Project IX: Big Data Meets Medical Physics Dosimetry

Foundations and Recent Advances

Fumbeya Marungo, Hilary Paisley, John Rhee
Dr. Todd McNutt
Dr. Scott Robertson
Goal – improve radiotherapy risk assessment through data mining.

Formal term for risk measure is normal tissue complication probability (NTCP)

Initial focus – xerostomia (dry mouth) due irradiation of the parotid gland.

Images courtesy of Dr. Todd McNutt, Dr. Scott Robertson
Conventional method for computing NTCP, Lyman-Kutcher-Berman (LKB).
This seminar presents four papers that form the foundation of LKB.
Seminar includes a more recent paper incorporating PCA.

Motivation for LKB

- The adoption of CT led to the emergence of 3D dose planning.
- Previous approach assumed uniform irradiation of the entire organ.
- NTCP assessment used $TD_{50}$ and $TD_5$ “tolerance doses” (Rubin & Casarett 1972).
- Need to calculate NTCP of non-uniform doses over parts of the volume.

Lyman (1985) – The Model

- Assumes a power equation relationship between whole and partial volume.
- Incorporates previous $TD_{50}$ approach.
- Requires parameterization of $n$ and $m$.
- Accounts for partial volume, but still assumes uniform dose.

\[
TD_{50}(V) = \frac{TD_{50}(1)}{V^n}
\]

\[
t \sim N(0, 1), \quad t = \frac{D - TD_{50}}{\sigma(V)},
\]

where $\sigma(V) = m[TD_{50}(V)]$
Emami, et al. (1991) – The Data

- Provides $TD_{50}$ and $TD_{5}$ values (estimates) for $\frac{1}{3}, \frac{2}{3}$, and whole volumes.
- Values from combination of literature review, hard data, estimates from clinical experience.
- For parotid, assume minimum 50% volume exposure for xerostomia.
- $TD_{5} = 3,200$, $TD_{50} = 4,600$ for $\frac{2}{3}$ and whole volumes; $TD_{100} = 5,000$.

Images courtesy of Dr. Todd McNutt, Dr. Scott Robertson
Burman, et al. (1991) – Parameters

- Uses data from Emani, et. al. to calculate Lyman parameters.
- Values from combination of literature review, hard data, estimates from clinical experience.
- For parotid, assume minimum 50% volume exposure for xerostomia.
- \( \text{TD}_{50} = 4,600, \text{TD}_{5} = 3,200 \) for \( \frac{2}{3} \) and whole volumes; \( \text{TD}_{100} = 5,000 \).
Kutcher & Burman (1989) – DVH

- Replace uniform with dose volume histogram (DVH).
- DVH may represent probability distribution or cumulative distribution.
- DVH removes spatial location.
- Typically visualized as cumulative distribution, “y% of the volume has received at least x dose.”
Kutcher & Burman – $D_{\text{max}}, V_{\text{eff}}$

- Reduces DVH to a single pair of $D_{\text{max}}, V_{\text{eff}}$ values.
- Assumes high doses to small volumes are equivalent to smaller doses to larger volumes.
- Equivalence described by power relationship.
- Results in inputs for Lyman equation.

\[ \Delta V_{\text{eff}} = \Delta V \left( \frac{D_i}{D_{\text{max}}} \right)^{\frac{1}{n}} \]

\[ V_{\text{eff}} = \sum_i V_i \left( \frac{D_i}{D_{\text{max}}} \right)^{\frac{1}{n}} \]
LKB – Summary

**Pros:**
- Adapts single dose whole volume $TD_5$ and $TD_{50}$ dose guidelines to NTCP values for non-uniform doses over a partial volume.
- Makes biological based assumptions.
- Only three parameters.

**Cons:**
- Does not account for treatment location.
- Conventional parameterization performed with scarcity of hard data.
- Using $(D_{max}, V_{eff})$ removes a great deal of shape data from the DVH.
Dawson et al. (2005) – PCA of DVH

- No need for parameterization.
- For parotid, two PCs described 94% of the variance.
- Three PCs richly capture DVH shape.
- Possible improvement by centering and scaling data.
PCA may provide better classification than $D_{max}$ $V_{eff}$.

Treatment based, not biologically based. PCs may not capture new protocols.
Application to Project IX

- We wish to include dose location in NTCP calculation.
- Divide our regions of interest into 125 equal sized 3D rectangular volumes.
- Calculate DVHs on the whole ROI and each subregion.
- Reduce DVHs to two PCs for data mining task.

Images courtesy of Dr. Todd McNutt, Dr. Scott Robertson
References


References


Thank You

- Dr. Todd McNutt, Mentor
- Dr. Scott Robertson, Mentor
- Dr. Russell Taylor, Instructor
- CIS II Classmates…