DOSIMETRY AUDIT AND COMPARISON OF TWO CALCULATION ALGORITHMS FOR LEKSELL GAMMA KNIFE

Josef Novotný Jr., Irena Koniarová, Ivana Horáková

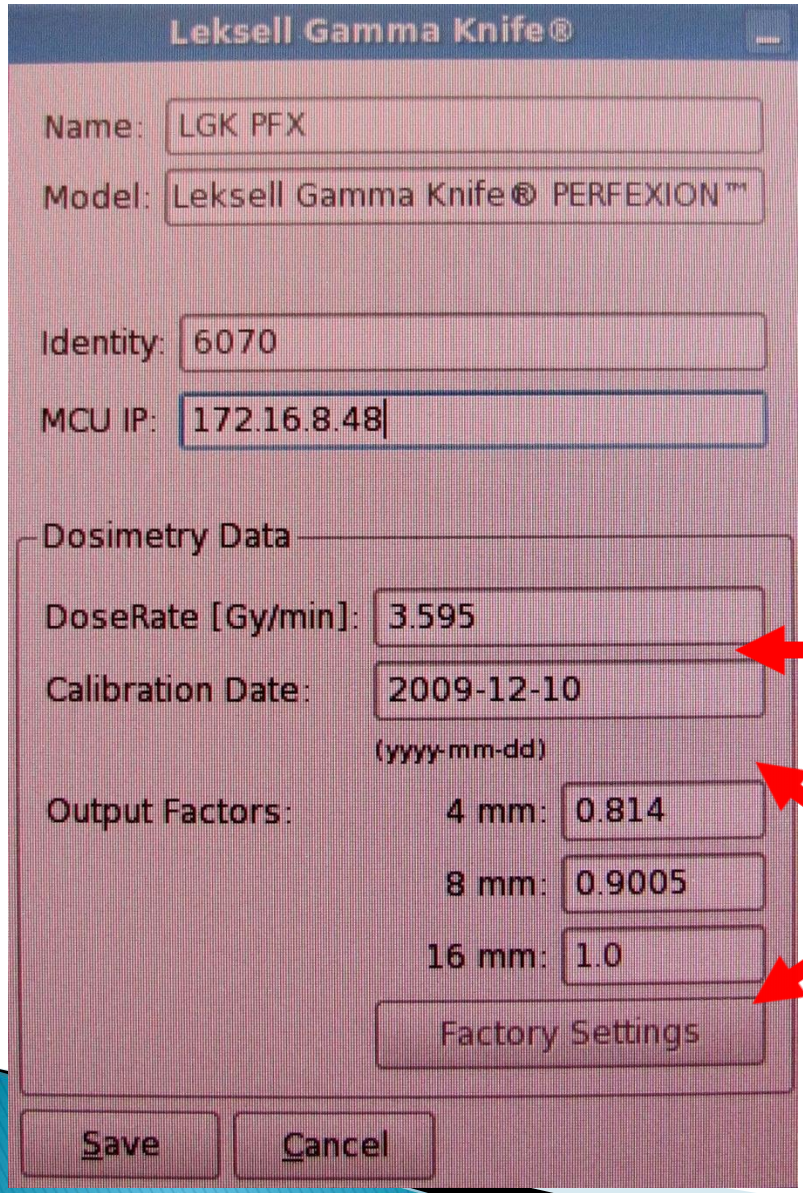
Department of Medical Physics, Na Homolce Hospital, Prague, Czech Republic

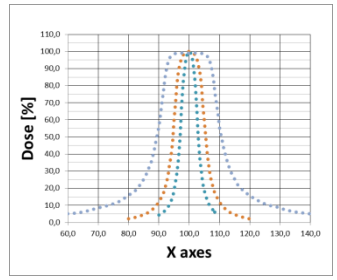
Department of Medical Exposures, National Radiation Protection Institute, Prague, Czech Republic

