
Associazione Italiana Radioterapia e Oncologia clinica

Società Italiana di Radiobiologia


# Simposio AIRO-AIFM

## La qualita' di un piano di cura in radioterapia stereotassica – valutazione del target

**Pierfrancesco Franco MD, PhD, MPH candidate**

Dipartimento di Medicina Traslazionale, Università del Piemonte Orientale, Novara

Dipartimento di Radioterapia Oncologica, AOU 'Maggiore della Carità', Novara

E-mail: pierfrancesco.franco@uniupo.it

twitter @Pier_Franco_MD

ESTRO

EORTC Quality of Life Group

UPO UNIVERSITÀ DEL PIEMONTE ORIENTALE

ESO European School of Oncology

ESCO

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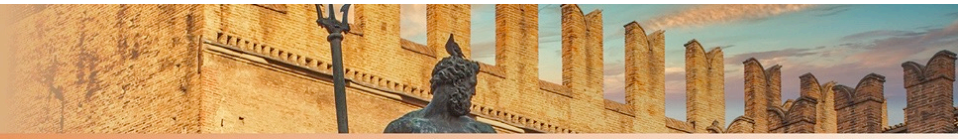
Società Italiana di Radiobiologia

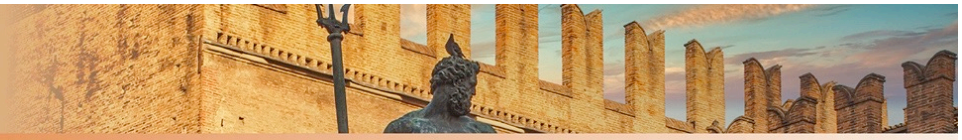


# DICHIARAZIONE

## Relatore: Pierfrancesco Franco

Come da nuova regolamentazione della Commissione Nazionale per la Formazione Continua del Ministero della Salute, è richiesta la trasparenza delle fonti di finanziamento e dei rapporti con soggetti portatori di interessi commerciali in campo sanitario.

- Posizione di dipendente in aziende con interessi commerciali in campo sanitario **(NIENTE DA DICHIARARE / NOME AZIENDA)**
- Consulenza ad aziende con interessi commerciali in campo sanitario **(NIENTE DA DICHIARARE / NOME AZIENDA)**
- Fondi per la ricerca da aziende con interessi commerciali in campo sanitario **(NIENTE DA DICHIARARE / NOME AZIENDA)**
- Partecipazione ad Advisory Board **(NIENTE DA DICHIARARE / NOME AZIENDA)**
- Titolarità di brevetti in compartecipazione ad aziende con interessi commerciali in campo sanitario **(NIENTE DA DICHIARARE / NOME AZIENDA)**
- Partecipazioni azionarie in aziende con interessi commerciali in campo sanitario **(NIENTE DA DICHIARARE / NOME AZIENDA)**
- Altro



# What is plan quality ?

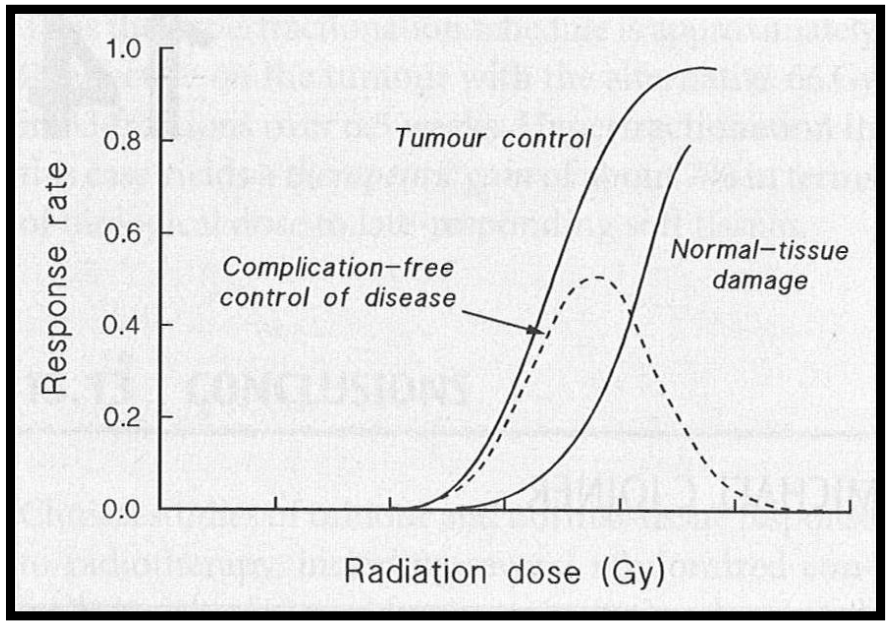
A high-quality treatment plan:

- ✓ Matches the required clinical objectives at best
- ✓ Delivers the prescribed dose to the target
- ✓ Limiting the dose to the organs at risk at least to the clinically required dose constraints, but also to as low as reasonably achievable

- ✓ Treatment plan expectations and standards evolve with time, as technology and clinical evidence symbiotically develop. TP and delivery modalities and methods must therefore advance together.

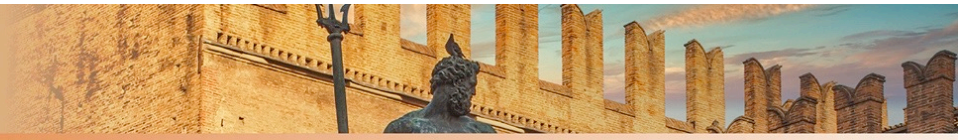
Hansen CR, J Med Imaging Rad Onc 2022

# Uncomplicated local tumour control rate as a bell-shaped curve




- ✓ Increasing total dose: not only tumour control rates but also incidence/severity of normal-tissue damage rises
- ✓ ULTC probability initially increases with total dose but then falls because of normal-tissue toxicity
- ✓Once the optimum, further improvements in ULTC rate needs shifts TCP to lower doses or NTCP to higher doses

Holthusen H, Strahlentherapie 1936



# Key elements in plan quality

- ✓ Appropriate choice and use of the available modalities
- ✓ Prescription and dose metrics aligned with the relevant evidence base at the time
- ✓ Target dose coverage and meeting dose objectives
- ✓ Critical OAR sparing, meeting constraints
- ✓ Protocol specific OAR sparing
- ✓ Target dose conformity
- ✓ Target dose homogeneity
- ✓ Plan robustness
- ✓ Plan complexity and deliverability

