# Biological Treatment Planning

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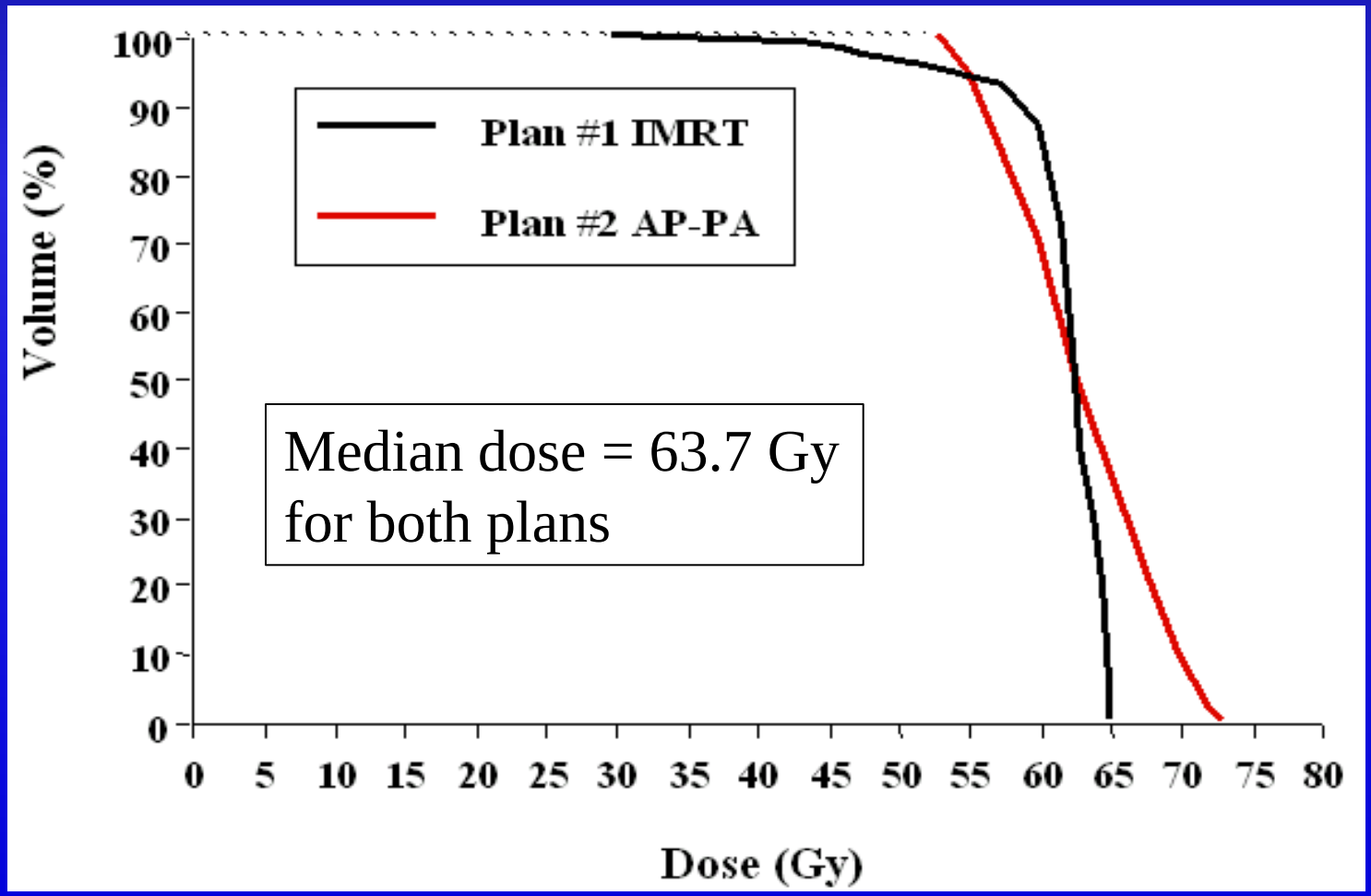
# Physical planning, optimization and evaluation

(derived from Andrzej Niemierko, ASTRO, 2001)



# Some quantitative measures to go by

| Plan | D90 | D100 | V90 | V100 | Range (Gy) | Std. dev. (Gy) |
|---|---|---|---|---|---|---|
| IMRT | 59Gy | 30Gy | 94% | 50% | 30 - 65 | 2.5 |
| AP-PA | 57Gy | 55Gy | 83% | 50% | 55 - 73 | 3.5 |

