MEDICAL UNIVERSITY OF VIENNA

A Christian Doppler Laboratory

# Dosimetric considerations to determine the optimal technique for localized prostate cancer

## among external photon, proton, or carbon-ion therapy and HDR or LDR brachytherapy

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# Introduction

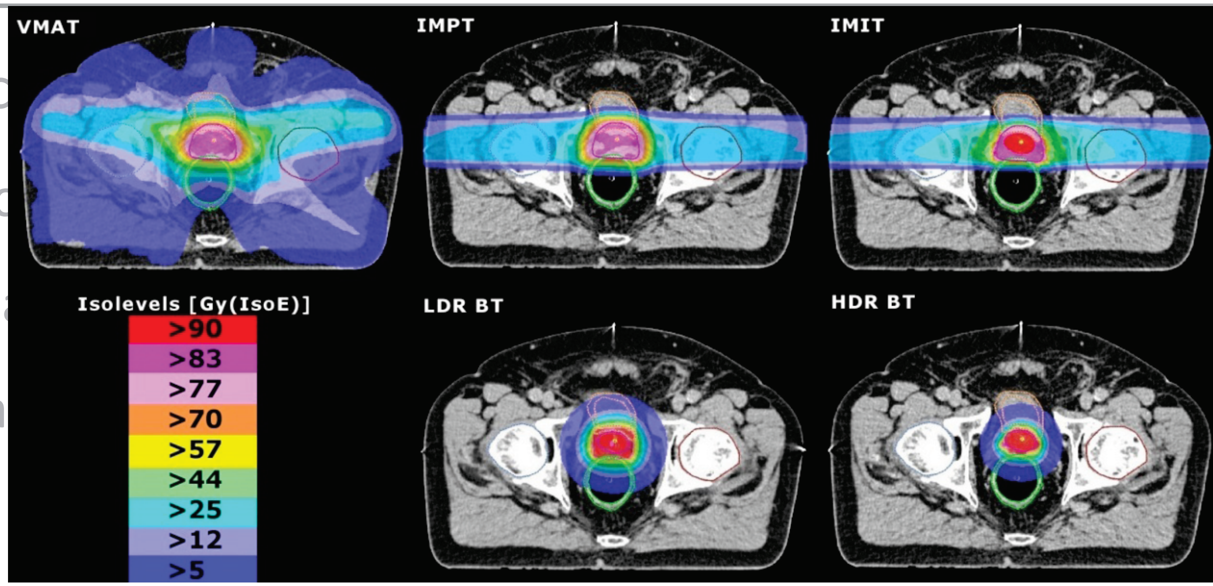
- Prostate cancer is No 1 form of cancer in men (382,000 cases in Europe)
- Increasing incidence (worldwide)
- Wide range of treatments can be offered vs. prostatectomy
  → external photon beam RT, ion RT, Brachytherapy (BT)
- *Purpose:*
  → *To compare five external beam and BT treatment modalities for localized PC with special focus on doses delivered to healthy tissues*

# Material and Methods (M&M)

- Patient characteristics and volume delineation
  - → 10 localized prostate cancer patients
    - CT (2 mm slice thickness)
    - endorectal ballon (40cc)
  - → Clinical Target Volume (CTV)
    - prostate gland
  - → Planning Target Volume (PTV)
    - Margin: 5 mm axial, 8 mm super-inferior
  - → Rectal wall, Bladder Wall, Urethra, Femoral Heads, 'Normal tissue' (Entire body structure minus respective target volumes)

# Material and Methods (M&M)

- Patient c
  - 10 loc
  - Clinic TV)
  - Recta nal tissue' (Entire body




- Treatment modalities, dose prescription and fractionation
  - VMAT: D/fx = 2 Gy; 39 fx; 1 arc, 10 MV (Monaco, Elekta)
  - IMPT: D/fx = 2 Gy(RBE); 39 fx; lateral opposed beams (XiO, Elekta)
  - IMIT: D/fx = 3.3 Gy(RBE); 20 fx; lateral opposed beams (TRiP98, GSI)
  - LDR-BT: 145 Gy; 171 d; I-125 seeds (VariSeed, Varian)
  - HDR-BT: 8.5 Gy; 4 fx; 192Ir afterloader; D = 34 Gy (Oncentra-Prostate, Elekta)

