MICHIGAN MEDICINE
UNIVERSITY OF MICHIGAN

AAPM TG 263:
The Benefits of Standardizing Radiation Therapy Nomenclature

AAPM Spring Clinical Meeting
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on behalf of AAPM TG 263

Disclosures

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- Projects with Modus Medical and ImageOwl

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Outline

- Why Big Data’s hasn’t give us big gains yet
- Life before TG 263
- Goals of TG 263
- Sample draft recommendations
- Leveraging Big Data as a Community

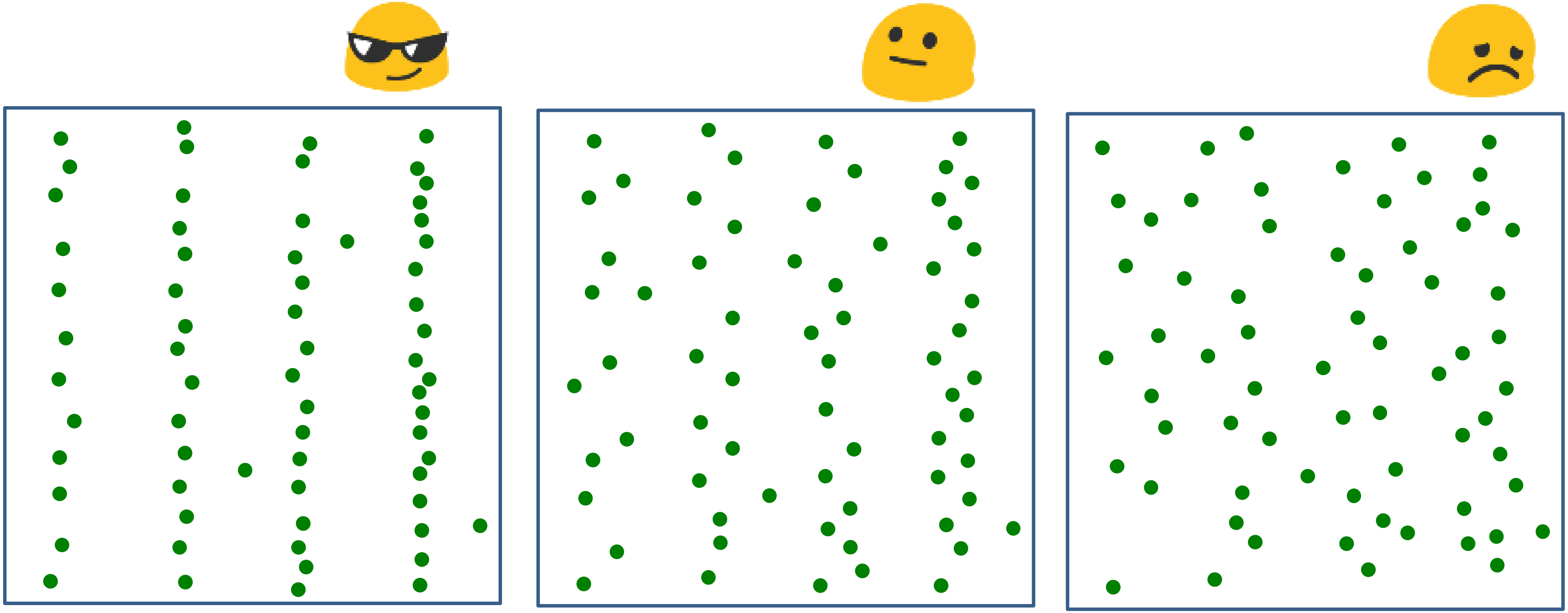
Do we know what we have in our databases so that we can assemble the information or tools into something meaningful?

Can we find what we need?

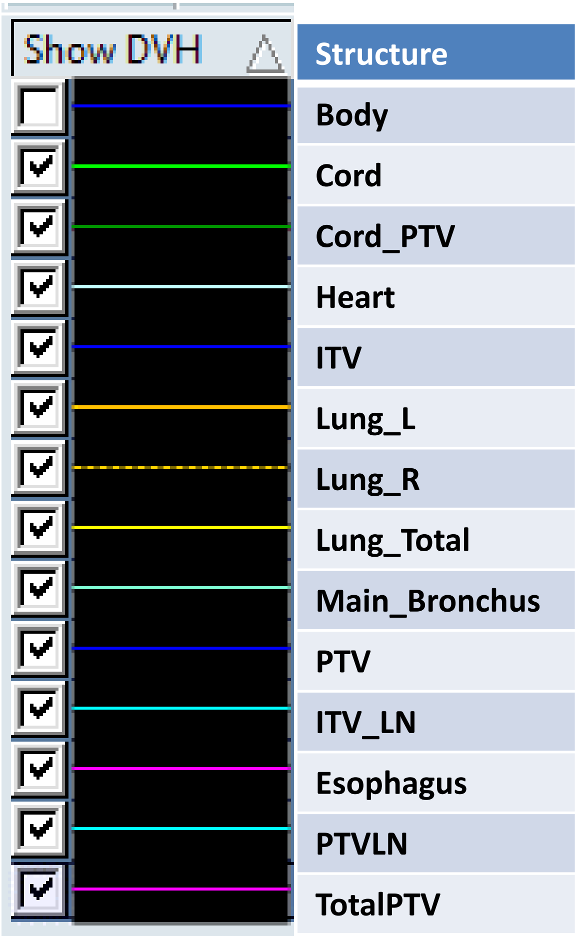
Sorting helps

Can we then build what we need?

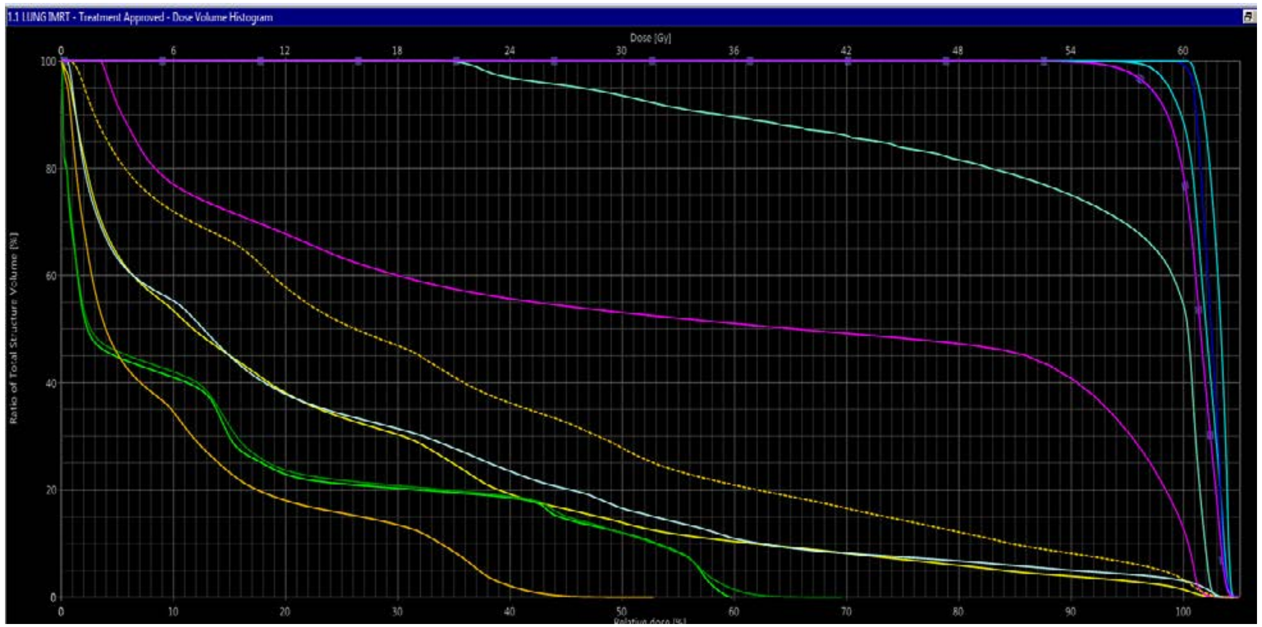
Are we organizing the data we care about into “rows” so that we can automate harvesting it later?



