

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

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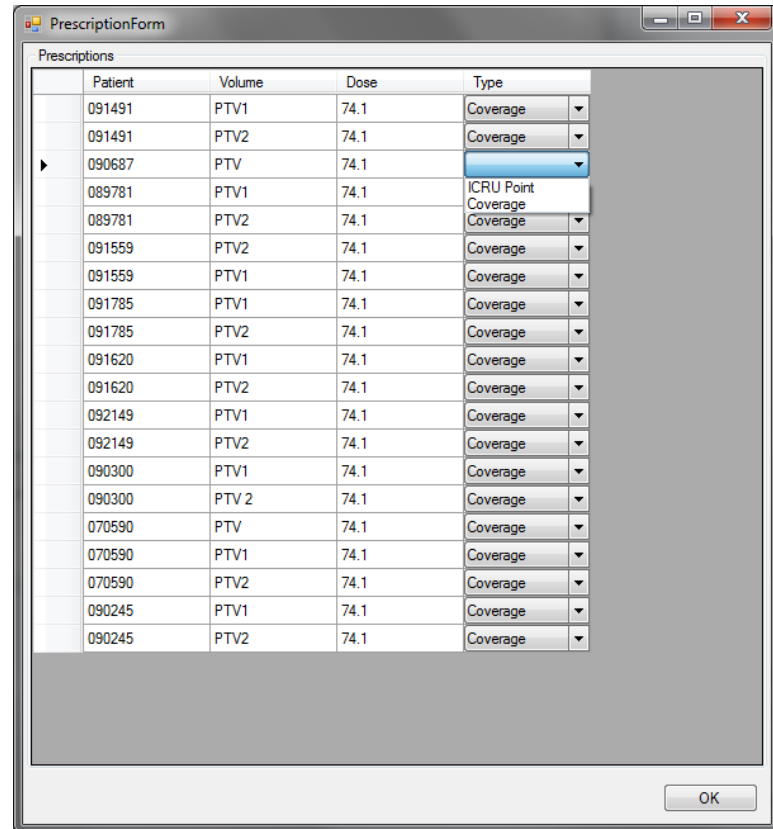
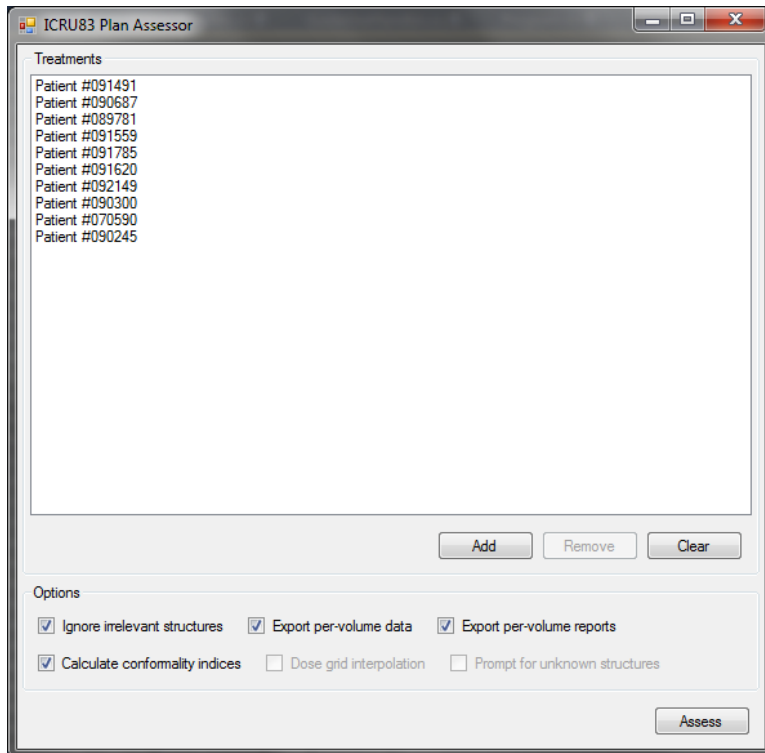
# Dose quality metrics

