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

- Few people involved
- Little coordination needed
- Happens often

Resource challenges in the cycle of building knowledge

- 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

Test and refine the idea

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

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

- Few people involved
- Little coordination needed
- Happens often

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

- 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

- Require 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

- 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
Knowledge Based Clinical Practice Improvement System

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

Vision - Routine aggregation of data for all patients to inform practice on the effect of treatment choices on outcomes.

The basis of knowledge is information
Changing paradigms is not easy. It requires many phases of building consensus among stakeholders.

- 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.
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.

- 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.
Requirements for Structure Nomenclature

• Inconsistent naming complicates automation

• Need a schema that accommodates the limitations of vended systems used in the clinic

• Need a schema that meets requirements of institutional data governance 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.
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 something that works and plan for change

### Partial list of our structure nomenclature

<table>
<thead>
<tr>
<th>Mayo Clinic Radiation Oncology</th>
<th>Standard Structure Nomenclature</th>
<th>v ersion- 20130328</th>
</tr>
</thead>
<tbody>
<tr>
<td>ptv_high</td>
<td>semi_cir_canal_l</td>
<td>parotid_total</td>
</tr>
<tr>
<td>ctv_high</td>
<td>semi_cir_canal_r</td>
<td>parotid-ptv_r</td>
</tr>
<tr>
<td>itv_high</td>
<td>ext_aud_canal_l</td>
<td>parotid-ptv_l</td>
</tr>
<tr>
<td>gtv_high</td>
<td>ext_aud_canal_r</td>
<td>parotid-ptv_total</td>
</tr>
<tr>
<td>ptv_intermediate</td>
<td>mastoid_l</td>
<td>sub_mandib_r</td>
</tr>
<tr>
<td>ctv_intermediate</td>
<td>mastoid_r</td>
<td>sub_mandib_l</td>
</tr>
<tr>
<td>itv_intermediate</td>
<td>cochlea_l</td>
<td>sub_mandib-ptv_r</td>
</tr>
<tr>
<td>gtv_intermediate</td>
<td>cochlea_r</td>
<td>sub_mandib-ptv_l</td>
</tr>
<tr>
<td>ptv_low</td>
<td>optic_nrv_r</td>
<td>oral_cavity</td>
</tr>
<tr>
<td>ctv_low</td>
<td>optic_nrv_l</td>
<td>nasal_cavity</td>
</tr>
<tr>
<td>itv_low</td>
<td>optic_nrv_prv_r</td>
<td>lips</td>
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<td>gtv_low</td>
<td>optic_nrv_prv_l</td>
<td>mandible</td>
</tr>
<tr>
<td>body-ptv</td>
<td>optic_chiasm</td>
<td>carotid_artery</td>
</tr>
<tr>
<td>body-ptv2cm</td>
<td>optic_chiasm_prv</td>
<td>jugular_vein</td>
</tr>
<tr>
<td>brain</td>
<td>eye_r</td>
<td>constrictors_p</td>
</tr>
<tr>
<td>brain-ptv</td>
<td>eye_l</td>
<td>constrictors_p-ptv</td>
</tr>
</tbody>
</table>
Put the standard structures into the treatment planning system templates to make it easy to conform to the standard

Key to enabling 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)[%]
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 constraint value and priority

\[
\text{lung\_total V20Gy[\%]} < 25\% \quad \text{Priority} = 1
\]