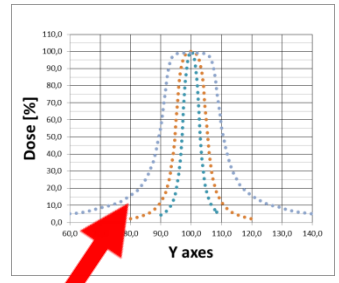
Leksell Gamma Knife Co-60 reloading

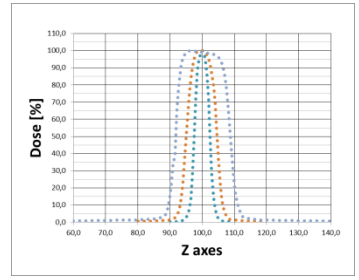
August 30 – September 8, 2016

Leksell GammaPlan dosimetry data configuration







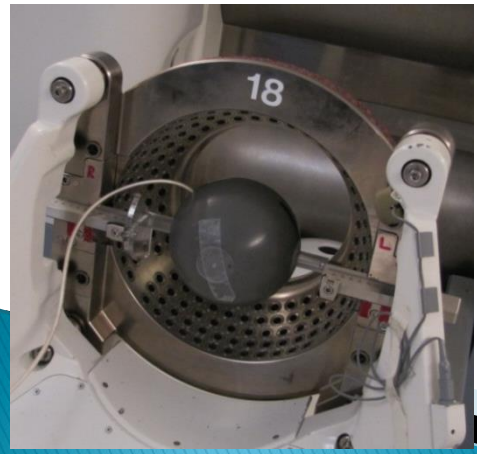


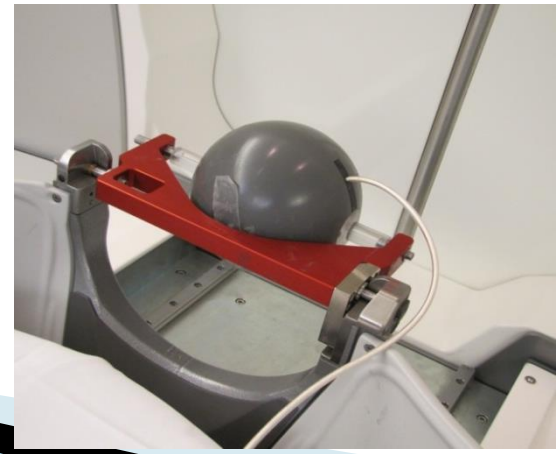
- Dose profiles
- Measured dose rate
- Output factors

Calibration of the Leksell Gamma Knife

- No specific international or national calibration protocols
- Existing calibration protocols IAEA TRS 277, AAPM TG21 and/or IAEA TRS 398, AAPM TG51 are used with smaller or larger approximations
- Small volume (typically less than 0.15 cm^3) ion chambers used
- Typically ELEKTA ABS plastic spherical phantom used
- Electrometer timer used

ELEKTA ABS plastic spherical phantom





ELEKTA solid water spherical phantom

Ion chambers used for calibration worldwide

Ion chamber manufacturer and type	Ion chamber volume [cm^3]	Frequency in International survey	
PTW 31010	0.125	32	41 %
Exradin A16	0.007	12	15 %
Capintec PR-05P	0.070	12	15 %
PTW 31002	0.125	8	10 %
PTW 31006	0.015	4	5 %
Exradin A1SL	0.057	4	5 %
Exradin A14SL	0.016	2	3 %
Wellhoffer IC-10	0.125	1	1 %
PTW 31016	0.016	1	1 %
Scanditronix RK-8305	0.120	1	1 %

Dosimetry verifications and audits performed in our center

- Independent measurement by Elekta Instrument AB, Stockholm, Sweden

- Alanine postal audit by the National Institute of Standards and Technology (NIST), Gaithersburg, Maryland, USA

Physics Laboratory
Ionizing Radiation Division
NIST National Institute of Standards and Technology

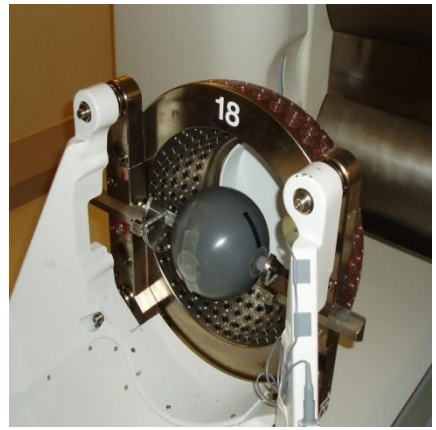
No official dosimetry audit!!!!

