A Universal Beam Model for SIMT-SRS VMAT on Varian TrueBeam™

Cameron Stanton[1], Peter Greer[2], Iliana Peters[1], Ching-Ling Teng[3], Ashley Cullen[4], Conor McGarry[5], Andrew Dipuglia[2], Xiaodong Zhao[6], Emily Searle[1], Michael Lovelock[7], Victoria Robinson[5], Sergei Zavgorodni[8], Baozhou Sun[9], Matthew Schmidt[6], Juan-Francisco Calvo-Ortega[10], Michael Barnes[2], Richard Popple[11], Seng Boh Lim[12], and Benjamin Zwan[2].

2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

CONTACT

Name: Cameron Stanton, MSc
Email: Cameron.Stanton@health.nsw.gov.au
Phone: +612 4320 9829

AFFILIATIONS

[1] Central Coast Cancer Centre, Gosford Hospital, Gosford NSW 2250, AUS
[2] Calvary Mater Newcastle Hospital, Waratah, NSW 2298, AUS
[3] Northwell, New Hyde Park, NY 10042, USA
[4] Chris O'Brien Lifehouse, Camperdown, NSW 2050, AUS
[5] Northern Ireland Cancer Centre, Belfast, Northern Ireland BT9 7JL, UK
[6] Washington University in St Louis School of Medicine, St. Louis, MO 63110, USA
[7] Mount Sinai Hospital, New York, NY 10029, USA
[8] BC Cancer – Victoria (Vancouver Island Centre), Victoria, BC V8R 6V5, CAN
[9] Baylor College of Medicine, Houston, TX 77030, USA
[10] Hospital Quironsalud Barcelona, Barcelona 08023, ESP
[11] The University of Alabama at Birmingham, Birmingham, AL 35233, USA
[12] Memorial Sloan Kettering Cancer Center, New York, NY 10065, USA

INTRODUCTION

Single-isocentre multi-target (**SIMT**) stereotactic radiosurgery (**SRS**), together with non-coplanar volumetric arc radiotherapy (**VMAT**), delivers highly conformal and ablative radiation doses for the treatment of small (≤ 20mm size) off-axis intracranial targets in a single plan delivery.

The electronic amorphous silicon p-i-n-based remote survey of small-field output (**ESPRESSO**) consortium consists of 11 international radiotherapy institutes, formed with a vision to mitigate the risks and challenges associated with SIMT-SRS VMAT beam model commissioning, PSQA and auditing (benchmarking).

Treatment planning system (TPS) **beam modelling** represents 4 of the 5 top ranking risk failure modes in radiotherapy [1] - with atypical beam model configuration identified as the largest cause of independent dosimetry audit failure in the large-field setting [2]. In the small-field SIMT-SRS VMAT setting, source occlusion and loss of lateral charge particle equilibrium (CPE) magnifies the sensitivity of any inaccuracies in beam model configuration [3, 4] – with associated dose measurements being resource intensive and subject to increased uncertainty due to phantom-detector positioning and perturbation effects.

AIM

The **aim** of the ESPRESSO group in this study was to develop and validate a universal beam model (**UBM**) for SIMT-SRS VMAT delivered on Varian TrueBeam™ to minimise risk of gross and systematic beam modelling errors. The **hypothesis** was the demonstrated small field dosimetric equivalence of Varian TrueBeam equipped with a high-definition multi-leaf collimator (HD-MLC) enables the implementation of a UBM capable of achieving dose calculations within ± 5% accuracy of measured dose.