# Radiobiological conversion

- Dosimetric comparison

→ Voxelwise conversion of physical and RBE weighted dose distributions into iso-effective ones based on a 2 Gy(IsoE) fractionation scheme according to

$$D_{IsoE}[Gy(IsoE)] = \begin{cases} D \cdot \left( \dfrac{\frac{D}{n} + \frac{\alpha}{\beta}}{2 + \frac{\alpha}{\beta}} \right) & \text{LQ Model} \\ D \cdot \left(1 + \dfrac{2 \cdot D \cdot \beta}{\alpha \cdot \mu \cdot t}\right) \cdot \left(1 - \left(\dfrac{1 - e^{-\mu \cdot t}}{\mu \cdot t}\right)\right) \cdot \dfrac{1}{1 + \frac{2 \cdot \beta}{\alpha}} & \text{Dale et al (1985)} \end{cases}$$

$\alpha, \beta$...radiobiol. parameters

$\mu$...repair rate constant

$t$...virtual irradiation time ($^{125}$I)

LQ Model

Dale et al (1985)

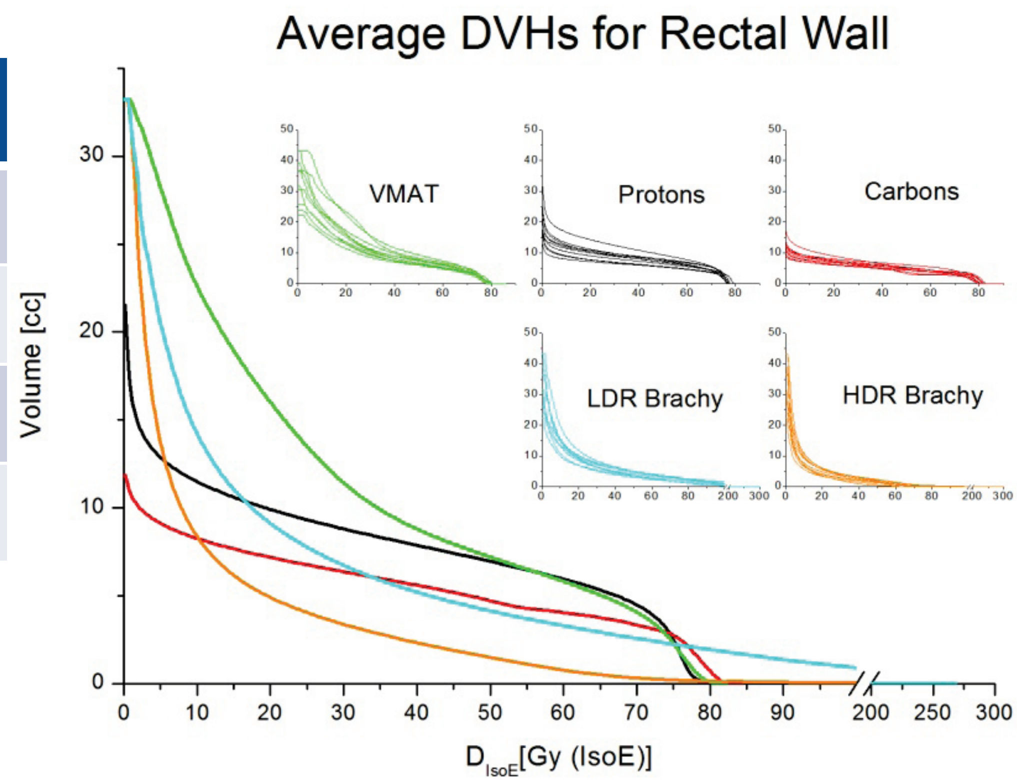
→ Population averaged DVH curves and dose indices

→ Dosimetric indices considered

- RW and BW: $D_{2cc}$, $D_{mean}$, $V_{30Gy(IsoE)}$, …
- Normal tissue: $V_{5Gy(IsoE)}$, $V_{10Gy(IsoE)}$, $V_{20Gy(IsoE)}$, $V_{30Gy(IsoE)}$ , $V_{40Gy(IsoE)}$