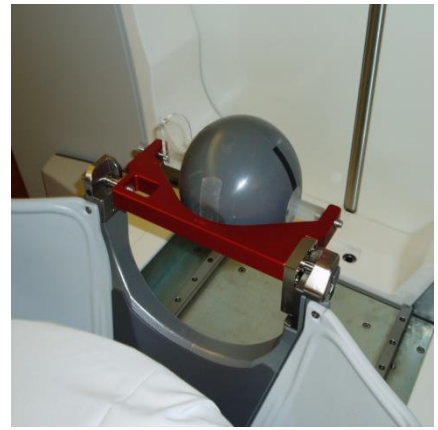
Alanine dosimetry audit

Gamma Knife Data

Calibration dose	3.633 Gy/min at 2007-09-20
Days since calibration at treatment date	623
Treatment dose rate (2009–06–04)	2.902 Gy/min
Effective output factors (4, 8, 16)	0.805 0.924 1
Ring 1 output factors (4, 8, 16)	0.799, 0.957, 0.961
Ring 2 output factors (4, 8, 16)	0.815, 0.946, 1.000
Ring 3 output factors (4, 8, 16)	0.792, 0.901, 0.986
Ring 4 output factors (4, 8, 16)	0.725, 0.808, 0.920
Ring 5 output factors (4, 8, 16)	0.663, 0.730, 0.851

Deliver 50.0 Gy





NIST evaluation of alanine dosimeters

- Five alanine pellets (4.8 mm in diameter and 3.0 mm in height)
- Alanine dosimeters measured with a Bruker ECS106 EPR spectrometer using the protocol described in the NIST Ionizing Radiation Division Quality System Manual

  http://www.physics.nist.gov/Divisions/Div846/QualMan/procedures.html

Physics Laboratory
Ionizing Radiation Division

NIST National Institute of Standards and Technology

ird QUALITY SYSTEM

IRD Quality Manual - Procedures

Select a Quality Manual by Service Code

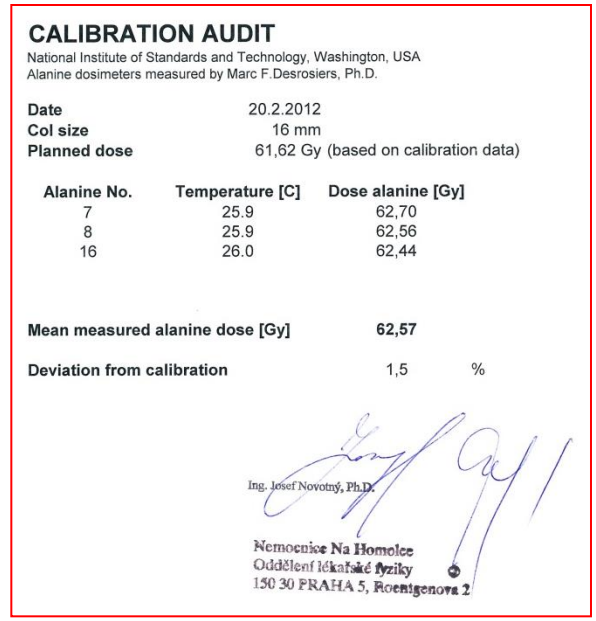
Procedure Number	Service Code	PDF Size	Procedure Description
12	49020C	233 kB	Dose Interpretation of Customer-Irradiated NIST Transfer Dosimeters

Results of dosimetry verifications and audits performed in our center in the past

- Independent measurements by Elekta Instrument AB, Stockholm, Sweden during installation and PM services

Typical results within 1.0 %

- Alanine postal audit by the National Institute of Standards and Technology (NIST), Gaithersburg, Maryland, USA in 2012



CALIBRATION AUDIT

National Institute of Standards and Technology, Washington, USA
Alanine dosimeters measured by Marc F.Desrosiers, Ph.D.

Date	20.2.2012
Col size	16 mm
Planned dose	61,62 Gy (based on calibration data)

Alanine No.	Temperature [C]	Dose alanine [Gy]
7	25.9	62,70
8	25.9	62,56
16	26.0	62,44

Mean measured alanine dose [Gy]	**62,57**	
Deviation from calibration	1,5	%

Ing. Josef Novotný, Ph.D.

