REACHING NEW HEIGHTS WITH SGRT



MEDICAL PHYSICS TRACK

Cross-vendor comparison of beam hold duration (latency)

NHS

University Hospitals Dorset NHS Foundation Trust

> Cymhariaeth trawswerthwr o hwyrni

Josh Naylor Physicist

Overview

- What / why?
- Therapist latency
- Manufacturer claims / guidance docs
- Method
- Results
- Clinical significance

- Latency
- Lag time
- Temporal accuracy for dynamic radiation delivery
- Beam hold performance
- Latency threshold
- Trigger performance
- Beam off

==Patient moves... radiation goes off!



Therapist latency!





Manufacturer specifications





End-to-end latency includes linac component

- RPM aka RGSC represents the linac component
- Measured w/ MV panel method







- Temporal accuracy of phase/amplitude 100 ms of expected gate on
- Calibration of surrogate for respiratory 100 ms of expected phase/amplitude

phase/amplitude

3.3.2 | Implications of temporal accuracy/latency for dynamic radiation delivery

TG302

The temporal accuracy/latency for dynamic radiation delivery (i.e., beam hold) and integration with the treatment unit, when available, may affect dosimetric accuracy.³⁶ Per TG-142, the SGRT system delay should be evaluated for the specific application and deemed appropriate before treatment. While direct measure-

ment of the latency time may be challenging, SGRT latency time should be confirmed to be below a clinically appropriate threshold (e.g., <1 s for breast DIBH treatment). For free-breathing (FB) gated treatment, TG-76 recommends that the total time latency be as short as possible, and not to exceed 0.5 s in any case, as prediction medals cannot perform will above this



GUIDANCE DOCUMENTS





Radiotherapy & Oncology

Journal of the European SocieTy for Radiotherapy and Oncology

ESTRO-ACROP guideline on surface guided radiation therapy

P. Freislederer A ¹ ⊠ • V. Batista • M. Öllers • ... D. Nguyen • C. Bert • J. Lehmann • Show all authors • Show footnotes

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Tracking Performance – Free Breathing-Gating Check, Lag Time 200 ms









PIN Photodiode + Csl(Tl) crystal





2023 US SGRT ANNUAL MEETING

The next stop on YOUR SGRT JOURNEY







TWA HOTEL JFK Airport, New York City

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Quantification of Beam Latency Using SGRT

MV panel

QUANTIFICATION OF BEAM LATENCY USING ALIGNRT

2023 US SGRT ANNUAL MEETING The next stop on YOUR SGRT JOURNEY

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Elekta and Varian

RESULTS

RESULTS





Elekta and Varian





• AlignRT v6 & v7 / ROI & patch (Vision RT) Identify (Varian)

- Catalyst (C-RAD)

 ExacTrac Dynamic Surface (Brainlab)





Free-breathe / DIBH latency threshold <200 ms?

(for 2%)

SBRT lung – clinical impact of latency

	2400 MU/min		
	40 MU /s		
	8 MU delive	ered in \rightarrow	200 ms
1000 MU /#	0.8%		
	2.0% (TG142 threshold)	2.5	Beam holds

DIBH breast – clinical impact of latency

Beam automatically held if patient in wrong position

Red light pattern instead of tattoos or marks

 $\bigcirc \bigcirc \bigcirc \bigcirc$



Patient in control – breathe to centre line

DIBH breast – clinical impact of latency

- Based on SimRT data: 4 mm/s "breath velocity"
- 500 ms == 2 mm (TG142 threshold)
- @600 MU/min: 5 MU incorrectly delivered
- For 2.6 Gy /beam/day, patient with poor compliance
- ~9% incorrectly delivered
- 200 ms latency tolerance allows 13 beam holds for 2% dose impact (TG142 threshold)
- Whole breast PTV lower significance than boost or nodal involvement