Hansen CR, J Med Imaging Rad Onc 2022

# Dose prescription and reporting -ICRU 50 and ICRU 62

- ✓ Acceptable dose heterogeneity: +7% to – 5% of the prescribed dose

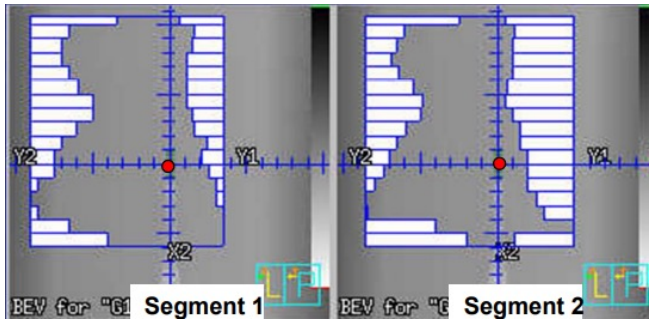
- ✓ Reported doses are:

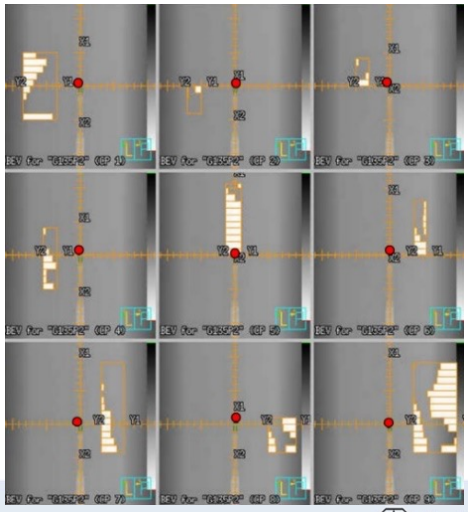
- Minimum dose to PTV (no volume limit defined)
- Maximum dose to PTV (volume at least 15 mm)
- Mean dose to PTV
- Median dose to PTV
- Dose at ICRU reference point (centre of the PTV; intersection of beam axes)
  - Dose at the point clinically relevant
  - Point easy and unambiguous to define
  - Point selected as to accurately determined the dose
  - Point should be outside a regione with steep dose gradient

# Towards IMRT

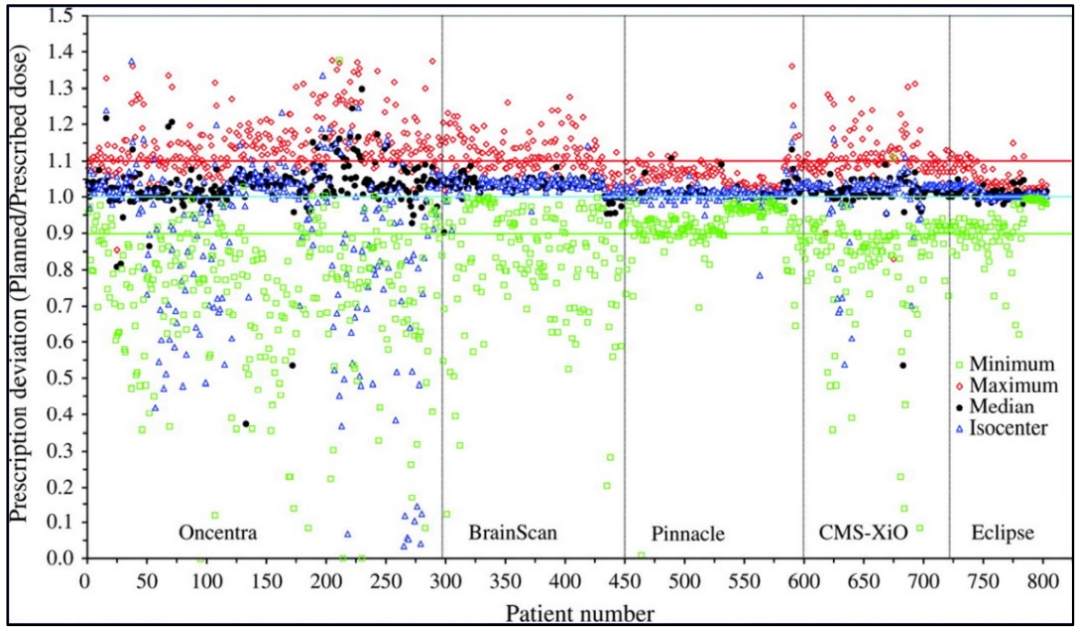
- ✓ Discrepancy between dose volume contraint prescription and dose delivery
- ✓ Single point dose prescription
- ✓ Single point dose reporting
- ✓ Biological metrics (EUD, TCP, NTCP)
- ✓ Uncertainties in dose prescription and reporting
- ✓ Need for more quality assurance