Nemocnice Na Homolce
Oddělení lékařské fyziky
150 30 PRAHA 5, Roentgenova 2

Objectives of this study

- To perform dosimetry audit after Leksell Gamma Knife Co-60 sources reload.
- To perform TMR10 and Convolution calculation algorithms comparison.

Dosimetry audits after Co-60 reloading

- On-site audit: performed by National Radiation Protection Institute, Prague, Czech Republic

SÚRO Státní ústav radiační ochrany, v. v. i. National Radiation Protection Institute

- Postal audit: MD Anderson Cancer Center, The MD Anderson Dosimetry Laboratory, Houston, TX, USA

THE UNIVERSITY OF TEXAS MD Anderson Cancer Center Making Cancer History® The MD Anderson Dosimetry Laboratory

Dosimetry audit performed by National Radiation Protection Institute, Prague, Czech Republic

Státní ústav radiační ochrany, v. v. i.
National Radiation Protection Institute

- Dose rate measured in Elekta spherical ABS plastic phantom by PTW 31010 ion chamber and PTW Unidos electrometer.

- Mean doses measured in anthropomorphic head phantom (adapted Alderson Radiation therapy phantom, RSD, CA, USA) for a clinical test plan calculated by both Leksell GammaPlan algorithms TMR10 and Convolution. Two PTW 31010 ion chambers and PTW Unidos electrometers were used for a measurement.

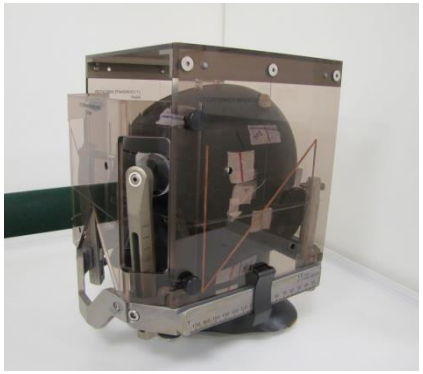
- Gafchromic EBT3 film measurement for TMR10 algorithm was done. Epson V750 film scanner used. Software OmniPro I’mRT was used for gamma analysis.

Phantoms setup and treatment planning

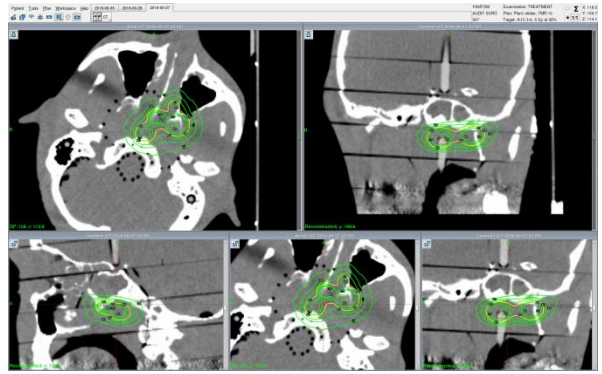
Státní ústav radiační ochrany, v. v. i.
National Radiation Protection Institute

- ABS plastic Elekta spherical phantom (six measurements in two different ion chamber setups)

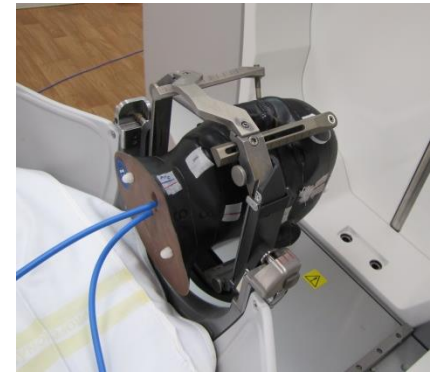
- Anthropomorphic head phantom with dosimetry film and two ion chambers



