Development of a dose assessment tool for the auditing of radiotherapy treatment dosimetric quality

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Dose quality metrics

• Dose reporting (per ICRU 85)
  • Dose volume metrics: minimum, maximum, mean doses
  • D98% (near min), D50% (median), D2% (near max)
  • Homogeneity index: HI = (D2% - D98%) / D50%

• Conformality
  • TROG conformity index, Van’t Riet conformation number, healthy tissue overdosage factor, geometric conformity

• Dose objectives
  • equivalent uniform doses

• Others
  • structure volumes (cc), overlaps between volumes, beam arrangement information
Plan processing

• Developed software in C# - extension to MCDTK code
• Application is pointed at a directory containing exported treatments: RTPLAN, RTDOSE, RTSTRUCT files
• Exports data as CSV, so can be easily analysed
• Export format is externalised – so if you want a D(X) value for any OAR in a cohort of plans you can specify for it to be calculated and exported
• Sanitises structure names: “Lt. Fem”, “Left Femoral”, etc will all be treated as the same structure with the same objectives
• Ignores volumes: couch, filling, artefact, set up, overlap, etc
Assessment software
Guidelines

Bladder: V65: 50; Grade 3+ toxicity  
Bladder: V70: 33; Grade 3 toxicity  
Bladder: V75: 23; Grade 3 toxicity  
Bladder: V80: 13; Grade 3 toxicity  
Brain; MAXIMUM: 60; Symptomatic necrosis (<3% toxicity rate)  
Brain; MAXIMUM: 72; Symptomatic necrosis (5% toxicity rate)  
Brain; MAXIMUM: 90; Symptomatic necrosis (10% toxicity rate)  
Brain Stem; MAXIMUM: 54; Neuropathy or necrosis (<5% toxicity rate)  
Brain Stem; MAXIMUM: 64; Neuropathy or necrosis (<5% toxicity rate)  
Cochlea; MEAN: 43; sensory-neural hearing loss (<30% toxicity rate)  
Esophagus; MEAN: 34; Grade 3+ esophagitis (5-20% toxicity rate)  
Esophagus; V35: 50; Grade 2+ esophagitis (<30% toxicity rate)  
Esophagus; V50: 40; Grade 2+ esophagitis (<30% toxicity rate)  
Esophagus; V70: 20; Grade 2+ esophagitis (<30% toxicity rate)  
Heart; MEAN: 26; Pericarditis (<1% toxicity rate)  
Heart; V25: 10; Long term cardiac mortality (<1% toxicity rate)  
Heart; V30: 46; Pericarditis (<1% toxicity rate)  
Kidney; MEAN: 18; Clinical dysfunction (<5% toxicity rate)  
Kidney; MEAN: 28; Clinical dysfunction (<5% toxicity rate)  
Kidney; V12: 33; Clinical dysfunction (<5% toxicity rate)  
Kidney; V20: 32; Clinical dysfunction (<5% toxicity rate)  
Kidney; V23: 30; Clinical dysfunction (<5% toxicity rate)  
Kidney; V28: 20; Clinical dysfunction (<5% toxicity rate)  
Larynx; MAXIMUM: 66; Vocal dysfunction (<20% toxicity rate)  
Larynx; MEAN: 50; Aspiration (<30% toxicity rate)  
Larynx; MEAN: 44; Edema (<20% toxicity rate)  
Larynx; V50: 27; Edema (<20% toxicity rate)  
Liver; MEAN: 32; RILD (<5% toxicity rate)  
Liver; MEAN: 42; RILD (<5% toxicity rate)  
Lung; MEAN: 7; Symptomatic pneumonitis (5% toxicity rate)  
Lung; MEAN: 13; Symptomatic pneumonitis (10% toxicity rate)  
Lung; MEAN: 20; Symptomatic pneumonitis (20% toxicity rate)  
Lung; MEAN: 24; Symptomatic pneumonitis (30% toxicity rate)  
Lung; MEAN: 27; Symptomatic pneumonitis (40% toxicity rate)  
Lung; V20: 30; Symptomatic pneumonitis (<20% toxicity rate)  
Optic Nerve; MAXIMUM: 55; Optic neuropathy (7% toxicity rate)  
Parotid; MEAN: 25; Long term salivary function <25% (<20% toxicity rate)  
Parotid; MEAN: 39; Long term salivary function <25% (<30% toxicity rate)  
Penile Bulb; p60: 70; Severe erectile dysfunction (<55% toxicity rate)
Exported data