## ICRU reference point is not a 'typical point for IMRT'



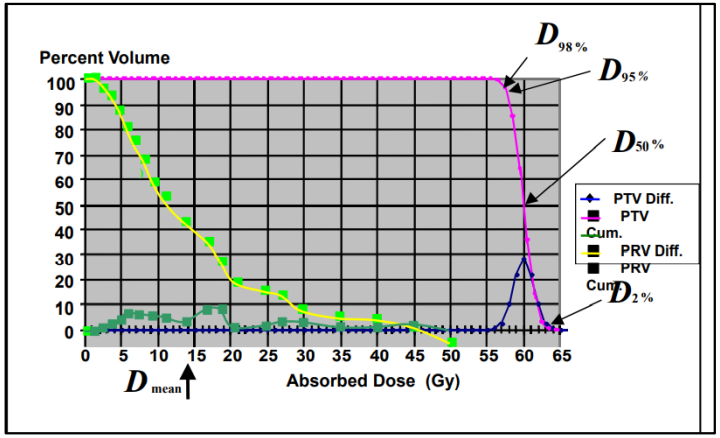



## Reliability of planning metrics

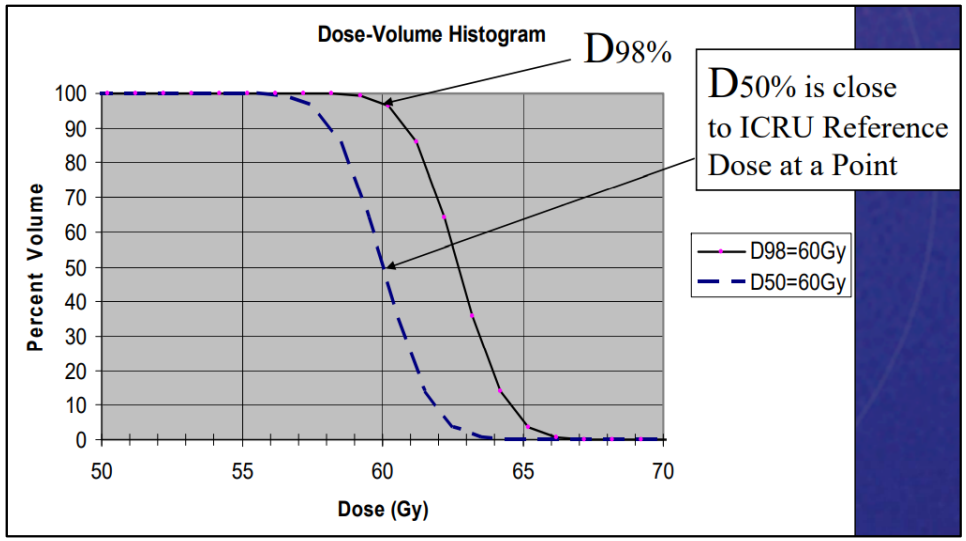


# Dose prescription and reporting -ICRU 71 and ICRU 83

- ✓ Dose-volume reporting (i.e. $D_v$)
- ✓ $D_{50\%}$ (Dmedian), prescription value, i.e. $D_{95\%}$
- ✓ $D_{mean}$
- ✓ Near Minimum Dose: $D98_{\%}$
- ✓ Near Maximum Dose: $D_{2\%}$



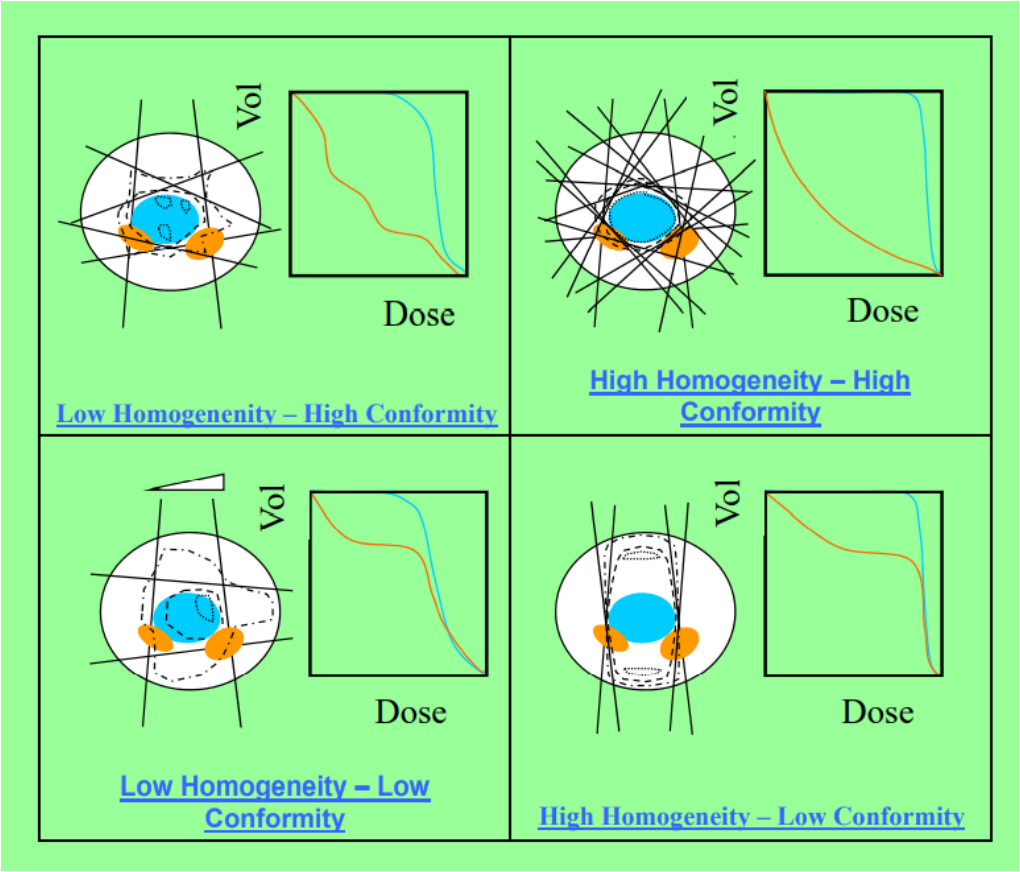

- Doses at a point are not as reliable as DVH near-min and near-max
- PTV median dose is the "typical dose" to the PTV
- PTV mean dose and PTV median dose are nearly identical
- PRV mean dose and PRV median dose are not necessarily similar



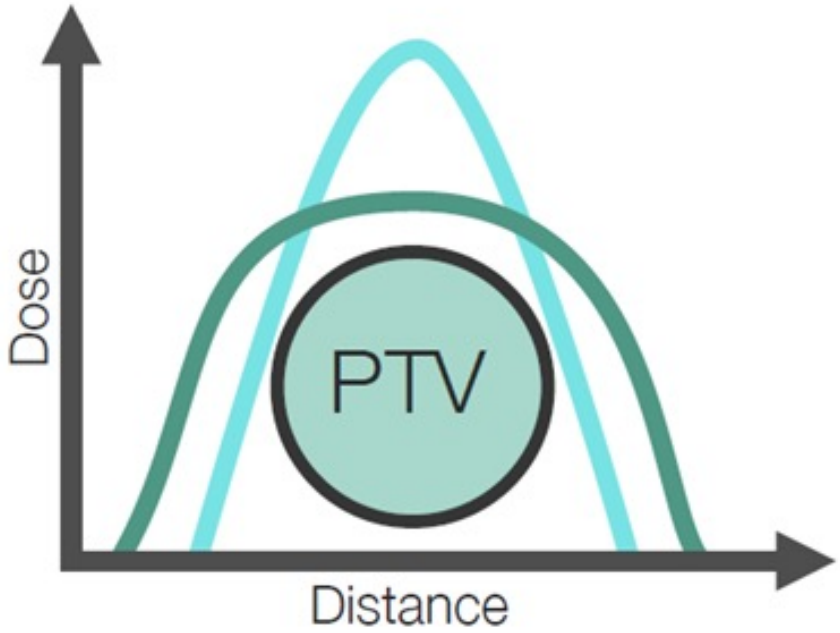
# Homogeneity and conformity

- ✓ **Homogeneity** is a measure of the uniformity of absorbed dose in the PTV indicated by the "squareness" of the DVH. It describes how flat the dose distribution is, often from near minimum to near maximum.
- ✓ **Conformity** is a measure of the overlap between the isodose surface defining a significantly large absorbed dose and the surface of the PTV. It represents how the planned dose matches the prescribed dose to the target volume at a specific dose level