IMRT: most uniform (lower standard deviation), higher V90, but lower D100

AP-PA: higher D100, but lower V90 and also higher $D_{max}$

# But which is the better plan?

- Need to consider both tumor and normal tissue DVHs
- Want good coverage of the target, low $D_{max}$ to normal tissues, and low volume of normal tissues receiving doses close to "tolerance"

# So what does the physical planner do?

- The skill of the planner is used to establish physical dose and volume constraints for each patient and to evaluate the DVHs generated by the optimization software to select the “best” plan
- But will this lead to the highest uncomplicated tumor control probability (UTCP)?
- Maybe we could reduce the DVHs for tumor and normal tissues to single numbers and use these as constraints to develop plans to maximize the UTCP

# Reducing the DVH to a single number: The *EUD* equation

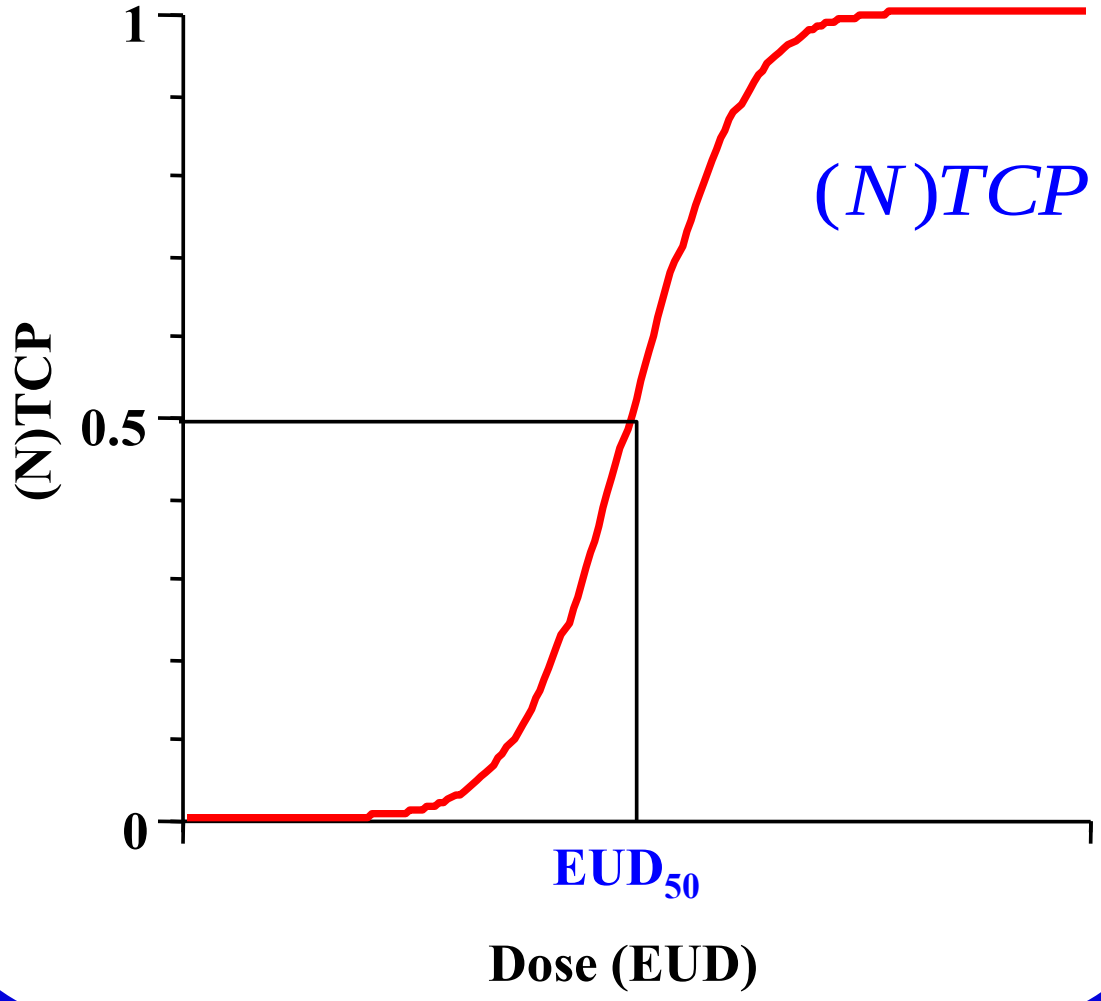
Niermierko originally defined the EUD only for tumors in 1997 but extended it to all tissues in 1999

$$EUD = \left[ \sum_i v_i D_i^{\,a} \right]^{1/a}$$

where $v_i$ is the volume of the tissue in dose bin $D_i$ as a fraction of the volume of the total organ or tumor i.e. $v_i = V_i/V_{tot}$

