Data Driven Automation and Practice Quality Evaluation

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Disclosures

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Todd McNutt is a Co-Founder of Oncospace Inc.

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https://globalcompliancy.com/quality-management-systems/

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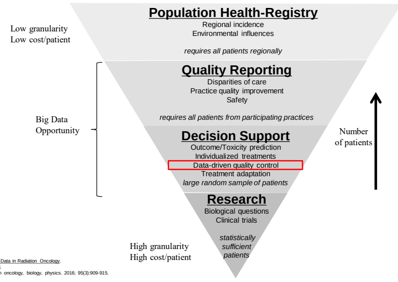
Levels of Big Data



Needs and Challenges for Big Data in Radiation Oncology.
McNutt TR, Moore KL, Quon H.
International journal of radiation oncology, biology, physics. 2016; 95(3):909-915.

Data for quality control

- Indications
  - Diagnosis, staging and histology
  - Guidelines
- Radiation
  - Prescription
  - Regions of interest
  - Dosimetry
  - Beam delivery (logs)
  - Imaging
- Patient outcomes
  - Clinician assessed toxicity
  - Patient reported
  - Disease response

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Measures for quality control

- Dose goals (DVH)
- Dose measurement (IMRT QA, diode)
- Delivery complexity (IMRT modulation)
- Region of interest features (volume)
- Patient localization (imaging and couch)
- Patient toxicity (modeled and measured)
- …

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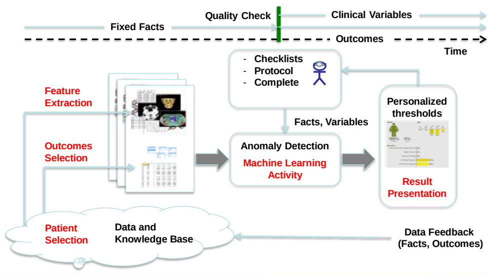
Learning health system – Quality Check



What does it mean to be data driven?

- Protocols are population based
- Each patient is different
- Data can provide personalization within population based guidelines
- Prediction models and refined cohort selection provide patient-specific guidelines

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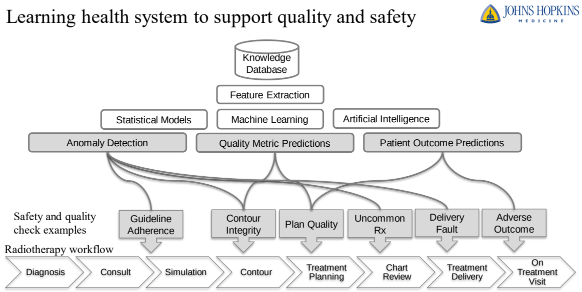
Learning health system to support quality and safety



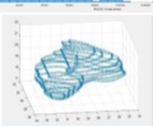
Potential data driven checks

- Region of interest anomalies
- Dose goals
- NTCP, TCP
- Treatment plan complexity
- Rx appropriateness

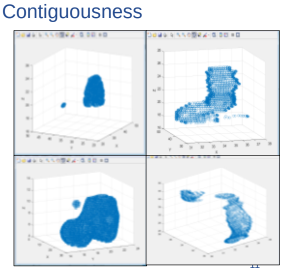
Contour integrity

Veeraj Shah

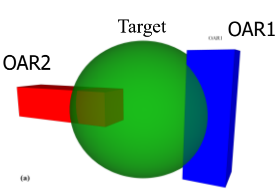
Data-driven

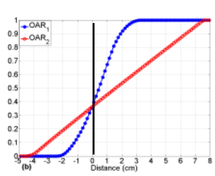


Contiguousness



OVH: serial vs parallel

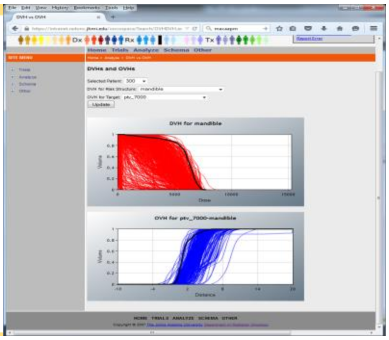




For parallel organs, **OAR2** is more easily spared.
For serial organs, **OAR1** is more easily spared.