- ❑ HI = D2%-D98%/D50%
- ❑ CI: TV/PTV or $V_{RI}$/PTV



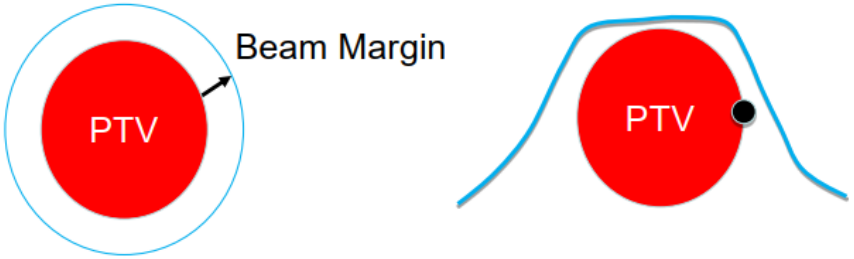
# Homogeneity vs conformity – a trade-off



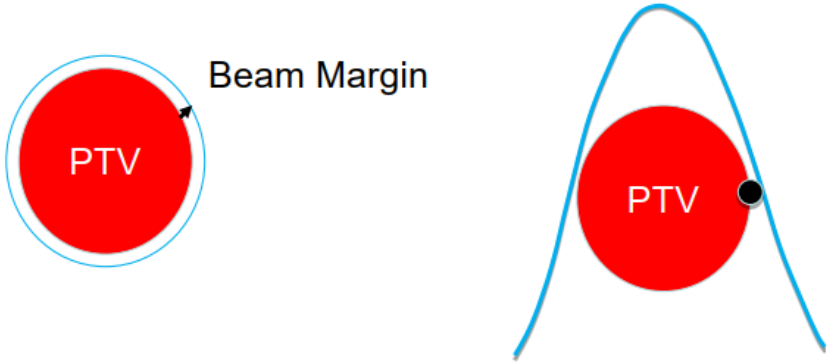
# SBRT treatment planning – basic principles

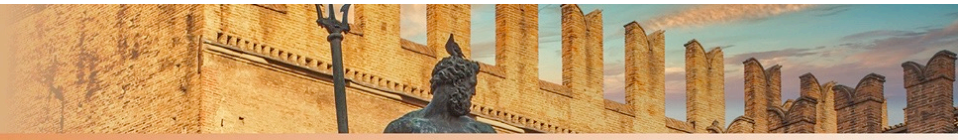
- ✓ SABR/SBRT treatments is to 'ablate' the tumor, i.e. tissues within the GTV (or PTV).
- ✓ Tissues within the target is not considered at risk for complications.
- ✓ Dose inhomogeneity inside the GTV (or PTV) is considered acceptable, even potenitally beneficial. It is not considered a priority in plan design.
- ✓ Maximum point dose up to 160% of prescription dose is commonly observed in SBRT plans
- ✓ The main plan objective is to minimize the normal tissue volume (outside the PTV) receiving high-dose per fraction – abrupt dose fall-off

- ✓ When beam margin is close to beam penumbra (5-6 mm)
- ✓ PTV dose is homogeneous
- ✓ Maximum dose is around 110% of prescribed dose
- ✓ Dose fall-off outside PTV is shallow



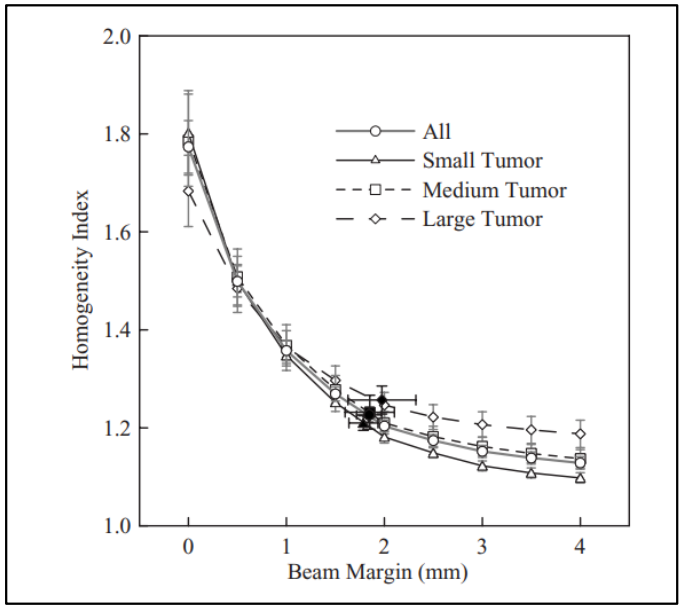

- ✓ When beam margin is less than beam penumbra (0-2 mm)
- ✓ PTV dose is inhomogeneous (heterogeneous)
- ✓ Maximum dose is around 125% of prescribed dose
- ✓ Dose fall-off outside PTV is steep