Stereotactic CT imaging



Treatment planning

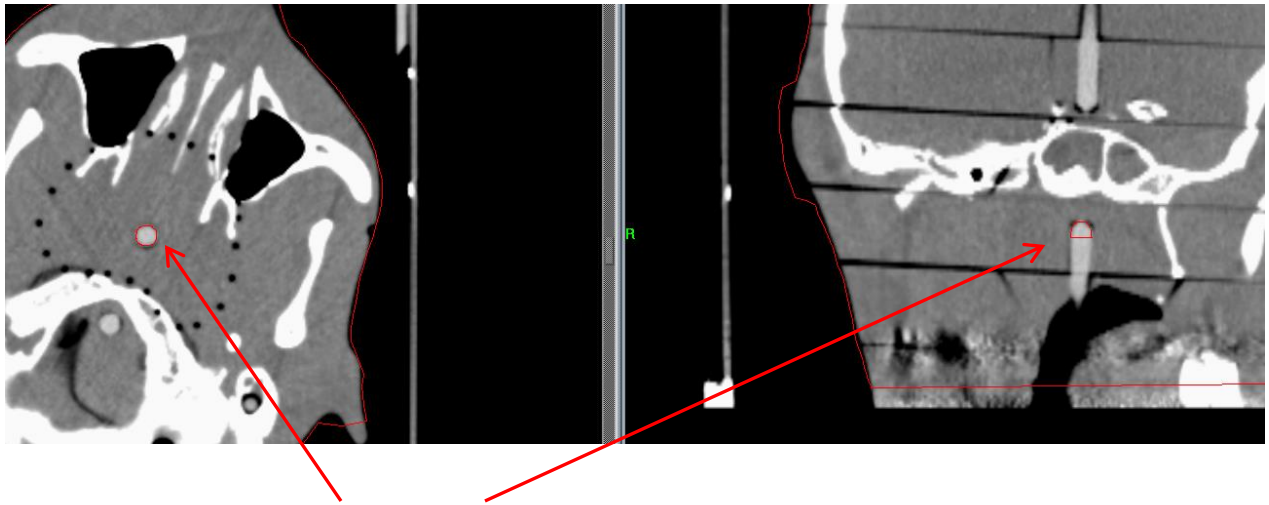


Dose delivery

Treatment planning

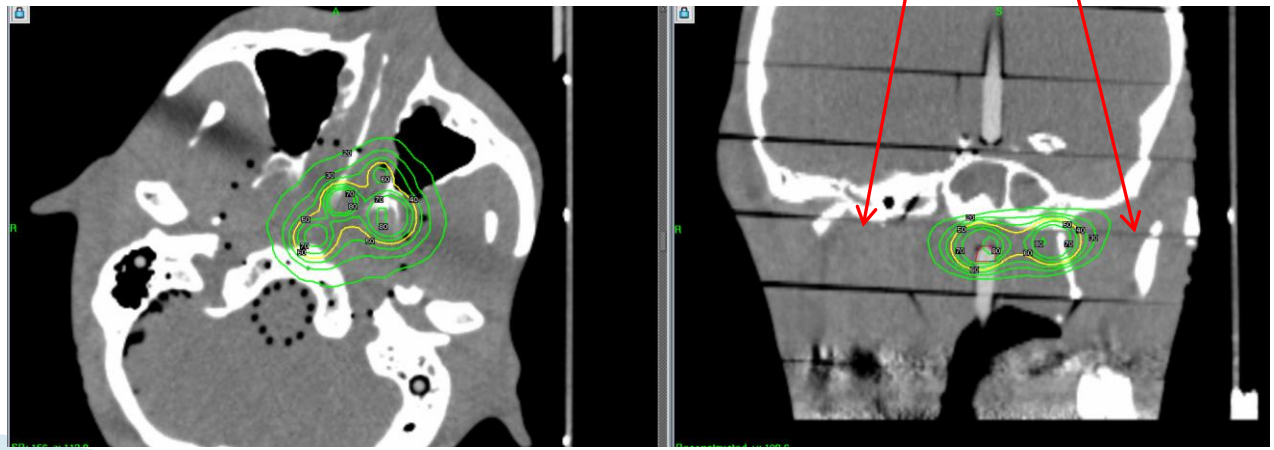
Státní ústav radiační ochrany, v. v. i.
National Radiation Protection Institute

- Anthropomorphic head phantom with dosimetry film and two ion chambers



Ion chamber sensitive volume countered within the accuracy better than 2 %.

