Individualized assessment of the probability for developing in-field solid tumors from radiation therapy for testicular cancer

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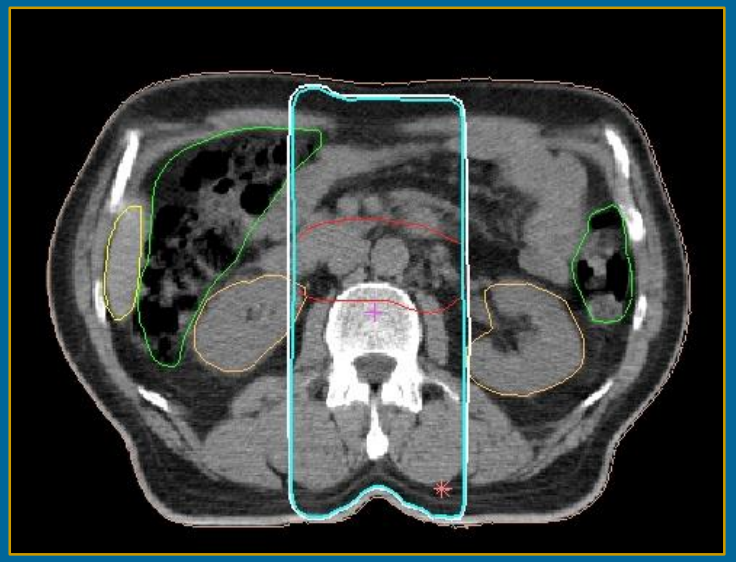
Introduction - Purpose

- Testicular cancer is a highly treatable malignant disease with a 10-year survival rate of more than 95 %.
  (L. B. Travis, et al. J Natl Cancer Inst 2010;102:1114-30)
- Testicular cancer mostly affects young adults aged 15-44 years.
  (R.H.A. Verhoeven, et al. Ann Oncol 2013;24:508-13)
- The objective of this study was to combine individualized dosimetric data with a non-linear risk model for the patient-specific estimation of the probability for solid cancer development after radiotherapy for testicular cancer.

Methods

3-d conformal radiotherapy

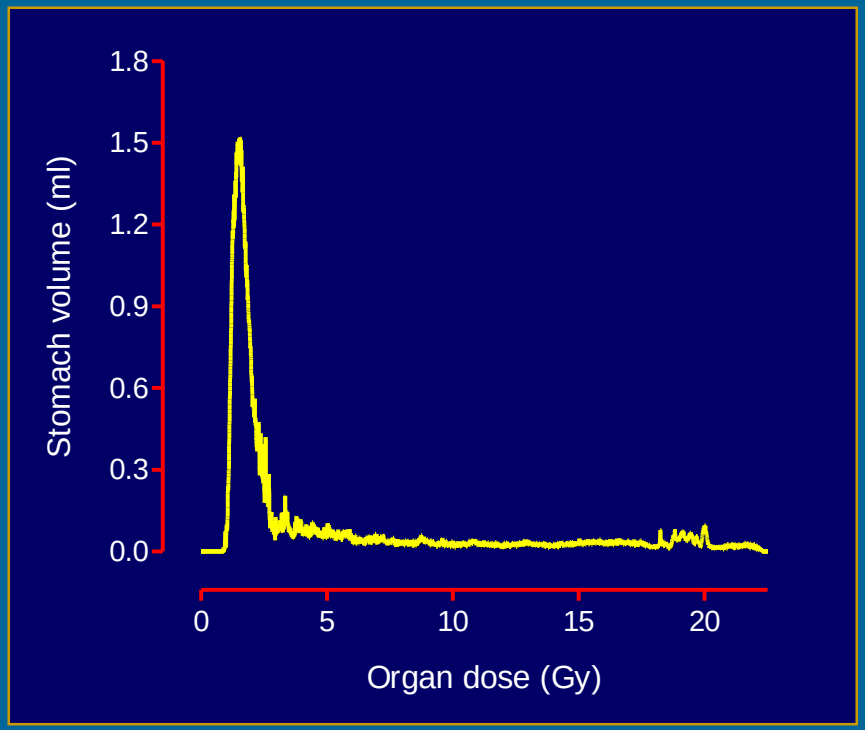
- Ten patients with early stage testicular cancer underwent a treatment planning CT scan.
- Treatment plans consisting of AP and PA fields delivering 20 Gy in 10 fractions to the para-aortic lymph node region were generated.
- The 3-d plans were calculated for use on a linac producing 6 and 18 MV X-rays (Primus, Siemens, Germany).



Methods

Differential dose-volume histograms (DVHs)

- Differential DVHs were computed for the liver, stomach and colon which were partly exposed to primary radiation.
- The histograms were analyzed by using a bin width of 1 cGy for all organs of interest.



Methods

Organ equivalent dose (OED) calculation with a mechanistic model

$$OED = \frac{1}{V_t} \sum_i V_{D_i} \frac{exp(-a_i' D_i)}{a_i' R} \left[1 - 2R + R^2 \, exp(a_i' D_i) - (1-R)^2 \exp\left(\frac{a_i' R}{1-R} D_i \right) \right]$$

- V_t: total volume of the organ of interest,
- V_{Di}: organ volume receiving a radiation dose of D_i,
- a_i' : organ-specific cell-kill parameter,
- R: organ-specific repopulation parameter.