Need clarity in communication among team members + systems: target, non-target, dose volume histogram metrics



Volume



Dose

Much of the information we need is linked to dose volume histograms … stored in our Treatment Planning Systems

Inspect your own data…you'll see variations over time, treatment planners, physicians, treatment planning systems

Plan for Lung Patient 1

Show DVH	Structure
☐	CORD_PRV5
☐	ITV
☐	LUNG_L
☐	LUNG_R
☐	MAIN_BRONCHUS
☐	BODY
☐	CARINA
☐	AORTA
☐	SVC
☐	LUNGS-ITV
☑	BRAC_PLX_R
☑	CHESTWALL
☑	CORD
☑	LUNG_TOTAL
☑	PTV
☑	TRACHEA
☑	GREAT_VESSEL
☑	Dose 50[Gy]
☑	Dose 25[Gy]

Patient 2

Show DVH	Structure
☐	MAIN_BRONCHUS
☐	BODY
☐	CT1PT1GTV
☐	CT1PT1CTV
☐	CT1GTV
☐	PT1GTV
☐	NonPTV
☐	Dose 95[%]
☐	CT2GTV
☐	PT2GTV
☐	PT2PTV
☐	2
☑	SpineCanal
☑	HEART
☑	LUNGS
☑	CT1PT1PTV
☑	ESOPHAGUS
☑	CT2PTV

Patient 3

Show DVH	Structure
☐	BODY
☑	CORD
☑	CORD_PRV5
☑	HEART
☑	ITV
☑	LUNG_L
☑	LUNG_R
☑	LUNG_TOTAL
☑	MAIN_BRONCHUS
☑	PTV
☑	ITV_LN
☑	Esophagus
☑	PTVLN
☑	TOTALPTV

Patient 4

Show DVH	Structure
☐	CTUN_EXTERNAL
☐	CTUN_ITV
☐	CTUN_LUNG_R
☐	CTUN_PTV
☐	Pacemaker

Look across multiple institutions …
You'll find much wider variation

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Have we standardized our data and how we share it?

- We purchase treatment planning systems (TPS) from a limited number of vendors
- But, we have different workflows and other computer systems
  - CT scanners, image registration software
  - Multiple datasets & times – adaptive plan, replan from previous treatment
  - How do we handle serial vs parallel organs with respect to changes in patient anatomy?
- We often have our own way of doing things…not just by institution but by physicist, dosimetrist, clinician

Previous Standardization Efforts

Table 2. Planning organs at risk volumes

Organ at risk name	Left/right	Margin (mm)	Proposed name
SpinalCord	N/A	Nonuniform	SpinalCord_PRV
SpinalCord_PRV	N/A	5	SpinalCord_05
Parotid	Left	0	Parotid_L
Parotid	Right	0	Parotid_R
Total parotid	Left+Right	0	Parotids
Kidney	Left	10	Kidney_L_10

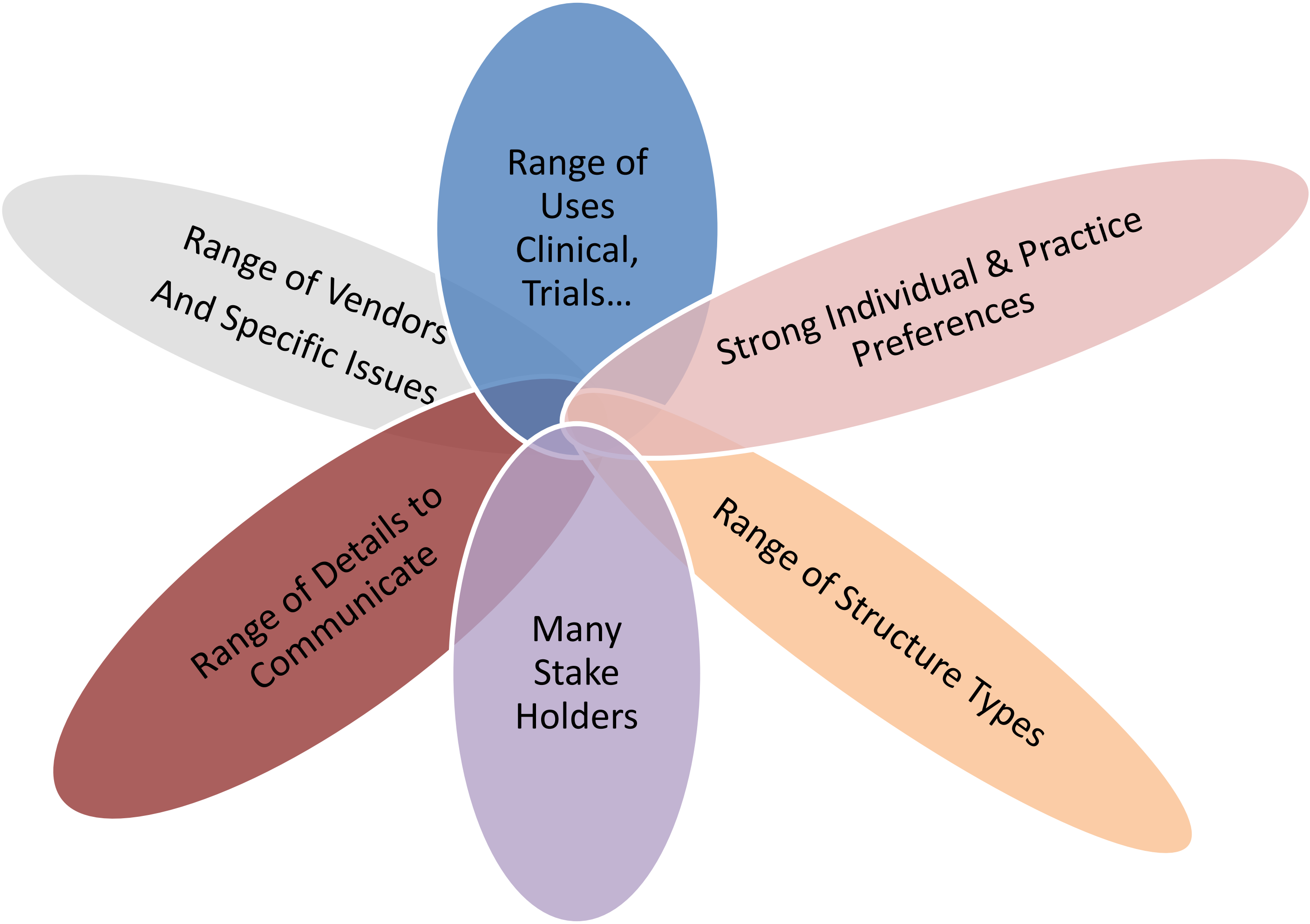
Santanam et al, IJROBP: Standardizing Naming Conventions in Radiation Oncology, 83: 1344-1349, 2012.

To reap benefits of

- Automated tools to extract data for trials and Clinical Practice Improvement
- Automated safety checks
- Automated planning
- Comprehensive outcomes databases
- Better plan evaluation tools

We have to overcome inconsistencies in

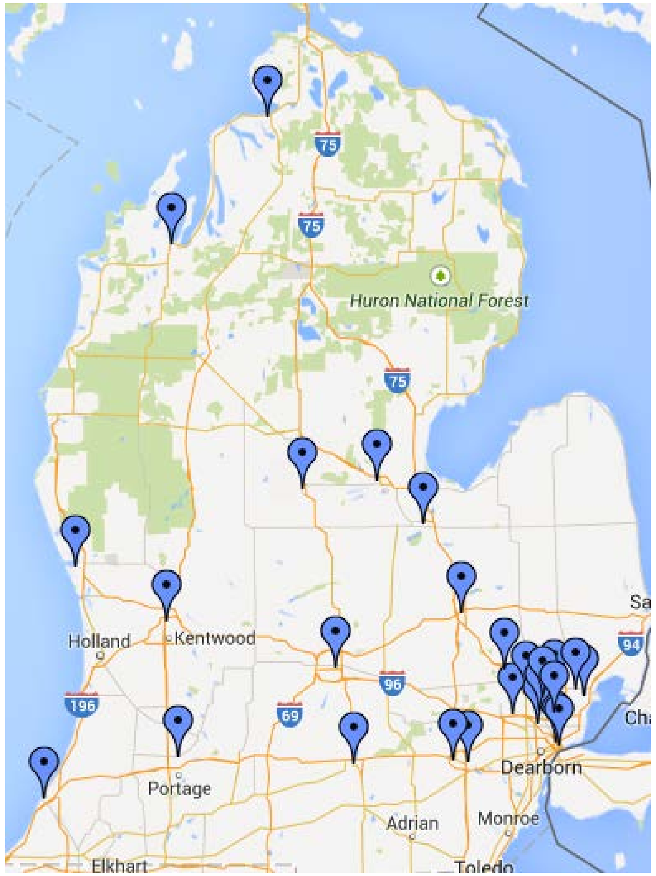
- Structure names
- Laterality indicators
- Constraints of vended systems
- DVH metrics
- Contouring descriptors
- ….



Previous methods of addressing the inconsistencies in structure names have involved making duplicate structures with the clinical name vs the clinical trial name or mapping structures.