EBT3 Gafchromic film position

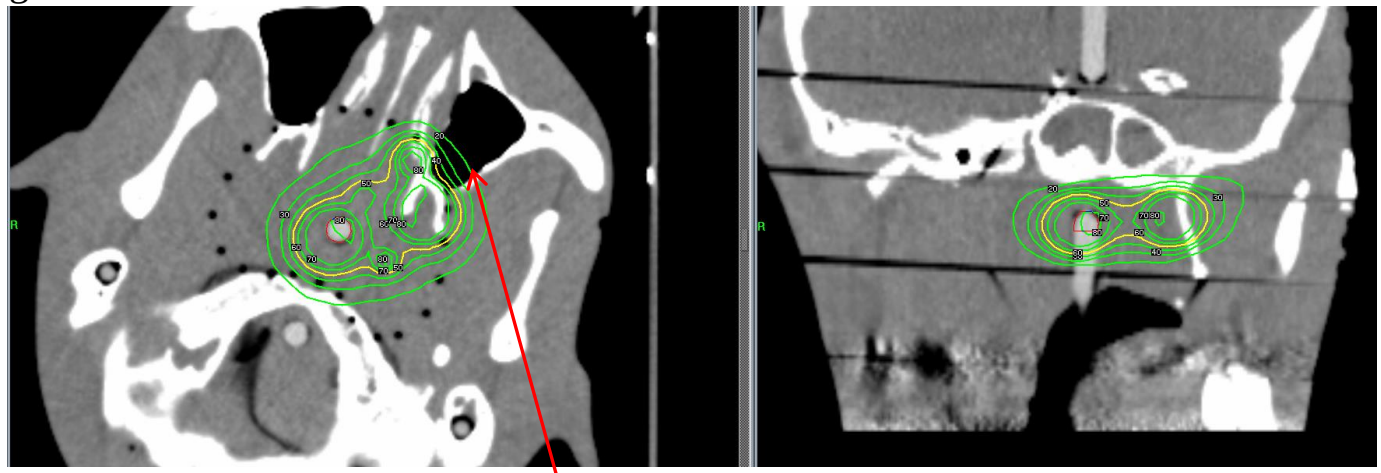


Treatment planning

Státní ústav radiační ochrany, v. v. i.
National Radiation Protection Institute

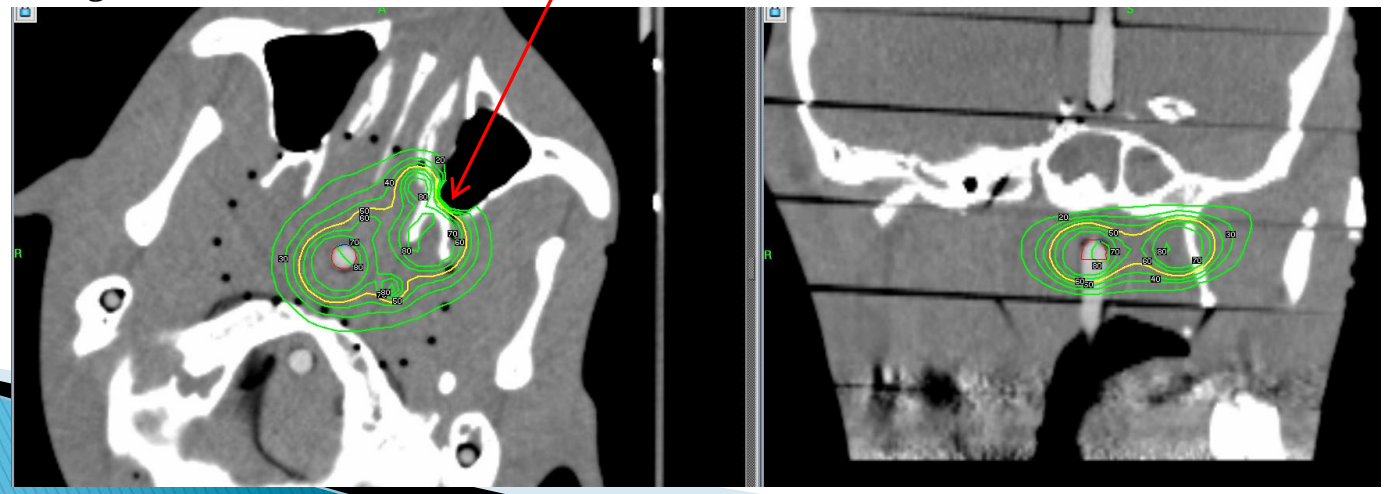
- Anthropomorphic head phantom with dosimetry film and two ion chambers