- 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
  - meeting of clinical objectives from Emami (1991), Hansen and Roach (2007), Milano (2007) and QUANTEC (2010)
  - 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



```
quantec.txt - Notepad
File Edit Format View Help
QUANTEC
Bladder;V65;50;Grade 3+ toxicity
Bladder;V70;35;Grade 3+ toxicity
Bladder;V75;25;Grade 3+ toxicity
Bladder;V80;15;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;45;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 (<15% toxicity rate)
Heart;V25;10;Long term cardiac mortality (<1% toxicity rate)
Heart;V30;46;Pericarditis (<15% toxicity rate)
Kidney;MEAN;18;clinical dysfunction (<5% toxicity rate)
Kidney;MEAN;28;Clinical dysfunction (<50% toxicity rate)
Kidney;V12;55;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 (<50% 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 (3% toxicity rate)
Optic Nerve;MAXIMUM;60;Optic neuropathy (7% toxicity rate)
Parotid;MEAN;25;Long term salivary function <25% (<20% toxicity rate)
Parotid;MEAN;39;Long term salivary function <25% (<50% toxicity rate)
Penile Bulb;D90;50;Severe erectile dysfunction (<35% toxicity rate)
Penile Bulb;D60;70;Severe erectile dysfunction (<55% toxicity rate)
```

# Exported data

```
Programmer's Notepad - [091491.txt *]
File Edit Search View Tools Window Help
Plain Text
091491.txt *
Patient #091491:
Physician: Dr MacKean^James^^Dr
Therapist: kellis
Machine: Aria RadOnc

Patient #091491 failed 0 of 20 tested guidelines

BODY [1083943 dose values]
Volume (cc), Minimum, Median, Maximum, :
16936.609 0.006 0.778 81.966
Guideline not found

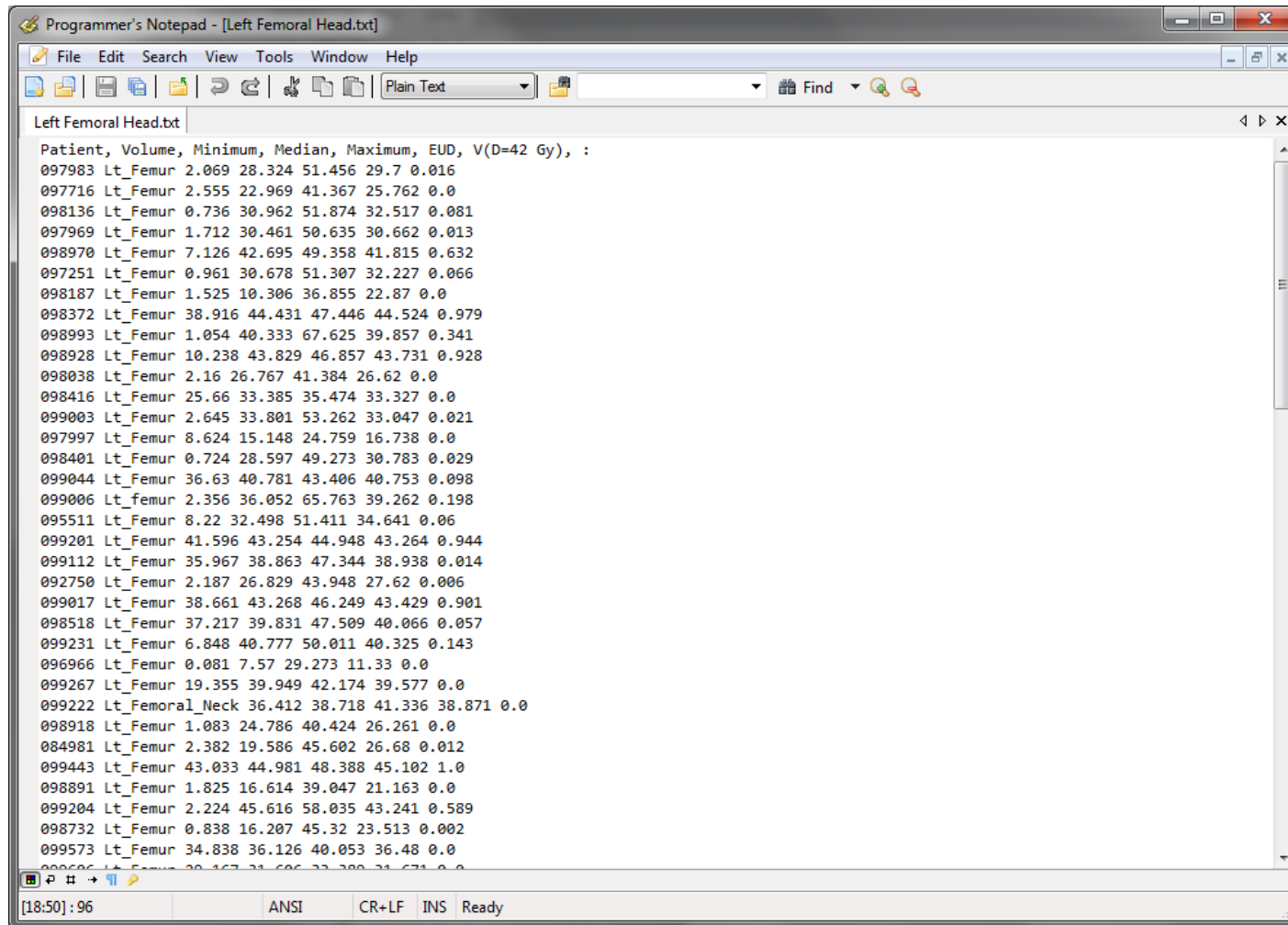
Bladder, NOS (assumed to be Bladder) [6641 dose values]
Volume (cc), Minimum, Median, Maximum, :
103.766 2.376 17.566 81.07
PASSED Bladder guideline of MINIMUM value <= 65 from Emami for TD 5/5
PASSED Bladder guideline of D67 value <= 80 from Emami for TD 5/5
PASSED Bladder guideline of MINIMUM value <= 80 from Emami for TD 50/5
PASSED Bladder guideline of D67 value <= 85 from Emami for TD 50/5
PASSED Bladder guideline of MINIMUM value <= 50 from Hansen and Roach
PASSED Bladder guideline of D33 value <= 60 from Hansen and Roach

PTV1 [5184 dose values]
Meter setting (MU), 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 78.452 80.7 81.966 0.058
Conformity Indices (TROG_CI, Van't Riet_CN, TVCF, TVUF, HTCI, HTOF, Geometric Conformity):
1.33545524691358 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=40 Gy), V(D=60 Gy), :
12.995 29.877 81.966 60.897 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 <= 80 from Emami for Severe proctitis, necrosis, fistula, stenosis TD 50/5
PASSED Rectum guideline of MINIMUM value <= 60 from Hansen and Roach

[18:71]: 50 Modified ANSI CR+LF INS Ready
```