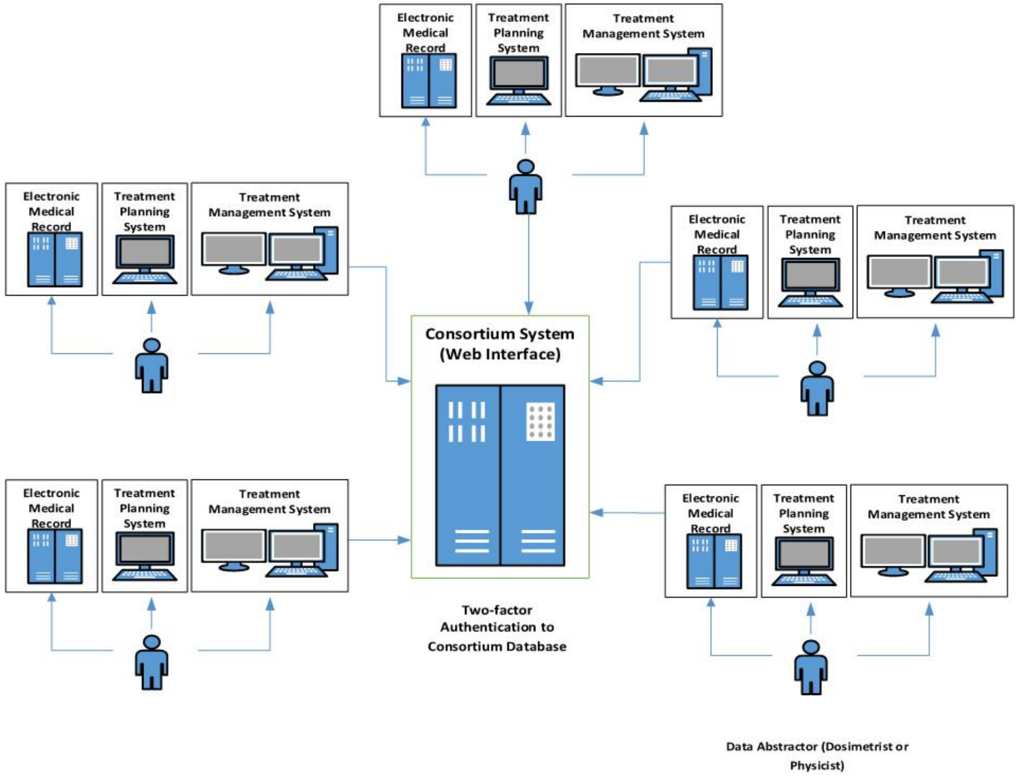
What can we do with Big Data?

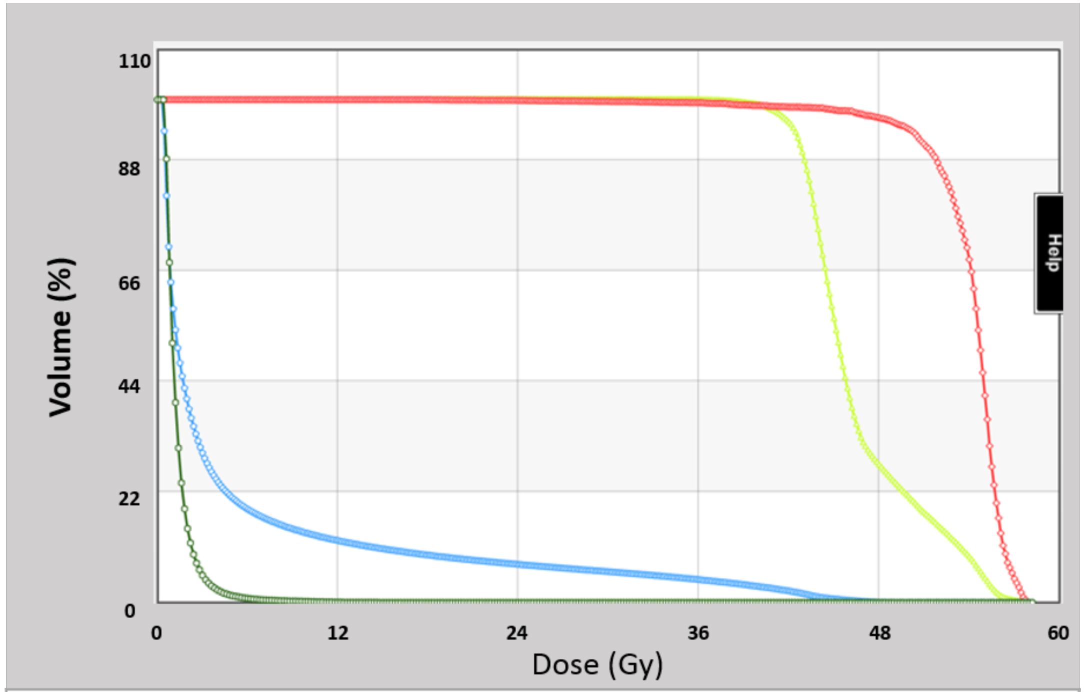
- The University of Michigan is the coordinating center for a statewide registry focused on breast and lung cancer which we launched in 2012.
- Focused registry:
  - Patient and physician reported outcomes
  - Photos for patients who consent
  - Physics/dosimetry details
- 25 institutions:
  - Community and academic centers represented
  - Thousands of patients
- There are a number of ongoing analyses related to technology use, target coverage, …



MROQC is funded by Blue Cross Blue Shield of Michigan and the Blue Care Network

MROQC
Michigan Radiation Oncology Quality Consortium





On/Off	Color	Structure	Total Volume (cc)	Bin Minimum (Gy)	Bin Maximum (Gy)	Mean (Gy)
☑		Breast95_L	896.4	34.5	57.9	46.65
☑		Surgical_bed	59.6	18.15	57.9	54.03
☑		Lung_L	2218.4	0.3	49.05	5.41
☑		Heart	569.7	0.4	19	1.34

User uploads data for each structure based on the label in the MROQC Database.
The nomenclature was prior to TG 263 efforts.

What is the rate of utilization of breath hold control for breast and lung cancer patients?

Michigan Radiation Oncology Quality Consortium

Variability in Rates of Hypofractionation for Eligible Patients with Breast Cancer in Michigan

1014 Jagsi et al. International Journal of Radiation Oncology • Biology • Physics

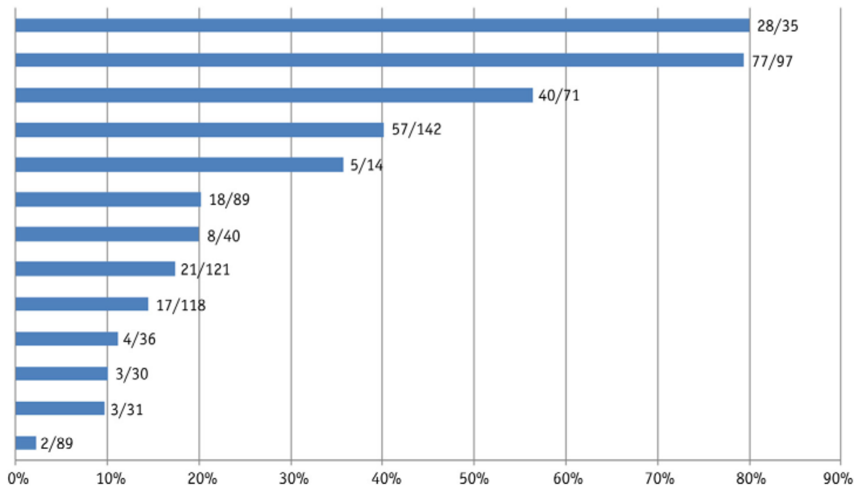
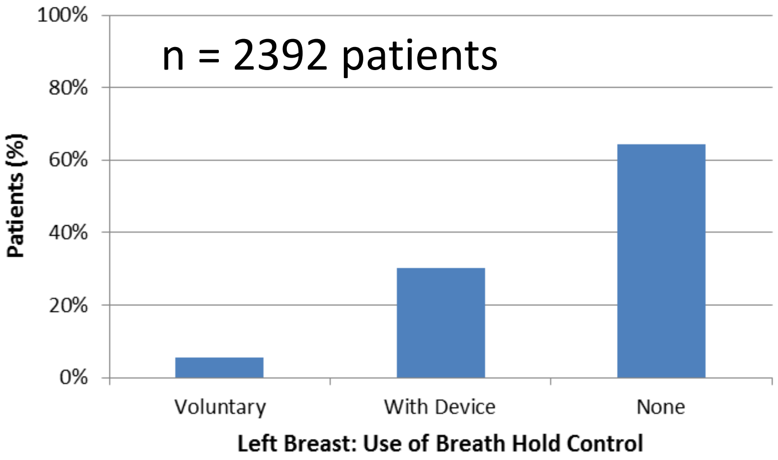
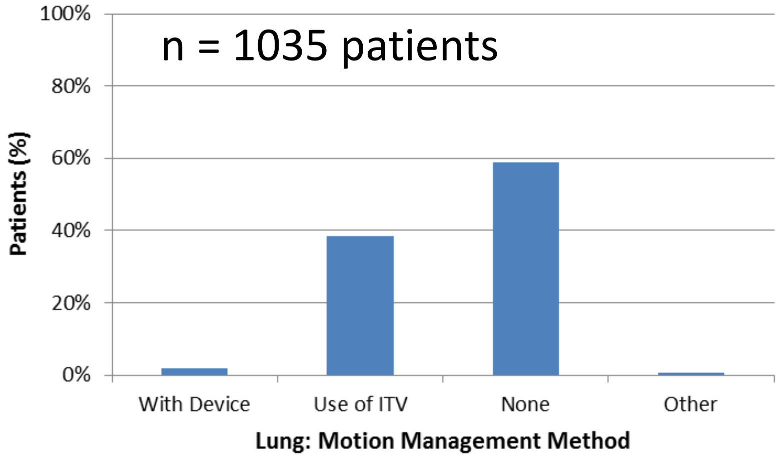