# EUDs can be used to estimate TCPs and NTCPs

(derived from Andrzej Niemierko, ASTRO, 2001)



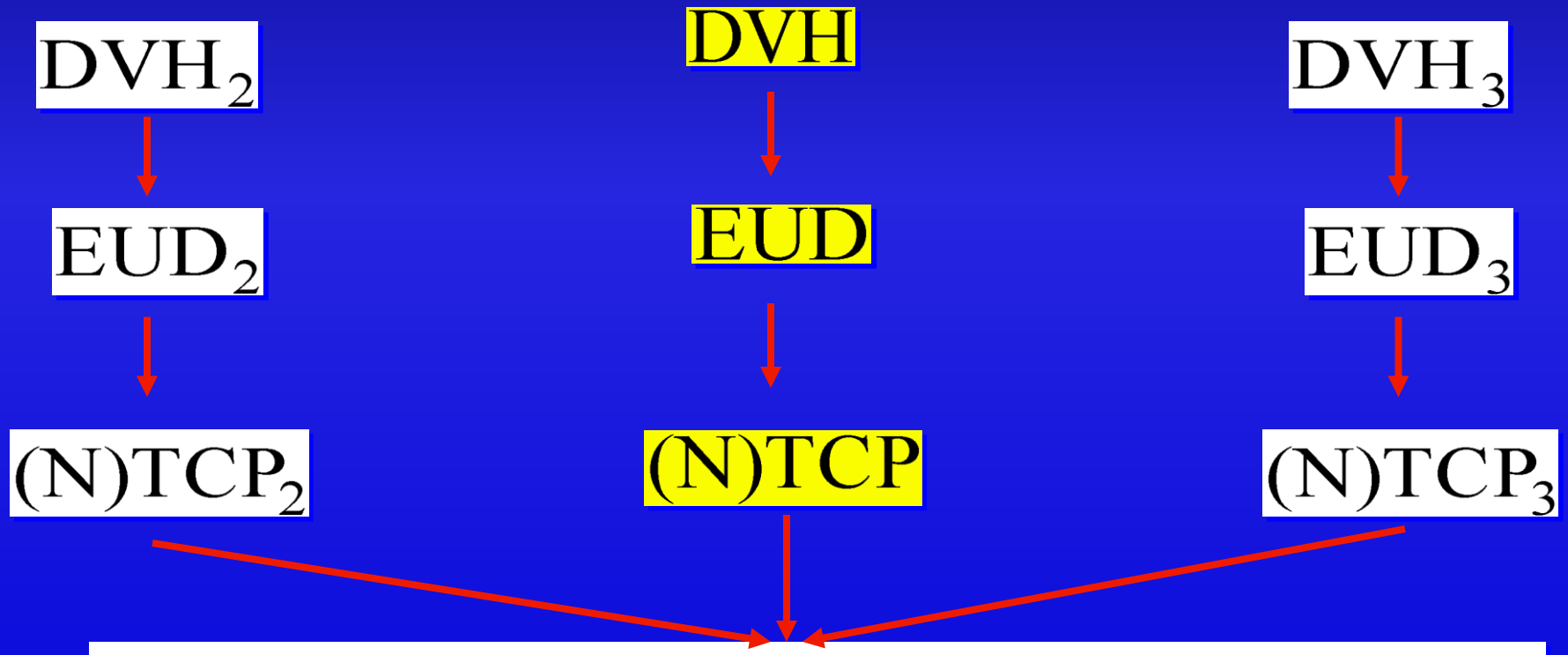

$$(N)TCP = \frac{1}{1 + \left[\frac{EUD_{50}}{EUD}\right]^{4\gamma_{50}}}$$

# Biological optimization

The objective is to develop the treatment plan which will deliver a dose distribution that will ensure the highest TCP that meets the NTCP constraints imposed by the radiation oncologist (or maximizes the UTCP)

