Collaborative Knowledge Modeling and Integration for Radiation Therapy Planning-

Challenges in standardizing treatment planning data for outcomes studies

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Disclosures

We have grants with Varian Medical Systems,
but those grants did not support the work presented.

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Resource challenges in the cycle of building knowledge

Great idea for a change in practice that improves outcomes for patients

- Few people involved
- Little coordination needed
- Happens often

Test and refine the idea

- More people involved
- Little coordination needed
- Happens often

Put the idea into practice

- Need to involve many people in the clinic
- Modification of work they would be doing anyway
- Takes effort but is done routinely

Gather and analyze data to prove that the idea worked for a small sample set of patients

- May need to involve many people in the clinic
- Not work that is done routinely
- Need extra effort to pull together resources
- Happens much less frequently, especially for non-academic clinics

Gather and analyze data to prove that the idea worked for a large number of patients i.e. routine practice

- Requires process change for the practice
- Need to make this part of work that is done routinely
- Dependence on manual effort or addition of staff will stop it
- Happens rarely

- **Statistics better reflect experience of the whole population including variability**
- **Data pooling**
- **Meaningful use**

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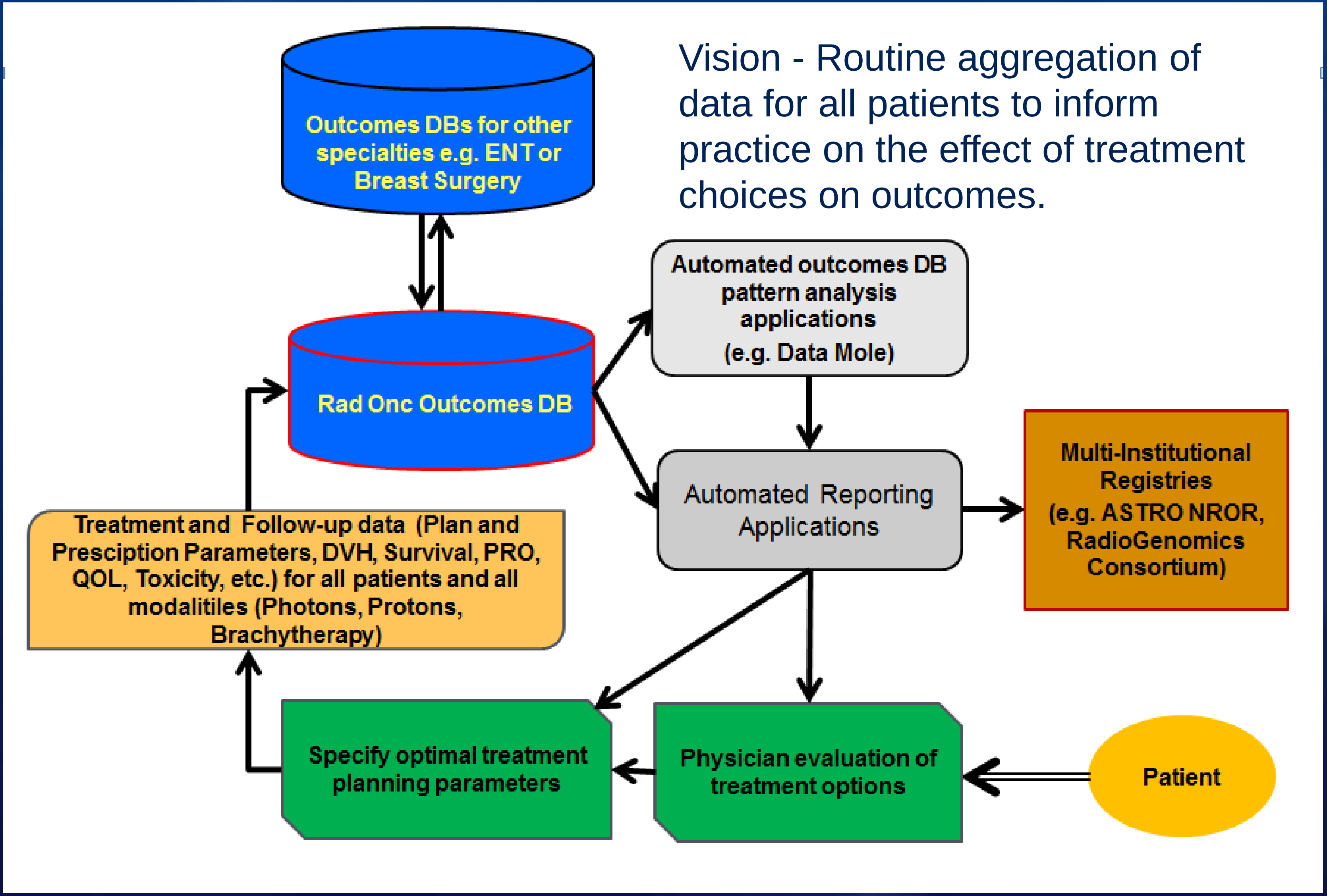
Knowledge Based Clinical Practice Improvement System

System we are building to routinely gather and analyze outcomes data for all patients



The basis of knowledge is information

Changing paradigms is not easy.
It requires many phases of building consensus among stake holders.