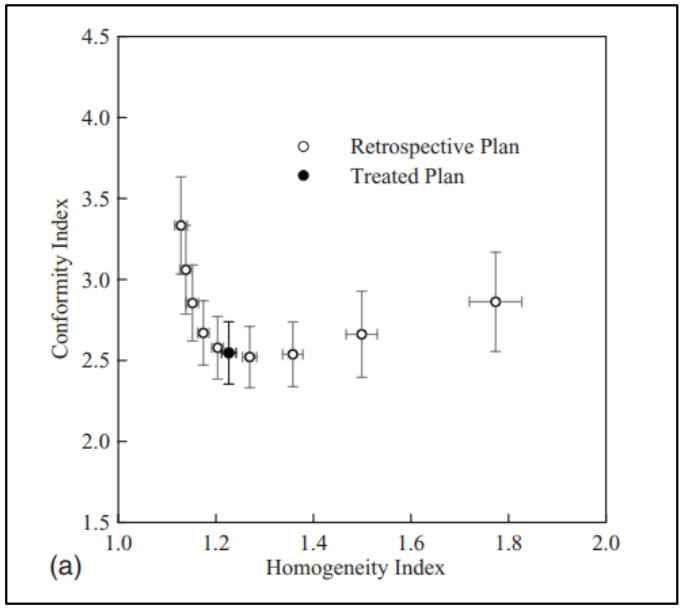


| | Conventional RT | SABR/SBRT |
|---|---|---|
| **Prescribed dose/per fraction** | $\leq$ 3 Gy | $\geq$ 5 Gy |
| **N° of fractions** | $\geq$ 10 fr | $\leq$ 5 fr |
| **Dose distribution** | Homogeneous (PTV max dose: 110%) | Heterogeneous (PTV max dose: up to 160%) |
| **Dose gradient outside PTV** | Shallow slope | Steep slope |

# Planning for brain SRS

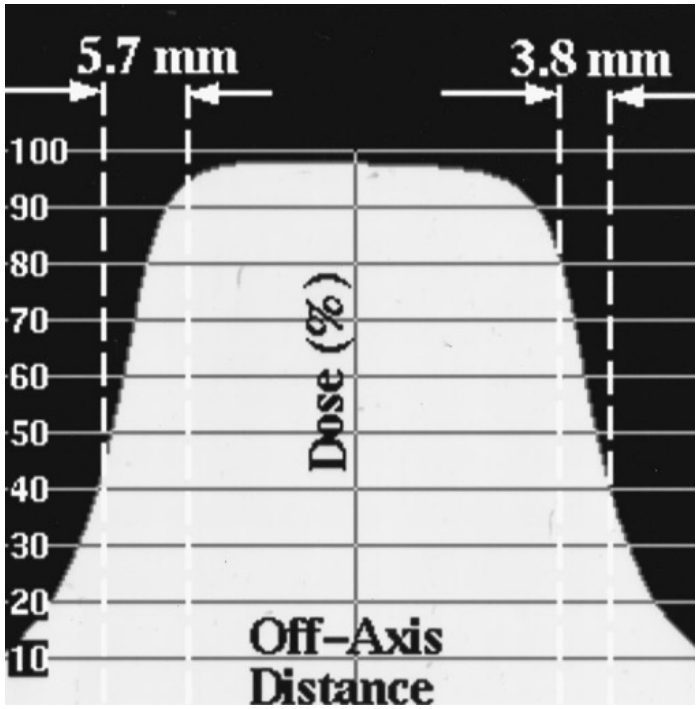



HI (ratio PTV $D_{max}$ vs PD) vs beam margin




CI (ratio PD volume vs PTV volume) vs HI

Hong LX, Med Phys 2011

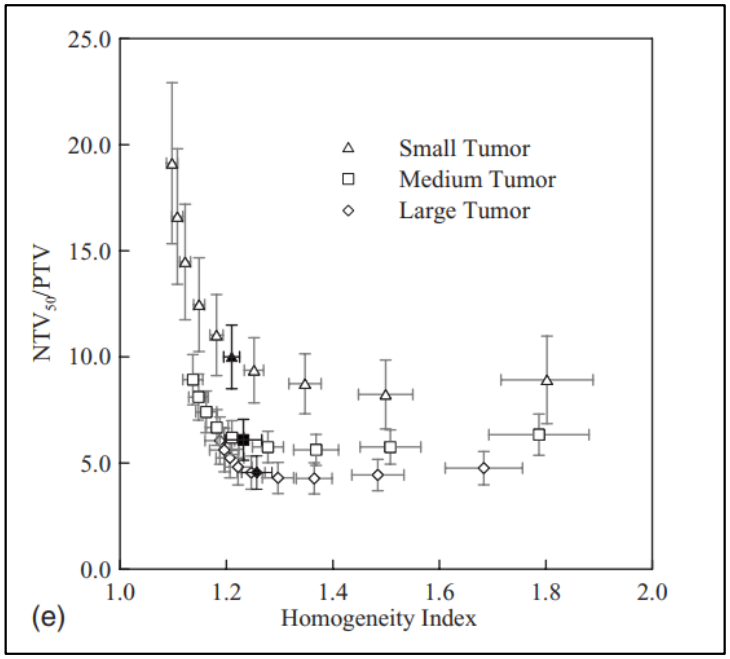



For single isocenter dose distributions, the dose fall-off from prescription isodose to half of the prescription dose typically occurs over the shortest distance if the dose is prescribed to the 80% isodose shell, with 100% as maximum dose

If 100% is PD, then 125% should be the maximum dose to have sharpest ratio of $R_{50\%}$ (Ratio of 50% Prescription isodose volume to the PTV volume)

Meeks SL, IJROBP 1998

# Planning for brain SRS




$NTV_{50\%}$ vs PTV

Normal Tissue Volume receiving 50% of PD increases sharply as PTV inhomogeneity decreases below 120% of PD

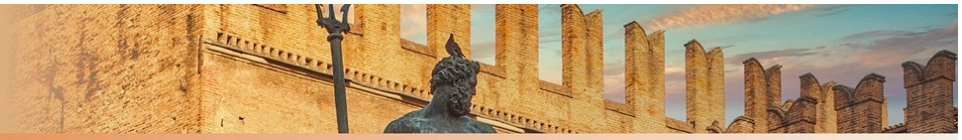
Hong LX, Med Phys 2011

# Conventional RT vs SABR/SBRT

| | SBRT | Conventional RT | |
|---|---|---|---|
| **N° of beams** | 11 | 11 | 3 |
| **Beam margin (mm)** | 1 | 5 | 5 |
| **PD per fraction** | 20 Gy | 2 Gy | 2 Gy |
| **PTV Max Dose (%)** | 124.2% | 110.8% | 110% |
| **$V_{100\%}$** | 38.6 cc | 44.3 cc (+5.7 cc) | 87.5 cc (+ 48.9 cc) |
| **$V_{50\%}(R_{50\%})$** | 146.3 cc | 212.4 cc (+ 66 cc) | 417.3 cc (+ 271 cc) |
| **$V_{25\%}$** | 630.4 cc | 799.2 cc (+ 169 cc) | 756.8 cc (+126 cc) |
| **50% PD** | 10 Gy | 1 Gy | 1 Gy |