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Patient #091491:
Physician: Dr. MacKeen^James^Dr
Therapist: kells
Machine: Arla RadOnc

Patient #091491 failed 0 of 20 tested guidelines

BODY [1083943 dose values]
Volume (cc), Minimum, Median, Maximum, :
16938.689 0.006 0.778 81.966
Guideline not found

Bladder, NOS (assumed to be Bladder) [6641 dose values]
Volume (cc), Minimum, Median, Maximum, :
183.766 2.376 17.566 81.07
PASSED Bladder guideline of MINIMUM value <= 85 from Emami for TD 5/5
PASSED Bladder guideline of D87 value <= 85 from Emami for TD 5/5
PASSED Bladder guideline of MINIMUM value <= 85 from Emami for TD 50/5
PASSED Bladder guideline of MINIMUM value <= 85 from Hansen and Roach
PASSED Bladder guideline of D33 value <= 60 from Hansen and Roach

PTV1 [5184 dose values]
Volume (cc), Minimum, D(V=98%), D(V=95%), Median, D(V=2%), Maximum, Homogeneity index, :
396 81.0 75.291 76.14 76.571 70.452 88.7 81.966 0.058
Conformity Indices (TROG_CI, Van't_Riet_CN, TVCF, TVUF, HTCI, HTOF, Geometric Conformity):
1.3354552460138 0.749 1.0 0.0 0.749 0.335 0.335
PASSED PTV1 guideline of D98 value > 0.95 of prescription dose from Prescription
PASSED PTV1 guideline of D2 value <= 1.07 of prescription dose from Prescription

Rectum, NOS (assumed to be Rectum) [2594 dose values]
Minimum, Median, Maximum, EUD, V(D=48 Gy), V(D=68 Gy), :
12.995 29.877 81.966 68.897 0.327 0.178
PASSED Rectum guideline of MINIMUM value <= 60 from Emami for Severe proctitis, necrosis, fistula, stenosis TD 5/5
PASSED Rectum guideline of MINIMUM value <= 60 from Emami for Severe proctitis, necrosis, fistula, stenosis TD 50/5
### Exported data

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Additional Functions

• Calculates beam complexity data:
  • modulation complexity score (McNiven et al, 2010)
  • modulation index (Webb, 2003)
  • fluence map complexity (Llacer et al, 2001)
  • small leaf aperture counts, cross-beam axis counts
  • aiming to correlate these metrics against gamma pass rates from EPIQA, MapCheck, etc – as a deliverability indicator

• Additions in pipeline
  • identification of SRS/SRT plans, when to use those objectives
Example of use

• Cohort of 163 delivered prostate treatments at 5 centres
  • matched Varian accelerators, Eclipse v8.6 with AAA
• 83x 3DCRT, 33x IMRT and 47 RapidArc treatments
• Oncologists and therapists worked across modalities
• Majority involving intact prostates, some following prostatectomies (both adjuvant and salvage cases)
• Avoided “non-standard” treatments where
  • patient had hip replacements (artefacts in CT)
  • HDR brachytherapy was utilised
  • intent was not listed as curative or radical
  • any replanning had occurred
Example of use

• Comparison of Gleason scores and clinical target volumes (cc) indicated no significant variance (P > 0.1)
• Target doses were expressed relative to ICRU point prescriptions (so 95% coverage and 107% limit)
• Organ-at-risk doses were expressed relative to PTV median dose (so healthy tissue sparing could be evaluated independently to prescriptions)
Example of use

Minimum / Median / Maximum dose relative to PTV median
Example of use
Example of use

- PTV dose homogeneity reduced in IMRT and RA
- IMRT and RA offered greater conformality and organ-at-risk dose sparing
  - in terms of total dose, despite prescription escalation
- 3DCRT did not meet D50% < 40 Gy on average
- RA offered significant (P < 0.001) reduction in median femoral dose compared to IMRT
Intended applications

- Planning studies typically utilise a small number of prospective plans on same patient
  - this data can be used to profile the dosimetric quality achieved at a centre
    - this could be compared to other centres or the literature
    - this could inform clinical practice and future expansion
    - this could be associated with recorded clinical outcomes
- Therapists exporting plans on approval, huge amounts of data generated at little time cost
- Possible academic use – comparing student plans done under identical conditions