- People believe in the vision, but act on the specifics of how the details impact their daily efforts.
- Real participation is driven by demonstration of ability to reduce effort or improve efficacy
- Physician partners, who champion the effort and are not daunted by iterating to evolve the solution, are essential

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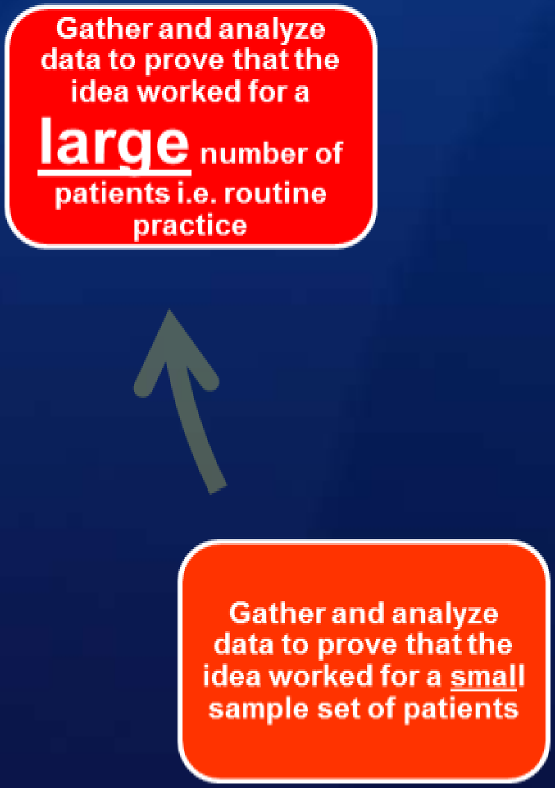
The barrier to routine analysis of data for all patients is largely the overhead of manual effort required



- Standardization underpins ability to create software tools that reduce need for manual effort.
- Standardization requires consensus – which takes time and effort.
- Discussions about standardization are best carried out in the context of practice rather than theory.

Build faith in achieving the whole and nurture proponents by creating it in phases that target solving current problems in the clinic.

1st Objective: Gather a uniform data set of Dose Volume Histogram (DVH) metrics for all patients and disease sites.

Why this one first? Ties into physician led initiative to develop and define standards of practice for treatment plans.

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- Variation in how structures are named undermines ability to inter-compare plans and build automation

- Variation in the what metrics are routinely gathered undermines ability to inter-compare plans

- Free text descriptions of DVH objectives for a plan are often ambiguous and vary greatly from one physician to another.

Demonstrate that of use of standardization enables creation of software to reduce manual effort and also add functionality: comparison of requested and obtained DVH metrics. Facilitates ability to publish on clinical experience.

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Requirements for Structure Nomenclature

- Inconsistent naming complicates automation
- Need a schema that accomodates the limitations of vended systems used in the clinic
- Need a schema that meets requirements of institutional data governace committee
- Need a schema that may be consistently applied as new structures are added
- Need a schema that will meet technical requirements for multiple purposes: clinic, vended systems, database storage, web based exchange among federated databases.

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Naming schema is left to right: general to specific with laterality at the end.

Character string length, use of capitals, spaces, etc are guided by vended systems used in the clinic (simulator, planning system, information system, etc)

Take an approach that allows a standard name plus an alias in the database
e.g. ptv_high = PTV7200

Now coordinating with other institutions as part of data pooling efforts. Expect changes/refinements as we find consensus with other institutions.

Important to start with with something that works and plan for change

Partial list of our structure nomenclature

Mayo Clinic Radiation Oncology	Standard Structure Nomenclature	version- 20130328
ptv_high	semi_cir_canal_l	parotid_total
ctv_high	semi_cir_canal_r	parotid-ptv_r
itv_high	ext_aud_canal_l	parotid-ptv_l
gtv_high	ext_aud_canal_r	parotid-ptv_total
ptv_intermediate	mastoid_l	sub_mandib_r
ctv_intermediate	mastoid_r	sub_mandib_l
itv_intermediate	cochlea_l	sub_mandib-ptv_r
gtv_intermediate	cochlea_r	sub_mandib-ptv_l
ptv_low	optic_nrv_r	oral_cavity
ctv_low	optic_nrv_l	nasal_cavity
itv_low	optic_nrv_prv_r	lips
gtv_low	optic_nrv_prv_l	mandible
body-ptv	optic_chiasm	carotid_artery
body-ptv2cm	optic_chiasm_prv	jugular_vein
brain	eye_r	constrictors_p
brain-ptv	eye_l	constrictors_p-ptv