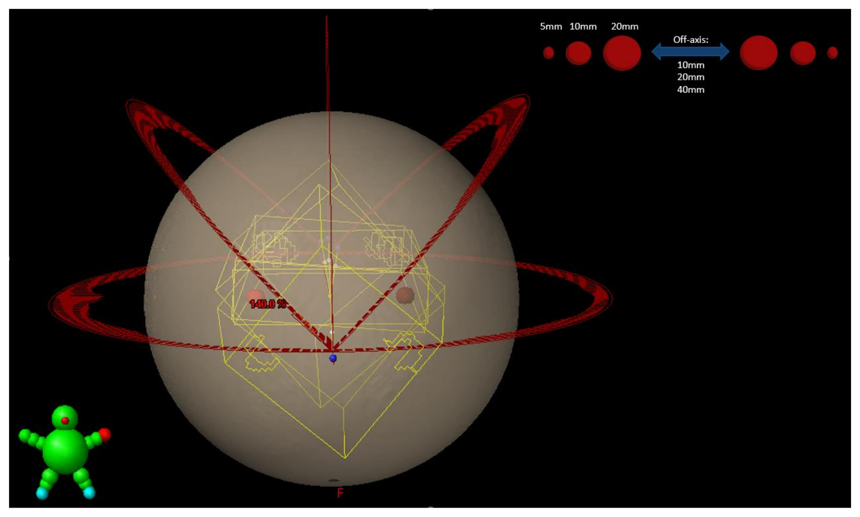

Fig. 1: Depiction of the planned SIMT-SRS coaxial target volumes and VMAT arc arrangement. Jaw positions were fixed to include both PTVs (jaw tracking disabled), with collimator rotations optimized to minimize jaw aperture size.

METHODS

Varian TrueBeam reference beam data (RBD) was used as input to **configure** a 6FFF AcurosXB (AXB) dose-to-medium (D_m) UBM in the Eclipse™ v18.1 TPS. To complete UBM configuration, the remaining modelling parameters listed in Table 1 relating to reference dose calibration, HD-MLC transmission/sweeping dosimetric leaf gap (DLG) and relative output (focal spot) were averaged from the respective measurements acquired across the 11 TrueBeam's used in the study (one for each ESPRESSO institute). Note that none of the TrueBeam's were specifically beam matched except within Vendor IPA specification for PDD_{10} (63.5 ± 1.0%, EPOM applied).

Table 1: 6FFF TrueBeam (HD-MLC) SIMT-SRS UBM configuration

Parameter	Institute: Mean (Min-Max)	UBM[b]	Reference Check
Varian Eclipse version	15.6-18.1	**18.1**	-
Dose-calculation algorithm	AAA (n=4)/AXB D_w (n=1)/AXB D_m (n=6)	**AXB D_m**	Kry et al [5]
Eclipse open beam configuration data	Measured (n=8)/RBD (n=3)	**Varian RBD**	-
*Minimum Jaw size, cm	1x1 - 3x3	**3x3**	Torsti et al [6]
*PDD_{10} (100cm SSD, jaws 10x10cm, EPOM applied)	0.633 (0.629-0.638)	**0.635**	0.625-0.645 (Varian IPA)
Ref dose cal factor, Gy/100MU (95cm SSD, jaws 10x10cm, d_{5cm})[a]	0.930 (0.922-0.936)	**0.930**	AAPM MPPG5b, Tol: 0.5%
Varian sweeping gap MLC DLG, mm (90cm SSD, d_{10cm})	0.54 (0.29-0.84)	0.54	0.56 (IROC, [7])
*ELM LG, mm	-0.36 (-0.05 to -0.60)	**-0.36**	-
MLC Transmission Factor	0.0101 (0.0095-0.0109)	**0.0101**	0.0100 (IROC, [7])
Effective spot size in X-direction (σ_x), mm	0.0-0.5 (AAA), 0.3-1.3 (AXB)	**0.9**	0.7-0.8 (Fogliata et al, [8])
Effective spot size in Y-direction (σ_y), mm	0.0-0.3 (AAA), 0.3-1.0 (AXB)	**0.9**	0.7-0.8 (Fogliata et al, [8])
Measured MLC output factor (90cm SSD, jaws 20x20cm, d_{10cm})			
*5x5mm	0.581 (0.558-0.601)	**0.572** (-1.6%)	AAPM MPPG9b, Tol: ± 2(5)%
*10x10mm	0.736 (0.731-0.742)	**0.748** (+1.7%)	
*20x20mm	0.823 (0.821-0.828)	**0.836** (+1.5%)	
*30x30mm	0.866 (0.863-0.869)	**0.869** (+0.4%)	

[a] 1MU = 1.00cGy at d_{max} in water (100cm SSD, jaws 10x10cm). For institutes calibrating the linac at 100cm SAD, a scaling factor of $(100/101.4)^2$ is applied
[b] Dose-calculation grid size: 1mm

To **assess** small field dosimetric equivalence of TrueBeam & **validate** UBM accuracy, nine non-coplanar SIMT-SRS VMAT plans of 20Gy prescription (single fraction) were generated on a virtual 20cm diameter spherical water phantom (Fig. 1). Each plan had two identical co-axial spherical targets (1mm GTV-PTV margin) parameterized by permutations of increasing PTV diameter (0.5, 1 and 2cm) and off-axis distance (1, 2 and 4 cm). UBM dose calculation was performed with 1mm grid size, and maximum plan complexity restricted to < 4.0MU/cGy. The 11 institutes proceeded to re-calculate each plan with fixed MU (1mm calc grid) using their respective clinical 6FFF SIMT-SRS Eclipse beam model (**TPS_{Inst}**). 3D dose distributions within the virtual phantom were then measured at each institute using a cine electronic portal imaging device (EPID) dose reconstruction model (Fig. 2), previously validated for SIMT-SRS application with a mean (± SD) dose accuracy of -0.2 ± 2.1% [9].

