Material and Methods: A bespoke QA programme was created for the 5 anatomical treatment sites which included spine and nodal metastasis. Prior to treatment centres were required to complete a QA process which included planning benchmark cases. Participating centres were provided with a pre-outlined planning CT. They created PTV expansions using local protocols. The centres were then required to create a plan based on a 30 Gy in 3 fraction prescription for the nodal case and a 24 Gy in 3 fractions prescription for the spine case. Both cases required a D95% of the prescription dose for the PTV coverage whilst ensuring OAR tolerances were met. All planning benchmarks were submitted and centrally analysed using VODCA 5.4 plan review software. The coverage of the PTV and CTV with the prescription dose, doses to OARs and measures of conformity were calculated. The values for the different submissions were compared to ensure plans were of suitable quality and comparable across different treatment platforms.

Results: A total of 10 and 11 plans were submitted for the spine and nodal benchmark cases respectively, including all 4 NHS cyberknife centres and the remainder using VMAT. 27% of the nodal and 18% of the spine plans had unacceptable deviations and the centres were given feedback and asked to resubmit their QA. The PTV coverage and max dose were compared for the different treatment techniques with the standard deviation. These can be seen in the table below.

Spine

Modality	Mean PTV Coverage (%)	S.D.	Mean Max Point Dose (Gy)	S.D.
All	92.2	3.4	31.3	2.7
Cyberknife	94.3	2.9	32.2	2.8
VMAT	90.9	3.4	31.4	2.3

Nodes

Modality	PTV 1		PTV 2		Mean Max Point Dose (Gy)	S.D.
	Mean PTV Coverage (%)	S.D.	Mean PTV Coverage (%)	S.D.		
All	90.5	5.8	96.5	3.1	38.0	3.3
Cyberknife	95.0	2.5	97.4	2.2	41.7	3.5
VMAT	87.4	5.3	95.9	3.6	36.0	1.1

A 2 tail Mann-Whitney test was performed on the PTV coverage data for both plans. This indicated that there was a significant difference between cyberknife and VMAT plans ($p=0.02$).

Conclusion: Cyberknife plans on average achieved superior PTV coverage when compared to VMAT plans. This was more evident for the spine PTV and nodal PTV 1, with both volumes being close to OARs, than for the nodal PTV 2 where OARs did not restrict the dose . The VMAT plans involved larger PTV and PRV expansions which would partly explain the difficulty in achieving the required PTV coverage. However, several of the VMAT plans had similar PTV coverage to the cyberknife plans, hence the greater variation in PTV coverage of the VMAT plans may reflect possible inexperience in SABR planning for some centres. Following resubmissions, all centres participating in the CtE programme have been able to produce acceptable benchmark plans regardless of treatment platform.

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Small animal irradiation by using Tomotherapy: dosimetric and preclinical results

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Purpose or Objective: Preclinical studies are critical steps in the medical research process, normally requiring dedicated instruments. For those centers in which both preclinical research and clinical practices are conducted, the dosimetric feasibility of small animal irradiation with clinical devices may be of economical and scientific interest. The aim of the present work is to investigate the feasibility of small animal irradiation with Tomotherapy Hi-Art by analyzing dosimetric results, toxicity and tumour response in xenograft models.

Material and Methods: Xenograft models were established by injecting human derived glioblastoma multiforme stem-like cells in immunocompromised NOD-SCID mice both subcutaneously (10 groups) and intracranially (7 groups). Mice of each group were anesthetized and placed in a plexiglas cage pie to perform CT scans for treatment planning purposes. Target volumes and organs at risk (OARs) where outlined on CT scans: for subcutaneous xenografts, target volumes were delineated on the right flank and contoured OARs were lung and gastro-intestinal tract. For orthotopic models, a ring-shaped target structure was delineated on mice's head; contoured OAR was lung. Three fractionation schedules were tested: 4Gy/1 fraction, 4 Gy/2 fractions and 6 Gy/3 fractions. TomoDirect IMRT technique was applied, with gantry fixed at 0° and 180. 5 subcutaneous and 1 orthotopic groups of xenografts were irradiated by covering the target volume with a 0.6 cm bolus layer in order to reduce the impact of the build-up effect. Irradiations originally performed without bolus were simulated with a 0.6 cm virtual bolus in order to compare dosimetric results. Before irradiation, a MVCT image has been acquired to correct irradiation setup. Mice were observed daily and sacrificed when they showed signs of suffering or when tumour volume reached the established endpoint. Different radiobiological outcomes were evaluated, regarding both radiotoxicity (survival experiments) and tumour response (assessed by caliper or bioluminescence imaging), comparing irradiated mice as respect to their controls.

Results: Dosimetric results showed that the presence of the bolus layer significantly impact the maximum dose received by both target volumes and OARs (t-test, $p<0.05$). Survival analysis showed that irradiation with a dose of 6 Gy in 3 fractions in the presence of a bolus layer prolong mice survival (Log-rank test, $p<0.02$), showing to be the safest irradiation protocol. Tumour volume response and mice survival were significantly different in irradiated xenografts as compared to their controls (t-test, $p<0.03$; Log-rank, $p<0.05$) demonstrating also the radiobiological potential of Tomotherapy in inducing tumour growth stabilization.

