Peripheral Doses in Children Undergoing Gamma Knife Radiosurgery

Saveta Miljanić[1], Hrvoje Hršak[2], Željka Knežević[1], Zdravko Heinrich[3] and Branko Vekić[1]

[1]Ruđer Bošković Institute, Bijenička c. 54, 10000 Zagreb, Croatia

[2]Radiophysics Unit, Clinic of Oncology, Clinical Hospital Centre Zagreb, Kišpatićeva 12, 10000 Zagreb, Croatia

[3]Department of Neurosurgery, Clinical Hospital Centre Zagreb, Kišpatićeva 12,

10000 Zagreb, Croatia

Motivation

- Radiotherapy and radiosurgery treatments: typically doses of tens of gray to the target volume, lower doses to all other parts of the body
- The carcinogenic properties of ionising radiation thus lead to a probability of inducing a second cancer in the irradiated patient
- The children population has higher susceptibility to radiation and longer life expectancy

The Aim of the Study

- To measure the out-of-field doses during the Leksell Gamma Knife Model C radiosurgery for children
- To give dosimetry basis for second cancer risk estimation:

  - by determination of the relation of surface doses to doses in some radiation sensitive organs

Leksell Gamma Knife (LGK)

Method

1. Dose measurements on patients

   - TLD (TLD-100, GR 200 A) and RPL (GD 352 M)

2. Dose measurements <u>on</u> and <u>in</u> child phantom

   - In the phantom: a) RPL

     b) TLD-700

   - On the phantom: the same as on patients

Dosimetry Methods

Some characteristics of RPL and TLD dosimeters

	GD-352M[1]	TLD-100[2]	TLD-700 [2]	GR 200 A[2]
Uniformity, ν(%)	1.0-1.7	4% (1 SD)	4% (1 SD)	2% (1 SD)
Reproducibility, ν(%)	0.4	4% (1 SD)	3% (1 SD)	5% (1 SD)
Detection threshold, H=10 µGy	5.89≤ H	5 µGy	9 µGy	0.2 µGy
		D_{LDL}: 3 x SD of zero reading		
Linearity, ν(%) =±10 (0.1-500 mGy)	0.6 -4.8	Up to 3 Gy		

[1]Knežević *et al.,* Radiat. Meas. (2011) – according to IEC 2007

[2]Miljanić *et al.,* Radiat. Prot. Dosim. (2002)

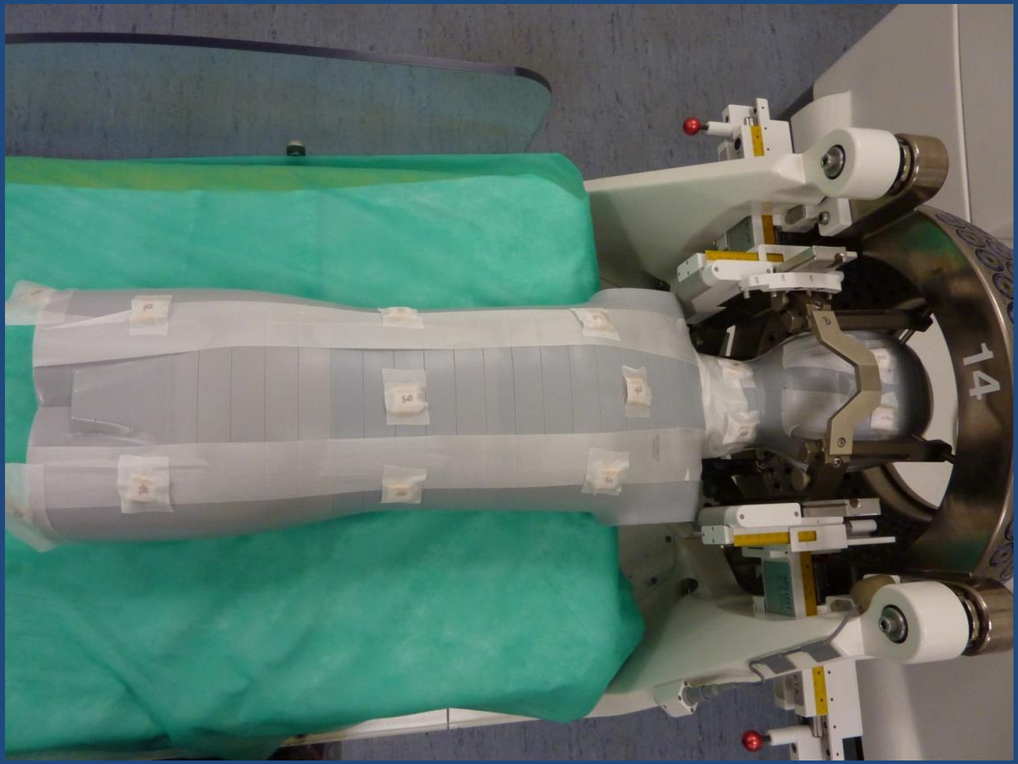
Calibration of TLD and RPL dosimeters at Ruđer Bošković Institute:

