What is different about IMRT?

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Why ask the question?

- In medicine, a new method should replace a tried one only if it is shown to be superior.

  No one wants a clever doctor
- A medical action may lead to unexpected results when the tools change

  Even fewer want a cleaver doctor
- Differences in treatment allow tradeoffs in results

  Club it or Cleave it

What can be different?

- Dose distribution
  - Is it unequivocally better?
- Dose delivery
  - Is it less free of error?
- Tradeoffs in results and process
  - Can we choose among them?

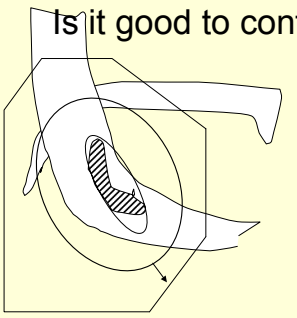
How can we test the differences?

- Clinical results – desired
- Planned doses – available
- Delivered doses - coming
- Costs – who's counting

2D → 3D

Dose distribution

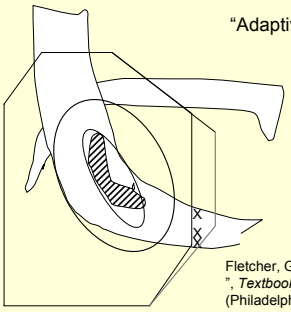
Is it good to conform?



2D → 3D

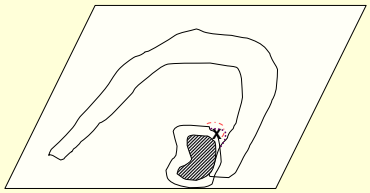
Dose distribution

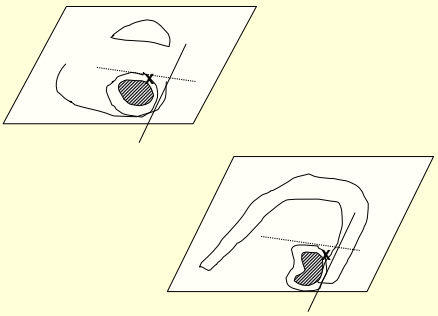
"Adaptive Radiotherapy"



Fletcher, G. , "Ch.3: 'Head and Neck' ", *Textbook of Radiotherapy*. 3rd ed. (Philadelphia: Lea and Febiger, 1980)

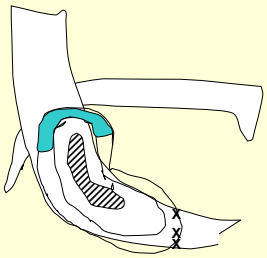
Field Design → Target Design





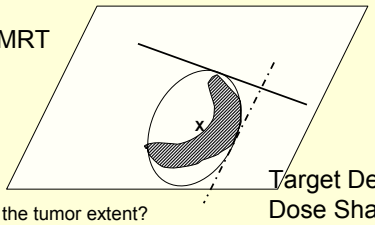
2D → 3D

Dose distribution



More Information $\overset{?}{\Rightarrow}$ Better Distribution

3D→IMRT



Target Design → Dose Shaping

Where is the tumor extent?

Is our uncertainty enlarged when dose conforms to a concave target?

Does conformance necessarily lead to an improved dose distribution?

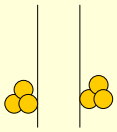
Tailored coverage or Emperor's New Clothes?

Questions for the Clinician

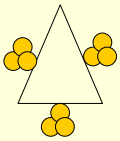
- When target extends outside the expected compartments, is coverage beneficial?
  - prevent untreatable symptomatic progression?
  - convert failure to cure
    - small amounts of disease may be chemosterilized
    - large amounts of disease more likely to fail distantly
- How does overcall of tumor extent propagate through multiple diagnostic tests? (CT,EUS,MRI,PET,MRS)
- What are the costs of changing the target?

Going off the beaten track:

As we change the shape of dose distributions, what is the difference in the amount of information required to keep treatment to a standard which tests, recognizes and corrects of sources of treatment failure?



2D→3D
3D→IMRT



Is it possible to collect enough information to ascertain outcomes as a function of changes to the dose distribution or is the required data set too large or too spread out to be attained?

NTCP, TCP, EUD, DVH, mean dose, conformality index, homogeneity

Really better or Optimal Illusion?

constraints	Dose limit	Fraction size	Volume limit
Lung	<2000	<210	30%
Heart	<3000	<210	50%
Cord	<4500	<210	100%
PTV1	>5000	>180	100%

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Dose Homogeneity
≥ 85%

Really Better or Optimal Illusion?

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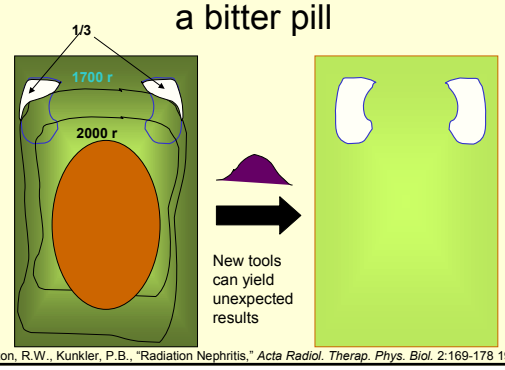
Dose Homogeneity
85%

Objective	Δ Objective
Maximize *min* tumor dose	To within 1 fraction size (200)

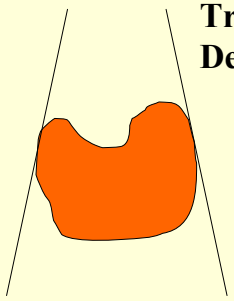
Really better or Optimal Illusion?