Mandible vs PTV_7000

pt: 300



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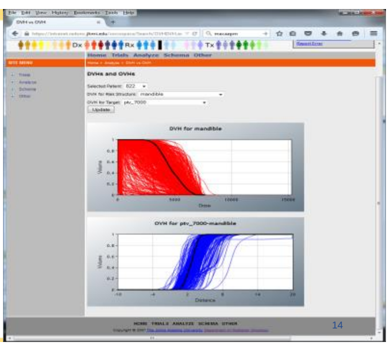
Mandible vs PTV_7000

pt: 822



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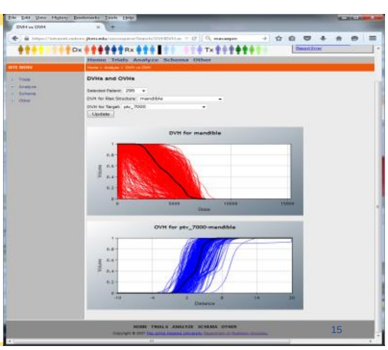
Mandible vs PTV_7000

pt: 295



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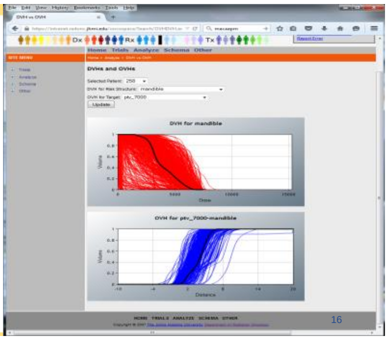
Mandible vs PTV_7000

pt: 258



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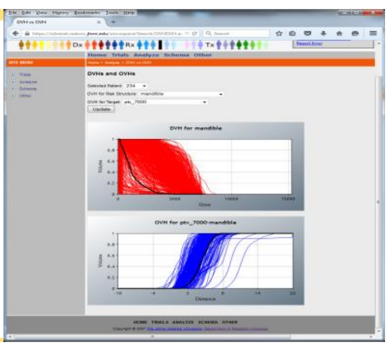
Mandible vs PTV_7000

pt: 234



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Shape-dose relationship for radiation plan quality

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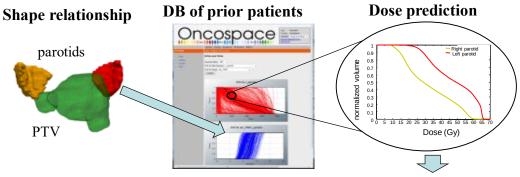
Shape relationship **DB of prior patients** **Dose prediction**

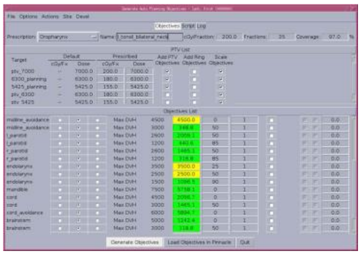


For a selected Organ at Risk and %V, find the lowest dose achieved from all patients whose %V is closer to the selected target volume?

Decisions:

- Plan quality assessment
- Automated planning
  - IMRT objective selection
- Dosimetric trade-offs

Predicted Achievable Dose Objectives



15 pts: OAR Sparing among CP,OP1 and OP2

Table 6. Summary of the dosimetric results for the OARs in the three sets of plans.

OAR	End point	CP	OP1	OP2	Wilcoxon p value		
		Avg.	Avg.	Avg.	CP vs OP1	CP vs OP2	OP1 vs OP2
cord+4mm	$D_{0.1\,cc}$	45.6	39.5	38.7	**<0.0001**	**<0.0001**	0.7
mandible	$D_{0.1\,cc}$	67.4	67.3	67.8	0.79	1	0.91
brainstem	$D_{0.1\,cc}$	47.7	40.4	40	**<0.005**	**<0.005**	0.85
brain	$D_{1\,cc}$	50.8	50	49.6	0.5	0.38	0.88
ipsi-lateral parotid	V(30 Gy)	65	57	58.5	0.21	0.3	0.8
contra-lateral parotid	V(30 Gy)	52	45	43.3	**<0.0001**	**<0.0001**	0.56
larynx	V(50 Gy)	55.4	53.3	50.1	0.66	0.57	0.91
esophagus	$D_{1\,cc}$	53.9	54.1	54	1	0.9	0.95
ipsi-lateral brachial plexus	$D_{0.1\,cc}$	62.2	62.7	62	0.97	0.93	0.9
contra-lateral brachial plexus	$D_{0.1\,cc}$	58.4	59.44	59.53	0.79	0.84	0.86
oral mucosa	V_{cc}(66.5 Gy)	37.6	39.5	40	0.6	0.74	0.93
ipsi-lateral inner ear	D_{mean}	31	25.7	26	0.32	0.47	1
contra-lateral inner ear	D_{mean}	25	19.5	21	0.2	0.43	1

