The use of equivalent dose to evaluate late effects in relation to radiation therapy

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Take home message

Using equivalent dose is recommended, because it is radiobiologically correct; it includes fractionation dose and allows us to compare radiation schedules and treatment modalities in a uniform way.
Radiobiology

Radiation ↔ Cell damage / death

Shoulder (less efficient killing)

Exponential

Fraction dose

Surviving fraction

Radiation dose (Gy)

Courtesy Fiona Stewart
Basic Linear-Quadratic model

\[ SF_d = \exp\left(-\alpha d - \beta d^2\right) \]
Single dose

\[ \alpha/\beta \approx 1-4 \text{ Gy} \]
for late responding tissues

\[ \alpha/\beta \approx 10 \text{ Gy} \]
for early responding tissues

Courtesy Fiona Stewart
Fractionation

Less effect per Gy at low doses
Recovery between fractions
Equal effects per fraction

Courtesy Fiona Stewart
**Equivalent dose in fractions of 2 Gy**

- **Prescribed dose**: \( D = \text{total dose} \)
- **Fractionation dose**: \( d = \text{fractionation dose} \)
- **\( \alpha/\beta = 3 \text{ Gy} \)**

\[
\text{EQD}_2 = D \times \frac{d + \alpha/\beta}{2 + \alpha/\beta}
\]

**Uniform comparison of radiation schedules and treatment modalities**
**EXAMPLE**

**fraction dose**

\[ d = 1.6 \text{ Gy} \]

**total dose**

\[ D = 40 \text{ Gy} \]

**n = 25**
\[
\text{EQD}_2 = D \times \frac{d + \alpha/\beta}{2 + \alpha/\beta}
\]

<table>
<thead>
<tr>
<th>Treatment schedules</th>
<th>Prescribed dose (Gy)</th>
<th>EQD$_2$* (Gy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 x 1.6 Gy</td>
<td>40</td>
<td>36</td>
</tr>
<tr>
<td>20 x 2.0 Gy</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>10 x 4.0 Gy</td>
<td>40</td>
<td>60</td>
</tr>
</tbody>
</table>

*Calculated with $\alpha/\beta = 2$ Gy
Cranial Radiation Therapy

EKZ/AMC:
N = 1362
5-year survivors
1966 – 1996

CRT = brain only
craniospinal
total body

CRT (N=285) | N | Median EQD₂* (Gy)
--- | --- | ---
brain tumor | 88 | 49.7
other cancer | 197 | 24.8

*Calculated with α/β = 2 Gy

Van Dijk et al, IJROBP 2013
Cranial Radiation therapy

Dose effect relationships for cognitive function

Van Dijk et al, IJROBP 2013
Strengths & limitations

- Fractionation dose
- Comparison of treatment schedules
- Comparison of treatment modalities
- Volume
- Prescribed dose
- Organs at risk

Future

DVHs
Dosimetry
In conclusion

EQD$_2$

- radiobiologically correct
- fractionation dose
- radiation schedules and treatment modalities

↑ Survival
↓ Late effects
Thank you

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