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

<table>
<thead>
<tr>
<th>Structure</th>
<th>DVH Metric</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>nvalues</th>
<th>Percent meeting constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>body-ptv</td>
<td>V100%[%]</td>
<td>0.22</td>
<td>0.29</td>
<td>145</td>
<td>100%</td>
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<tr>
<td>body-ptv</td>
<td>V110%[%]</td>
<td>0.00</td>
<td>0.00</td>
<td>147</td>
<td>100%</td>
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<tr>
<td>brachial_plex_l</td>
<td>Max[Gy]</td>
<td>59.42</td>
<td>11.86</td>
<td>91</td>
<td>59%</td>
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<td>brachial_plex_r</td>
<td>Max[Gy]</td>
<td>57.59</td>
<td>14.64</td>
<td>99</td>
<td>67%</td>
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<tr>
<td>brain</td>
<td>Max[Gy]</td>
<td>45.33</td>
<td>18.85</td>
<td>130</td>
<td>61%</td>
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<tr>
<td>brain</td>
<td>V60Gy[cc]</td>
<td>0.75</td>
<td>4.19</td>
<td>115</td>
<td>94%</td>
</tr>
<tr>
<td>brain_extra</td>
<td>Max[Gy]</td>
<td>37.03</td>
<td>15.56</td>
<td>129</td>
<td>89%</td>
</tr>
<tr>
<td>brain_extra</td>
<td>V53Gy[%]</td>
<td>16.20</td>
<td>18.15</td>
<td>123</td>
<td>94%</td>
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<td>brain_extra_prv</td>
<td>V54Gy[cc]</td>
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<td>0.25</td>
<td>114</td>
<td>97%</td>
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<td>113</td>
<td>92%</td>
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<tr>
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<td>Mean[Gy]</td>
<td>17.92</td>
<td>13.71</td>
<td>113</td>
<td>92%</td>
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<tr>
<td>constrictors_p</td>
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<td>47.75</td>
<td>14.86</td>
<td>106</td>
<td>54%</td>
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<tr>
<td>constrictors_p</td>
<td>V55Gy[%]</td>
<td>48.41</td>
<td>32.10</td>
<td>101</td>
<td>87%</td>
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<tr>
<td>constrictors_p</td>
<td>V65Gy[%]</td>
<td>17.90</td>
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<td>104</td>
<td>74%</td>
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<tr>
<td>cord</td>
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<td>37.32</td>
<td>12.41</td>
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<tr>
<td>cord_prv</td>
<td>V50Gy[cc]</td>
<td>0.03</td>
<td>0.19</td>
<td>130</td>
<td>96%</td>
</tr>
<tr>
<td>esophagus</td>
<td>Mean[Gy]</td>
<td>28.81</td>
<td>12.17</td>
<td>129</td>
<td>81%</td>
</tr>
<tr>
<td>esophagus</td>
<td>V35Gy[%]</td>
<td>38.69</td>
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<td>131</td>
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<tr>
<td>esophagus</td>
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<td>Mean[Gy]</td>
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<td>88%</td>
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<tr>
<td>ext_aud_canal_l</td>
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</tr>
<tr>
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<td>19.88</td>
<td>13.30</td>
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<td>ext_aud_canal_r</td>
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<td>0.04</td>
<td>0.16</td>
<td>90</td>
<td>94%</td>
</tr>
<tr>
<td>eye_l</td>
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<td>6.78</td>
<td>11.67</td>
<td>102</td>
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<tr>
<td>eye_l</td>
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<td>17.80</td>
<td>96</td>
<td>98%</td>
</tr>
<tr>
<td>eye_l</td>
<td>V50Gy[cc]</td>
<td>0.24</td>
<td>1.31</td>
<td>96</td>
<td>95%</td>
</tr>
<tr>
<td>eye_r</td>
<td>Mean[Gy]</td>
<td>4.90</td>
<td>5.59</td>
<td>105</td>
<td>100%</td>
</tr>
<tr>
<td>eye_r</td>
<td>V40Gy[%]</td>
<td>0.33</td>
<td>2.12</td>
<td>98</td>
<td>100%</td>
</tr>
<tr>
<td>eye_r</td>
<td>V50Gy[cc]</td>
<td>0.00</td>
<td>0.01</td>
<td>98</td>
<td>100%</td>
</tr>
</tbody>
</table>
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 distributions 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

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

We’ve moved from it being rare to complete the feedback loop toward it becoming routine.

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

Gather and analyze data to prove that the idea worked for a small 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

Robert Foote, MD
Michael Haddock, MD
Robert Miller, MD
Scott Stafford, MD
Yolanda Garces, MD
Nadia Laack, MD
Ivy Petersen, MD
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Mark Parry
Sorin Alexandru
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