Alternative regimens for treating prostate cancer using equivalent uniform dose and Monte Carlo methods

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Motivation

Prostate cancer

- 2nd most diagnosed
- 2nd most diagnosed in males
- 1,100,000 new cases in 2012
- 300,000 deaths in 2012

IARC: GLOBOCAN 2012

globocan.iarc.fr/Pages/fact_sheets_cancer.aspx
Motivation

Radiotherapy for prostate cancer

**EBRT**

Conventional fractionation:
- 1.8 – 2 Gy/fraction
- 45 – 50 Gy (+ 110 Gy (125I))

(NCCN: Guidelines Version 2.2014 Prostate Cancer)

**Interstitial BT**

- LDR BT: 125I, 103Pd
- HDR BT: 192Ir

45 – 50 Gy + 1.8 - 2 Gy/fraction

110 Gy (125I)
Evidences of the prostate cancer

Slow cell replication rates

Response to radiation as a late-responding normal tissue

Low $\alpha/\beta$ ratio

$\sim 2.7$ Gy
(Oliveira et al. 2012)

Benefits from hypofractionated regimens
Evidences of the prostate cancer

Year:
- 2000: 1
- 2002: 3
- 2004: 7
- 2006: 9
- 2008: 10
- 2010: 16
- 2012: 16
- 2014: 33
- 2016: 45

Results:
- 2000: 1
- 2002: 3
- 2004: 7
- 2006: 9
- 2008: 10
- 2010: 25
- 2012: 16
- 2014: 39
- 2016: 41

PubMed search: (prostate cancer) AND hypofractionation

NCBI Resources How To
To indentify alternative regimens for treating prostate cancer using:

- EBRT
- LDR BT with $^{125}\text{I}$

biologically equivalent to conventional treatments in terms of:

- EUD
  - 72 Gy
  - 80 Gy
  - 90 Gy
  - 110 Gy
Effective radiobiological dose that, if distributed uniformly, would lead to the same cell killing in the target volume as the actual nonuniform dose distribution

(Nimierko, 1997)

EUD that will result in the survival fraction $S$:

$$EUD = -\frac{\ln(S)}{\alpha + \beta \cdot d - 1,4 \frac{k}{d}}$$

(Wang & Li, 2003)

EUD is generalized from the $dDVH$ of a given distribution:

$$gEUD = \left( \sum_{i=1}^{N} v_i D_i^a \right)^{1/a}$$

(Nimierko, 1999; Wu et al. 2002)
Methods and Materials

Segmentation of 2 voxel phantoms
Methods and Materials

Segmentation of 2 voxel phantoms

EBRT
- Implementation of the LA

LDR BT
- Implementation of the $^{125}\text{I}$ source

Monte Carlo
- Treatment simulation

Energy deposition/voxel

Conversion to absorbed dose/voxel

Determination of the $S_{\text{EBRT}}$

Determination of the $S_{\text{LDR BT}}$
## Results

**EUD = 80 Gy**

<table>
<thead>
<tr>
<th>$d_{\text{EBRT}}$ (Gy)</th>
<th>$n_{\text{EBRT}}$</th>
<th>EUD$_{\text{Rectum}}$</th>
<th>$n_{\text{EBRT}}$</th>
<th>EUD$_{\text{Rectum}}$</th>
<th>$n_{\text{EBRT}}$</th>
<th>EUD$_{\text{Rectum}}$</th>
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<td>41</td>
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</tbody>
</table>
Prostate

Results

EUD = 72 Gy

EUD = 80 Gy

EUD = 90 Gy

EUD = 110 Gy
Results

- LDR - BT
  - EUD = 72 Gy
  - EUD = 80 Gy
  - EUD = 90 Gy
  - EUD = 110 Gy
Conclusion

• It is possible to design new alternative schemes for the treatment of prostate cancer with EBRT and LDR BT based on EUD concept and Monte Carlo methods

• The results of these schemes may be useful for the design of new clinical trials with alternative fractionations for the treatment of prostate cancer

• The rational for the use of brachytherapy becomes less relevant with the increasing therapeutic ratio achieved with hypofractionated EBRT
Thank you!