D_w (according to TRS No. 398, IAEA, Vienna, 2000)

Dose Measurements on Patients

Position of dosimetry sets contaning 2TLDs +2RPLs:

1. Eyes (L+R)
2. Thyroid (L+R)
3. Breasts (L+R)
4. Sternum
5. Upper abdomen (L+M+R)
6. Gonads (L+R)

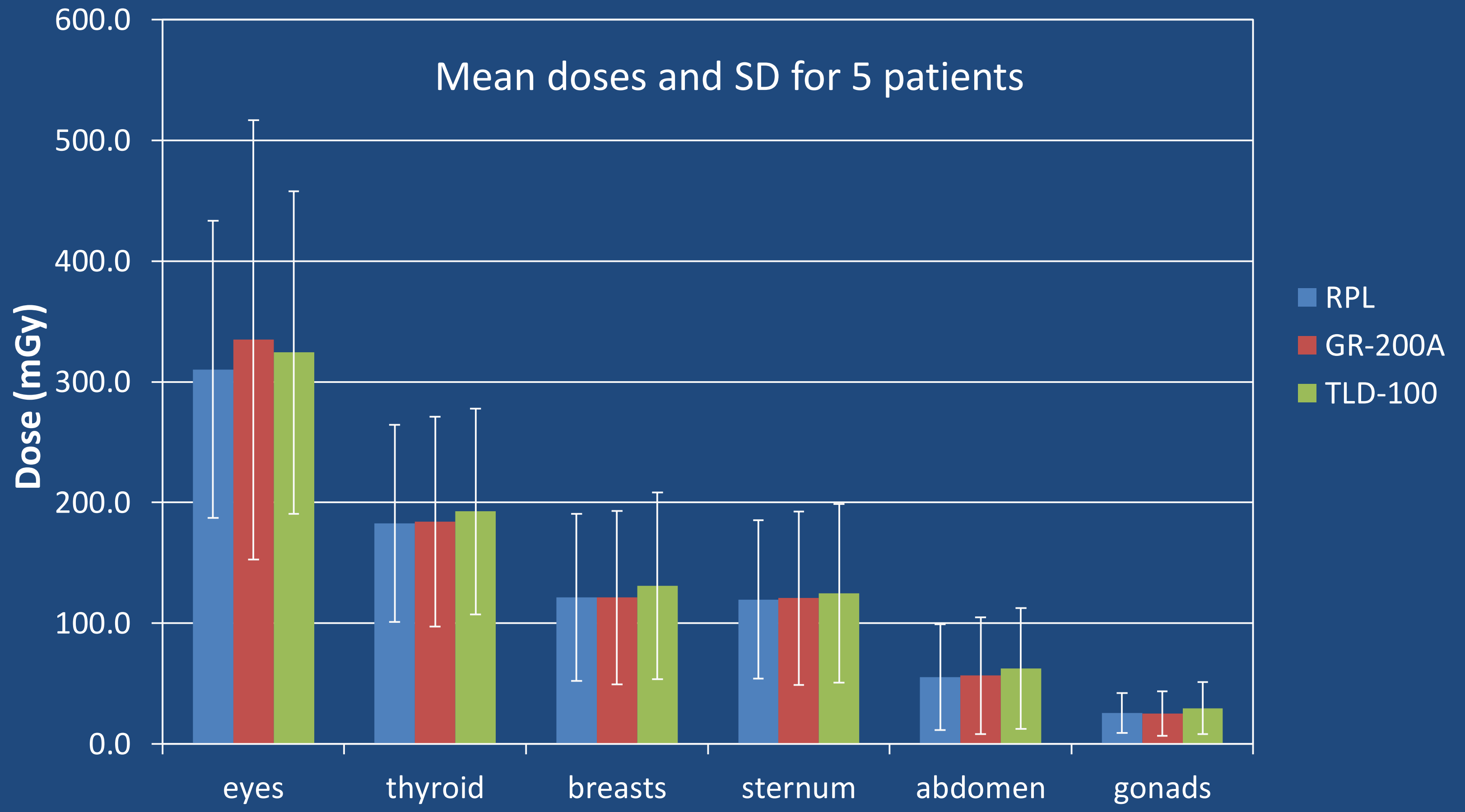


Data about Patients

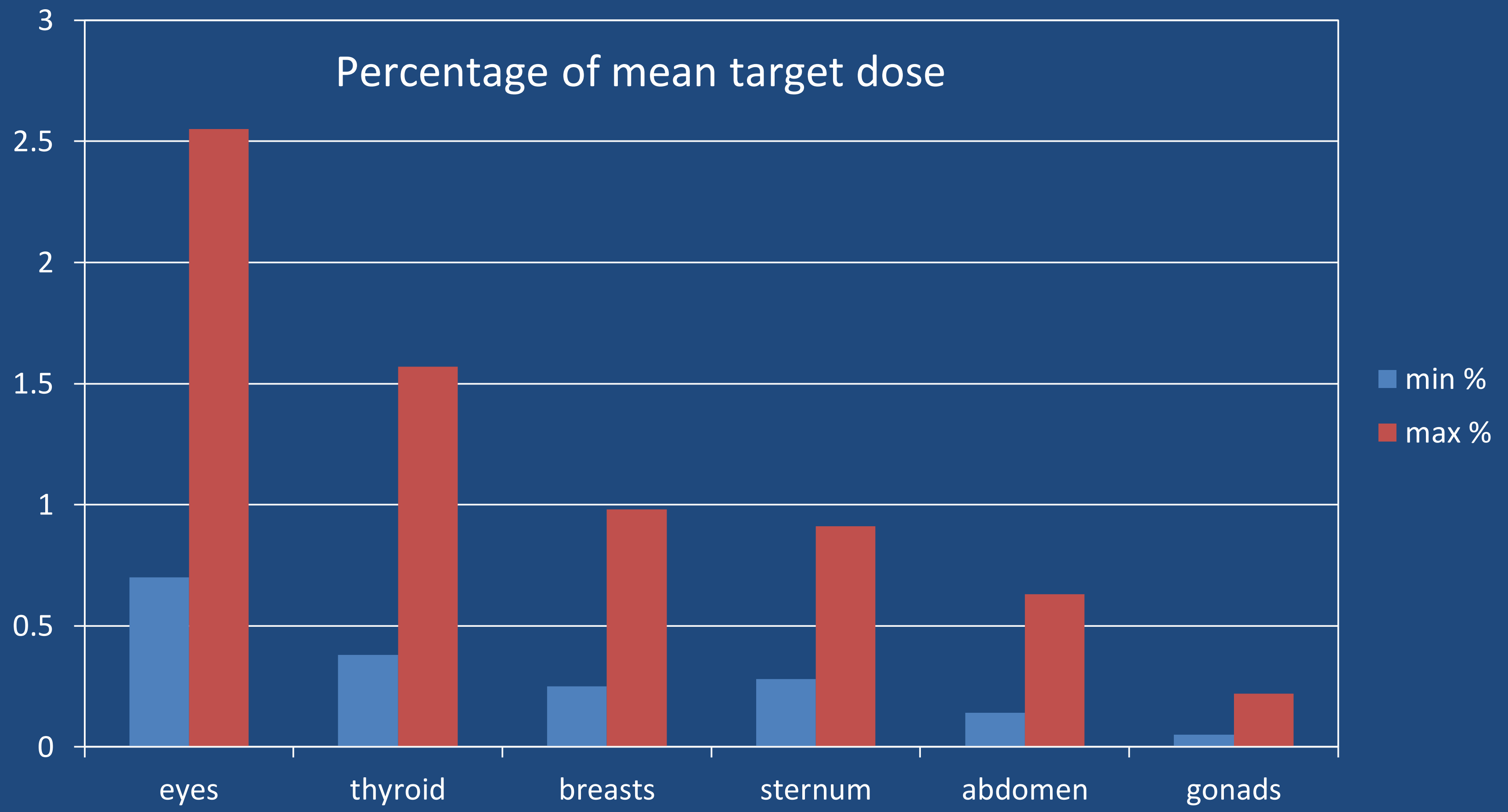
Patient	1 (KK)	2 (ZK)	3 (GK1)	4 (GK2)	5 (GK3)
Gender/age	F/14 y	M/7 y	M/8 y	F/11 y	M/4
Height/weight	150 cm /50 kg	120 cm	130 cm	140 cm /40 kg	Aver. for 4 y 102 cm/16 kg
Diagnosis	Astrocitoma pilocisticum	Astrocitoma pilocisticum	Astrocitoma grad I	Craniofa-ringeoma	Ependymoma anaplasticum
Position and target size	Left cavernous sinus 5.2 cm^3	Right temporal lobe 6.5 cm^3	Right posteroinferior cerebellar lobe 0.5 cm^3	Suprasellar region 3.1 cm^3	Left posteroinferior cerebellar lobe 0.82 cm^3
Mean target dose	19 ± 2.9 Gy	22.5 ± 3.6 Gy	16.9 ± 2.7 Gy	15.4 ± 2.2 Gy	24.8 ± 4.2 Gy
Number of isocenters/ collimator	10/8 mm + 12/4 mm	3/14 mm + 12/8 mm	10/4 mm	24/4 mm + 2/8 mm	17/4 mm

