Plan Quality monitoring: Planning and delivery

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Outline

1. What is Quality and how do we assess it
2. How Quality is linked to clinical outcomes
3. Treatment process
4. Treatment planning
   ① Plan Quality (dosimetry)
   ② Complexity
   ③ Robustness
5. Treatment delivery accuracy
   ① Linac
   ② Patient
6. Final remarks
Quality perception may differ depending on who you ask; professionals or patients

BUT all will agree on

- GOOD QUALITY WILL RESULT ON BETTER PATIENT OUTCOMES
- WILL GUARANTEE PATIENT SAFETY REDUCING ADVERSE EVENTS
Poor Quality Radiotherapy will produce poor clinical outcomes
Quality in clinical trials: lessons learned

HeadSTART trial (2000-2005)

Overall survival by protocol compliance

Patient survival directly correlated to the quality of treatment plan

Quality assessment; how do we know that we are performing well?

- We need **quality indicators** that we can measure and compare with **quality standards**
- A quality programme assures that the **quality standards** are fulfilled
- Need that the **quality standards** are well defined
- Tolerances have to be set with “clinical” criteria
Quality indicators

![Diagram of quality indicators]

- **Outcome indicators in RT: Time**
- **Process indicators:** can be used as surrogates of outcome indicators, and can be collected during patient treatment.

*Figure 1: The Donabedian model of measuring health care system performance*
Planning CT

Treatment planning

Data transfer

Treatment delivery

Dose prescription

Plan QI (dose distribution)
Plan complexity
Plan robustness to changes

Plan deliverability
Patient variations
Planning CT

Treatmen t planning

Data Transfer

Treatment delivery

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Plan complexity
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Plan deliverability

Dose prescription

PATIENT

PATIENT
Dose distributions:

What is the best one?
Could it be further improved?
Dose distributions, the standards.

1. Fulfilment of dose objectives for PTVs and dose constraints for OARs.

<table>
<thead>
<tr>
<th>Volum blanc: PTV60-Pell</th>
<th>Larynx:</th>
<th>Spinal Cord:</th>
</tr>
</thead>
<tbody>
<tr>
<td>V95 98.4% Dmean100.9% (60.5Gy)</td>
<td>V50Gy 24.3% PASS (&lt;27%)</td>
<td>V30Gy 39.7% PASS (&lt;50%)</td>
</tr>
<tr>
<td>D98 95.3% (57.2Gy)</td>
<td>Dmean43.3Gy PASS (&lt;44Gy)</td>
<td>Dmax 44.5Gy PASS (&lt;45-50Gy)</td>
</tr>
<tr>
<td>D2 104.6% (62.7Gy)</td>
<td>Dmax 61.7Gy WARNING (&lt;60-66Gy)</td>
<td></td>
</tr>
<tr>
<td>BODY:</td>
<td>Mandible:</td>
<td>Spinal Cord_03:</td>
</tr>
<tr>
<td>Dmax 109.0% (65.4Gy)</td>
<td>Dmax 64.0Gy FAIL (&lt;60Gy)</td>
<td>V50Gy 0.0cc PASS (&lt;1cc)</td>
</tr>
<tr>
<td>Parotid_L:</td>
<td>TMJoint_L:</td>
<td>Brachial Plexus_1:</td>
</tr>
<tr>
<td>V30Gy 45.8% PASS (&lt;50%)</td>
<td>V75Gy 0.0cc PASS (&lt;1cc)</td>
<td>V60Gy 33.7% FAIL (&lt;5%)</td>
</tr>
<tr>
<td>Dmean34.8Gy FAIL (&lt;20-26Gy)</td>
<td>Dmax 59.1Gy PASS (&lt;70Gy)</td>
<td>Dmax 61.8Gy PASS (&lt;66Gy)</td>
</tr>
<tr>
<td>Parotid_R:</td>
<td>TMJoint_R:</td>
<td>Brachial Plexus_R:</td>
</tr>
<tr>
<td>V30Gy 42.8% PASS (&lt;50%)</td>
<td>V75Gy 0.0cc PASS (&lt;1cc)</td>
<td>V60Gy 40.4% FAIL (&lt;5%)</td>
</tr>
<tr>
<td>Dmean31.7Gy FAIL (&lt;20-26Gy)</td>
<td>Dmax 62.7Gy PASS (&lt;66Gy)</td>
<td></td>
</tr>
<tr>
<td>Parotids:</td>
<td></td>
<td>Pharynx/Const:</td>
</tr>
<tr>
<td>V20Gy 29.0cc FAIL (&lt;20cc)</td>
<td>Dmean49.4Gy PASS (&lt;50Gy)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Esophagus:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V60Gy 4.9% PASS (&lt;15%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dmean55.1Gy FAIL (&lt;34Gy)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dmax 103.4% PASS (&lt;105%)</td>
</tr>
</tbody>
</table>
Even if fulfilling the constraints one plan can do better than the other.