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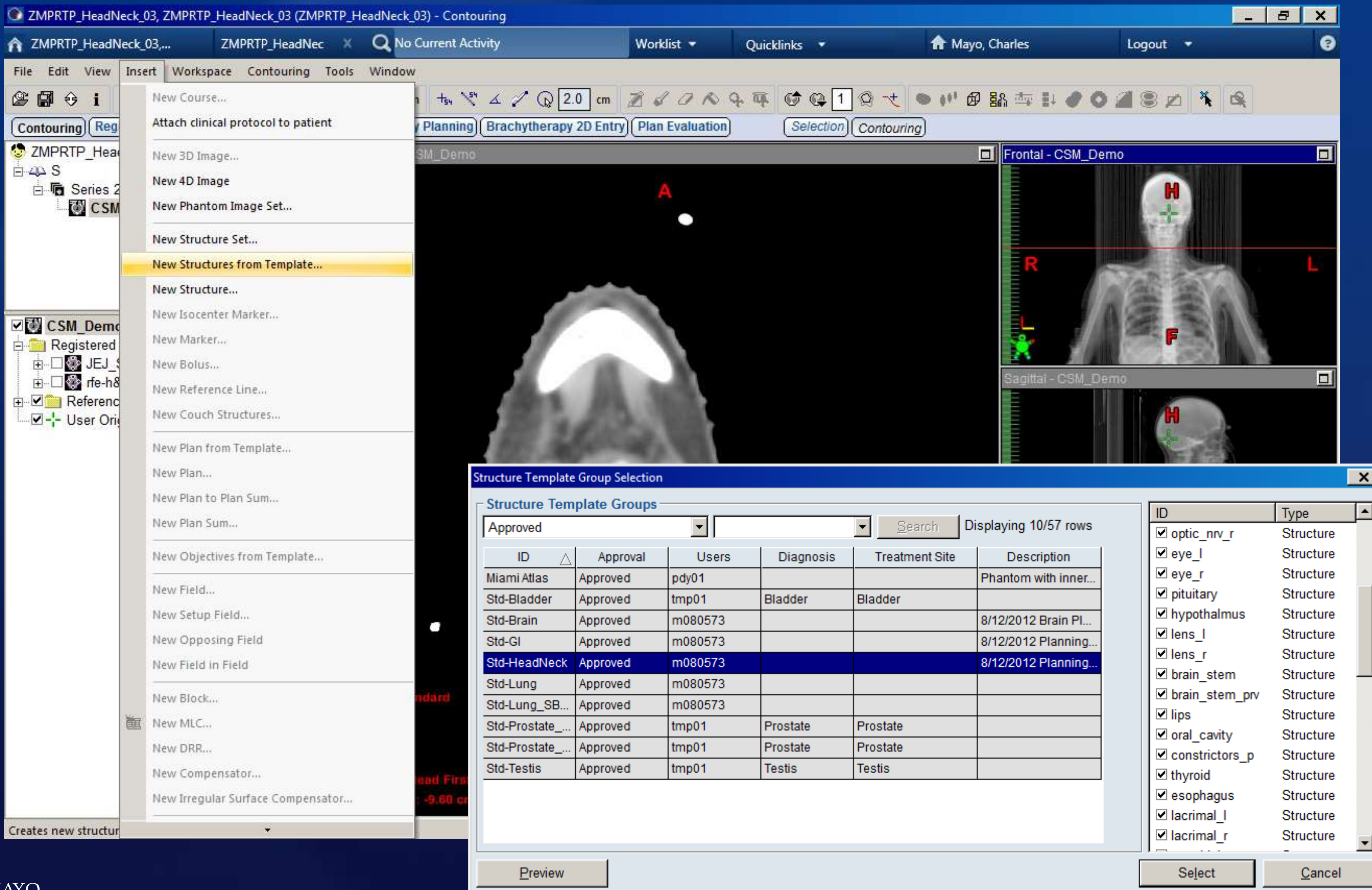
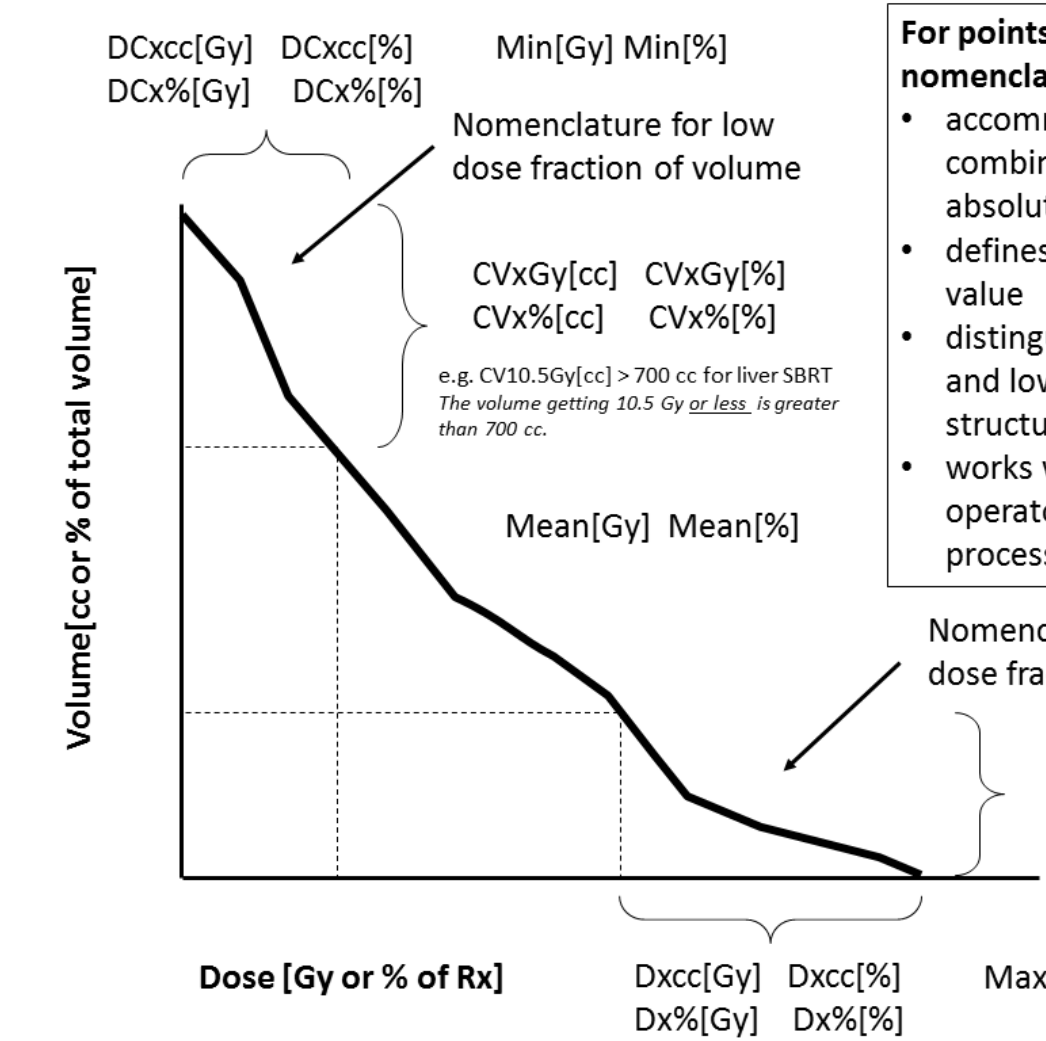
Put the standard structures into the treatment planning system templates to make it easy to conform to the standard