U. Schneider, et al. Theor. Biol. Med. Modell. 2011;8:27

Methods

Lifetime attributable risk (LAR) of cancer development

$$LAR = \sum_{age_e+L}^{age_{a,max}} \beta' OED \exp\left[\gamma_e(age_e - 30) + \gamma_a \ln\left(\frac{age_a}{75}\right)\right] \frac{S(age_a)}{S(age_e)}$$

- β':initial slope of radiation-induced cancer at the low-dose region,
- L: free latent period of 5 years,
- age_e: patient's age during radiotherapy,
- age_a: attained patient's age ($age_{a,max}$ = 75 years),
- γ_e ,γ_a: organ-specific age parameters,
- $S(age_a)/S(age_e)$: probability of a healthy male to survive from age_e to age_a .

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Results

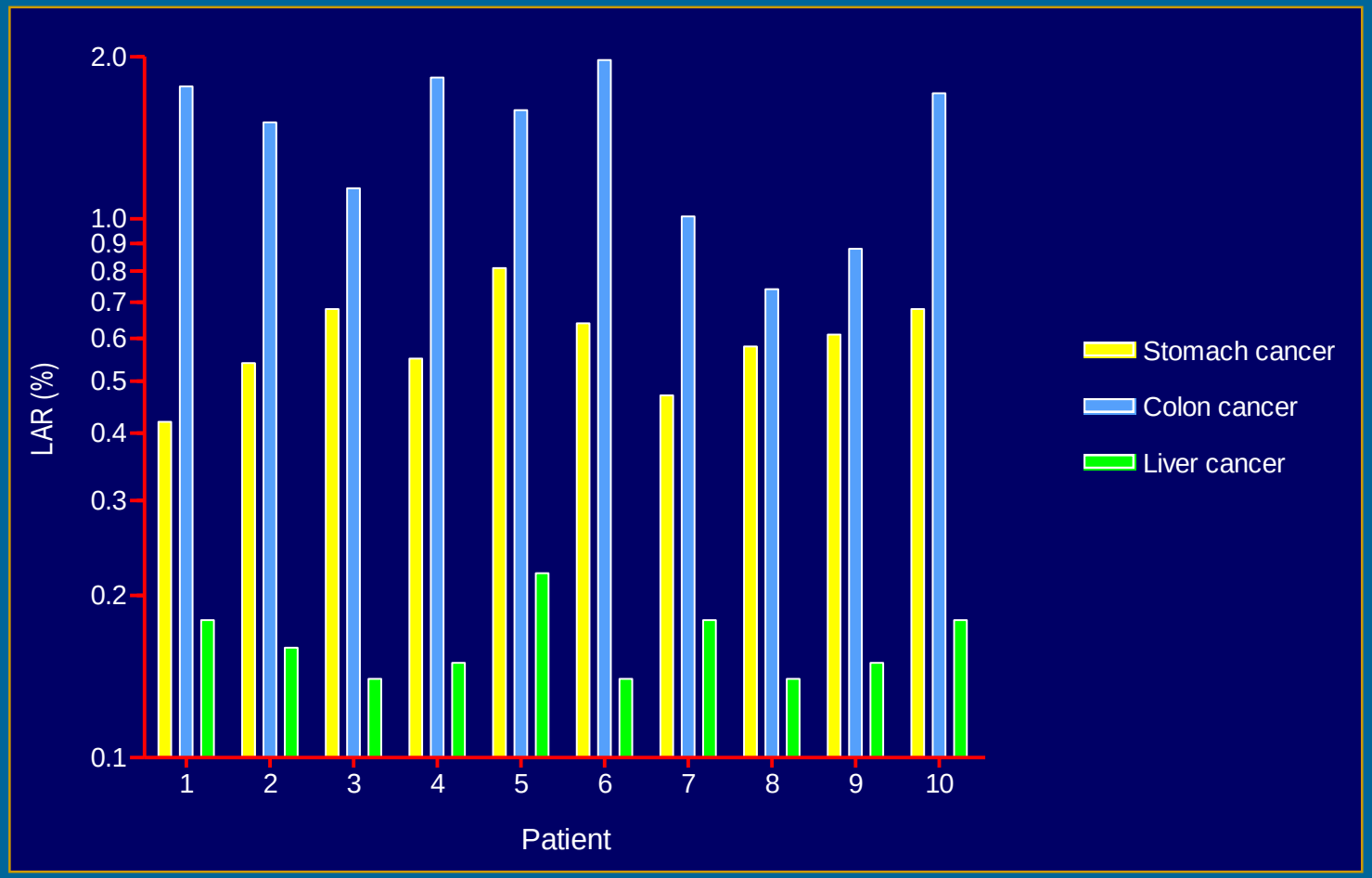
OED calculations

Organ of interest	OED range (cGy)
Stomach	37.3 – 79.8
Colon	251.3 – 500.4
Liver	43.0 – 70.3

Dose values correspond to a target dose of 20 Gy.

Results

LAR estimation



Conclusions

- The organ-dependent lifetime cancer risk associated with radiotherapy for testicular cancer varies widely by the organ dose magnitude and the age of the irradiated patient.

- The accurate knowledge of the patient-specific probability for developing solid tumors may facilitate treatment decisions and improve the risk management.