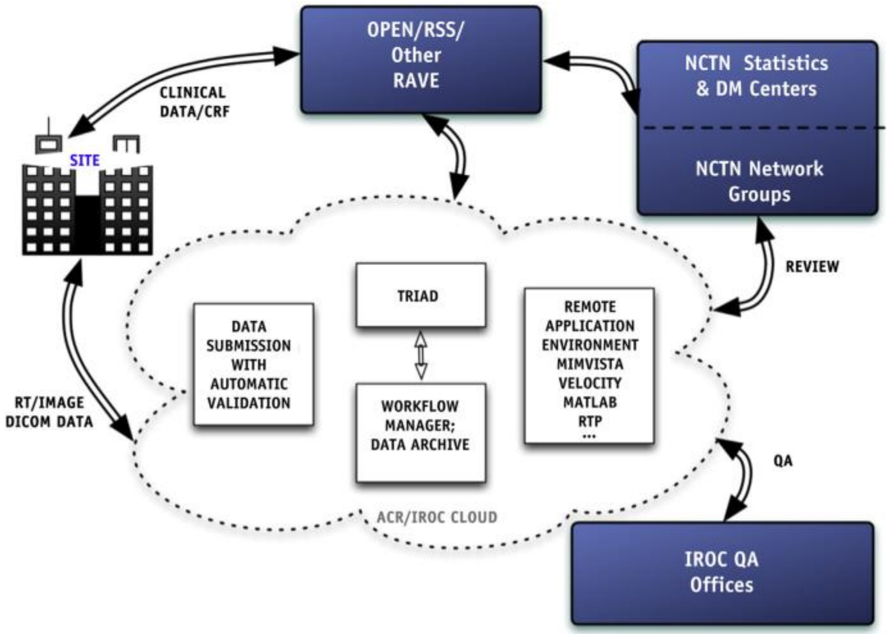
Fig. 1. Rates of hypofractionation use by institution for patients with T1-2, N0 tumors treated with lumpectomy and whole-breast radiation therapy (n=913).

Jagsi et al, "Choosing Wisely?" IJROBP 90: 1010-1016, 2014





Clinical Trials Data Submission



Radiation Therapy Digital Data Submission Process for National Clinical Trials Network

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Supplement: Radiotherapy Structure Name Library

"The TRIAD system includes built-in functions that can be used to automate digital data QA during the transmission process. In particular, it includes **an automated evaluation of the consistency between the submitted structure names and protocol requirements**."

Prescription Structures	Description
A_Aorta_CTV	Used to construct CTV for Pancreatic studies.
A_Celiac_CTV	Used to construct CTV for Pancreatic studies.
A_SupMes_CTV	Used to construct CTV for Pancreatic studies.
CT1GTV	Adaptive - GTV based on initial CT scan
CT1PT1CTV	Adaptive - CTV based on initial CT and PET scan
CT1PT1GTV	Adaptive - GTV based on initial CT and PET scan
CT1PT1PTV	Adaptive - PTV based on initial CT and PET scan
CT2GTV	Adaptive - GTV based on interim CT scan
CT2PTV	Adaptive - PTV based on interim CT scan

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TG 263 - Standardizing Nomenclature for Radiation Therapy: Creating Group Consensus

- Group of 57 stake holders
- Domestic and international groups
- Broad range of perspectives represented

Roles	Professional Societies	Clinic Types	Specialty Groups
Physician	ASTRO	Academic	IHE-RO
Physicist	AAPM	Community	DICOM Working Group
Vendor	ESTRO	Large Practice	NRG
Dosimetrist	AAMD	Small Practice	IROC

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Current Status AAPM TG263

- The report is under a 2nd review by Therapy Physics Committee after approval by the Work Group on Clinical Trials and QA & Outcome Subcommittee
- Emphasis for the report is on non-target structures and DVH nomenclature and rules for targets
- Good participation from a radiation therapy clinical trials perspective – members from IROC-Houston and IROC-Philadelphia and NRG

Sample Recommendation for Non-Target Structure Names	Reasoning
Structure names limited to ≤16 characters	Compatibility with multiple vendor systems
Unique regardless of capitalization	Prevent conflicts in the database
First character of the structure category is capitalized	Femur_Head, Ear_Externals
Spatial categories for the primary name are at the end of the string: Lung_LUL	Standard for interpretation
Two allowed names for each structure: e.g. Read right to left or left to right; Kidney_R or R_Kidney	Some systems allow for longer strings but may only display 16 characters; want to see correct structure name without ambiguity; Two methods gives users flexibility to choose one.

Sample of Proposed Guiding Principles for Non-Target Nomenclature

Sample Recommendation for Non-Target Structure Names	Reasoning
Use tilde to indicate partial structures, e.g. Lungs vs Lungs~	For example when a CT scan may be cut off. Flags incomplete data automatically.
Underscore character to separate categorization	Bone_Pelvic
For structures not used in prescription dose constraints, put a 'z' in front of the structure	Allows for alphabetic sorting to minimize confusion in a clinical setting; valuable in the post-treatment analysis setting!

Brainstem
CTV_5000
PTV_5000
zD95%
zHot
zOptPTV5000

In our clinic these 'z' labeled structures are applied to structures which aid in optimization and for draft resident contours.

Sample of Proposed Guiding Principles for Non-Target Nomenclature

Allow two standard names for each structure. Reading Left->Right:

1) Categorizes from General -> Specific preferred default

   Alphabetic sort groups structure categories, Lung_R, Lung_L, Lungs

2) Categorizes from Specific -> General

   Better safety for limited character displays in some systems

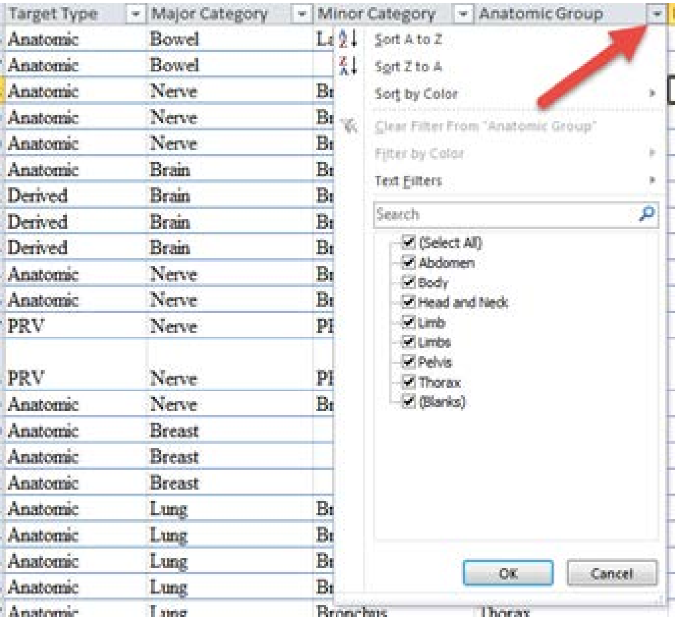
L_OpticNrv	OpticNrv_L

TG263 – Tested during development!

- We had multiple participants pilot the TG263 nomenclature as we were developing the rules
  - Multiple vendor settings and clinical environments
- Manufacturer stakeholders at the table
- Clinical trial representation at the table

Report Includes a sortable spreadsheet of standardized names including FMAID labels where they exist.

Connection to other ontologies where they exist is valuable.