Key to enableing automated DVH calculations

Define a DVH nomenclature schema that fully defines all parts of the curve and can be expanded upon to accommodate other DVH derived metrics as they evolve.
endpoint name(calculation parameters)[output units]



For points on DVH curve , the nomenclature

- accommodates all combinations of relative and absolute, dose and volume
- defines units of output result value
- distinguishes between high and low dose fractions of the structure volume
- works with regular expression operators for automated data processing

Example of use for radiobiological metrics: V35EQ2Gy(4)[%]

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Build consensus with physician disease site groups define standard DVH metrics and objectives to use for all patient treatment plans ~ 18 months

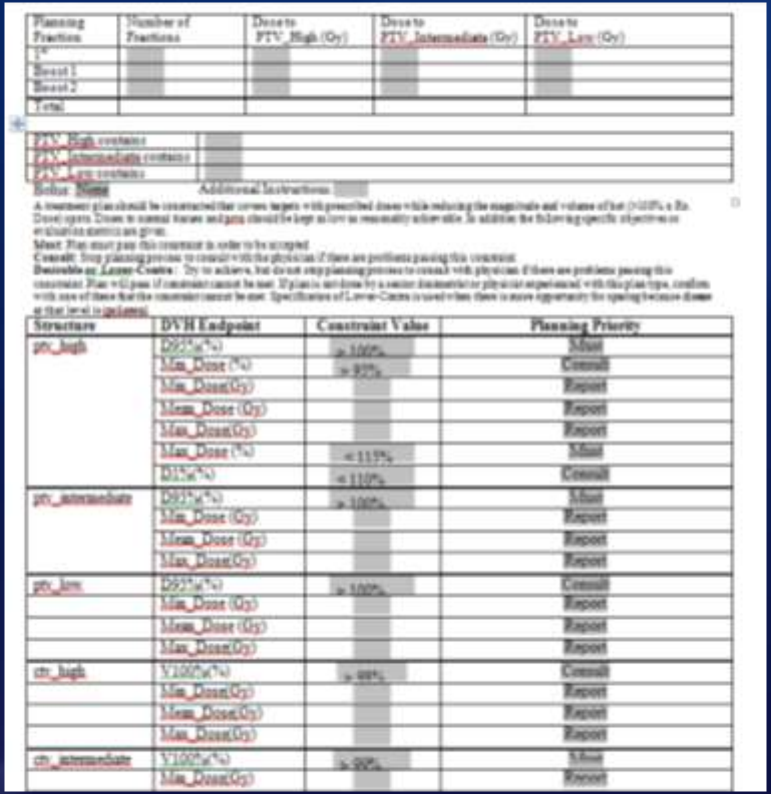
- Supports physician led initiative to develop and define standards of practice for treatment plans.

- Replace free text word documents with standardized tabular templates

- Critical point in dialog for building consensus is distinction between agreement on what metrics we measure vs. the the constraint value and priority

  lung_total V20Gy[%] < 25% Priority = 1

- While defining vanilla (standard), must take an approach that allows for chocolate (per patient changes)



Planning Fraction	Number of Fractions	Dose to PTV_High (Gy)	Dose to PTV_Intermediate (Gy)	Dose to PTV_Low (Gy)
1st				
Boost 1				
Boost 2				
Total				

PTV_High contains:	
PTV_Intermediate contains:	
PTV_Low contains:	

Bolus: None Additional Instructions:

Structure	DVH Endpoint	Constraint Value	Planning Priority
ptv_high	D95%(%)	≥ 100%	Must
	Min_Dose (%)	≥ 95%	Consult
	Min_Dose(Gy)		Report
	Mean_Dose (Gy)		Report
	Max_Dose(Gy)		Report
	Max_Dose (%)	≤ 115%	Must
	D1%(%)	≤ 110%	Consult
ptv_intermediate	D95%(%)	≥ 100%	Must
	Min_Dose (Gy)		Report
	Mean_Dose (Gy)		Report
	Max_Dose(Gy)		Report
ptv_low	D95%(%)	≥ 100%	Consult
	Min_Dose (Gy)		Report
	Mean_Dose (Gy)		Report
	Max_Dose(Gy)		Report
ctv_high	V100%(%)	[illegible]	Consult
	Min_Dose(Gy)		Report
	Mean_Dose(Gy)		Report
	Max_Dose(Gy)		Report
ctv_intermediate	V100%(%)	[illegible]	Must
	Min_Dose(Gy)		Report

