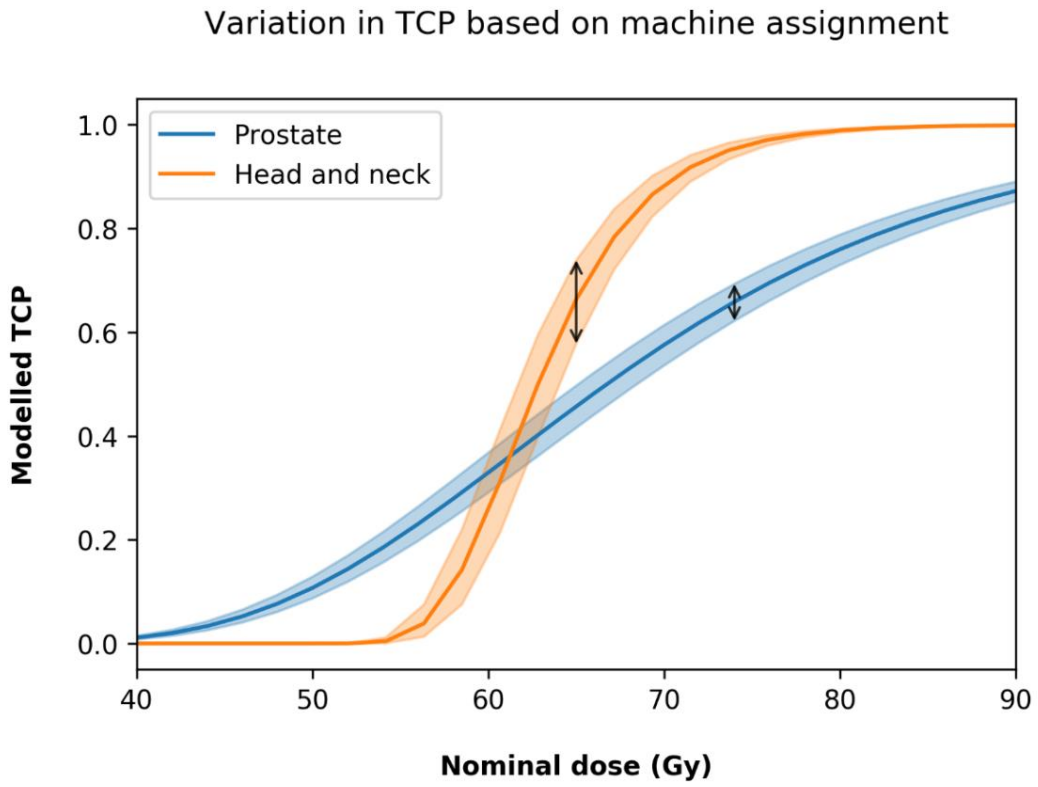
Source of dose deviation		Standard deviation	95% CI
A – Initial beam calibration		0.7%	1.4%
B – Systematic beam output deviation		0.7%	1.4%
C – Beam output daily fluctuations		0.2%	0.4%
Combined uncertainties:	A ∗ B	1.0%	1.9%
	A ∗ B ∗ C	1.0%	2.0%

Clinical site	Outcome measure		Fractionation
	TCP	NTCP	
Prostate	bPFS @ 10yrs	Rectal bleeding	74Gy/37#
Head & Neck	2yr survival	xerostomia	65Gy/30#

Models used	
TCP	Linear Quadratic
NTCP	Lyman Kutcher Burman

Variation due to treatment machine

- Take same patient with fixed biological parameters.
    - E.g. α/β = 1.5 for prostate, 10 for H&N
- Model same treatment on 1000 different linacs (1.0% SD in dose)