Inputs

- Amplitude
- BPM
- Latency
- Interrupt phase
- Cos^4

Gated SBRT lung – clinical impact of latency

e (A)	15	mm				BPM	18							latency	150	ms			interrupt phase	84
						period	3.3 s							latency	0.15	s			beam off phase	88.5
			-										phas	e change	4.5	%	-			
	main	plots																latency	/ sub plots	
rad	time (t) / :	s A * c	osine(t)) A*"cos4"	A*"cos6"	20										phase / %	phase / rac	time (t) / s	A * cosine(t)	A*"cos4"
	0.00	15	5.000	15.00	15.00											84.00	5.28	2.80	8.04	2.69
	0.03	14	1.970	14.94	14.91	15									1	84.23	5.29	2.81	8.22	2.97
	0.07	14	1.882	14.76	14.65										2	84.45	5.31	2.82	8.39	3.24
	0.10	14	1.734	14.47	14.21	10									3	84.68	5.32	2.82	8.57	3.51
	0.13	14	1.529	14.06	13.61	F									4	84.90	5.33	2.83	8.74	3.79
	0.17	14	1.266	13.55	12.85	JE 5									5	85.13	5.35	2.84	8.91	4.06
	0.20	13	3.947	12.93	11.95	ent									6	85.35	5.36	2.85	9.08	4.33
	0.23	13	3.572	12.21	10.92	e o			\backslash						7	85.58	5.38	2.85	9.25	4.60
	0.27	13	3.145	11.40	9.77	plac			\backslash						8	85.80	5.39	2.86	9.42	4.87
	0.30	12	2.665	10.51	8.53	dis -o									9	86.03	5.41	2.87	9.58	5.14
	0.33	12	2.135	9.54	7.20	-10									10	86.25	5.42	2.88	9.74	5.41
	0.37	11	1.558	8.51	5.81	-10									11	86.48	5.43	2.88	9.90	5.67
	0.40	10).935	7.42	4.38	-15									12	86.70	5.45	2.89	10.06	5.93
	0.43	10).268	6.28	2.93										13	86.93	5.46	2.90	10.22	6.20
	0.47	9	.561	5.11	1.46	-20									14	87.15	5.48	2.91	10.37	6.46
	0.50		017	2.01	0.01		0 10	20	30	40	50 60	70	80 90	100	15	87.38	5.49	2.91	10.52	6.71
		1	14	1	l In	puts	S			1	se / %				16	87.60	5.50	2.92	10.67	6.97
	1	0088													17	87.83	5.52	2.93	10.82	7.22
	100			. 90	N .	Δmn	litud	ما			o4"				18	88.05	5.53	2.94	10.97	7.48
	leam (0.0		1	163		uluu				6				19	88.28	5.55	2.94	11.11	7.72
	100.00	1000	1			RDM										88.50	5.56	2.95	11.25	7.97
	1997		1		38	DELL											displac	ement / mm	3.2	5.3
	10	83	1			lata	nov										_			
		Name	14	+			псу					ſ	hat		P	RT	lur	ισ _		
	1	1	22	1.6		Intor	runt	nh	200				Jayo	u u			ч	'6 [—]		
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	and the second s	0-		6		$ \mathbf{C} $	<u>^ л</u>					C	;uni	cal	Iľ	nba	act	OT L	aten	CV
F		Gal	Le O	100	and the second s	COS	4											— — — —		~ 」

1.5

puts			
Amnlitude			
RPM			
latency			
Latonoy			
Interrunt phase			
Cos^4			
Catad	DT		

Gated SBRT lung – clinical impact of latency

amplitude	8	mm		BPM	19		period	3.2
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	C II U	μιμ	10307	