# Results: OAR exposure I

| Rectal Wall | | | | | |
|---|---|---|---|---|---|
| | *VMAT* | *IMPT* | *IMIT* | *HDR* | *LDR* |
| $D_{mean}$ | 28.2 | 19.5 | 14.2 | 10.5 | 20.2 |
| $D_{2cc}$ | 75.6 | 75.8 | 77.3 | 39.4 | 78.7 |
| $V_{30}$ | 11.4 | 8.8 | 6.4 | 3.4 | 6.7 |

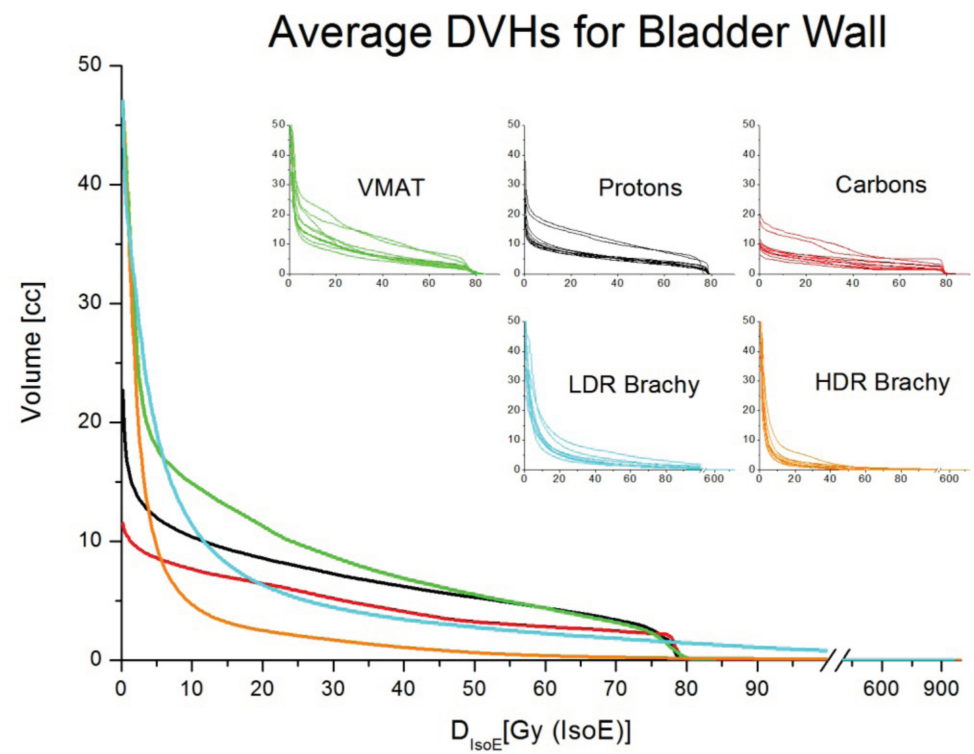



→ High dose region identical for VMAT and IMPT

→ IMIT and HDR BT good performance

# Results: OAR exposure II

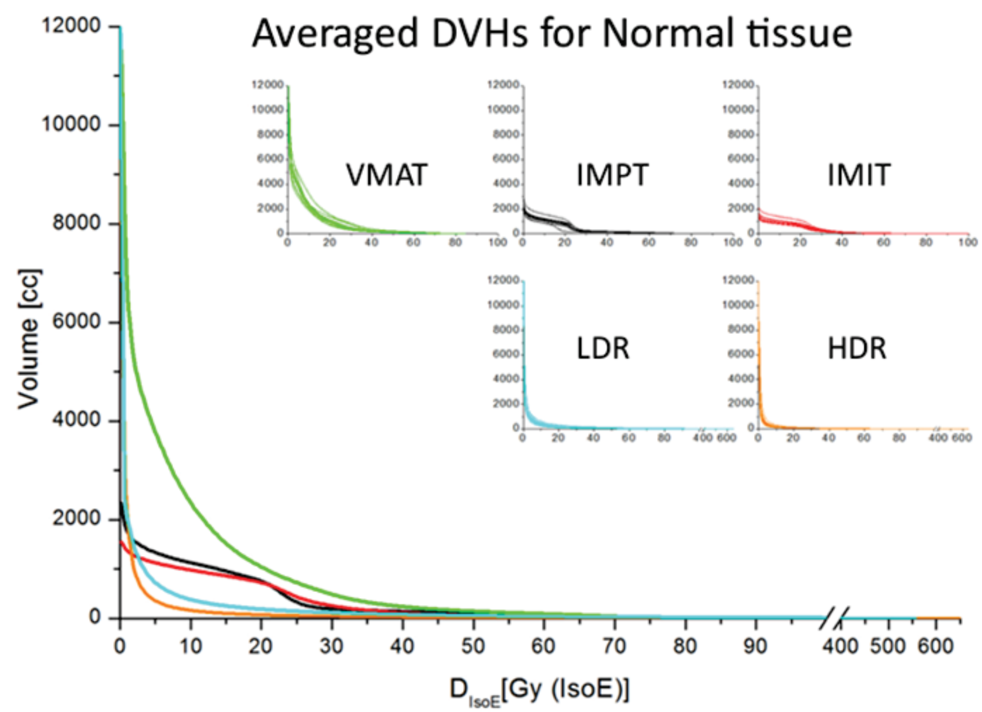
| Bladder Wall | | | | | |
|---|---|---|---|---|---|
| | ***VMAT*** | ***IMPT*** | ***IMIT*** | ***HDR*** | ***LDR*** |
| $D_{mean}$ | 16.0 | 12.4 | 8.5 | 6.4 | 12.0 |
| $D_{2cc}$ | 74.1 | 75.6 | 64.0 | 20.7 | 61.4 |
| $V_{30}$ | 8.7 | 7.3 | 5.2 | 1.7 | 4.4 |




- ➔ Similar trend as for rectal wall
  - high dose region for VMAT and IMPT
  - IMIT and HDR BT good performance
- ➔ $D_{0.1cc}$ for LDR 163 Gy(IsoE)

# OAR exposure III

- → Exposure of NT >50% lower for IMPT and IMIT wrt VMAT
- → BT techniques characterized by lowest exposure of NT (>75% and >90% dose reduction wrt VMAT)




| | VMAT | IMPT | IMIT | HDR | LDR |
|---|---|---|---|---|---|