SBRT plan for a small lung lesion (PTV volume 33 cc)

Comparing PD: 20Gy x 3 plan vs 2Gy x 30 plan



# SABR/SBRT vs Conventional RT

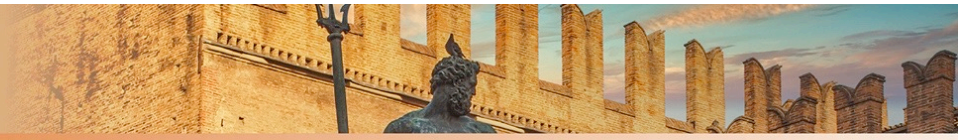
## SBRT plans

- ✓ Prescription Isodose level is usually not 100%
- ✓ PD covering 100% PTV
- ✓ Often 95% PD covering 95% PTV or higher
- ✓ Or 100% PD covering 95% PTV or higher

This coverage was chosen because of the increased tissue volumes that must be irradiated to cover the corners of the PTV on each consecutive CT slice if 100% coverage is required.

## Conventional plans

- ✓ Often 100% PD dose to 100% PTV

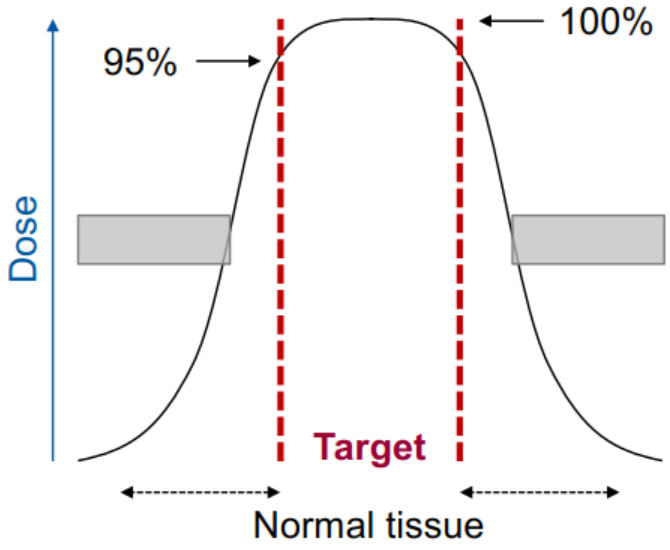


# SABR/SBRT planning principles are similar to SRS

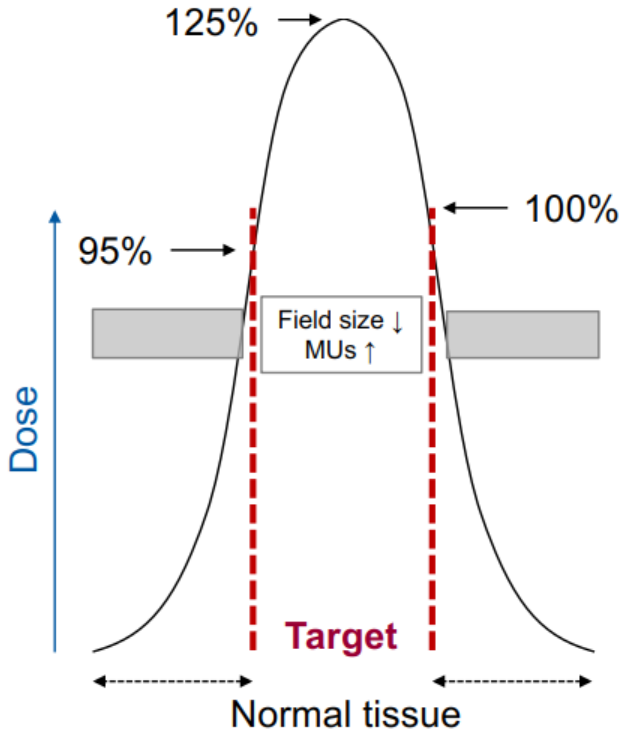
- ✓ Inhomogeneous dose inside the PTV
- ✓ Sharp dose fall off outside the PTV
- ✓ Multiple (non co-planar) beams or arc are needed to create a conformal dose distribution

- ✓ Beam clearence for non co-planar approaches is lower for LINAC-based SBRT than SRS

# Conventional RT




# SABR/SBRT and SRS



# Homogeneity vs conformity

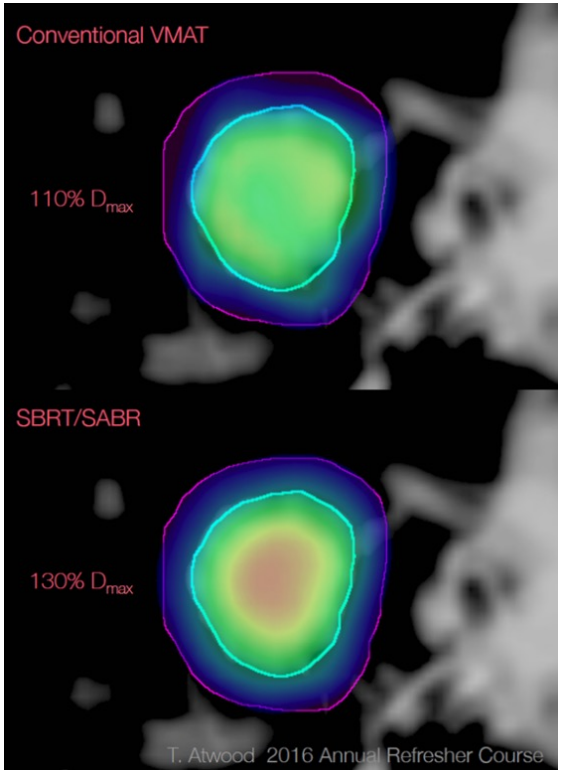
## Dose specifications:

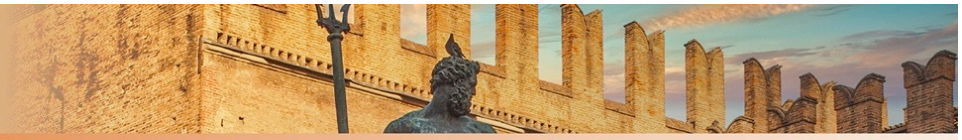
### Normalization and conformality

- ✓ 100% PD covering 95% of the PTV
- ✓ 100% PD covering 100% of the GTV or ITV
- ✓ Conformality index (CI) $\leq$ 1.2
- ✓ ~ 60% PD 2 cm away from PTV (small lesions)

