Redesigning the Planner and Physicist Roles in the Era of Automated Planning

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Automated Planning and the Role of the Physicist

Kevin Moore, PhD
Associate Professor
Deputy Director of Medical Physics
Radiation Medicine & Applied Sciences
UC San Diego Health
RETHINKING MEDICAL PHYSICS

Disclosures

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Travel and honoraria from Varian Medical Systems

2 patents related to knowledge-based dose estimation

Outline

- **What effect will automated planning have on clinical radiotherapy?**

Outline

- **What effect ~~will~~ has automated planning ~~have~~ had on clinical radiotherapy?**
- **What is the physicist's role in driving this change?**

The twin claims of automated planning

	Evidence from retrospective studies	Evidence in real-world clinical practice
Improved quality	Lots[2-16]	Little[1,15-16]
Higher efficiency	Lots (of claims)[2-16]	Little[1,16]

[1]Moore *et al*, IJROBP **81**, 545-551 (2010)
[2]Appenzoller *et al*, Med Phys **39**, 7446 (2012)
[3]Moore *et al*, US Patent 20120310615 (2014)
[5]Shiraishi *et al*, Med Phys **42**, 908-917 (2014)
[6]Moore *et al*, Journal of Physics, **489**, 012055 (2014)
[4]Moore and Shiraishi, Patent WO2016081916A1 (2014)
[7]Moore *et al*, IJROBP, **92**, 228-235 (2015)
[8]Shiraishi and Moore, Med Phys, **43**, 378-387 (2016)
[9]Li *et al*, IJROBP, **97**, 164-172 (2017)
[10]Li *et al*, Radiotherapy and Oncology, **123**, 325-330 (2017)
[11]Ziemer *et al*, Med Phys, **44**, 5001-5009 (2017)
[12]Ziemer *et al*, PRO, **7**, e569-e578 (2017)
[13]Kaderka *et al*, PRO, PMID: 30826481 (2019)
[14]Moore, Sem. Rad. Onc., **29**, 209 (2019)
[15]Cornell *et al*, submitted (2019)
[16]Kaderka *et al*, submitted (2019)

Roadmap for implementation

Implementation Phase	Implementation Action	Implementation Endpoint
Phase 0 (~500 pts)	KBP modeling and validation	KBP development, quality gap quantification
Phase 1 (376 pts)	Blinded comparison	Establishment of KBP non-inferiority
Phase 2 (>1500 pts)	KBP, then human planner	Efficiency + any improvements
Phase 3	KBP only	"Planning as a service"

Phase 0-2 methods

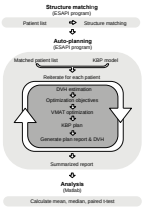
$\Delta D_x = D_{x,clinical} - D_{x,KBP}$ → **Mean → Plan quality**

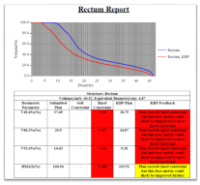
$\Delta D_x = D_{x,clinical} - D_{x,KBP}$ → **Standard deviation → Plan variability**

- If $\Delta D_x > 0$ → KBP plan is superior for this metric
- If $\Delta D_x < 0$ → Clinical plan is superior for this metric