General Type	Major Category	Minor Category	Anatomic Group	N Characters	TG263-Mapping 1	TG-263Mapping 2	Description	FMAID
Anatomic	Artery	Aorta	Thorax	7	A_Aorta	Aorta_A	Aorta	3734
Anatomic	Artery	Brachiocephalic	Thorax	15	A_Brachiocephls	Brachiocephls_A	Brachiocephalic Artery	3932
Anatomic	Artery	Carotid	Head and Neck	9	A_Carotid	Carotid_A	Common Carotid Artery	3939
Anatomic	Artery	Carotid	Head and Neck	11	A_Carotid_L	L_Carotid_A	Carotid Artery	4058
Anatomic	Artery	Carotid	Head and Neck	11	A_Carotid_R	R_Carotid_A	Carotid Artery	3941
Anatomic	Artery	Celiac	Abdomen	8	A_Celiac	Celiac_A	Celiac Artery	
Anatomic	Artery	Coronary	Head and Neck	10	A_Coronary	Coronary_A	Coronary Artery	49893
Anatomic	Artery	Coronary	Thorax	12	A_Coronary_L	L_Coronary_A	Coronary Artery Left	50040
Anatomic	Artery	Coronary	Thorax	12	A_Coronary_R	R_Coronary_A	Coronary Artery Right	50039
Anatomic	Nerve	Brachial	Thorax	14	BrachialPlex_R	R_BrachialPlex	Brachial plexus Right	5906
Anatomic	Nerve	Brachial	Thorax	13	BrachialPlexs	BrachialPlexs	Brachial plexusi	5906
Anatomic	Brain	Brain	Head and Neck	5	Brain	Brain	Brain	50801
Derived	Brain	Brain	Head and Neck	9	Brain-GTV	Brain-GTV	Brain minus the GTV	
Derived	Brain	Brain	Head and Neck	9	Brain-CTV	Brain-CTV	Brain minus the CTV	
Anatomic	Nerve	Brainstem	Head and Neck	9	Brainstem	Brainstem	Brain Stem	79876
Anatomic	Nerve	Brainstem	Head and Neck	14	Brainstem_Core	Core_Brainstem	Core of the brainstem	
PRV	Nerve	PRV	Head and Neck	15	Brainstem_PRVxx	PRVxx_Brainstem	PRV margin on the brain stem that is an xx millimeter expansion	
Anatomic	Lymph Node		Thorax	13	LN_Pulmonarys	Pulmonarys_LN	Lymph nodes of thorax - Pulmonary	5968
Anatomic	Lymph Node		Thorax	15	LN_Supmammary_L	L_Supmammary_LN	Lymph nodes of thorax - Supramammary Left	232604
Anatomic	Lymph Node		Thorax	15	LN_Trachbronchs	Trachbronchs_LN	Lymph nodes of thorax - Tracheobronchial	5950
Anatomic	Brain	Lobe	Head and Neck	12	Lobe_Frontal	Frontal_Lobe	Frontal Lobe	61824
Anatomic	Brain	Lobe	Head and Neck	14	Lobe_Frontal_L	L_Frontal_Lobe	Frontal Lobe Left	72970
Anatomic	Brain	Lobe	Head and Neck	14	Lobe_Frontal_R	R_Frontal_Lobe	Frontal Lobe Left	72969
Anatomic	Brain	Occipital Lobe	Head and Neck	14	Lobe_Occipital	Occipital_Lobe	Occipital Lobe	67325
Anatomic	Brain	Occipital Lobe	Head and Neck	16	Lobe_Occipital_L	L_Occipital_Lobe	Occipital Lobe Left	72976

Target Nomenclature: First set of characters must be one of following allowed target types

- GTV
- CTV
- ITV
- IGTV (Internal GTV, i.e. gross disease with margin for motion)
- ICTV (Internal CTV, i.e. clinical disease with margin for motion)
- PTV
- PTV!: For low dose PTV volumes that exclude overlapping high dose volumes (See section discussing segmented vs non-segmented PTVs)

Target Nomenclature: If dose is indicated, it's at the end of the target string prefixed with an underscore character

- Numeric values are in cGy, e.g. GTV_5400, CTV_5400, PTV_5400*
- Text values define relative dose levels
  - High : e.g. PTV_High, CTV_High, GTV_High
  - Low : e.g. PTV_Low, CTV_Low, GTV_Low
  - Intermediate : e.g. PTV_Intermediate
  - Mid+2 digit enumerator: allows specification of more than 3 relative dose levels e.g. PTV_Low, PTV_Mid01, PTV_Mid02, PTV_High

*Note Evans et al 2016, ASTRO White Paper Prescription Guideline recommends dose in cGy.

The Value of Looking at Our Data: Prescriptions alone are not enough

State of dose prescription and compliance to international standard (ICRU-83) in intensity modulated radiation therapy among academic institutions

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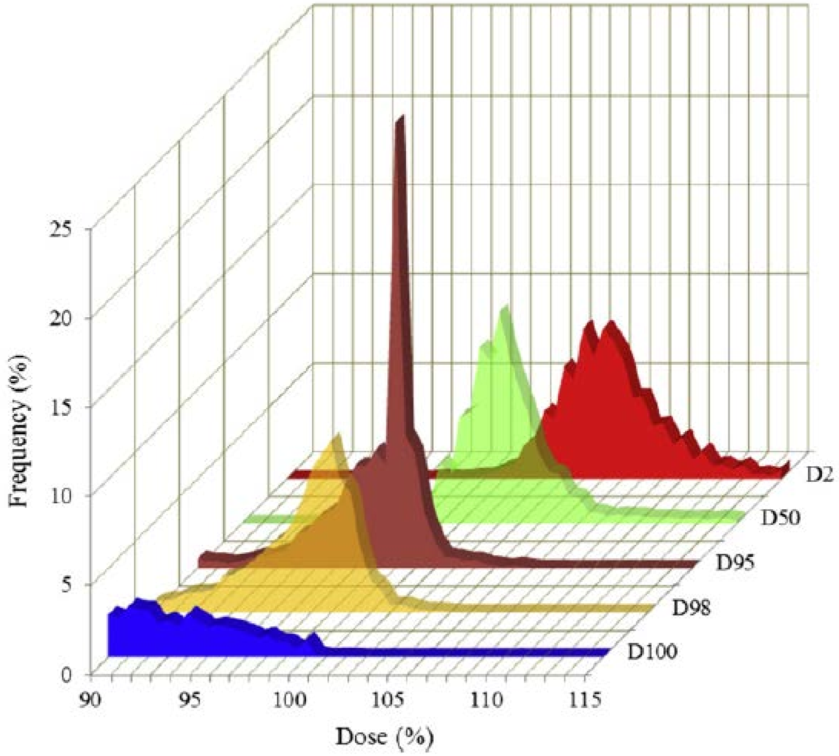


Fig. 2. Frequency distribution of ICRU-83 dose parameters. N=5094 patients; D95% has a peak at 1.