### Target inhomogeneity

- ✓ PTV Dmax $\geq$ 120% of PD
- ✓ PTV Dmax located in GTV or ITV

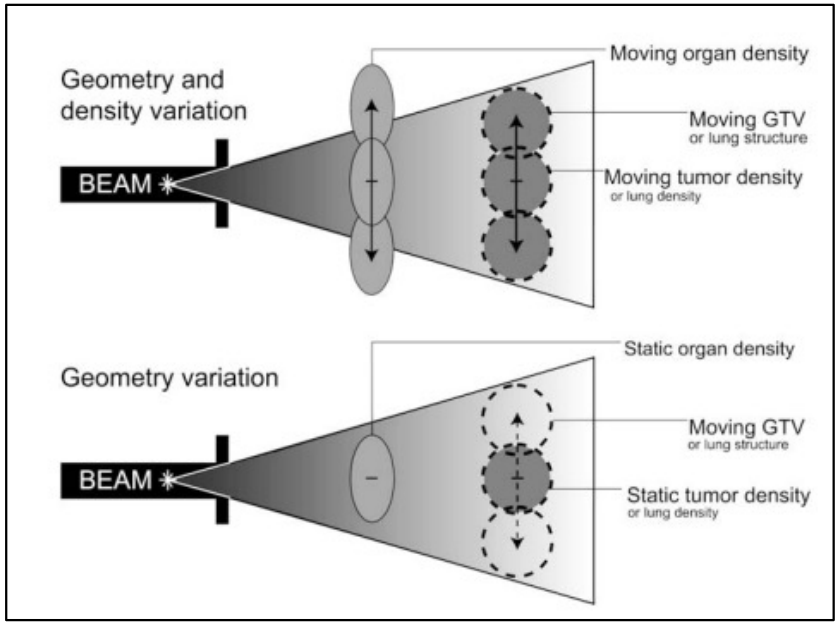


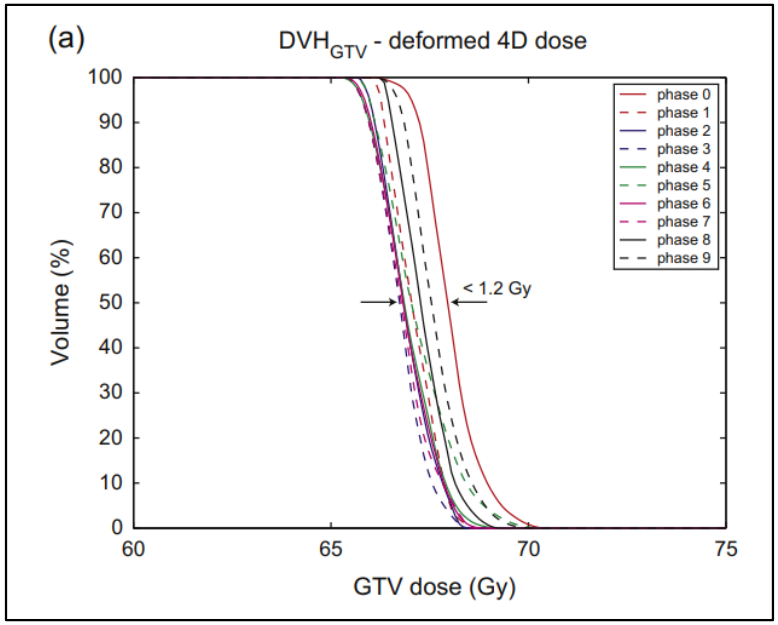


# Requirements for SBRT planning (as per RTOG 0813 and 0915 lung protocols)

- ✓ **Maximum Dose:** normalized to 100%, must be within PTV
- ✓ **Prescription Isodose:** must be ≥ 60% and < 90% of the maximum dose
- ✓ **Prescription Isodose Surface Coverage:** 95% of the target volume (PTV) is conformally covered by the prescription isodose surface (PTV V100% PD = 95%) and 99% of the target volume (PTV) receives a minimum of 90% of the prescription dose (PTV V90%PD > 99%)
- ✓ **High Dose Spillage**: The cumulative volume of all tissue outside the PTV receiving a dose > 105% of prescription dose should be no more than 15% of the PTV volume
- ✓ **Intermediate Dose Spillage:** The falloff gradient beyond the PTV extending into normal tissue structures must be rapid in all directions and meet specific criteria
- ✓ **Meet the constraints of dose limiting organs at risk**

# Influence of motion on dose distribution

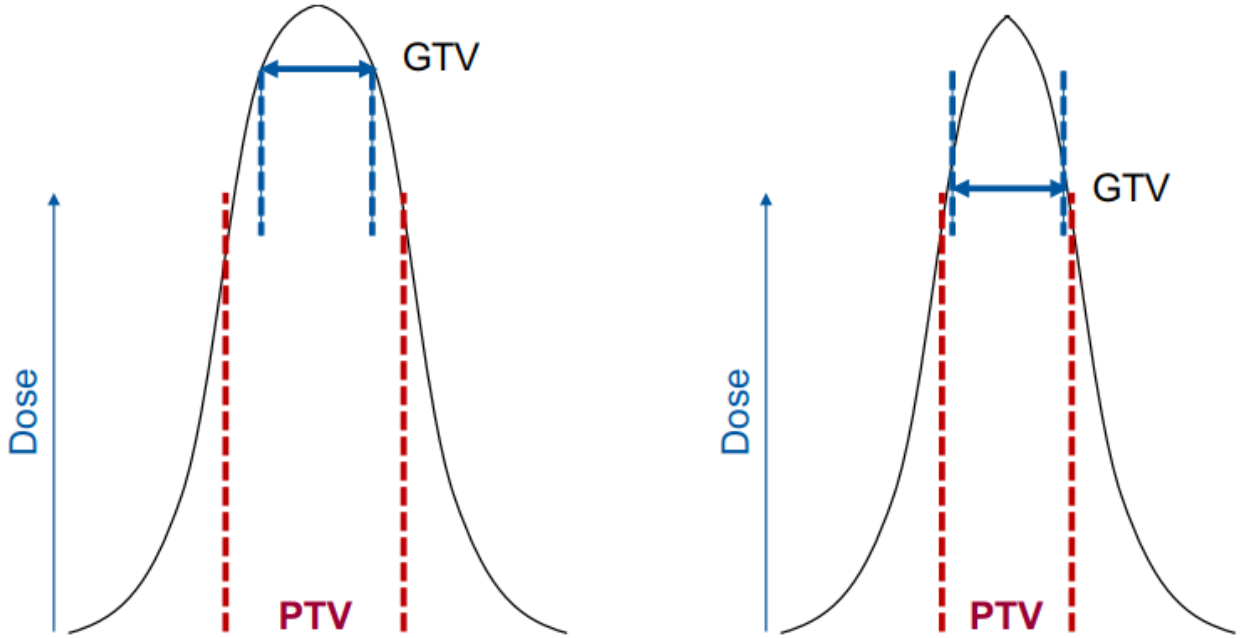



✓ Limited variation in **GTV-dose** between all breathing phases, even end-inhalation and end-exhalation
✓ Same for ITV (Guckenberger IJROBP 2007)