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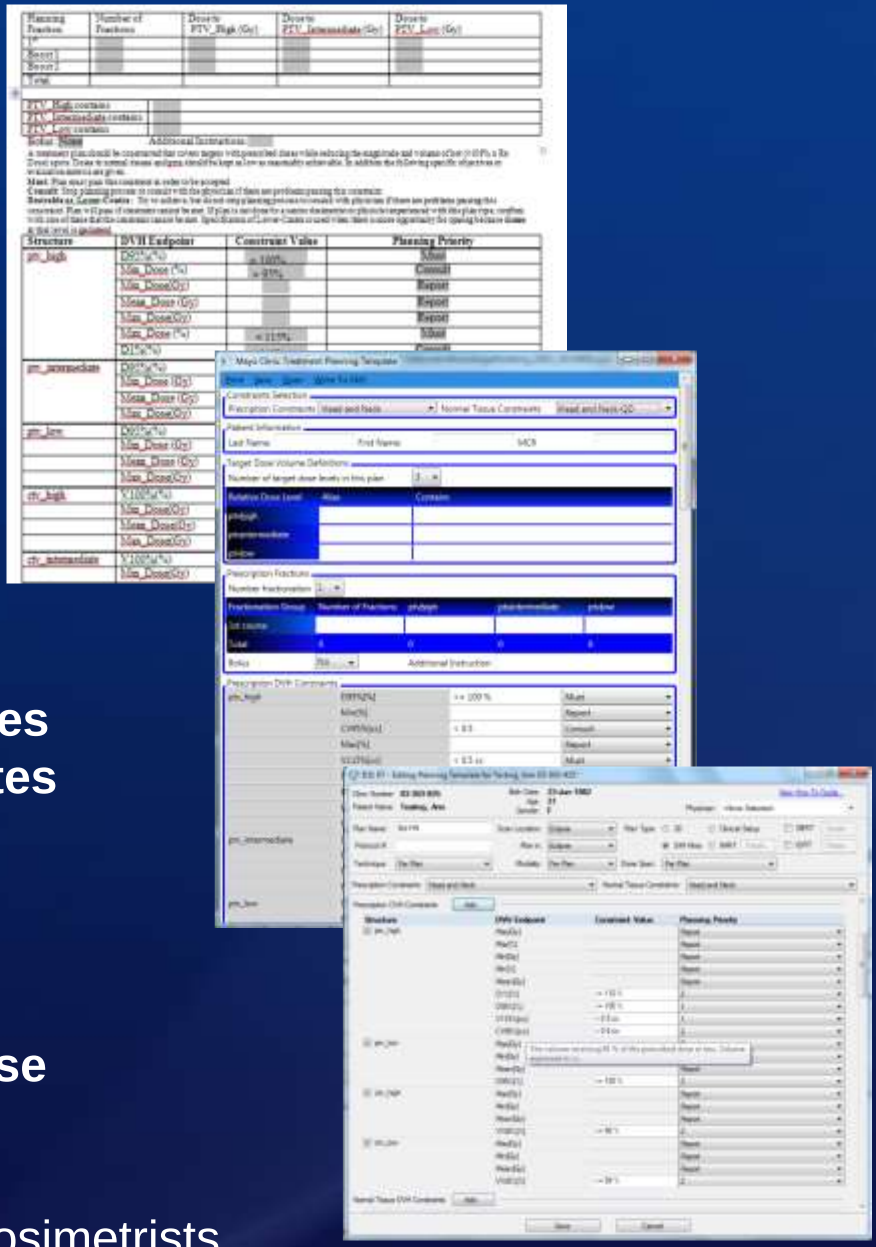
Building Consensus on the IT design and function.



Free text Word

Physician driven

↓

Standardized formatted Word

Physician + Physicist driven

↓

Stand alone application that demonstrates automation and software driven templates

Physicist + Physician driven

↓

Production application that uses database

IT driven with multidisciplinary committee: physicians, dosimetrists, therapists, physicists

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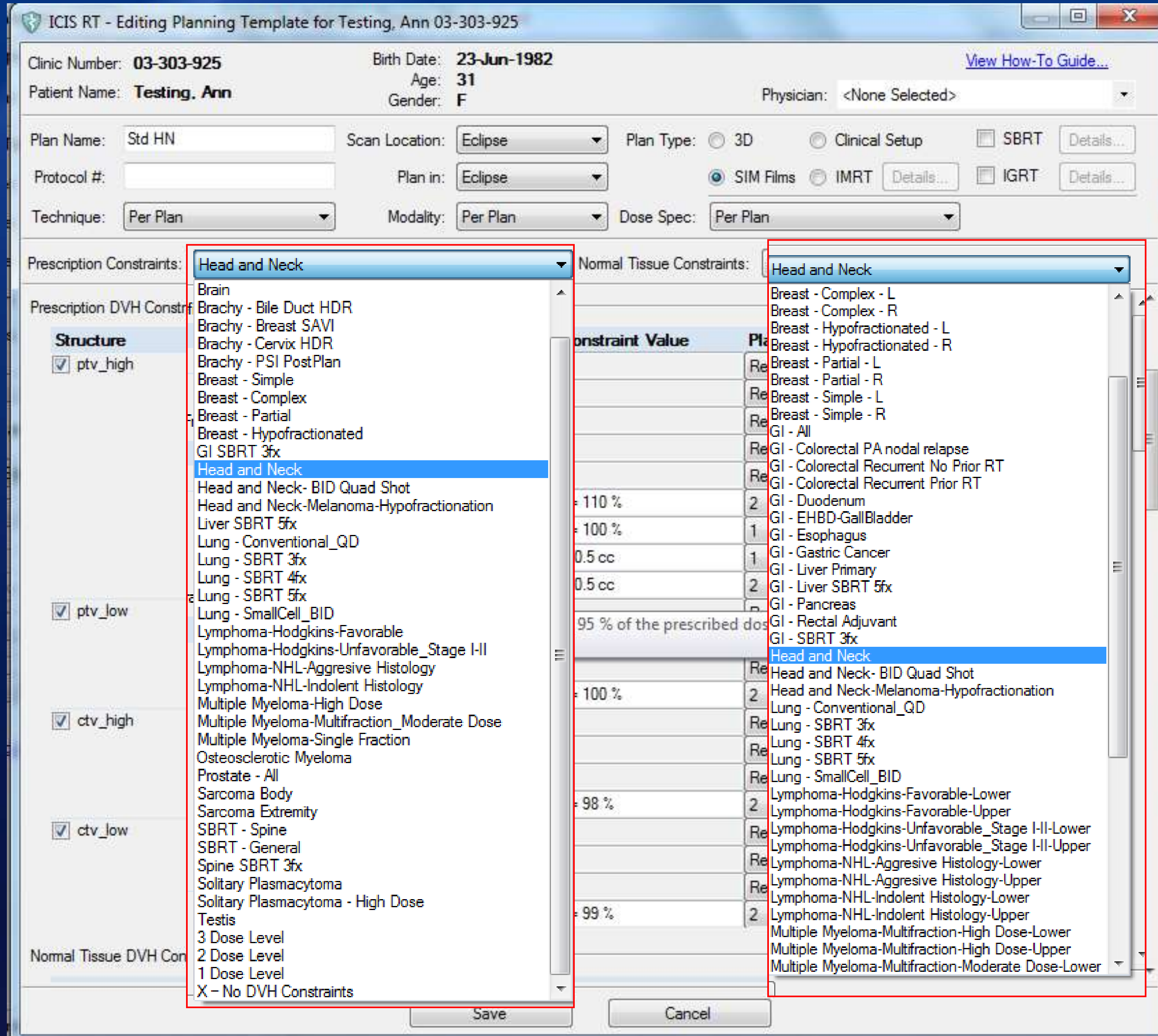
Application becomes our standard prescription.