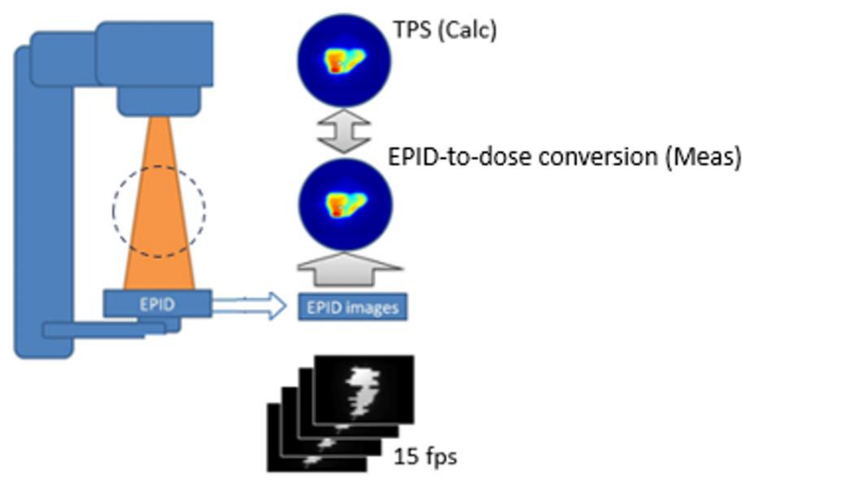

Fig. 2: Illustration of the EPID-based 3D dose SIMT-SRS VMAT measurement

RESULTS and DISCUSSION

Dosimetric equivalence of Varian TrueBeam 6FFF SIMT-SRS VMAT across the 11 institutions demonstrated a coefficient of variation (standard deviation/mean) in measured GTV D_{mean} < 2.5% down to 5mm target size (Fig. 3a). This level of agreement is comparable that reported in large-field findings [10], realised by utilising the EPID dose reconstruction model which reduces the measurement uncertainty otherwise associated with small field phantom setup, detector positioning and calibration. As demonstrated in Fig. 3b, these findings support the feasibility of implementing a UBM for SIMT-SRS VMAT capable of achieving dose calculations within ± **5% accuracy** of measured dose across the range of beam qualities (PDD_{10}), HD-MLC DLG's and small MLC defined output factors reported in Table 1.

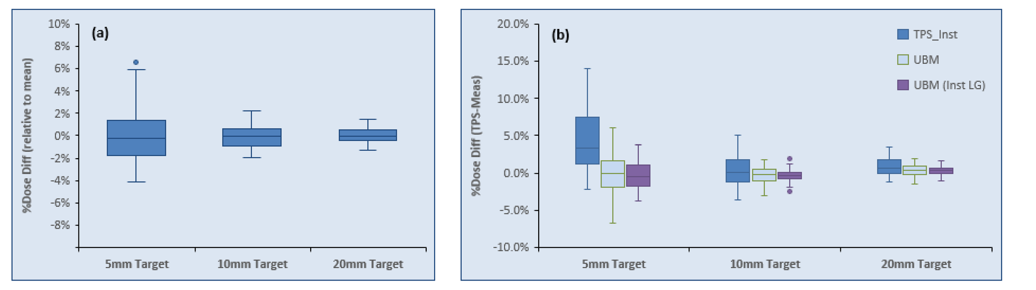

Fig. 3: Population based box & whisker distribution plots of percentage dose differences in measured SIMT-SRS VMAT GTV D_{mean} grouped by target diameter (n = 6x11) relative to **(a)** the measured average, and **(b)** the TPS dose calculation (where a positive value indicates TPS is higher than measured).