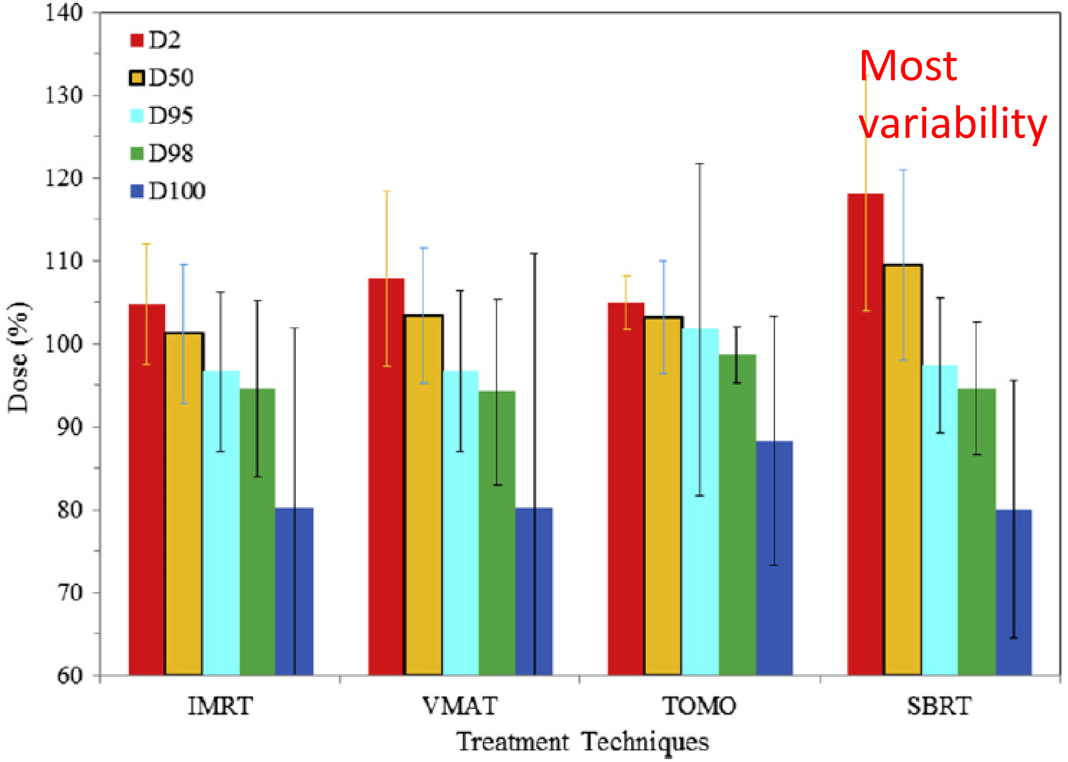
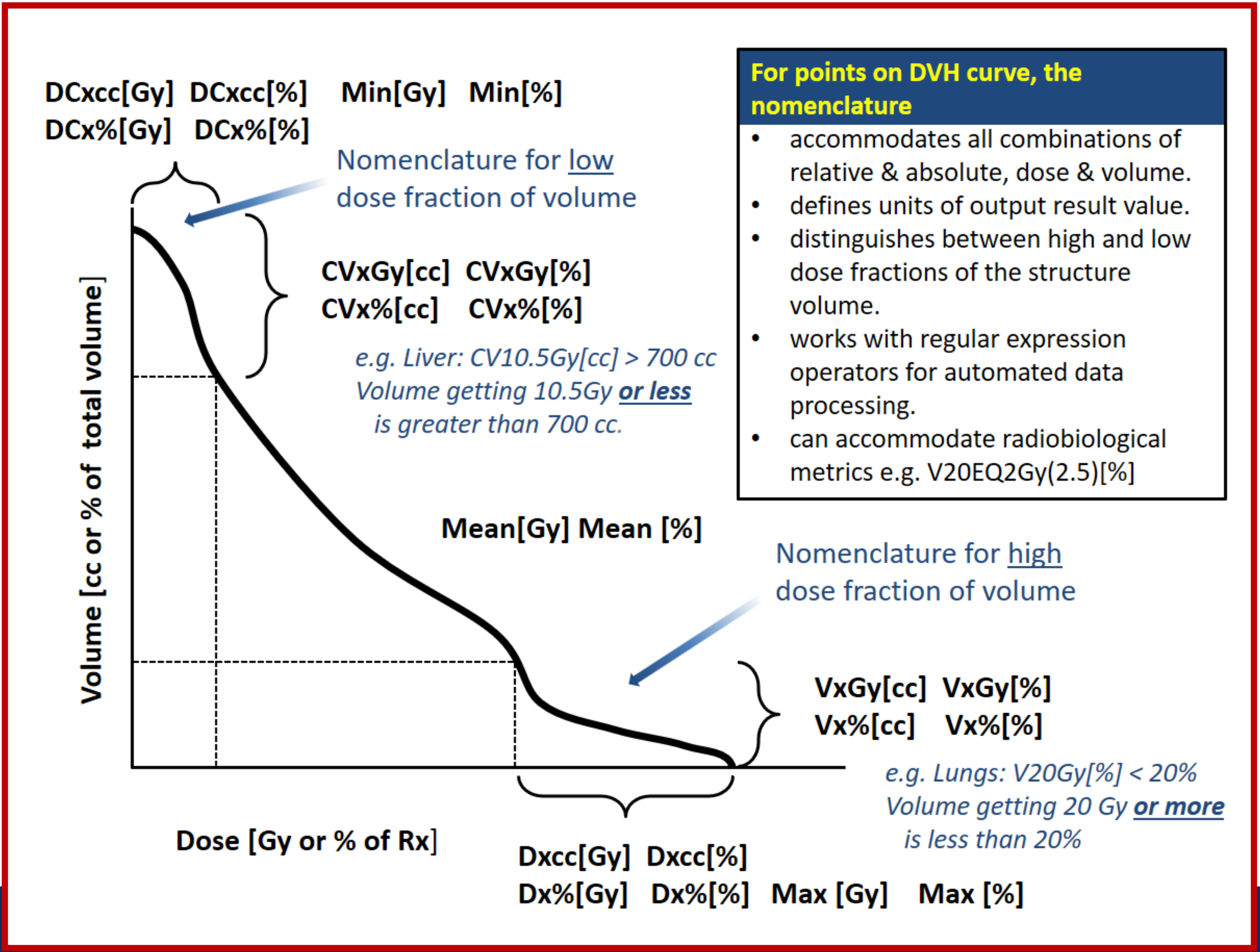


Fig. 5. Dose parameters versus treatment techniques. Minimal variations in IMRT vs VMAT.

Standardizing Dose Volume Histogram Nomenclature



- Input & Output units
- High & Low dose metrics

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Goal: Improve patient care by connecting radiation therapy Big Data to other Big Data

Key Element Category	Demand Ranking	ETL Difficulty	Typical Source Systems	Access	Multiple Source Systems	Use or Used Free Text Entry	Missing Data	Data Accuracy	Lack of Standardization	PHI Constraints Limit Access	Legacy Formats or Systems	Require Process Changes	Extensive Transformation	Other
Demographics ●	1	L	EHR	×										E
Health Status Factors	2	L	EHR	×										E
Pathology ⊙	3	M to H	EHR	×		×	×		×		×	☒		E, X
Surgery ⊙	2	M to H	EHR	×		×	×		×		×	☒		E, X
Chemotherapy ●	2	M	EHR, ODB	×										E
Encounter Details ● Office, Emergency Room, Hospitalization	3	L	EHR	☒									×	R
Diagnosis ●,▲,◉	1	M	EHR, ROIS	×	×			×			×	☒		R, E
Staging ●,▲,◉	1	H	EHR, ROIS	×	×	×		×			×	☒		E
Prescription ▲,◆	1	H	ROIS, ODB						☒			×		E, X, R
As Treated Plan Details ●	1	M	ROIS										×	
DVH ●,□,◆	1	M	TPS				×		×		×	☒	×	ATPS
Survival ●	1	M	EHR, XLS, ODB	×						☒				UD, E
Recurrence ▲,◉	1	H	EHR	×		×	×			×	×	☒		E, X
Toxicity ●,▲	1	H	EHR, ROIS	×		×	×			×	×	☒		E, X
Patient Reported Outcomes ▲	2	H	EHR, P	×			×			×	×	☒		E, X

Other Efforts: University of Michigan Radiation Oncology Analytics Resource (M-ROAR) – Led by Check Mayo

Use Cases Drive Prioritization of Development of Input ETLs, M-ROAR Schema, and Architecture Supporting Reporting, Research & Collaboration

ETL Source Systems

- ● (blue) Radiation Oncology Information System (ARIA)
- ● (gray) Treatment Planning System (Eclipse)
- ● (red) Electronic Health Record (EPIC)
- ● (yellow) Health System Data Warehouse
- ● (purple) Legacy Systems
- ● (green) Spread Sheets
- ● (pink) PACS System