Also serves as documentation tool for image setup, notes, IMRT justification, etc.

Physician groups define consensus for DVH metrics for all treatment sites!



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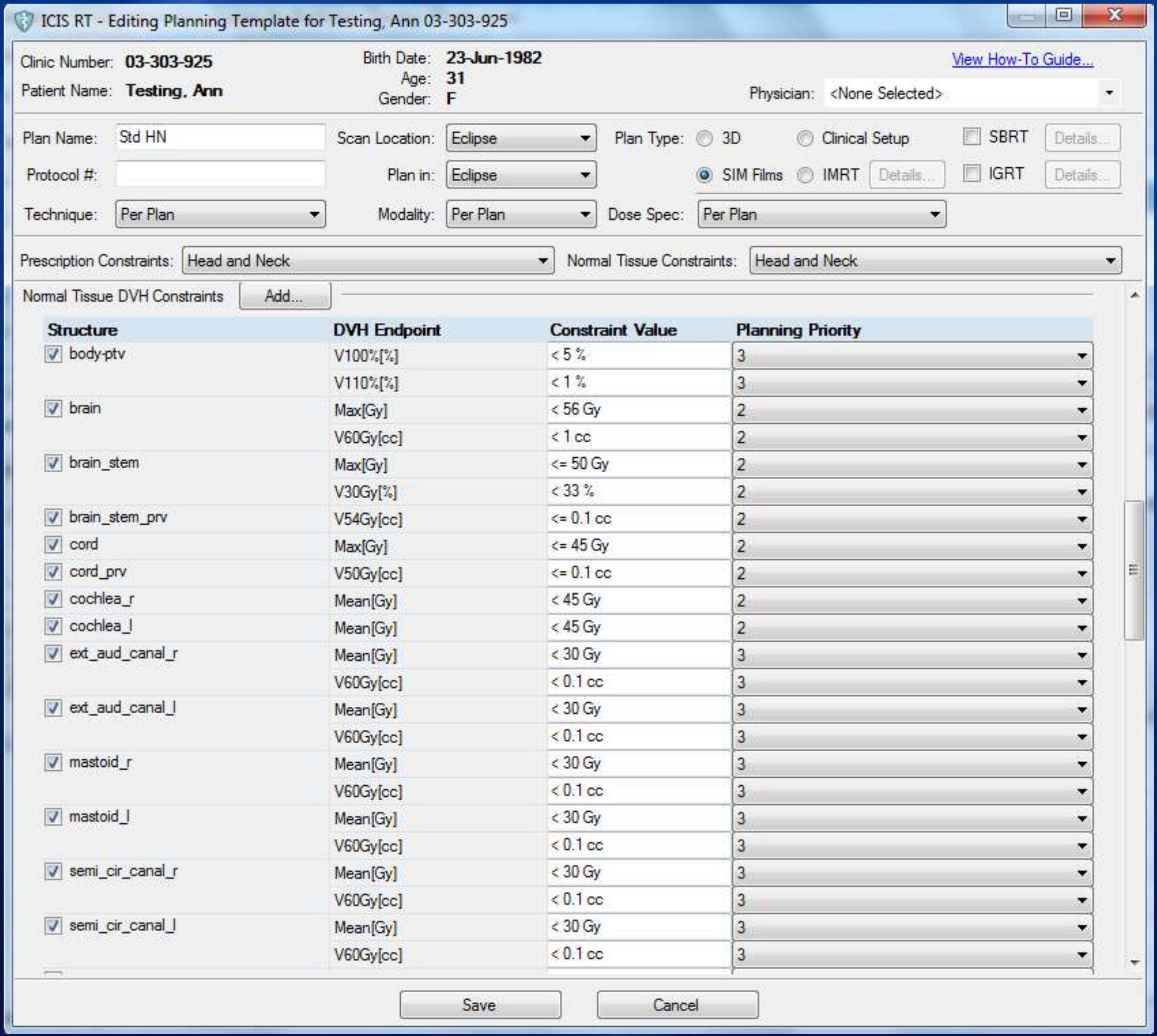
Users can

- add/remove constraints
- select which structures to use
- change constrain values and prioritization



Now carry out comparisons of desired and achieved DVH metrics for all patients and for all disease sites …

and save DVH metrics data for data mining in our outcomes database.