The intersections between PTVs and OAR will set a limit to the minimal dose to the OAR before losing PTV coverage.
The best plan for a particular patient

The Radiation Oncologist should clearly state:

**Dose to the PTVs**

<table>
<thead>
<tr>
<th>Name of Structure</th>
<th>Dosimetric Parameter</th>
<th>Per Protocol</th>
<th>Variation Acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTV</td>
<td>$D_{95%}(%)^*$</td>
<td>100% of prescribed dose (PD)</td>
<td>at least 95% of PD</td>
</tr>
<tr>
<td></td>
<td>$D_{10%}(%)^*$</td>
<td>$\leq 105%$ of PD</td>
<td>$\leq 110$ of PD</td>
</tr>
<tr>
<td></td>
<td>$D_{0.03cc}(%)^*$</td>
<td>$\leq 106%$ of PD</td>
<td>$\leq 112%$ of PD</td>
</tr>
</tbody>
</table>

**Dose constraints to OARs**

<table>
<thead>
<tr>
<th>Name of Structure</th>
<th>Dosimetric Parameter</th>
<th>Per Protocol</th>
<th>Variation Acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>SpinalCord</td>
<td>$D_{0.03cc}$</td>
<td>$\leq 50$ Gy</td>
<td>$\leq 60$ Gy</td>
</tr>
<tr>
<td>Brainstem</td>
<td>$D_{0.03cc}$</td>
<td>$\leq 55$ Gy</td>
<td>$\leq 60$ Gy</td>
</tr>
<tr>
<td>OpticChiasm_PRV</td>
<td>$D_{0.03cc}$</td>
<td>$\leq 55$ Gy</td>
<td>$\leq 60$ Gy</td>
</tr>
<tr>
<td>OptNrv_PRV_L or OptNrv_PRV_R</td>
<td>$D_{0.03cc}$</td>
<td>$\leq 55$ Gy</td>
<td>$\leq 60$ Gy</td>
</tr>
<tr>
<td>Retina_L or Retina_R</td>
<td>$D_{0.03cc}$</td>
<td>$\leq 45$ Gy</td>
<td>$\leq 50$ Gy</td>
</tr>
<tr>
<td>Brain</td>
<td>$D_{5%}$</td>
<td>$\leq 65$ Gy</td>
<td>$\leq 67$ Gy</td>
</tr>
<tr>
<td>Lens_L or Lens_R</td>
<td>$D_{0.03cc}$</td>
<td>$\leq 7$ Gy</td>
<td>$\leq 10$ Gy</td>
</tr>
<tr>
<td>Glnd_Lacrimal_L or Glnd_Lacrimal_R</td>
<td>$D_{0.03cc}$</td>
<td>$\leq 40$ Gy</td>
<td>$\leq 45$ Gy</td>
</tr>
<tr>
<td>Cochlea_L or Cochlea_R</td>
<td>Mean dose</td>
<td>$\leq 45$ Gy</td>
<td>$\leq 50$ Gy</td>
</tr>
</tbody>
</table>

**Priorities**

1. SpinalCord
2. Brainstem
3. OptChiasm_PRV
4. OptNrv_PRV_L and OptNrv_PRV_R
5. PTV1
6. PTV2
7. Brain
8. Retina_L and Retina_R
9. Glnd_Lacrimal_L and Glnd_Lacrimal_R
10. Lens_L and Lens_R

RTOG3508/Abbvie M13813
The best plan for a particular patient

The Radiation Oncologist should understand:

- That intersections between PTV and OAR will either compromise PTV coverage or OAR dose
Plan Quality Indicators are useful to compare different plans