Ranges: 4-14 years, 102-150 cm, 16-50 kg, 0.5 cm^3- 6.5 cm^3, 15.4-24.8 Gy, 10-24 isocenters, 4, 8 and 14 mm collimators

Results on Patients

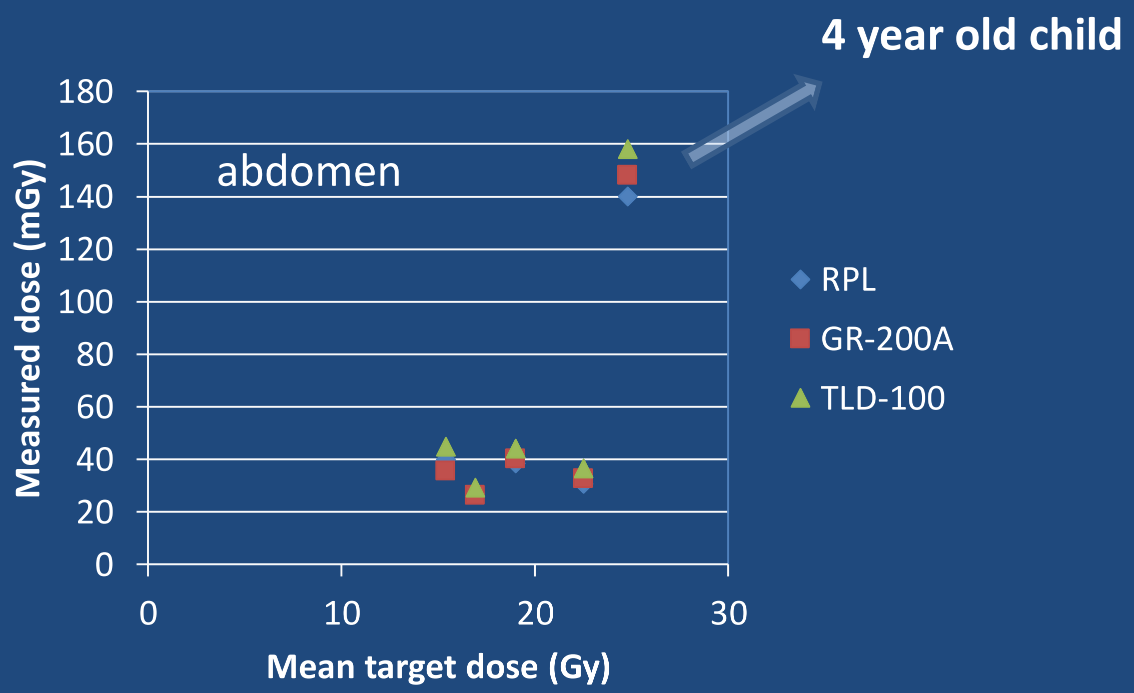


Results on Patients



Results on Patients

- Large dissipation of the mean doses is expected and depends on many influencing factors.
- It is not possible for so small sample (5 patients) to find any reliable correlation between out-of-field doses and irradiation conditions
- Exception that shows the importance of peripheral dose measurement on children:



Phantom

CIRS phantom characteristics type 706 D:

- pediatric 10 years
- height: 140 cm, weight: 32 kg
- tissue equivalent (different tissue simulations)
- hole locations specific to 21 radiosensitive internal organs
- 32 sections, 196 holes

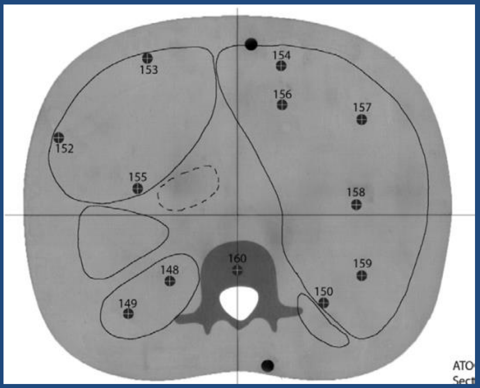
Calculation of organ dose (D):