Mayo Clinic Prescription and Dose/Volume Histogram

Clinic Number: [redacted] Patient: [redacted] Gender: [redacted] DOB: [redacted]

Physician Signature: The prescription has been approved by [redacted]

RTP Name:	hypopharynx and neck	Scan Location:	Eclipse	PROTOCOL #:	
Plan In:	Eclipse	Plan Type:	IMRT, IGRT		
Technique:	Multiple fields	Modality:	Per Plan	Dose Spec:	Per Plan

Target Volume Definitions

ptv high (ptv_high)	ctv high + 5 mm margin
ptv low (ptv_low)	ctv low + 5 mm margin

Prescription

Group	Number of Fractions	ptv high (ptv_high)	ptv low (ptv_low)
Initial Volume	35	7000 (200 cGy per Fx)	6300 (180 cGy per Fx)
Total	35	7000 cGy	6300 cGy

Bolus: No

Instructions:

Target DVH Objectives			Priority	Achieved
ptv high	Max[Gy]		Report	78.22 Gy
	Max[%]		Report	111.75 % (78.22Gy)
	Min[Gy]		Report	41.47 Gy
	Min[%]		Report	59.24 % (41.47Gy)
	Mean[Gy]		Report	71.72 Gy
	D1%[%]	<= 110 % (77Gy)	2	106.85 % (74.8Gy)
	D95%[%]	>= 100 % (70Gy)	1	99.17 % (69.42Gy)
	V115%[cc]	< 0.5 cc	1	0 cc
	CV95%[cc]	< 0.5 cc	2	2.4 cc
ptv low	Max[Gy]		Report	73.92 Gy
	Min[Gy]		Report	44.1 Gy
	Mean[Gy]		Report	65.5 Gy
	D95%[%]	>= 100 % (63Gy)	2	99.89 % (62.93Gy)
ctv_high for ptv high	Max[Gy]		Report	77.8 Gy
	Min[Gy]		Report	61.54 Gy

Now carry out comparisons of desired and achieved DVH metrics for all patients and for all disease sites …

and save DVH metrics data for data mining in our outcomes database.

brain	Max[Gy]	< 56 Gy	2	61.09 Gy
	V60Gy[cc]	< 1 cc	2	0.03 cc
brain_stem	Max[Gy]	<= 50 Gy	2	49.18 Gy
	V30Gy[%]	< 33 %	2	30.55 %
brain_stem_prv	V54Gy[cc]	<= 0.1 cc	2	0 cc
cord	Max[Gy]	<= 45 Gy	2	43.57 Gy
cord_prv	V50Gy[cc]	<= 0.1 cc	2	0.03 cc
cochlea_r	Mean[Gy]	< 45 Gy	2	10.91 Gy
cochlea_l	Mean[Gy]	< 45 Gy	2	15.45 Gy
ext_aud_canal_r	Mean[Gy]	< 30 Gy	3	11.18 Gy
	V60Gy[cc]	< 0.1 cc	3	0 cc
ext_aud_canal_l	Mean[Gy]	< 30 Gy	3	15.31 Gy
	V60Gy[cc]	< 0.1 cc	3	0 cc
mastoid_r	Mean[Gy]	< 30 Gy	3	20.88 Gy
	V60Gy[cc]	< 0.1 cc	3	0 cc
mastoid_l	Mean[Gy]	< 30 Gy	3	24.85 Gy
	V60Gy[cc]	< 0.1 cc	3	0.08 cc
semi_cir_canal_r	Mean[Gy]	< 30 Gy	3	12.08 Gy
	V60Gy[cc]	< 0.1 cc	3	0 cc
semi_cir_canal_l	Mean[Gy]	< 30 Gy	3	15.71 Gy
	V60Gy[cc]	< 0.1 cc	3	0 cc
eye_r	Mean[Gy]	<= 30 Gy	2	2.47 Gy
	V50Gy[cc]	<= 0.1 cc	2	0 cc
	V40Gy[%]	<= 50 %	2	0 %
eye_l	Mean[Gy]	<= 30 Gy	2	2.63 Gy
	V50Gy[cc]	<= 0.1 cc	2	0 cc
	V40Gy[%]	<= 50 %	2	0 %
parotid_r	Mean[Gy]	< 26 Gy	3	37.55 Gy
	V30Gy[%]	<= 50 %	3	51.84 %
	V40Gy[%]	< 33 %	3	42.8 %
parotid_l	Mean[Gy]	< 26 Gy	3	40.31 Gy
	V30Gy[%]	<= 50 %	3	57.1 %
	V40Gy[%]	< 33 %	3	48.87 %
parotid_total	Mean[Gy]	< 39 Gy	3	38.7 Gy
sub_mandib_r	Mean[Gy]		Report	71.38 Gy

We are now systematically gathering a wide set of DVH metrics for all patients and all disease sites (sample below shows some of the DVH metrics gathered during a 4 month period for head and neck patients). Compiling information allows examining practice patterns.

Structure	DVH Metric	Mean	Standard Deviation	nvalues	Percent meeting constraint
body-ptv	V100%[%]	0.22	0.29	145	100%
body-ptv	V110%[%]	0.00	0.00	147	100%
brachial_plex_l	Max[Gy]	59.42	11.86	91	59%
brachial_plex_r	Max[Gy]	57.59	14.64	99	67%
brain	Max[Gy]	45.33	18.85	130	61%
brain	V60Gy[cc]	0.75	4.19	115	94%
brain_stem	Max[Gy]	37.03	15.56	129	89%
brain_stem	V30Gy[%]	16.20	18.15	123	94%
brain_stem_prv	V54Gy[cc]	0.04	0.25	114	97%
cochlea_l	Mean[Gy]	16.54	11.88	112	96%
cochlea_r	Mean[Gy]	17.92	13.71	113	92%
constrictors_p	Mean[Gy]	47.75	14.86	106	54%
constrictors_p	V55Gy[%]	48.41	32.10	101	87%
constrictors_p	V65Gy[%]	17.90	27.12	104	74%
cord	Max[Gy]	37.32	12.41	150	87%
cord_prv	V50Gy[cc]	0.03	0.19	130	96%
esophagus	Mean[Gy]	28.81	12.17	129	81%
esophagus	V35Gy[%]	38.69	23.75	131	72%
esophagus	V55Gy[%]	10.99	19.15	123	92%
esophagus	V70Gy[%]	1.19	6.58	118	97%
ext_aud_canal_l	Mean[Gy]	17.86	13.23	96	88%
ext_aud_canal_l	V60Gy[cc]	0.06	0.30	91	96%
ext_aud_canal_r	Mean[Gy]	19.88	13.30	93	89%
ext_aud_canal_r	V60Gy[cc]	0.04	0.16	90	94%
eye_l	Mean[Gy]	6.78	11.67	102	96%
eye_l	V40Gy[%]	4.22	17.80	96	98%
eye_l	V50Gy[cc]	0.24	1.31	96	95%
eye_r	Mean[Gy]	4.90	5.59	105	100%
eye_r	V40Gy[%]	0.33	2.12	98	100%
eye_r	V50Gy[cc]	0.00	0.01	98	100%