- Are there steps we can take to improve the planned dose distribution?
- Does IMRT take those steps?
- When are there "miles and miles" to go in planning, and when are we on a treadmill, and can we tell the difference?

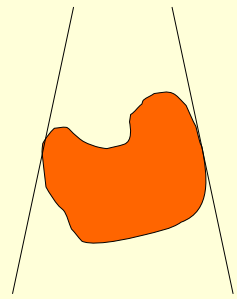
A dose formulation can be a bitter pill



Luxton, R.W., Kunkler, P.B., "Radiation Nephritis," *Acta Radiol. Therap. Phys. Biol.* 2:169-178 1964

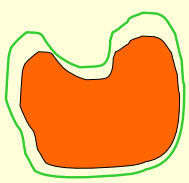


3D→IMRT **Differences in Error Tolerance**

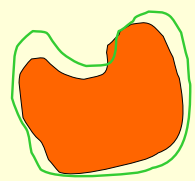


Differences in Error Tolerance

IMRT



IMRT



There is a CON in Concave

Rotational Differences: A Matter of Degree

Size of Error
on anteroposterior check films

	L-R error	S-I error	Coronal angle error
#checks	96	96	96
Mean abs. value error	.35 cm	1.43 cm	1.6º
95th percentile error	.93 cm	1.13 cm	5.0º

Essapen S; Brit J. Radiol. 75:162-9 (2002)

CONCAVITY

- Does a concave dose distribution carry a lower tolerance to error?
- Can we measure error tolerance?
  - to rotations?
  - to translations?
- Is this an important difference?
- How should we adjust for it?

Tradeoffs

Does IMRT make new tradeoffs possible?

Can the tradeoffs be recognized?

How to choose among them?

Are there social and economic tradeoffs and should prescriptions consider them?

Delta Force or Delta Blues ?

How big a difference is desired?

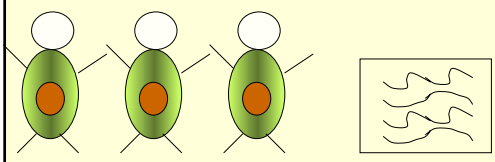
- Should we make small Δ changes in the face of uncertainty?
- What is a small Δ change?
  - Homogeneity relaxation?
  - D_{00}, $D_{100} \rightarrow D_{05}$, D_{95} in GTV, PTV, OAR?
  - Geometric/aperture derived plans or delivery?
  - Incremental changes to treatment volumes
  - Smoothing concavities in treatment or target volumes

Effect on Minimum Tumor Dose (MTD) of 3%-7% change in allowed inhomogeneity

Case No.	% contralateral lung allowed ≥20 Gy	Strict Inhomogeneity		Relaxed Inhomogeneity	
		inhomogeneity	Largest MTD	inhomogeneity	Largest MTD
1	35%	13%	63 Gy	20%	**>80 Gy**
2	35%	13%	64 Gy	20%	**>80 Gy**
3	40%	13%	55 Gy	20%	**>80 Gy**
4	40%	15%	48 Gy	20%	**>80 Gy**
5	35%	13%	64 Gy	20%	**>80 Gy**
6	35%	17%	44 Gy	20%	**>80 Gy**

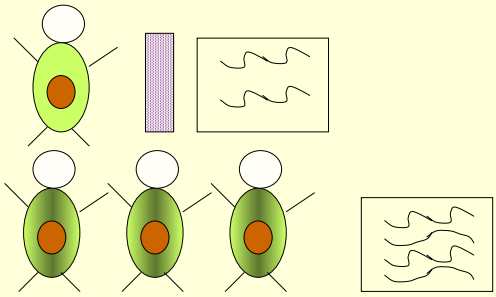
Langer, M.; Kijewski, P.; Brown, R.; Ha. C.*Rad. Onc.* 21:245-56;1990 "The effect on min. tumor dose of restricting target dose inhomogeneity"

Cancer Ward



Solzyenitsyn, A. *Cancer Ward* , transl. Bethell, N. and Burg, D. (New York: Bantam Books,1980).

Cancer Ward



Solzyenitsyn, A. *Cancer Ward* , transl. Bethell, N. and Burg, D. (New York: Bantam Books,1980).

Tradeoffs

- As choices become greater, do economic tradeoffs become obscured?
- Does IMRT change the tradeoffs between uncertainty in dose and the planned dose distribution?
- Does IMRT change the tradeoffs between predicted outcome and its uncertainty (EUD,mean dose vs. min tumor dose,eg.)
- Does IMRT expand the available tradeoffs?

What is different…?

" ונטה עליה קו־תהו"

"and he will stretch upon it the measuring line of chaos"

Isaiah 34:11

as suggested by a translation and observation of Luis Alonso Schökel, *A Manual of Hebrew Poetics,* Editrice Pontificio Instituto Biblico, Rome (2000).