R. Kaderka et al, Prac Rad Onc, PMID: 30826481 (2019)

Phase 0 analysis

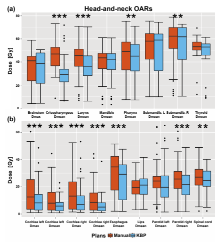




R. Kaderka et al, Prac Rad Onc, PMID: 30826481 (2019)

Phase 0 results

Comparison of manual and KBP treatment plans			
		Head-and-neck (48-70 Gy)	
Structure	PTV High	PTV Int	PTV Low
Dose parameter	$\Delta D_{1\%}$	$\Delta D_{95\%}$	$\Delta D_{95\%}$
Percentage difference	0.7%	0.2%	-1.1%
p-Value	p=0.167	p=0.722	p=0.016
Number of patients	n=67	n=60	n=43
Structure	Spinal cord	**Spinal cord**	Brainstem
Dose parameter	$\Delta D_{1\%}$	ΔD_{mean}	ΔD_{max}
Dose difference [Gy]	1.15	**-1.44**	-0.43
p-Value	p=0.063	**p=0.010**	p=0.549
Number of patients	n=67	**n=66**	n=65
Structure	**Larynx**	**Pharynx**	Oral Cavity
Dose parameter	ΔD_{mean}	ΔD_{mean}	$\Delta V_{50\%}$
Dose difference [Gy]	**-5.98**	**-1.29**	0.8%
p-Value	**p<0.001**	**p=0.007**	p=0.528
Number of patients	**n=61**	**n=60**	n=57
Structure	Mandible	Mandible	Lips
Dose parameter	ΔD_{max}	ΔD_{mean}	ΔD_{mean}
Dose difference [Gy]	0.94	-0.19	0.65
p-Value	p=0.015	p=0.652	p=0.107
Number of patients	n=61	n=61	n=58
Structure	**Esophagus**	Left parotid	**Right parotid**
Dose parameter	ΔD_{mean}	ΔD_{mean}	ΔD_{mean}
Dose difference [Gy]	**-4.32**	-1.81	**-3.77**
p-Value	**p<0.001**	p=0.013	**p<0.001**
Number of patients	**n=44**	n=64	**n=65**
Structure	**Cricopharyngeus**	**Left cochlea**	**Right cochlea**
Dose parameter	ΔD_{mean}	ΔD_{mean}	ΔD_{mean}
Dose difference [Gy]	**-14.96**	**-4.98**	**-4.62**
p-Value	**p<0.001**	**p<0.001**	**p<0.001**
Number of patients	**n=37**	**n=59**	**n=60**
Structure	Thyroid	Left submandibular	**Right submandibular**
Dose parameter	ΔD_{mean}	ΔD_{mean}	ΔD_{mean}
Dose difference [Gy]	-3.11	-2.04	**-2.12**
p-Value	p=0.061	p=0.115	**p=0.010**
Number of patients	n=25	n=33	**n=30**



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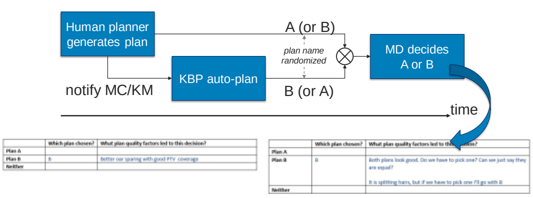
R. Kaderka et al, Prac Rad Onc, PMID: 30826481 (2019)

Moore / AAPM 2019 / #10

Phase 1 methods



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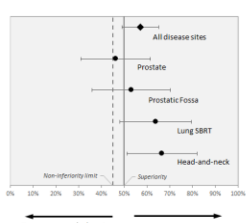
M. Cornell et al, submitted

Moore / AAPM 2019 / #11

Phase 1 results

Disease site	KBP chosen	KBP equiv.	Human chosen	Total plans	KBP equiv or superior
Prostate	16	3	22	41	46.3%
Prostatic fossa	17	0	15	32	53.1%
Left Lung SBRT	9	2	6	17	64.7%
Right Lung SBRT	12	0	7	19	63.2%
Head-and-neck	22	2	12	36	66.7%
Total	**76**	**7**	**62**	**145**	**57.2%**



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M. Cornell et al, submitted

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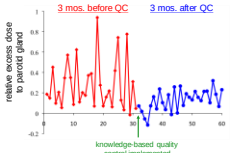
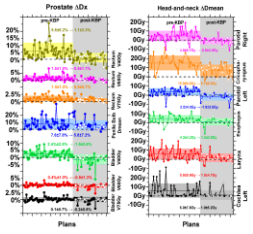
Phase 1 results



WashU 2009



UCSD 2016

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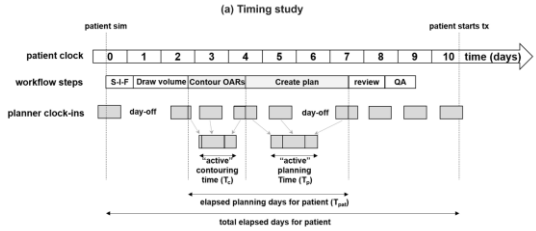
M. Cornell et al, submitted

Phase 2 methods



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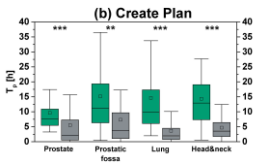
R. Kaderka et al, submitted

Phase 2 results



	Manual planning (hrs)	Post-KBP planning (hrs)	p-value
Head-and-neck	12.9	3.5	<0.001
Lung SBRT	9.9	2.0	<0.001
Prostatic Fossa	11.1	3.7	<0.01
Prostate	7.6	1.8	<0.001