$$D_i = 1/n \sum_{j} D_{ij}$$

D_i – dose in I-organ

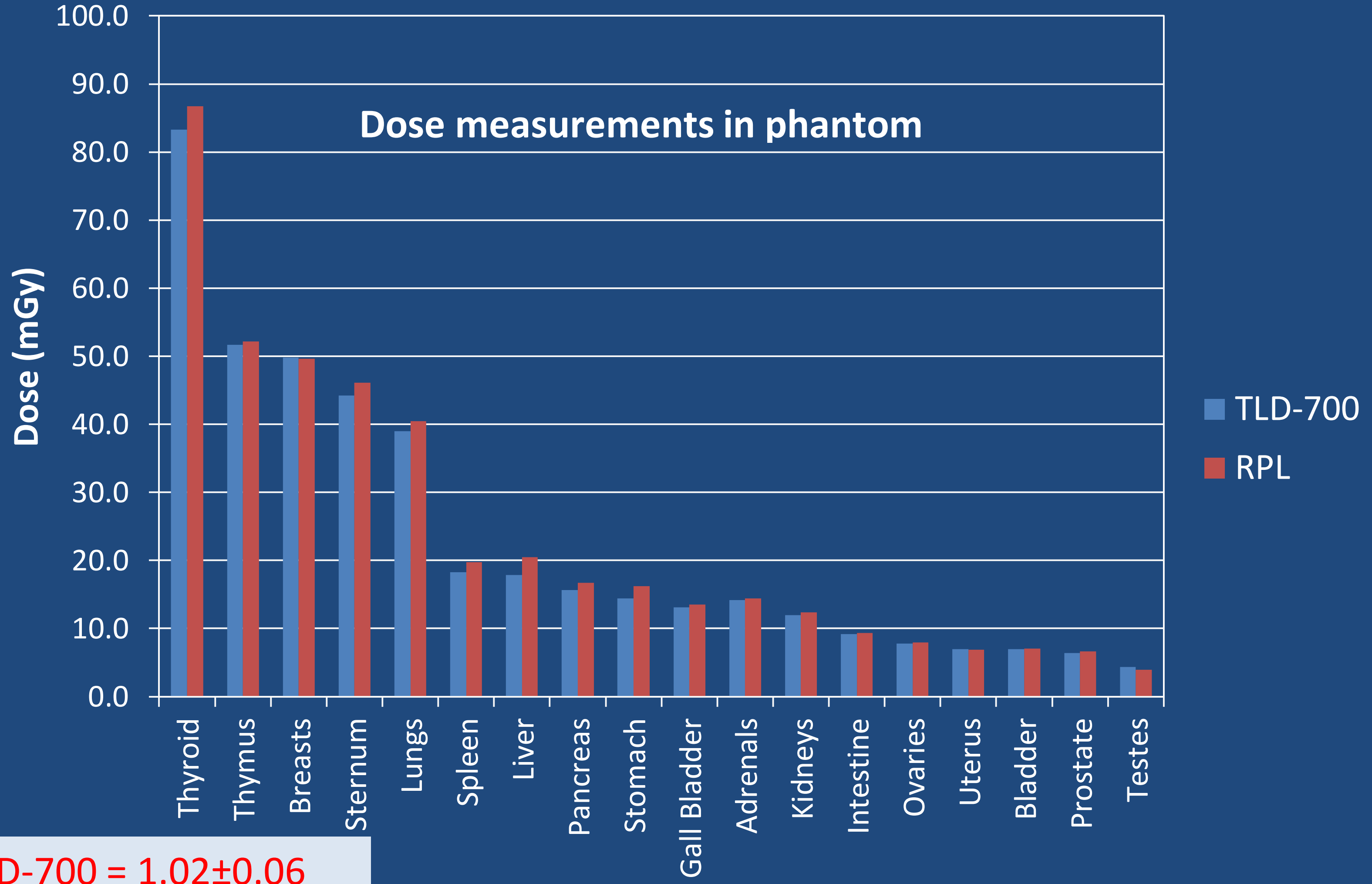
j = 1, ...n – number of detectors in I-organ

“Patient”	Vernon Marijan
Age	10 y
Height/weight	140 cm/32 kg
Diagnosis	Benign brain tumor
Position and target size	Midbrain, 9.2 cm^3
Mean target dose	22.8 ± 4.2 Gy
Number of isocenters/ collimator	11/4 mm