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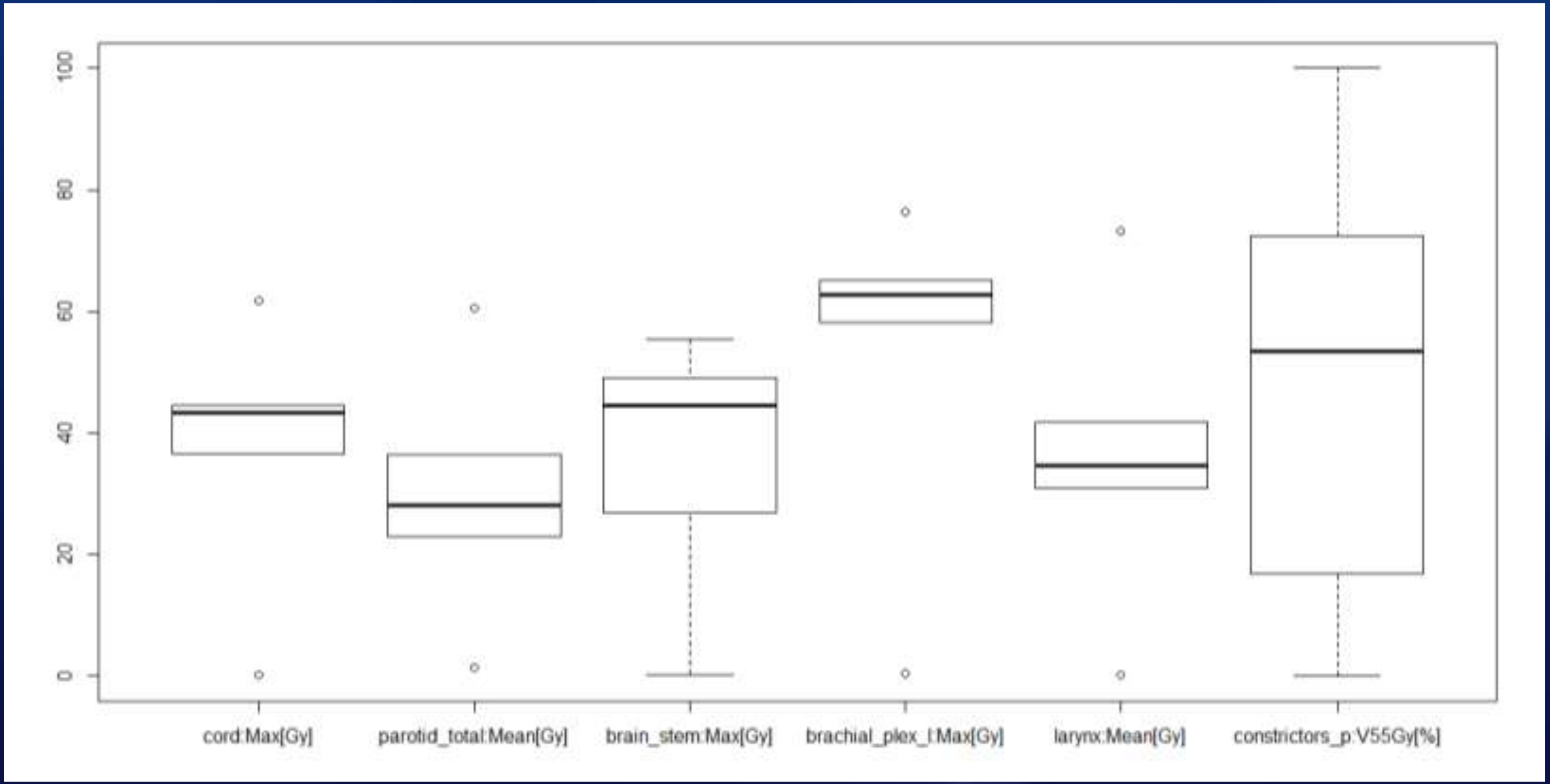
We are now systematically gathering a wide set of DVH metrics for all patients and all disease sites.

- It now becomes easy to monitor the <u>distributions</u> of values of DVH metrics for all patients… and to watch the evolution over time.

- More meaningful evaluation of quality of practice.



The basis of knowledge is information

Standardization + Consensus + Software

We've moved from it being rare to complete the feed back loop toward it becoming routine.

Gather and analyze data to prove that the idea worked for a <u>large</u> number of patients i.e. routine practice

Gather and analyze data to prove that the idea worked for a <u>small</u> sample set of patients

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Gather and analyze data to prove that the idea worked for a <u>small</u> sample set of patients

The work presented is the result of the work of a large group of collaborators

It takes a village to raise a child… and a lot of bright people to build an outcomes database

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