| $V_{5Gy(IsoE)}$[cc] | 3775 | 1340 | 1127 | 254 | 747 |
| $V_{10Gy(IsoE)}$[cc] | 2342 | 1132 | 980 | 162 | 392 |
| $V_{20Gy(IsoE)}$[cc] | 1042 | 765 | 723 | 72 | 192 |
| $V_{30Gy(IsoE)}$[cc] | 487 | 198 | 253 | 42 | 120 |

# Limitations

- Radiobioligcal conversion is based on given α/β values

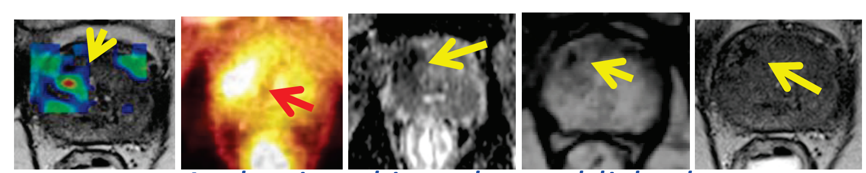
  *(Tumor: 1.93 Gy; RW, FH & Body: 3 Gy; BW & Urethra: 5 Gy)*

  → LDR: DVH parameters were changing using different α/β values

  → Other modalities were robust → overall results did not change (α/β-ratio variations of > 200%)

- Whole prostate was boosted

  → Boost to the intra-prostetic lesion



*Andrzejewski et al unpublished*

- CT information is only a snapshot

# Conclusion

- Exposure to OARs reduced for IMPT, IMIT, HDR and LDR BT
- Best dosimetric values for RW and BW were reached using BT
  - Urethra → hightest $D_{2\%}$ for LDR and HDR
- Best RT treatment technique?
  - Dosimetric considerations
  - BT not always possible (prostate volume, advanced stage, TURP,...)
  - Unavailability of particle therapy center
  - Costs

**Thanks for your attention!**