Evaluating the **efficacy** of the UBM, a statistically significant ($p < 0.05$) improvement in dose calculation accuracy for more than half the participating institutes (6 of 11) was demonstrated at the 5mm target size (Fig. 4). This increased to 73% (8 off 11) when the UBM's ELM LG and transmission were updated with the institute specific values (**UBM_{InstLG}**). These findings are consistent with previous large-field observations where use of representative data for beam modelling has been shown to improve the dose calculation accuracy, on average, when compared with institution derived models [11-12]. Significantly, 2 institutes showed a dose deviations > 10% attributed to atypical DLG (Inst. D) or spot size (Inst. K) modelling parameters. For the larger targets of 10mm and 20mm size, UBM_{InstLG} exhibited improvement in dose calculation accuracy for 6 and 3 institutes, respectively.

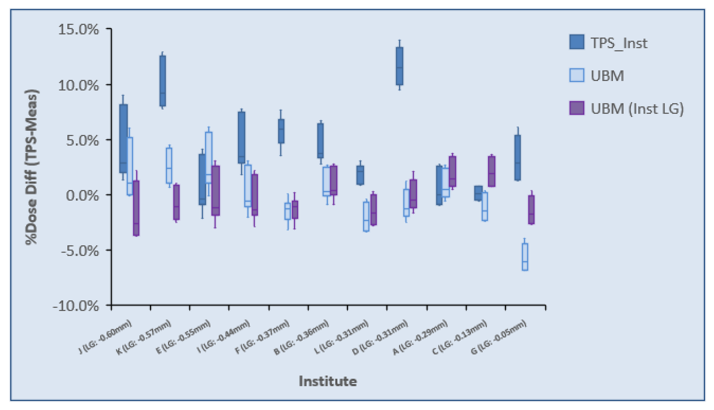

Fig. 4: Institute based box & whisker plots of percentage dose differences in measured SIMT-SRS VMAT GTV D_{mean} for the 5mm target size (n = 6) relative to TPS dose calculation. Compared to the Institute's own TPS, clear benefit in dose-calculation accuracy was observed using the UBM for institutes J, K, I, F, B, and D with the updated UBM_{InstLG} also benefiting institutes L and G.

REFERENCES

[1] O'Daniel et al (2025), *Med Phys*; 52:88–98. DOI:10.1002/mp.17468
[2] Glenn et al (2022), *Radiother Oncol*; 166:8-14. DOI: 10.1016/j.radonc.2021.10.021
[3] Prentou et al (2022), *J Appl Clin Med Phys*; 23:e13708. DOI: 10.1002/acm2.13708
[4] Gardner et al (2017), *J Appl Clin Med Phys*; 18:3:170–181. DOI: 10.1002/acm2.12091
[5] Kry et al (2021), *Radiother Oncol*; 159:106-1111. DOI: 10.1016/j.radonc.2021.03.006
[6] Torsti et al (2013), Varian Small Field White Paper
[7] Glenn et al (2020), *Med Phys*; 47:282-288. DOI: 10.1002/mp.13892
[8] Fogliata et al (2025), *J Appl Clin Med Phys*; 26:e70315. DOI: 10.1002/acm2.70315
[9] Zwan et al (2026), *PhIRO*; 39: 100979. DOI: 10.1016/j.phro.2026.100979
[10] Ghazal et al (2020), *J Appl Clin Med Phys*;1–11. DOI: 10.1002/acm2.13058
[11] Kerns et al (2017). *Int J Radiation Oncol Biol Phys*; 98(5): 1197e1203. DOI: 10.1016/j.ijrobp.2017.03.049
[12] Miyasaka et al (2025). *J Appl Clin Med Phys*; 26:e70360. DOI: 10.1002/acm2.70360

KEY FINDINGS

First study to demonstrate **small field dosimetric equivalence** on Varian TrueBeam for SIMT-SRS VMAT treatment

Potential change in **paradigm** for SIMT-SRS beam model commissioning to improve safety and resource efficiencies:
- Tune beam quality (PDD_{10}) to match the Varian Reference Beam Data of 63.5% ± 0.5% as used by the UBM.
- Tune MLC leaf gap calibration to match DLG (ELM LG) of 0.54 ± 0.30mm as used by the UBM.

CONCLUSION

Application of a **UBM** in Varian Eclipse v18.1 with fixed open beam configuration and direct input of an institute's measured HD-MLC leaf gap and transmission is feasible for **accurate** SIMT-SRS VMAT dose calculation on TrueBeam.

caring FOR THE coast

NSW GOVERNMENT Health Central Coast Local Health District

ESPRESSO