Abbreviations: CP = clinical plan; OP1 = first-around OVH-assisted plan; OP2 = final OVH-assisted plan

Significantly lower in both OPs: cord4mm (~6 Gy), brainstem (~7.4 Gy) and contra-lateral parotid (~7%)

Binbin Wu

NTCP quality using KBP

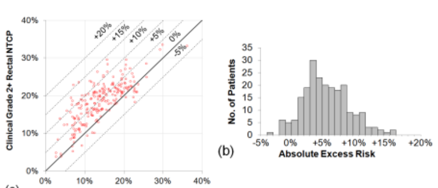


Figure 3: A secondary study on Radiation Therapy Oncology Group (RTOG) 0126 quantified excess risk of late rectal complication due to sub-optimal IMRT planning. (a) Data-driven prediction of normal tissue complication probability (NTCP) vs. the actual treated plans' NTCP. (b) Frequency histogram showed a mean excess risk of 4.7%±3.9%.

Courtesy of Kevin Moore

Physics new start check

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Patient Name:
MRN:
DOB:

Gender:
Attending:
Diagnosis:
Stage:

Quick Checks

Site Name	Item Checked	Check 1	Check 2	Result
R oral cav, R neck	Dose Per Fraction	Prescription: 210 cGy/fx	Beam total: 210 cGy/fx	Pass
R oral cav, R neck	Prescription Modality	Rx modality: x06	Beam energy: 6 MV	Pass
R oral cav, R neck	Site Setup vs Beam Machine	Site setup: VersaEB2	Beams: VersaEB2	Pass
R oral cav, R neck	Site Setup vs Beam Tolerance	Site setup tolerance table: indexed s	Beam tolerance table: indexed	Pass
R oral cav, R neck	Field Name	Current field name: 1_vmat182-20	Expected field name: 1_VMAT_182-20	Warning: Check Field Names
R oral cav, R neck	Field Name	Current field name: 2_vmat20-180	Expected field name: 2_VMAT_20-182	Warning: Check Field Names
R oral cav, R neck	CBCT Field Name	Currently: R oral cav, R neck	Expecting: CT R oral cav, R nec	Warning: Check field names (should be "CT [Site_Name]")
R oral cav, R neck	CBCT Field Name	Currently: R oral cav, R neck	Expecting: CT R oral cav, R nec	Warning: Check field names (should be "CT [Site_Name]")
	Pre-Treatment Checklist-Phys	Approved: 7/8/2019 12:20:46 PM	Approved by: TRM	Pass
	Action Points			None

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Prescription Dose Details

Course	Site Name	Technique	Modality	Fx Dose	Dose Spec	Fractions	Ttl Dose	Cum Dose	Rx Dose Tracking Site	Total Cum
1	R oral cav, R neck	IMRT VMAT IG	x06	210 cGy	Isodose 96.5%	30	6300 cGy	6300 cGy		

Prescription Delivery Details

Course	Site Name	Fx Pattern	Interval	Pattern	Comment	Approved By
1	R oral cav, R neck	Daily	24 hrs	CBCT daily per HN prot; Pr2	SIB 6000, 5400 cGy	APK

Site Setup Details

Course	Site Name	Orientation	Machine	Verify	Tolerance	Devices	Setup Note	DICOM X, Y, Z (mm)	Approved By
1	R oral cav, R neck	Head In, Supine	VersaEB2	Verify	indexed s	S-Frame 'C' headrest Aquaplast Long O - Small	Indexed at 7 ...	(-2.5, 29.9, -82.7)	EHO

Don't forget to check site setup photos and the reference CT if available

Treatment Field Details

Course	Site Name	Field Label	Field Name	Machine	Energy	Modality	Isocenter	SSD	Meterset	Wedge MU	Open MU	Field Type	Ctrl Points	Dose Rate	Approved By
1	R oral cav, R neck	1	1_vmat182-20	VersaEB2	6 MV	Photons		80.2	399.5			VMAT	100	0	EHO
1	R oral cav, R neck	2	2_vmat20-180	VersaEB2	6 MV	Photons		91.4	361.9			VMAT	100	0	TRM

Treatment Field Details (cont'd)