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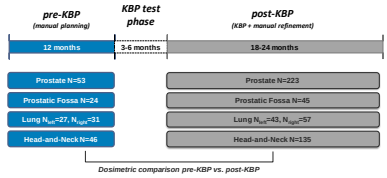
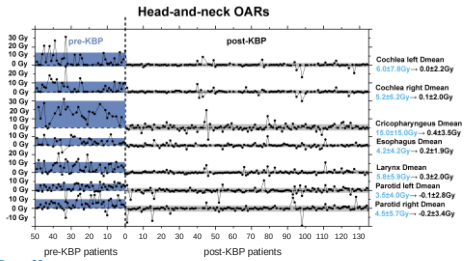
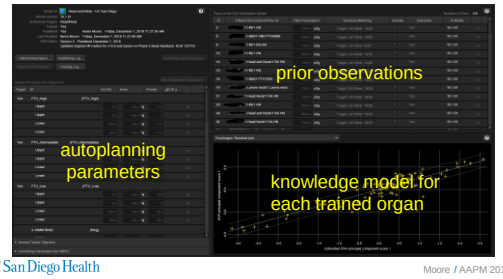
The durability of KBP QC effect



The durability of KBP QC effect



The physicist's role in clinical KBP



The physicist's role in clinical KBP

	Still to be developed	Model training underway (Phase II)	Routine in clinical use (Phase 2)	Routines being updated/tested ahead of Phase 3	Phase 3 routine (KBP only unless hard constraint violated)
SRS isolated					In practice
Prostate					Awaiting disease team
Prostatic Fossa					Awaiting disease team
Lung SBRT					Awaiting disease team
Head-and-neck				Updated Q3 2018	
SRS involved/MM			In Practice		
Prostate + nodes		Revising Q1 2019			
GYN					
Liver SBRT		Revising Q1 2019			
Pancreas SBRT		Revising Q1 2019			
Anorectal					
Glioblastoma					
SRS v15.RapidPlan					
Lymphoma					
Spine SBRT					
Lung (fractionated)			Q1 2019		
GI (fractionated)	Q3 2018				
Sarcoma			Q1 2019		
CSI					
VMAT breast					
Oligomet general					

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Which to focus on as physicists?

Mitigating the risks of automated planning implementation

vs.

Accelerating the pace of automated planning adoption

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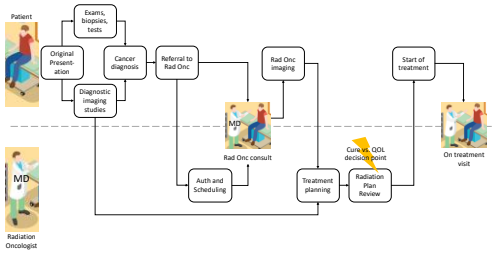
Current radiotherapy workflow



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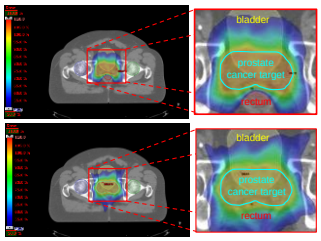
Automation implies new conversations



CONSERVATIVE
(PRIORITY: QUALITY OF LIFE)

PERSONALIZED DECISION MAKING AXIS

AGGRESIVE
(PRIORITY: CURE)

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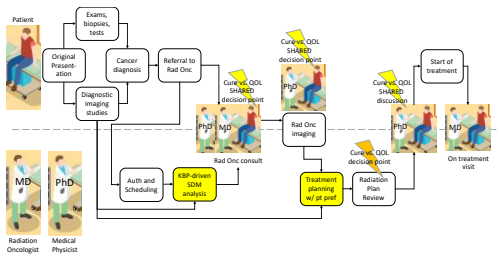
Physicist-driven shared decision making?



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Conclusions

- **This time is different.**
- **Inaction is risky. To patients, and to the health of our field.**
- **If you are not currently involved heavily in the day-to-day treatment ~~planning~~ design process, the implementation of automated planning is the perfect opportunity to reclaim a critical role.**

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@KevinMoorePhD

Collaborators

Mariel Cornell, CMD
Robert Kaderka, PhD
Xenia Ray, PhD
Todd Atwood, PhD
Todd Pawlicki, PhD
AJ Mundt, MD

Support

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Padres Pedal the Cause
UC Academic Senate
UCSD MEET Innovation
Varian Medical Systems