Conclusion: Tomotherapy systems may be a useful mean for small animal irradiation.

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Evaluation of dosimetric properties of 3D printed flat bolus for external beam radiotherapy

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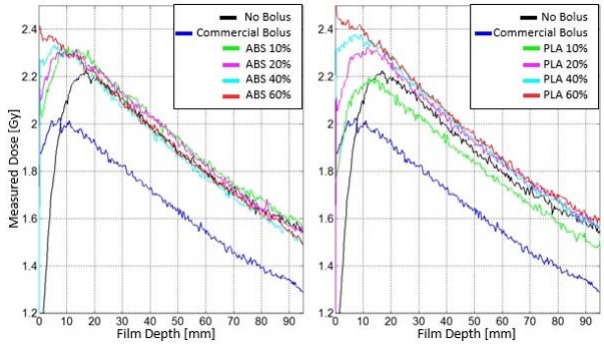
Purpose or Objective: To evaluate the dosimetric properties of acrylonitrile butadiene styrene (ABS) and polylactide (PLA) plastics, and their suitability for bolus printing applied in high-energy radiotherapy to overcome the skin-sparing effect.

Material and Methods: The measurements were performed with Vero® System (Brainlab AG, Feldkirchen, Germany) delivering 200 monitor units (dose rate of 500 MU/min) with a 6 MV photon beam, 5x5 cm open field with 90-degree gantry angle at 100 cm surface to surface distance (SSD) on a water-equivalent RW3 slab phantom in three configurations: without bolus, with a commercial bolus and with the eight 3D

printed boluses. Gafchromic EBT3 film (International Specialty Products, Wayne, NJ) placed between phantom slabs provided dose profile measurements. An Epson Expression Scanner 10000 XL (Epson, Long Beach, CA) was used to determine the optical density of the films and film analysis were performed using Film QA Pro software (Ashland Inc., Bridgewater, NJ).

Results: The mean value of Hounsfield unit (HU) of the 3D printed boluses was provided analyzing their Computed Tomography (CT) scans. Negative HU were due to the air gap inside the infill pattern. The mean HU increased with the percentage infill, resulting in higher bolus density (Tab. 1). This reduced the distance from the surface of the phantom where the maximum dose occurs (dmax) as shown in Fig.1. Build-up peaks shifted towards the phantom surface when any bolus was used. ABS and PLA boluses with an infill percentage of 40% had comparable performance to the commercial bolus.

	%infill	HU	density [g/cm³]	d_{max} [mm]
no Bolus	--	--	--	16.9
commercial Bolus	--	0	1.0	7.4
ABS	10	-694.0	0.28	10.6
	20	-593.8	0.39	9.4
	40	-393.5	0.60	5.6
	60	-166.5	0.87	0
PLA	10	-629.7	0.35	14.5
	20	-492.5	0.49	11.6
	40	-245.2	0.78	9.2
	60	-51.2	0.97	0



Conclusion: The dosimetric analysis of the 3D printed flat boluses showed that they can decrease the skin-sparing as a commercially available bolus. The performed analysis accurately describes the physical behavior of these plastic materials, in order to represent them in treatment planning system for precise treatment delivery. Moreover, patient-specific boluses could be outlined from patient CT images and 3D printed, thus shaping the actual anatomy of the patient. This procedure may represent a viable alternative to commercially available conventional boluses, potentially improving the fitting between bolus and skin surfaces.

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Multicentre comparison for small field dosimetry using the new silicon diode RAZOR

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Purpose or Objective: Multicentre comparisons of dosimetrical parameters are important to ensure the same quality of the treatment in radiotherapy centres, and allow to identify systematic errors. In this study, small fields dosimetric parameters were collected in a national context using a common acquisition procedure and a specific dosimeter. The aim of this study was to provide indicative values for each Linac model for small field dosimetry measurements. This can be useful for centres with reduced experience in small fields dosimetry.

Material and Methods: Thirty-four centres with different LINACs joined this project: 2 Siemens, 7 Elekta Agility, 6 Elekta Beam Modulator, 12 Varian CLINAC and 7 Varian TrueBeam. All measurements were performed using the new IBA unshielded silicon diode RAZOR and the Stealth flat ionization chamber fixed on the gantry as reference. The RAZOR was positioned at 10cm depth in water phantom and SSD=90cm. In and Cross-line beam profiles ranging from 0.6-5cm (nominal field size). The actual in-plane (I) and cross-plane (C) FWHM were considered to calculate the effective field size, defined as (A*B)^0.5. Ouput factors (OF) were calculated and normalized to the 3x3 cm2. OF were calculated for both nominal (OF_N) and effective (OF_E) field sizes. The penumbra width was defined as the distance between the 80% and 20% isodose levels. Two identical diodes were adopted to speed up the data collection.

Results: OF_N were in agreement over the different models up to 1x1 cm2 field size. Higher agreement was obtained with OF_E, for the smallest fields different trends were obtained depending on vendors and models, see Fig.1. Penumbra measurements were in agreement each other for each field size and accelerator model.