# Exported data



```
Programmer's Notepad - [Left Femoral Head.txt]
File Edit Search View Tools Window Help
Plain Text
Left Femoral Head.txt
Patient, Volume, Minimum, Median, Maximum, EUD, V(D=42 Gy), :
097983 Lt_Femur 2.069 28.324 51.456 29.7 0.016
097716 Lt_Femur 2.555 22.969 41.367 25.762 0.0
098136 Lt_Femur 0.736 30.962 51.874 32.517 0.081
097969 Lt_Femur 1.712 30.461 50.635 30.662 0.013
098970 Lt_Femur 7.126 42.695 49.358 41.815 0.632
097251 Lt_Femur 0.961 30.678 51.307 32.227 0.066
098187 Lt_Femur 1.525 10.306 36.855 22.87 0.0
098372 Lt_Femur 38.916 44.431 47.446 44.524 0.979
098993 Lt_Femur 1.054 40.333 67.625 39.857 0.341
098928 Lt_Femur 10.238 43.829 46.857 43.731 0.928
098038 Lt_Femur 2.16 26.767 41.384 26.62 0.0
098416 Lt_Femur 25.66 33.385 35.474 33.327 0.0
099003 Lt_Femur 2.645 33.801 53.262 33.047 0.021
097997 Lt_Femur 8.624 15.148 24.759 16.738 0.0
098401 Lt_Femur 0.724 28.597 49.273 30.783 0.029
099044 Lt_Femur 36.63 40.781 43.406 40.753 0.098
099006 Lt_femur 2.356 36.052 65.763 39.262 0.198
095511 Lt_Femur 8.22 32.498 51.411 34.641 0.06
099201 Lt_Femur 41.596 43.254 44.948 43.264 0.944
099112 Lt_Femur 35.967 38.863 47.344 38.938 0.014
092750 Lt_Femur 2.187 26.829 43.948 27.62 0.006
099017 Lt_Femur 38.661 43.268 46.249 43.429 0.901
098518 Lt_Femur 37.217 39.831 47.509 40.066 0.057
099231 Lt_Femur 6.848 40.777 50.011 40.325 0.143
096966 Lt_Femur 0.081 7.57 29.273 11.33 0.0
099267 Lt_Femur 19.355 39.949 42.174 39.577 0.0
099222 Lt_Femoral_Neck 36.412 38.718 41.336 38.871 0.0
098918 Lt_Femur 1.083 24.786 40.424 26.261 0.0
084981 Lt_Femur 2.382 19.586 45.602 26.68 0.012
099443 Lt_Femur 43.033 44.981 48.388 45.102 1.0
098891 Lt_Femur 1.825 16.614 39.047 21.163 0.0
099204 Lt_Femur 2.224 45.616 58.035 43.241 0.589
098732 Lt_Femur 0.838 16.207 45.32 23.513 0.002
099573 Lt_Femur 34.838 36.126 40.053 36.48 0.0
099506 Lt_Femur 30.167 31.606 33.300 31.671 0.0
[18:50] : 96 ANSI CR+LF INS Ready
```