5th – 95th percentile range

TCP

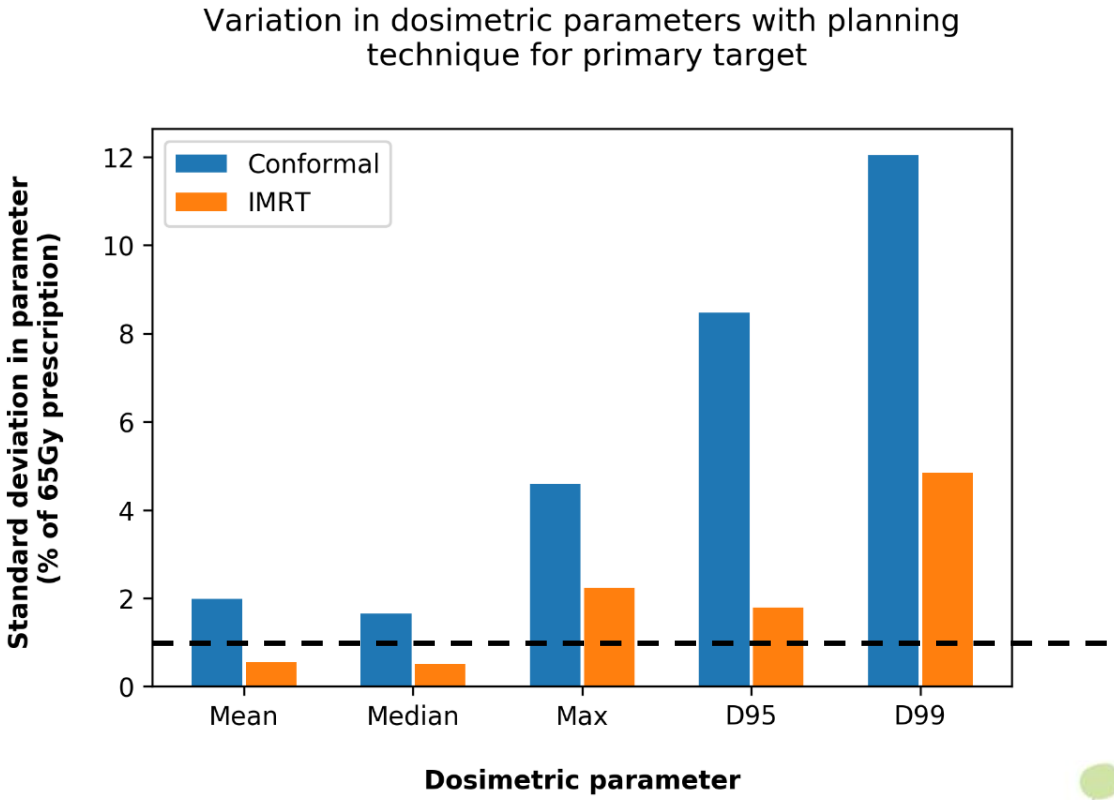
Prostate:	7.1%
H&N:	16.1%

NTCP

Rectum:	8.9%
Par. Conf.:	2.0%
Par. IMRT:	2.7%

Dose variation in context

- DVHs were extracted from PARSPORT trial plans.
- Use of IMRT reduces variation in planned Target doses



Dose variation due to beam output alone

Summary

- Variation in dose delivery due to beam output is normally distributed with standard deviation of 0.7%.

- The move from conformal to IMRT planning reduces the target dose variation by over 50%.
    - Resulting in the magnitude of beam output variations being larger than variation due to treatment planning.

- Clinically realistic values of beam output may give rise to variations in clinical outcome of >15% for typical patients.

Thank you

Additional thanks

- NPL staff in the radiation dosimetry group.
- All those who dedicated time to collate and submit routine output data for this study.

References

Thomas, R. A. S. et al. (2017) 'Radiotherapy reference dose audit in the United Kingdom by the National Physical Laboratory: 20 years of consistency and improvements', **Physics and Imaging in Radiation Oncology, 3, pp. 21–27**.

Bolt, M. A. et al. (2017) 'A multi-centre analysis of radiotherapy beam output measurement', **Physics and Imaging in Radiation Oncology. Elsevier, 4(October), pp. 39–43.**

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