Course	Site Name	Field Label	Field Name	X2	X1	Y1	Y2	Gantry Start	Gantry Stop	Couch	Collimator	Block	Wdg Appl	Bolus	FDA	Tolerance
1	R oral cav, R neck	1	1_vmat182-20	20.0	-20.0	-9.0	8.5	182	20	0	5					indexed
1	R oral cav, R neck	2	2_vmat20-180	20.0	-20.0	-9.0	9.0	20	182	0	355					indexed

Treatment Field Dose Summary

Course	Site Name	Field Label	Field Name	Meterset	% of Total MU	Field Dose	% of Total cGy	Rx: R oral cav, R neck	Sec: ptv6000	Sec: ptv 5400
1	R oral cav, R neck	1	1_vmat182-20	399.5	52 %	97 cGy	46 %	1.000 (97 cGy)	0.952 (92 cGy)	0.857 (83 cGy)
1	R oral cav, R neck	2	2_vmat20-180	361.9	48 %	113 cGy	54 %	1.000 (113 cGy)	0.952 (108 cGy)	0.857 (97 cGy)
1	**R oral cav, R neck**		**Total**	**761.4**	**100 %**	**210 cGy**	**100 %**	**210 cGy**	**200 cGy**	**180 cGy**

Setup Field Summary

Course	Site Name	Field Label	Field Name	Machine	Energy	Gantry	SSD	Meterset	cGy	Tolerance	Has DRR	XVI Preset	Approved By
1	R oral cav, R neck	APSU	AP_Setup	VersaEB2	6 MV	0	90.3	1	0	indexed	Yes		–
1	R oral cav, R neck	RLSU	RLAT_Setup	VersaEB2	6 MV	270	94.9	1	0	indexed	Yes		–
1	R oral cav, R neck	CT1	R oral cav, R neck	VersaEB2	CT	0	90.3	0	0	CBCT ONLY		LT Sweep S20	–
1	R oral cav, R neck	CT1A	R oral cav, R neck	VersaEB2	CT	0	90.3	0	0	CBCT ONLY		LT Sweep S20 ver	–
1	**R oral cav, R neck**		**Total**					**2**	**0**				

Radiation prescription safety

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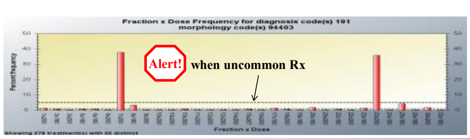
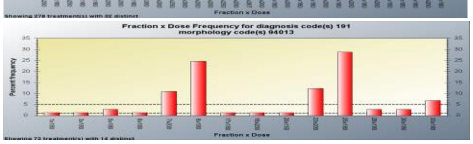
191 Brain *AND* Pathology of Glioblastoma