			Interru	ipt phase	2/%																																	
			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	10	0.3	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
	20	0.6	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.1	
	30	1.0	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2	
	40	1.3	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.2	
	50	1.6	0.1	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.3	0.3	
	60	1.9	0.1	0.2	0.3	0.5	0.6	0.7	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.0	1.0	0.9	0.8	0.8	0.7	0.6	0.6	0.5	0.4	0.4	0.3	
	70	2.2	0.2	0.3	0.4	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.2	1.2	1.1	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.4	0.4	
	80	2.5	0.2	0.4	0.5	0.7	0.8	0.9	1.1	1.2	1.3	1.4	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5	1.5	1.4	1.3	1.3	1.2	1.1	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.4	
	90	2.9	0.3	0.4	0.6	0.8	0.9	1.1	1.2	1.3	1.5	1.6	1.6	1.7	1.8	1.8	1.8	1.9	1.9	1.8	1.8	1.8	1.7	1.6	1.6	1.5	1.4	1.3	1.2	1.1	1.0	0.9	0.8	0.7	0.6	0.5	0.4	
	100	U 3.2	0.3	0.5	0.7	0.9	1.1	1.2	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.1	2.1	2.0	2.0	1.9	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.0	0.9	0.8	0.7	0.6	0.5	
	110	S 3.5	0.4	0.6	0.8	1.0	1.2	1.4	1.5	1.7	1.8	1.9	2.0	2.1	2.2	2.2	2.3	2.3	2.3	2.2	2.2	2.1	2.1	2.0	1.9	1.8	1.7	1.5	1.4	1.3	1.2	1.1	0.9	0.8	0.7	0.6	0.5	
ŝ	120	3.8	0.5	0.7	0.9	1.1	1.3	1.5	1.7	1.9	2.0	2.1	2.2	2.3	2.4	2.4	2.5	2.5	2.5	2.4	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.5	1.4	1.3	1.1	1.0	0.9	0.8	0.7	0.5	
	130	0. 4.1	0.5	0.8	1.0	1.3	1.5	1.7	1.9	2.0	2.2	2.3	2.4	2.5	2.6	2.6	2.7	2.7	2.7	2.6	2.6	2.5	2.4	2.3	2.2	2.1	1.9	1.8	1.6	1.5	1.4	1.2	1.1	0.9	0.8	0.7	0.6	
\geq	140 2	\$ 4.4	0.6	0.9	1.1	1.4	1.6	1.8	2.0	2.2	2.4	2.5	2.6	2.7	2.8	2.9	2.9	2.9	2.9	2.8	2.7	2.7	2.6	2.5	2.3	2.2	2.0	1.9	1.7	1.6	1.4	1.3	1.1	1.0	0.9	0.7	0.6	
S.	150	4.8	0.7	1.0	1.3	1.5	1.8	2.0	2.2	2.4	2.6	2.7	2.8	2.9	3.0	3.1	3.1	3.1	3.0	3.0	2.9	2.8	2.7	2.6	2.5	2.3	2.2	2.0	1.8	1.7	1.5	1.3	1.2	1.0	0.9	0.8	0.6	
5	160	5.1	0.8	1.1	1.4	1.7	1.9	2.2	2.4	2.6	2.8	2.9	3.0	3.1	3.2	3.3	3.3	3.3	3.2	3.2	3.1	3.0	2.9	2.8	2.6	2.5	2.3	2.1	1.9	1.8	1.6	1.4	1.2	1.1	0.9	0.8	0.7	
Ę	170	2 5.4	0.9	1.2	1.5	1.8	2.1	2.3	2.6	2.8	3.0	3.1	3.3	3.4	3.4	3.5	3.5	3.5	3.4	3.4	3.3	3.2	3.0	2.9	2.7	2.6	2.4	2.2	2.0	1.8	1.7	1.5	1.3	1.1	1.0	0.8	0.7	
g	180	Ð 5.7	1.0	1.3	1.7	2.0	2.3	2.5	2.8	3.0	3.2	3.3	3.5	3.6	3.6	3.7	3.7	3.7	3.6	3.5	3.5	3.3	3.2	3.0	2.9	2.7	2.5	2.3	2.1	1.9	1.7	1.5	1.3	1.2	1.0	0.8	0.7	
	190	6.0	1.1	1.5	1.8	2.1	2.4	2.7	2.9	3.2	3.4	3.5	3.7	3.8	3.8	3.9	3.9	3,9	3.8	3.7	3.6	3.5	3.3	3.2	3.0	2.8	2.6	2.4	2.2	2.0	1.8	1.6	1.4	1.2	1.0	0.9	0.7	1
	200 -	6.3	1.2	1.6	1.9	2.3	2.6	2.9	3.1	3.4	3.6	3.7	3.9	4.0	4.0	4.1	4.1	4.0	4.0	3.9	3.8	3.7	3.5	3.3	3.1	2.9	2.7	2.5	2.3	2.1	1.8	1.6	1.4	1.2	1.1	0.9	0.7	1
	210	6.7	1.3	1.7	2.1	2.4	2.8	3.1	3.3	3.6	3.8	3,9	4.1	4.2	4.2	4.3	4.3	4.2	4.2	4.1	4.0	3.8	3.6	3.5	3.3	3.0	2.8	2.6	2.4	2.1	1.9	1.7	1.5	1.3	1.1	0.9	0.7	1
	220	7.0	1.5	1.9	2.3	2.6	2.9	3.2	3.5	3.8	4.0	4.1	4.3	4.4	4,4	4.5	4.5	4.4	4.4	4.2	4.1	4.0	3.8	3.6	3.4	3.1	2.9	2.7	2.4	2.2	2.0	1.7	1.5	1.3	1.1	0.9	0.8	1
	230	7.3	1.6	2.0	2.4	2.8	3.1	3.4	3.7	4.0	4.2	4.4	4.5	4.6	4.7	4.7	4.7	4.6	4.5	4.4	4.3	4.1	3.9	3.7	3.5	3.2	3.0	2.8	2.5	2.3	2.0	1.8	1.5	1.3	1.1	0.9	0.8	1
	240	7.6	1.7	2.2	2.6	3.0	3.3	3.6	3.9	4.2	4.4	4.6	4.7	4.8	4.9	4.9	4.8	4.8	4.7	4.6	4.4	4.2	4.0	3.8	3.6	3.3	3.1	2.8	2.6	2.3	2.1	1.8	1.6	1.4	1.1	1.0	0.8	
	250	7.9	1.9	2.3	2.7	3.1	3.5	3.8	4.1	4.4	4.6	4.8	4.9	5.0	5.1	5.1	5.0	5.0	4.9	4.7	4.6	4.4	4.2	3.9	3.7	3.4	3.2	2.9	2.6	2.4	2.1	1.9	1.6	1.4	1.2	1.0	0.8	
	260	8.2	2.0	2.5	2.9	3.3	3.7	4.0	4.3	4.6	4.8	5.0	5.1	5.2	5.2	5.3	5.2	5.1	5.0	4.9	4.7	4.5	4.3	4.1	3.8	3.5	3.3	3.0	2.7	2.4	2.1	1.9	1.6	1.4	1.2	1.0	0.8	
	270	8.6	2.2	2.6	3.1	3.5	3.9	4.2	4.5	4.8	5.0	5.2	5.3	5.4	5.4	5.4	5.4	5.3	5.2	5.1	4.9	4.7	4.4	4.2	3.9	3.6	3.3	3.0	2.8	2.5	2.2	1.9	1.7	1.4	1.2	1.0	0.8	1
	280	8.9	2.3	2.8	3.3	3.7	4.1	4.4	4.7	5.0	5.2	5,4	5.5	5.6	5.6	5.6	5.6	5.5	5.4	5.2	5.0	4.8	4.5	4.3	4.0	3.7	3.4	3.1	2.8	2.5	2.2	2.0	1.7	1.4	1.2	1.0	0.8	1
	290	9.2	2.5	3.0	3.4	3.9	4.3	4.6	4.9	5.2	5.4	5.6	5.7	5.8	5.8	5.8	5.8	5.7	5.5	5.4	5.2	4.9	4.7	4.4	4.1	3.8	3.5	3.2	2.9	2.6	2.3	2.0	1.7	1.5	1.2	1.0	0.8	
	300	9.5	2.6	3.1	3.6	4.1	4.5	4.8	5.1	5.4	5.6	5.8	5.9	6.0	6.0	6.0	5.9	5.8	5.7	5.5	5.3	5.0	4.8	4.5	4.2	3.9	3.6	3.2	2.9	2.6	2.3	2.0	1.7	1.5	1.2	1.0	0.8	1
			^^m	ım dis	place	ement	t																															