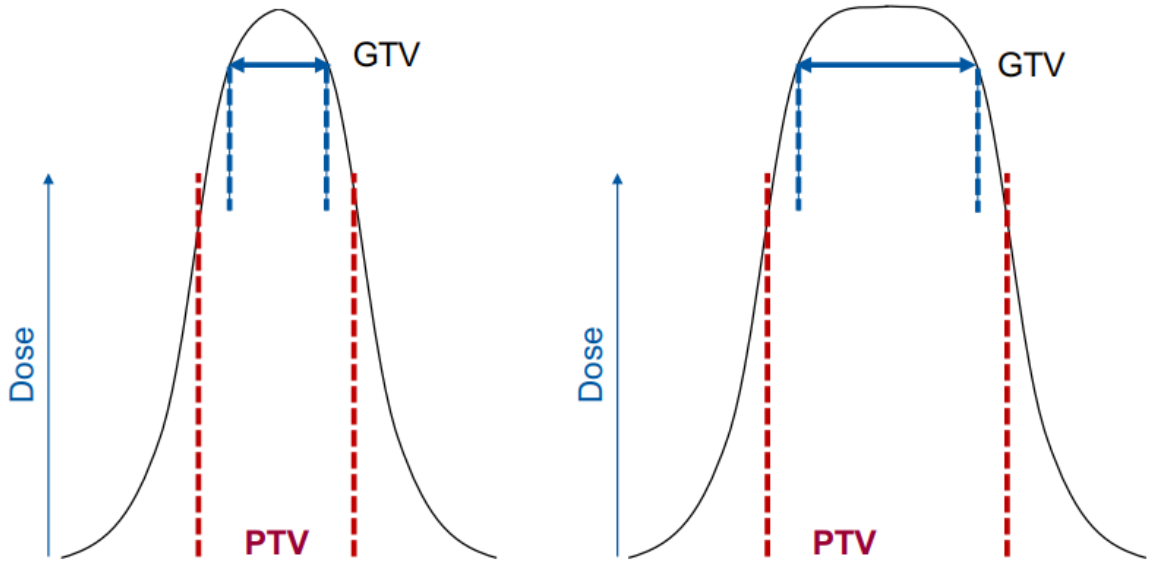
Mexner V et al, IJROBP 2009

# Influence of GTV-PTV margin



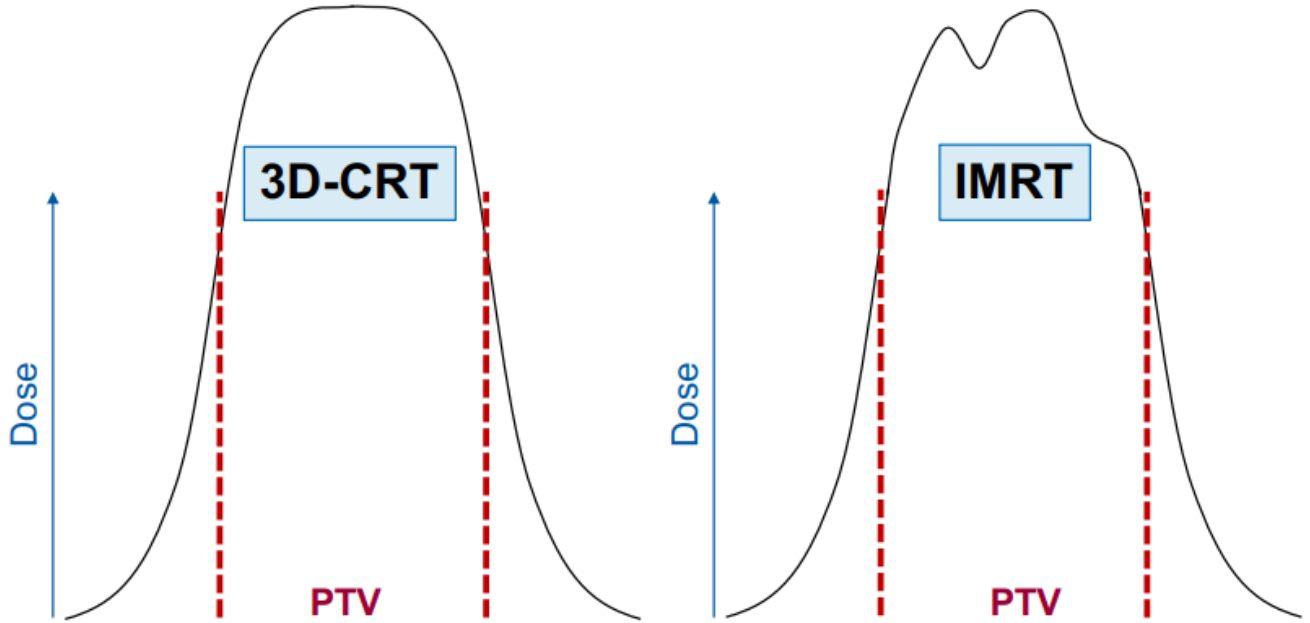

✓ Smaller GTV-to-PTV margins push the dose penumbra into the GTV

# Influence of GTV size




- ✓ Dose plateau in larger sized targets
- ✓ Sometimes, a constant dose prescription may result in inconsistent effective GTV doses

# Influence of treatment planning




✓ Dose plateau with 3DCRT vs possibility for sharp optimization with IMRT

# Plan quality in (SB)RT

'Simplicity is complexity resolved'

Constantin Brancusi