PQI tries to collapse the achievement of all dose goals in one number giving a better score to those plans that, while keeping dose coverage and homogeneity at PTV reduce as much as possible doses to OARs.

\[ PQI = \sum k_i \text{Score}_i \]

Score based on ‘plan quality metrics’ → need for consensus…
Dosimetric plan comparison multicenter VMAT intercomparison
Automatic planning will need to be populated with the best plans.
But Plan Quality is not only about fulfillement of dosimetric goals

For IMRT and VMAT we need to include PLAN COMPLEXITY analysis:

- Dose calculation accuracy
- Delivery achievability
Plan complexity analysis: Plan Analyser

Provides information on HOW the dose distribution is produced. Developed with MATLAB® (Victor Hernandez, Jordi Saez. Catalan Society of Medical Physicsits project)

It reads RTPlans and computes:

- Plan complexity indices: MCS, Leaf travel LT, LTMCS, EdgeMetric, BeamIrregularity, MI speed, MI accel, MI total.

- Distribution of MLC gap sizes

- Ammount of T&G effect and interdigitate

- Modulation of dose rate & gantry speed

- MLC movements: speed, acceleration

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Jordi.saez@gmail.com
Plan complexity analysis: Dose calculation accuracy

The smaller the MLC opening the higher the mean fraction of Tongue and Groove

Tongue and groove is not well modelled in some TPS

Dose calculation accuracy is compromised
Plan complexity analysis: Delivery

Higher modulation Index leads to a lower gamma pass rate

V. Hernandez, J. Saez, D. Jurado. SEFM meeting 2016

Head and neck patients
Plan complexity analysis: Delivery

Different vendors achieve the dose distributions by either modulating MLC, gantry speed, dose rate.

This could be beneath the worse results on gamma pass rates when working with different manufacturers (TPS-linac).
Plan robustness

Different plans may result in very similar dose volume histograms and therefore very similar PQI but with a different level of uncertainties in relation to patient changes.
The more robust a plan is the more insensitive to patient changes it should be.

Ideally we should include patient reproducibility uncertainties in the optimiser: PROBABILISTIC and ROBUST PLANNING.
A plan with a high complexity index is less forgiving to changes (patient, machine delivery)

Gamma evaluation between two film dose measurements, one static and the other with motion

V. Hernandez, J. Saez, D. Jurado. SEFM meeting 2016

The interplay effect increases with Total Modulation Index
Planning CT

Treatmen t planning

Data Transfer

Treatmen t delivery

Dose prescription

PATIENT

Plan QI (dose distribution)
Plan complexity
Plan Robustness to changes

Plan deliverability
Patient variations
Plan deliverability is checked by pre-treatment verification

Compare planned dose distribution calculated in a phantom, fluence in the EPID plane with measurements

**Metrics for comparison:**

Gamma pass rate, mean gamma, DVH differences...

Should we do pre-treatment verification for all plans and all patients?

Linked to complexity metrics??
How to account for patient differences between Planning and treatment

CTV and OAR **margins** account for positioning differences between planning and delivery

**BUT** they do not account for changes in the diameter, tissue density...

**AND** involve the irradiation of healthy tissue
IGRT, robust or probabilistic planning, adaptive strategies help to adapt to patient changes

But there will always residual variations:

• Changes within tolerances of machine performance

• Small differences in patient set up, internal structure changes (size, density)
Differences between planning and delivery can be assessed by in vivo dosimetry

In vivo dosimetry is the measure of the dose delivered to the patient during the treatment.
Differences between planning and delivery can be assessed by in vivo dosimetry

Dose delivered to the patient agrees with the planned dose

- Verification of data transfer for the actual patient plan
- Beam data acquired during patient treatment
  - Log files
  - Fluence
- Checking the dose distribution as delivered to the patient (patient changes)
Final remarks

Plan Quality monitoring has to include:

• Fulfillment of dose prescription (PTV and OAR), dose distribution
• Plan complexity
• Plan robustness to patient changes
• Deliverability: machine and patient

Monitoring plan quality is an essential part of a Quality management programme

• Prevent incidents/accidents
• Quality standardization
• Quality improvement
• Better patient outcomes (increase tumor control, decrease toxicity)
Aknowledgments

Victor Hernandez-Masgrau
Jordi Saez
Diego Jurado