Inputs

• Amplitude

Gated SBRT lung – clinical impact of latency

• BPM

Inp	outs	5		am	plitude	8	mm		BPM	19		period	3.2					
• A	mp	litud	de	"\	Vors	t cas	se"	-			-	S	BR	Τιι	ing -	- C	lini	cal
• B	• BPM (90% patients) ¹											i	mpa	act	ofla	ate	ency	У
_				interrup	t phase	/ %							_					
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10		0.3	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
	20		0.6	°G	ating	late	encv	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4
	30		1.0	0.0 ₊ h			-100	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.6
	40		1.3	0.1	resn	Ulu '	- 1.00	1115	0.4	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8
	50		1.6	0.1	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.0
	60		1.9	0.1	0.2	0.3	FG142).6	0.7	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.2	1.2
	70		2.2	₀_₂(fo	r 2 mn	n) <mark>thr</mark>	esholo) 0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.4	1.4
	80		2.5	0.2	0.4	0.5	0.7	0.8	0.9	1.1	1.2	1.3	1.4	1.5	1.5	1.6	1.6	1.6
	90		2.9	0.3	0.4	0.6	0.8	0.9	1.1	1.2	1.3	1.5	1.6	1.6	1.7	1.8	1.8	1.8
	100	Ð	3.2	0.3	0.5	0.7	0.9	1.1	1.2	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.0	2.1
	110	Э.С	3.5	0.4	0.6	0.8	1.0	1.2	1.4	1.5	1.7	1.8	1.9	2.0	2.1	2.2	2.2	2.3
SC	120	Ĕ	3.8	0.5	0.7	0.9	1.1	1.3	1.5	1.7	1.9	2.0	2.1	2.2	2.3	2.4	2.4	2.5
Ч	130	d	4.1	0.5	0.8	1.0	1.3	1.5	Re	snir	ator	1 mo	dule	Δli	ơnRT	C	atal	vet
\geq	140	%	4.4	0.6	0.9	1.1	1.4	1.6				y 1110 -			<u> 5 </u>		atat	yur
ΰ	5 150 4.8 0.7 1.0 1.3 1.5						1.8		aten	cy[r	/ [ms] n=2			84		144		
	100	-	E 4															



Conclusions / summary



Latency matters:

- Measure it
- Tolerances DIY, but <100 ms for gating, else <200 ms for compliant patients
 - For latency commissioning / annual QA
 - & for real-time delta SGRT thresholds
- Lower is always better
- Vision RT has lowest latency of any SGRT vendor (and only one to meet thresholds above)
- Use auto beam hold (not therapist beam off)

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Joshua.Naylor@UHD.NHS.UK

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