191 Brain *AND* Pathology of Anaplastic Astrocytoma

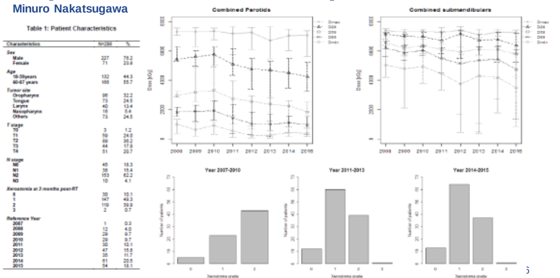


Radiation prescription safety

ID	ICD9	Morphology	Site	Fx	Dose	Freq	Count	Total
[redacted]	191 Brain: MN	Glioblastoma, NOS (T-191.__)	Right pariet-occ GBM	23	200	35.97%	100	278
[redacted]	191 Brain: MN	Glioblastoma, NOS (T-191.__)	CD Right par-occ GBM	7	200	37.77%	105	278
[redacted]	154 Rectum,Rectosigmoid Junction	Adenocarcinoma, NOS	rectal CD	3	180	29.23%	38	130
[redacted]	154 Rectum,Rectosigmoid Junction	Adenocarcinoma, NOS	whole pelvis PTV	25	180	43.08%	56	130
[redacted]	150 Esophagus: MN	Adenocarcinoma, NOS	Esophagus	25	180	65.71%	46	70
[redacted]	191 Brain: MN	Medulloblastoma, NOS	Craniospinal	23	180	0%	0	27
[redacted]	191 Brain: MN	Medulloblastoma, NOS	Left cerebellar CD	7	180	0%	0	27
[redacted]	157 Pancreas: MN	Adenocarcinoma, NOS	Left Retroperitoneum	11	250	0.40%	1	252
[redacted]	174 Female Breast: MN	Infiltrating duct carcinoma	L CW+Low ax	28	180	5.54%	34	614
[redacted]	174 Female Breast: MN	Infiltrating duct carcinoma	LT PAB	25	58	0.49%	3	614
[redacted]	174 Female Breast: MN	Infiltrating duct carcinoma	LT hi Ax+Sc	25	200	18.57%	114	614
[redacted]	141 Tongue: MN	Squamous cell carcinoma, NOS	PTV left neck, L BOT	40	130	1.89%	1	53
[redacted]	162 Trachea, Bronchus, Lung: MN	Adenocarcinoma, NOS	Left parietal PTV	1	2000	0.51%	1	197
[redacted]	162 Trachea, Bronchus, Lung: MN	Adenocarcinoma, NOS	Rt lung & SCV node	6	200	1.52%	3	197
[redacted]	162 Trachea, Bronchus, Lung: MN	Adenocarcinoma, NOS	rt lung tumor c/dABC	8	200	1.52%	3	197
[redacted]	162 Trachea, Bronchus, Lung: MN	Adenocarcinoma, NOS	rt lung/SVC nodeABC	21	200	1.02%	2	197
[redacted]	C40, C41 Bones and joints	Malignant melanoma, NOS	Right T10 Paraspinal	5	500	0%	0	0
[redacted]	162 Trachea, Bronchus, Lung: MN		RUL lung mass	4	1200	4.21%	38	902
[redacted]	202 Lymphoid/Histiocytic Tiss	Malignant lymphoma, large cell	boost ptv	3	180	0%	0	27
[redacted]	202 Lymphoid/Histiocytic Tiss	Malignant lymphoma, large cell	whole brain	10	300	11.11%	3	27

Importance of model update

Minuro Nakatsugawa



Importance of model update

Method A: yearly update

Training data

Test data

2007-'09 | '10
2007-'10 | '11
2007-'11 | '12
...
2007-'14 | '15

Method B: condition-based update

2007-'09 | '10
2007-'10 | '11-'12
2007-'12 | '13
2007-'13 | '14-'15

Method C: no update

2007-'09 | 2010-'15

Table 3: Comparison of AUC for grade ≥ 2 xerostomia prediction in three model updating methods

	Model updating	Training data	Test data	AUC (2010-2015)
A	Every year (6 times)	2007 - year X (2009 ≤ X ≤ 2014)	year X+1	0.633
B	Condition-based updates (update if AUC < 0.6, 3 times)	2007 - year Y Y = max(y) where AUC(y) < 0.6, y≤X	year X+1	0.604
C	No updates (Baseline model)	2007 - 2009	2010 - 2015	0.489

How to stay safe and maintain quality?

- Data is not always the highest quality – must make sure methods/models don't assume it is
- Data does not contain all knowledge. Existing knowledge is often absent
  - If all patients in database meet a dose goal, then there is no knowledge outside of that goal contained in the data.
  - Be wary of situations where you may be outside of the available data bounds
- Data gets old
  - How to keep models current?
  - Do we want to be treated the way patients were treated a 2 decades ago?
  - The Rx anomaly may be using an old Rx that has been superseded.

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Summary

- Quality follows a system of checks
- Predefined checklists and scorecards provide population level quality
- Data driven methods can personalize the measures of quality
- The learning health system concept offers the opportunity to include data driven quality systems into clinical practice

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Thank You

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- **University of Washington**
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  - Mark Philips PhD
  - Kristi Hendrickson PhD

Manufacturing Quality

- Do things the same way every time
- Control of process
- Testing samples
- Feedback from measures

- But each patient is different

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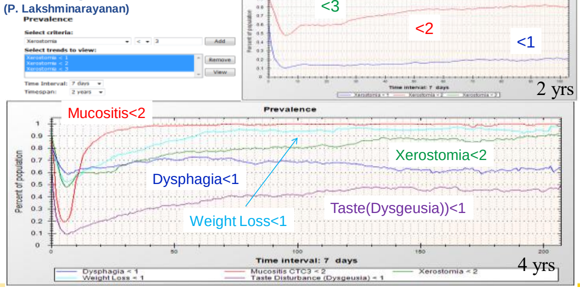
Toxicity Prevalence

(P. Lakshminarayanan)



Which patient will do better?

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69-year-old man with Stage Squamous cell carcinoma, NOS of the Right Malignant neoplasm of tonsil

63-year-old man with T3 N2b M0 Stage IVA Squamous cell carcinoma, NOS of the Malignant neoplasm of larynx