# Creating a Score function for plan optimization or plan evaluation

(derived from Andrzej Niemierko, ASTRO, 2001)




$$\text{Score} = \prod_{i}^{\#\text{targets}} \left(\text{TCP}_i\right)^{w_i} \prod_{k}^{\#\text{normal}} \left(1 - \text{NTCP}_k\right)^{w_k}$$

# DVH data can be used directly without calculation of EUDs: the NTCP probit-based model

The Pinnacle and Eclipse TP systems use the Kutcher and Burman DVH reduction method to calculate the effective volume $\upsilon_{eff}$

$$\mathrm{NTCP}_{(\mathrm{dose,volume})} = \frac{1}{2}\left[1 + \mathrm{erf}\left(\frac{t}{\sqrt{2}}\right)\right].$$

The parameter $t$ is determined by the effective volume method,

$$t = \frac{D_{\max} - D_{50}(\nu_{\mathrm{eff}})}{\mathbf{m}D_{50}(\nu_{\mathrm{eff}})} : D_{50}(\nu_{\mathrm{eff}}) = D_{50}\nu_{\mathrm{eff}}^{-N},$$

$$\mathbf{m} = \frac{1}{\sqrt{2\pi} \times \gamma_{50}} \quad \text{and} \quad \nu_{\mathrm{eff}} = \frac{1}{\nu_{\mathrm{ref}}} \sum_i \nu_i \left(\frac{D_i}{D_{\max}}\right)^{1/N},$$

# EUD, NTCP and TCP calculations: effect of dose/fraction

- Since biological effects are a function of dose/fraction, EUD, NTCP and TCP calculations need to take this into account
- One way to do this is to transform all doses within the irradiated volume to “effective” doses at some standard dose/fraction e.g. 2 Gy, using the linear-quadratic model, before calculation of the EUD, TCP or NTCP

# Alternatively could use the LQ model directly: TCP calculations using Poisson statistics

According to the Poisson statistics model:

$$TCP_i = e^{-N_{0,i}S_{m,i}} \; and \; TCP = \prod_i TCP_i$$

where, using the L-Q model:

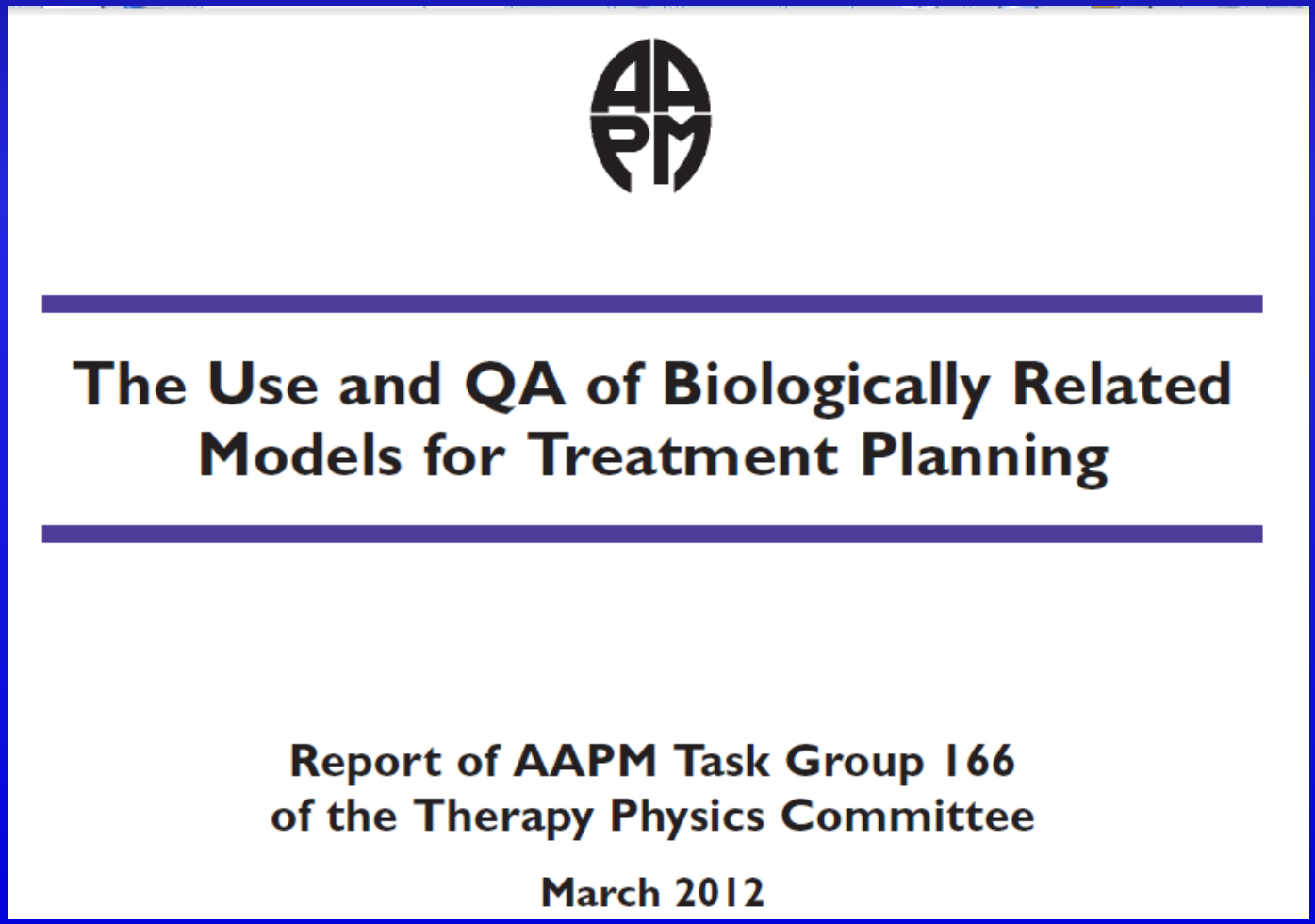
$$S_{m,i} = e^{-\left(\alpha d_i + \beta d_i^{\,2}\right)N}$$