Model 702-D Section 23 Organ Map

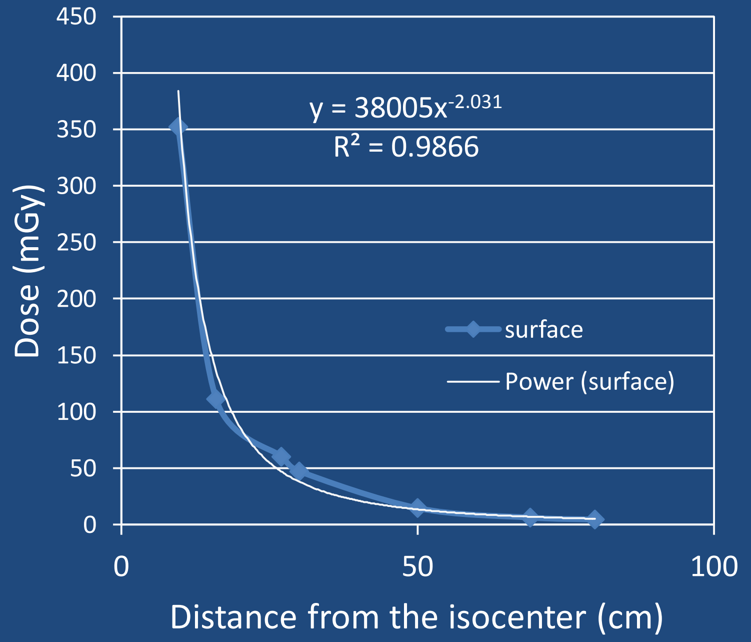
Phantom Irradiations

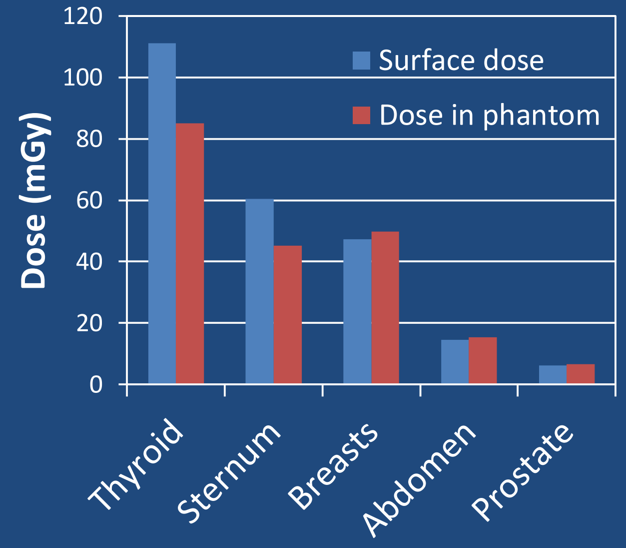


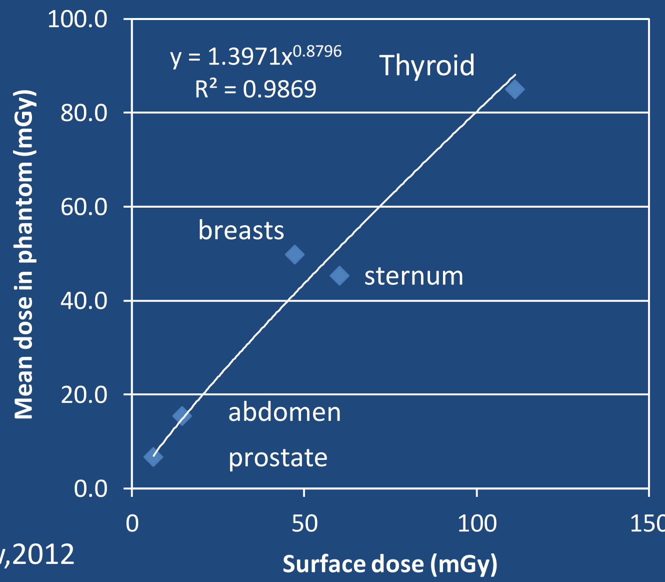
RPL/TLD-700 = 1.02±0.06

Phantom Irradiation

Mean doses measured at phantom surface as a fuction of distance from the isocenter







Conclusions and future work

- **Both type of dosimeters are suitable for out-of-field dose measurements:**
  - **RPL dosimeters** show **very good uniformity** and there is no need for individual sensitivity determination
  - **Background reading of RPL dosimeters is negligible** down to very low doses
  - **Both types of dosimeters** show similar and **very good reproducibility**, about 1.4% on average
  - **RPL automatic reader is very suitable** for dose determination of large number of dosimeters enabling the same reading conditions for the badge containing 20 samples

- It is possible to estimate dose in **some organs** from the dose measurements **on the surface**
  - Construction of the “belt” for dosimeters
- There is a need for further sistematically investigations of the **peripheral doses in children**
- The importance of **second cancer risk modelling for children**