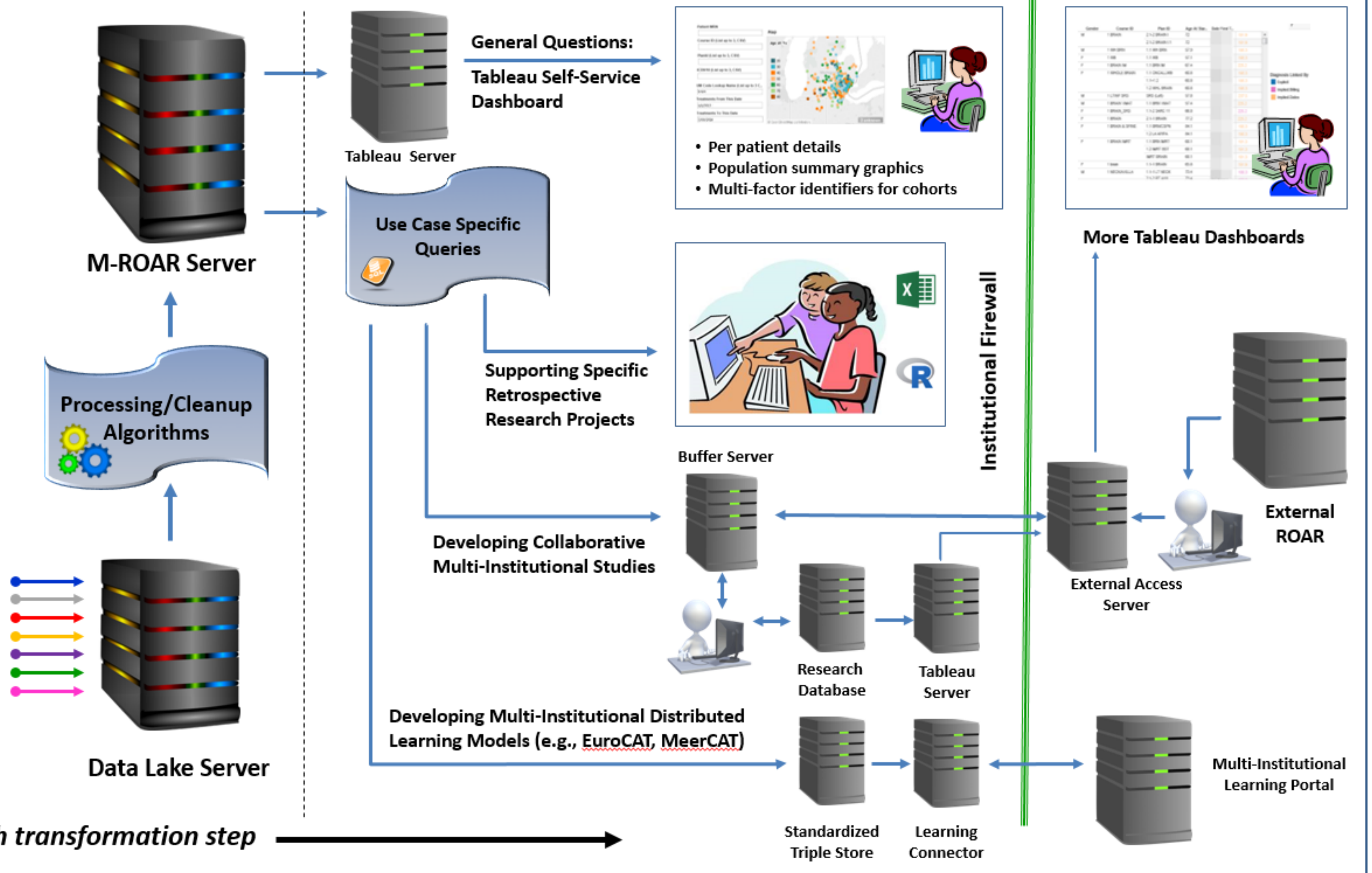
ETL Issues

- ■ (blue) Access to server systems
- ■ (gray) Missing data or inconsistent entry
- ■ (red) Changes over time in format, quality, detail
- ■ (yellow) Unstructured Free Text
- ■ (purple) Inconsistent nomenclature
- ■ (green) Challenges detailing needed relationships to other elements
- ■ (brown) Manual effort needed in extraction
- ■ (pink) Extensive processing of raw data needed

ETL Status

- ◆ (green) Existing processes work
- ◆ (blue) Making processes changes to allow automated extractions
- ◆ (yellow) In development

Data Type	Source System	ETL Issues	ETL Status
Demographics	red	blue	green
Labs	red, yellow	blue, red	green
Medications	red, yellow	blue	green
Survival	red	blue	green
Health Info (e.g. smoking status)	red, yellow	blue	green
Encounters (Office Visits, Emergency, Hospitalizations) + diagnosis codes	red	blue	green
Toxicity – Provider Reported	red	blue, gray, red	green, blue
Patient Reported Outcomes	red	blue	blue, yellow
Recurrence	red	blue, gray, yellow, brown	blue, yellow
Pathology	red	blue, yellow, brown	yellow
Surgery	red	blue, yellow, brown	yellow
Chemotherapy Treatment Details	red	blue	green
Radiation Treatment Details	blue	red, purple	green
Prescription	blue	gray, purple, brown	blue
Diagnosis and Staging	blue, red	blue, gray, yellow	green
Tx Imaging and Timeline Details	blue	green, pink	green
DVH Curves	gray, purple	gray, purple	green
DVH Metrics	gray, purple	gray, purple	green
Imaging	gray, pink	blue, purple	yellow
Radiomics	gray, pink	blue, pink	yellow
Genomics	green	gray, brown	yellow
Historic Research Results	green	gray, brown	green

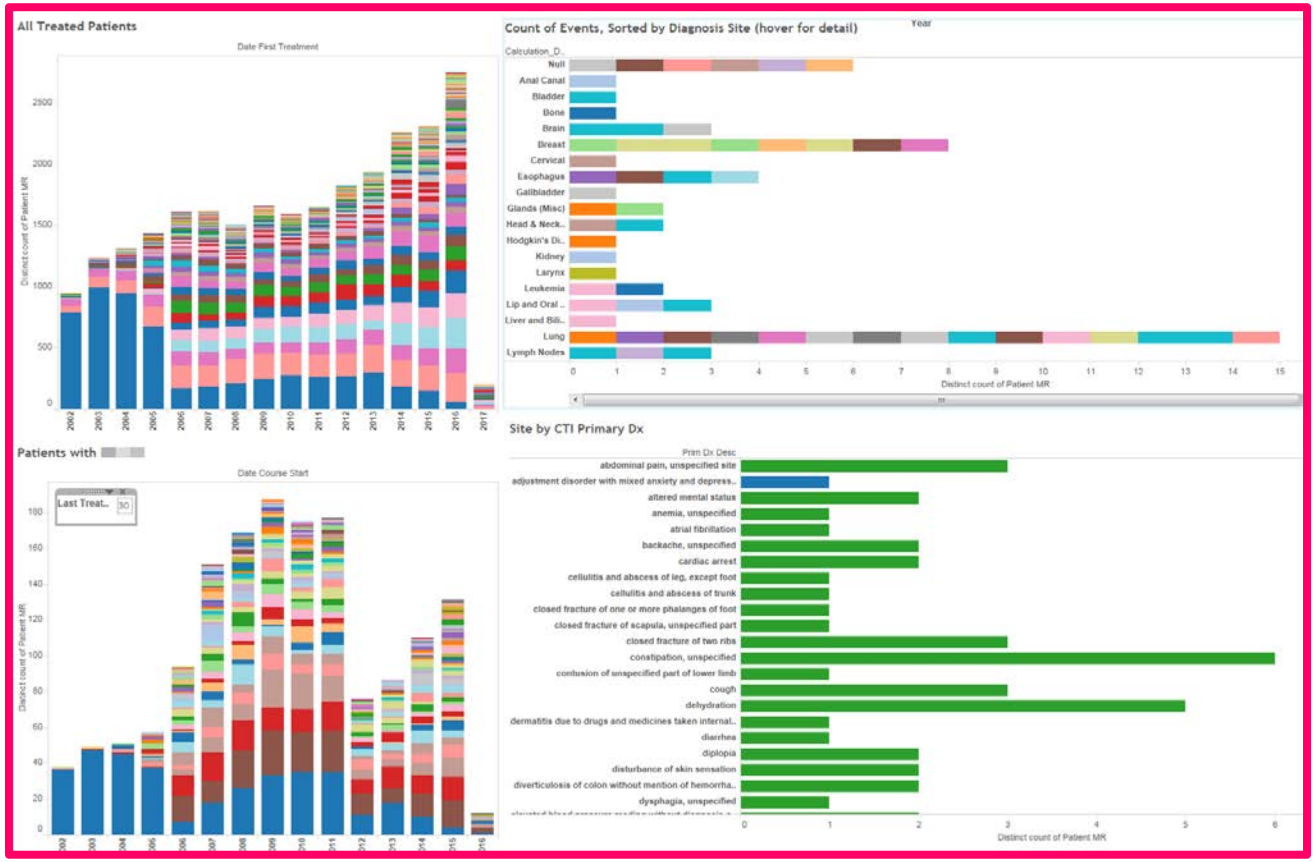


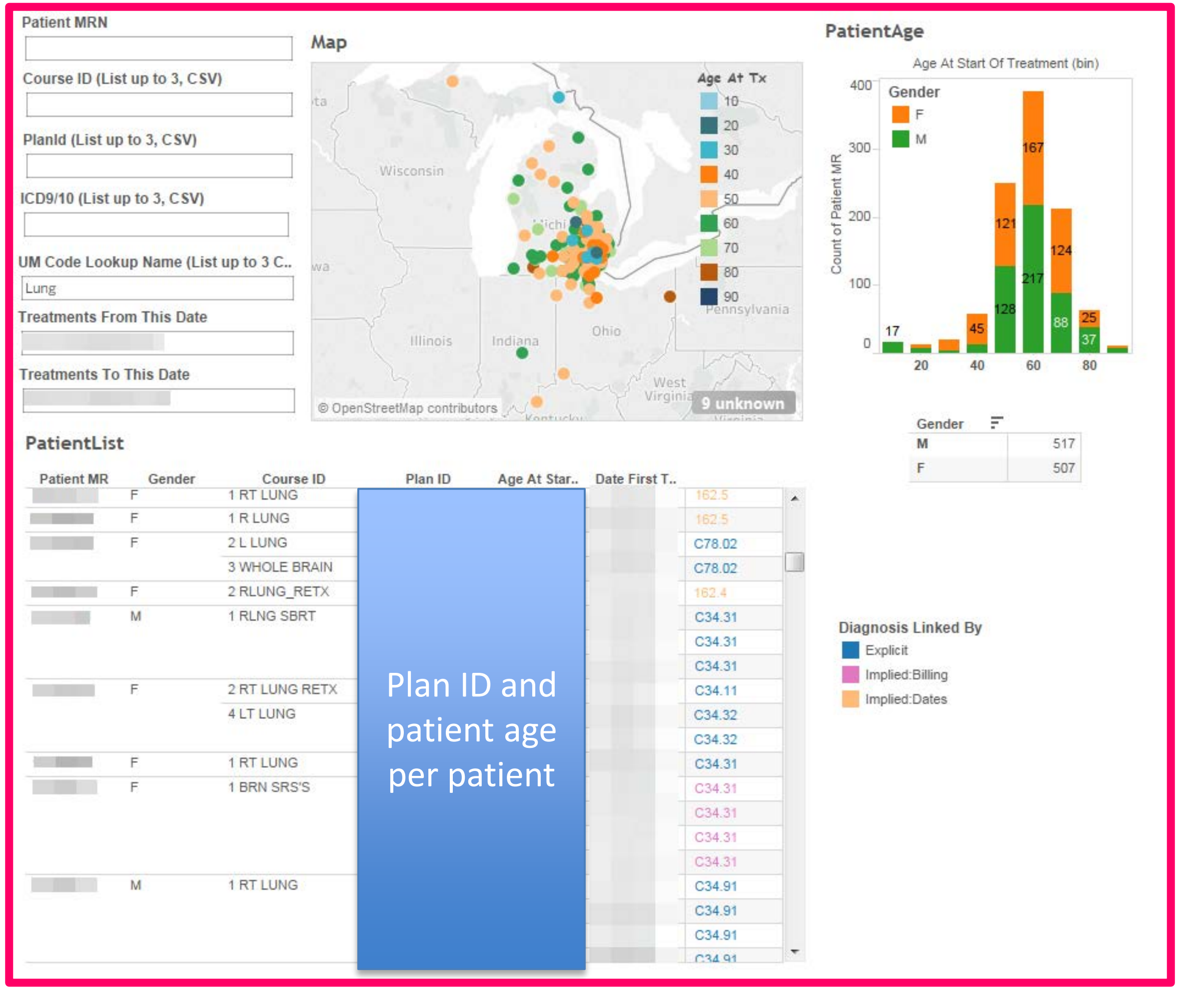
Reduce information entropy with each transformation step