$$\text{so } TCP_i = e^{-N_{0,i}e^{-\left(\alpha d_i + \beta d_i^{\,2}\right)N}}$$

# Biological models used in commercial treatment planning systems

- Monaco
  - *Tumor: Poisson statistics cell kill model*
  - *Normal tissues: EUD*
- Pinnacle
  - *Tumor: LQ-based Poisson TCP model; EUD*
  - *Normal tissues: Lyman-Kutcher NTCP model; EUD*
- Eclipse
  - *Tumor: LQ-based Poisson TCP model; EUD*
  - *Normal tissues: LQ-based Poisson NTCP model; Lyman-Kutcher NTCP model*

# Great reference!



**The Use and QA of Biologically Related Models for Treatment Planning**

**Report of AAPM Task Group 166**
**of the Therapy Physics Committee**

**March 2012**

*Anaheim, CA*
*July 15, 2015*

# Debate Motion

"Treatment Planning Evaluation and Optimization Should Be Biologically and not Dose/volume Based"

**Speakers:**

**FOR** the Motion:

**Joseph O. Deasy, Ph.D.**

**AGAINST** the Motion:

**Charles S. Mayo, Ph.D.**

*Anaheim, CA*
*July 15, 2015*

# Joseph O. Deasy, Ph.D.

- Chair, Department of Medical Physics, Memorial Sloan Kettering Cancer Center, New York, NY
- Past-Chair of the AAPM Biological Effects Subcommittee

*Anaheim, CA*
*July 15, 2015*

# Charles S. Mayo, Ph.D.

- Associate Professor, Radiation Oncology, University of Michigan, Ann Arbor, MI
- Chair of AAPM TG 263 on Standardizing Nomenclature for Radiation Therapy

*Anaheim, CA*
*July 15, 2015*

# Debate Rules

- ***Each speaker will make a 12-minute Opening Statement***
- ***Rebuttals follow with speakers allowed four minutes each***
- ***The Moderator will strictly enforce the time limits***
- ***At the end of the Debate the Audience Vote will be determined by a show of hands***

*Anaheim, CA*
*July 15, 2015*

# The Audience

- *Audience participation is encouraged*
- *Remember, this is a participation sport*
- *However, only "polite" heckling will be tolerated!*
- *Positively no interruptions or heckling by speakers!*

# My opinion (for what it's worth!)

- As Moderator of this debate, I should, of course, be impartial, but my opinion is that about 90% of treatment planning is physical
- And the other 50% is biological (with apologies to Yogi Berra!)