# 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



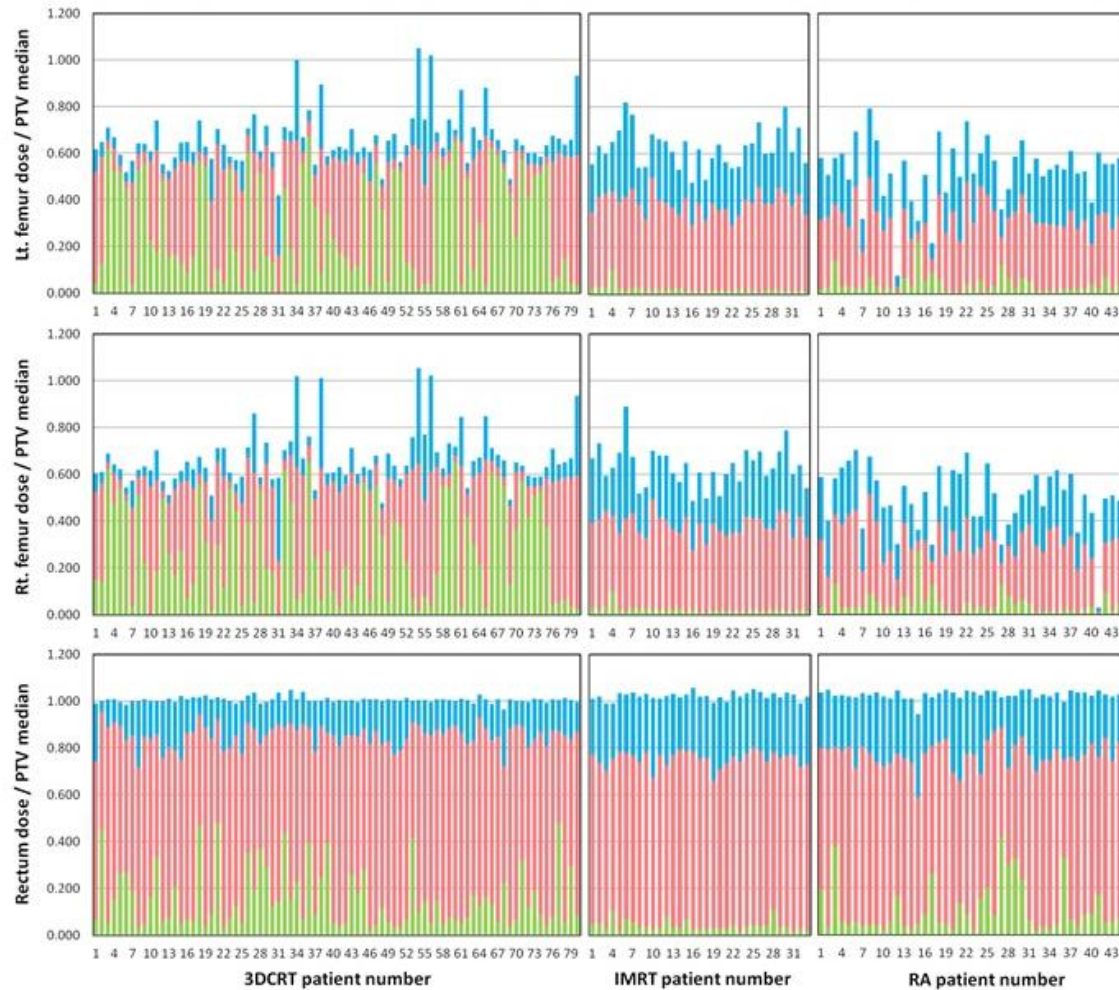
# Example of use

- 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

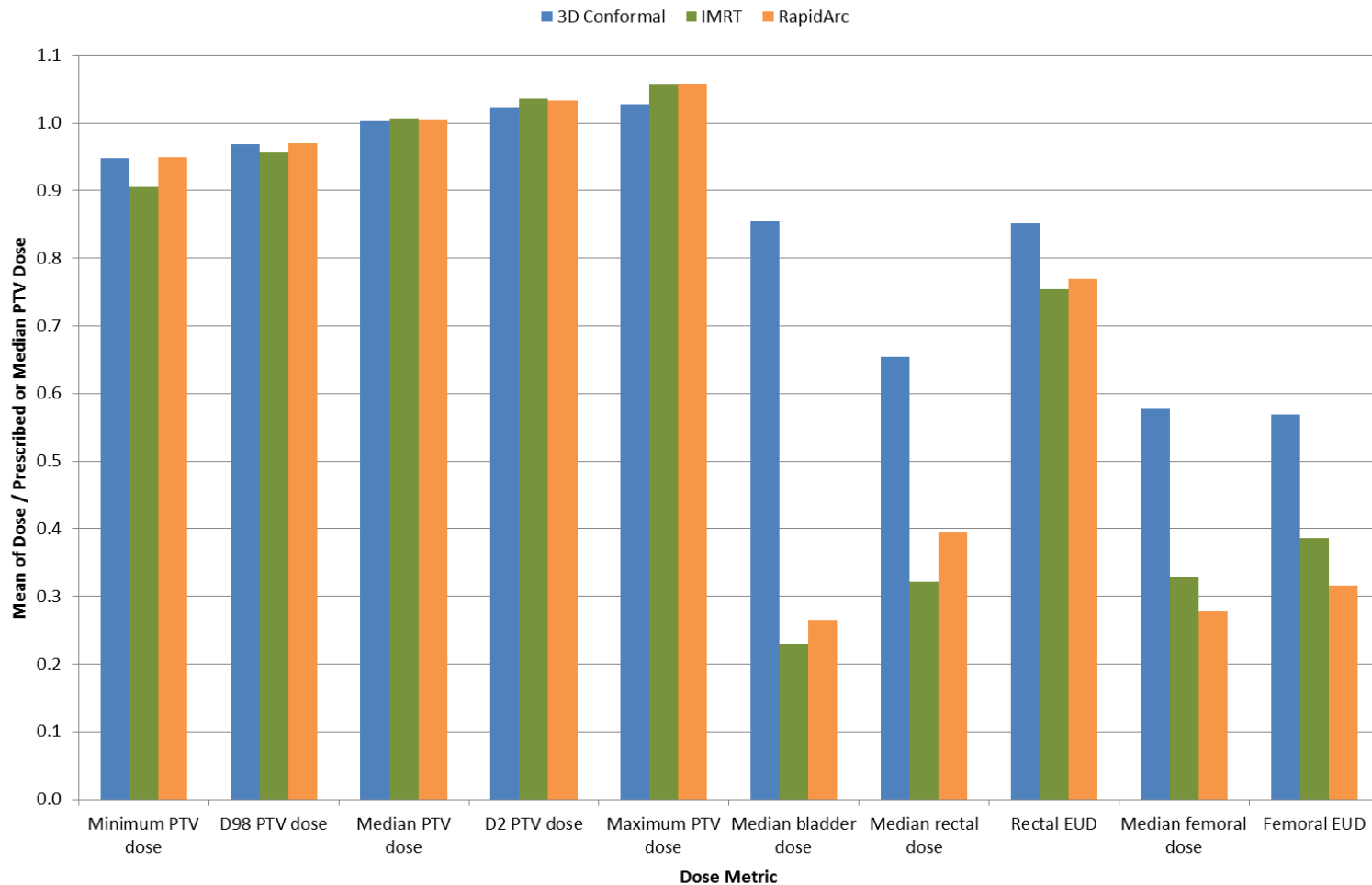
- Comparison of Gleason scores and clinical target volumes (cc) indicated no significant variance ( $P > 0.1$ )
- Target doses were expressed relative to ICRU point prescriptions (so 95% coverage and 107% limit)
- Organ-at-risk doses were expressed relative to PTV median dose (so healthy tissue sparing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