Charles Mayo – M-ROAR

- Can analyze a wide range of dosimetric, treatment, labs, diagnostic, hospital encounters and other data … to look for interactions.
- Standardize, Curate, Aggregate…USE!

Patient characteristics such as age, location, gender, …





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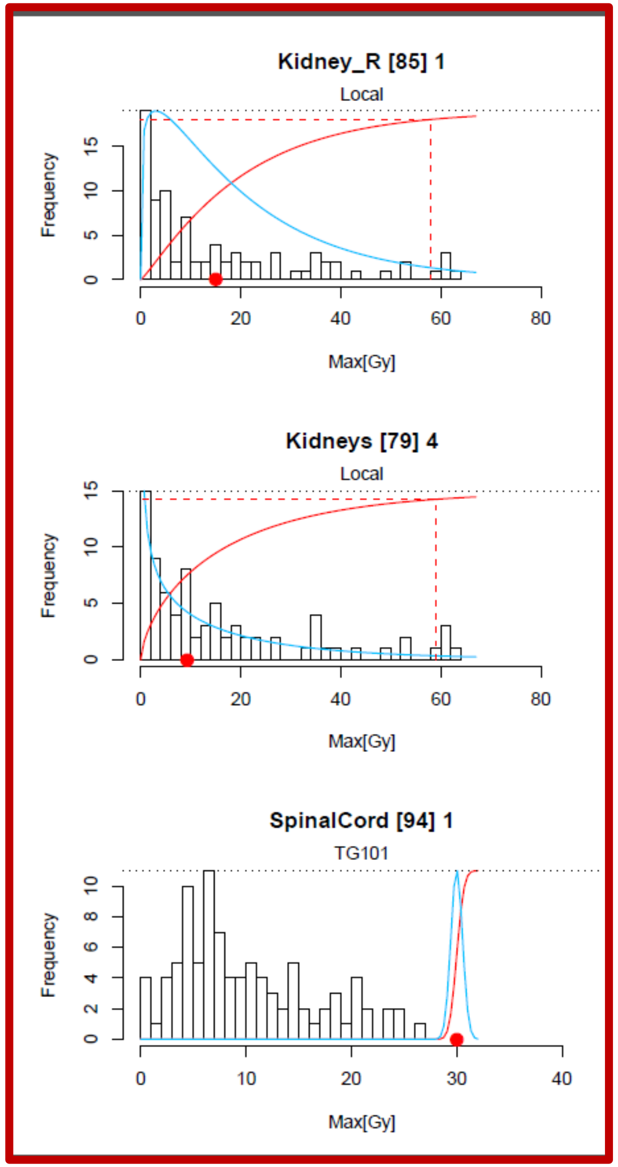
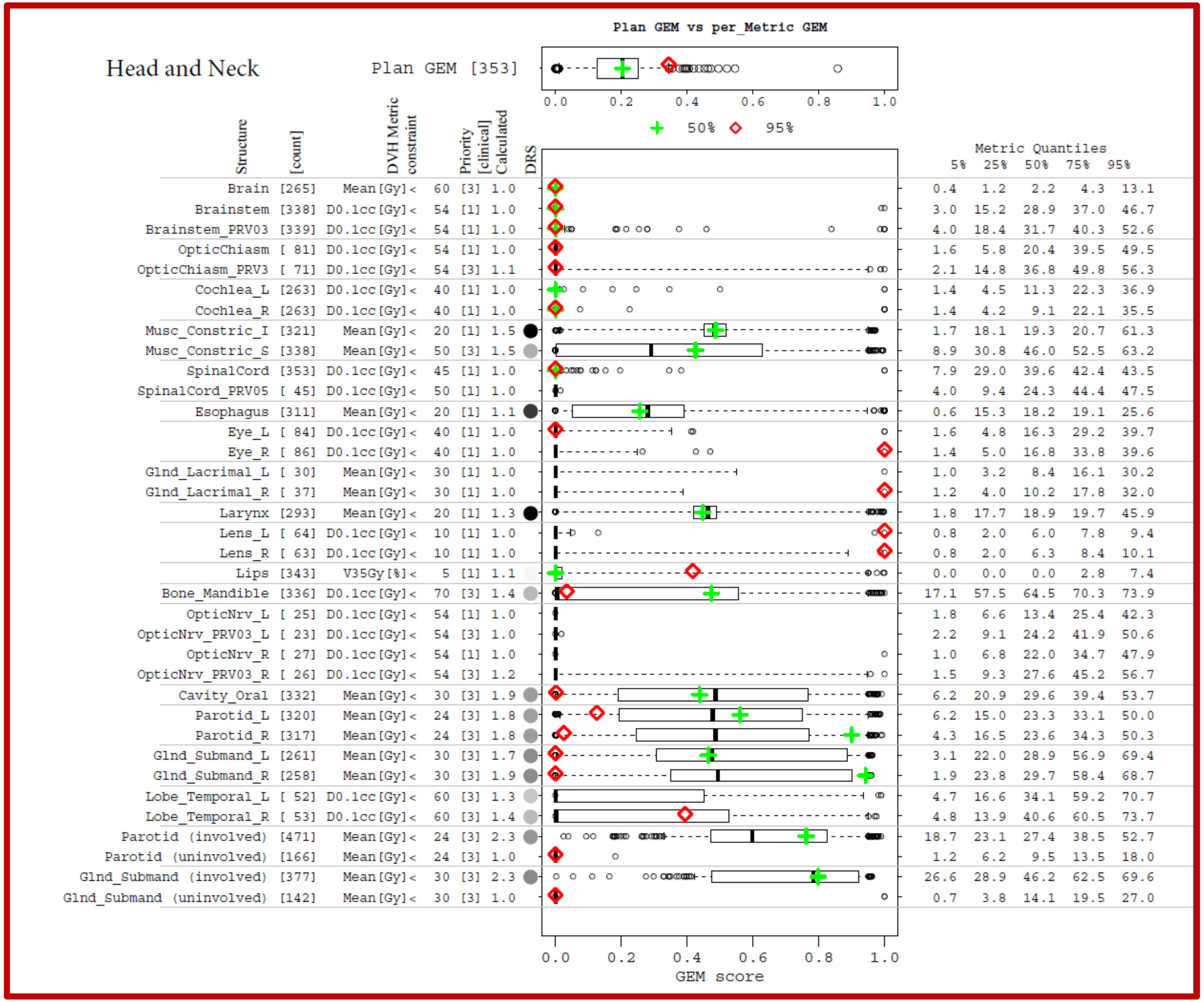


Any dose metric can be queried and plotted for any existing structure.



Generalized Evaluation Metric: Allows comparison against the requested MD value as well as the patient population results.

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Summary

- There is substantial knowledge and efficiency to be lost by not creating and using standardization as part of our daily clinical practice
- Standardization lowers cost and increases the quality of data that can be automatically extracted
  - Treatment Planning System
  - Radiation Oncology Information System
  - Electronic Health Record
- TG-263 Nomenclature in use in many centers enabling creation of software improving clinical processes and learning
- Paves the way for future ontology developments and in sharing with other ontologies too!
  - Makes our sandbox bigger and more valuable to our patients!

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