TMR10 calculation algorithm



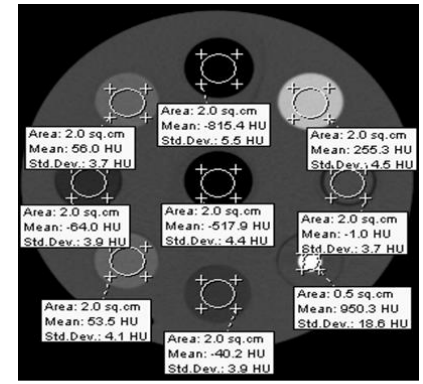
Difference between TMR10 an Convolution algorithms

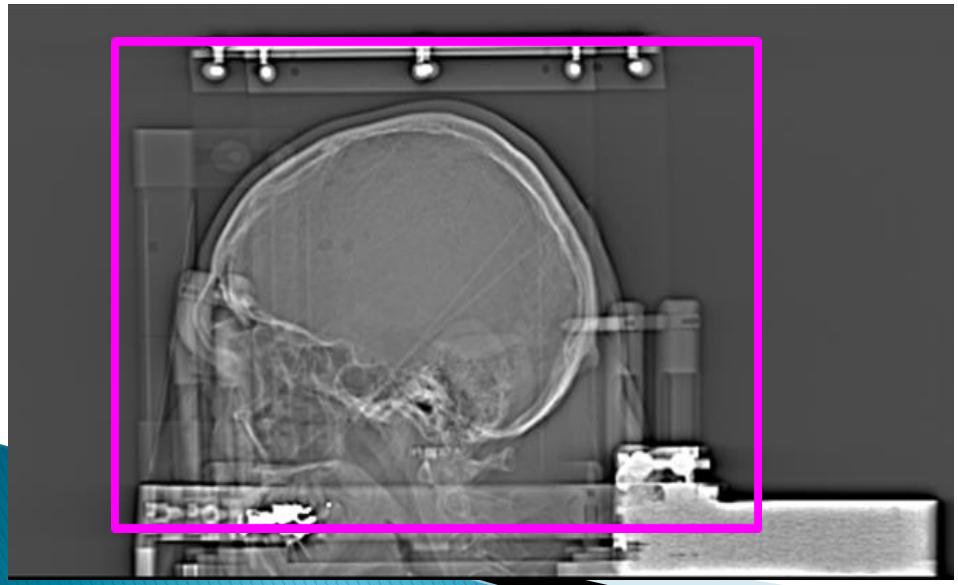
Convolution calculation algorithm

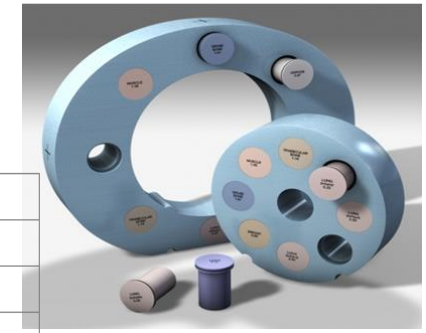


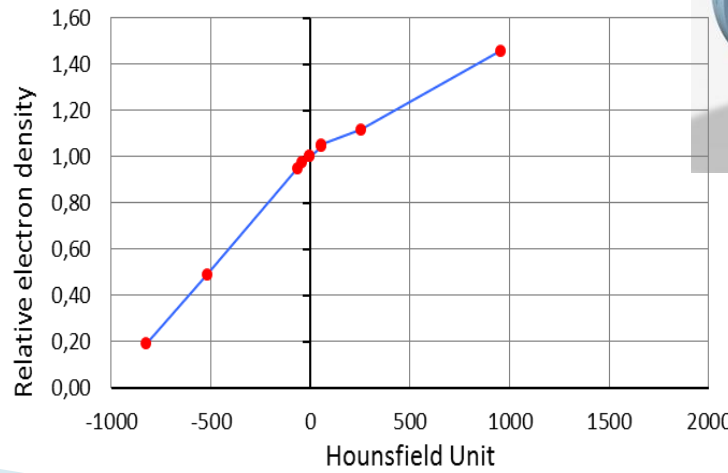
Convolution

- Models build-up effects as well as heterogeneity effects
- CT calibration curve is required in LGP
- Requires a full-head CT scan

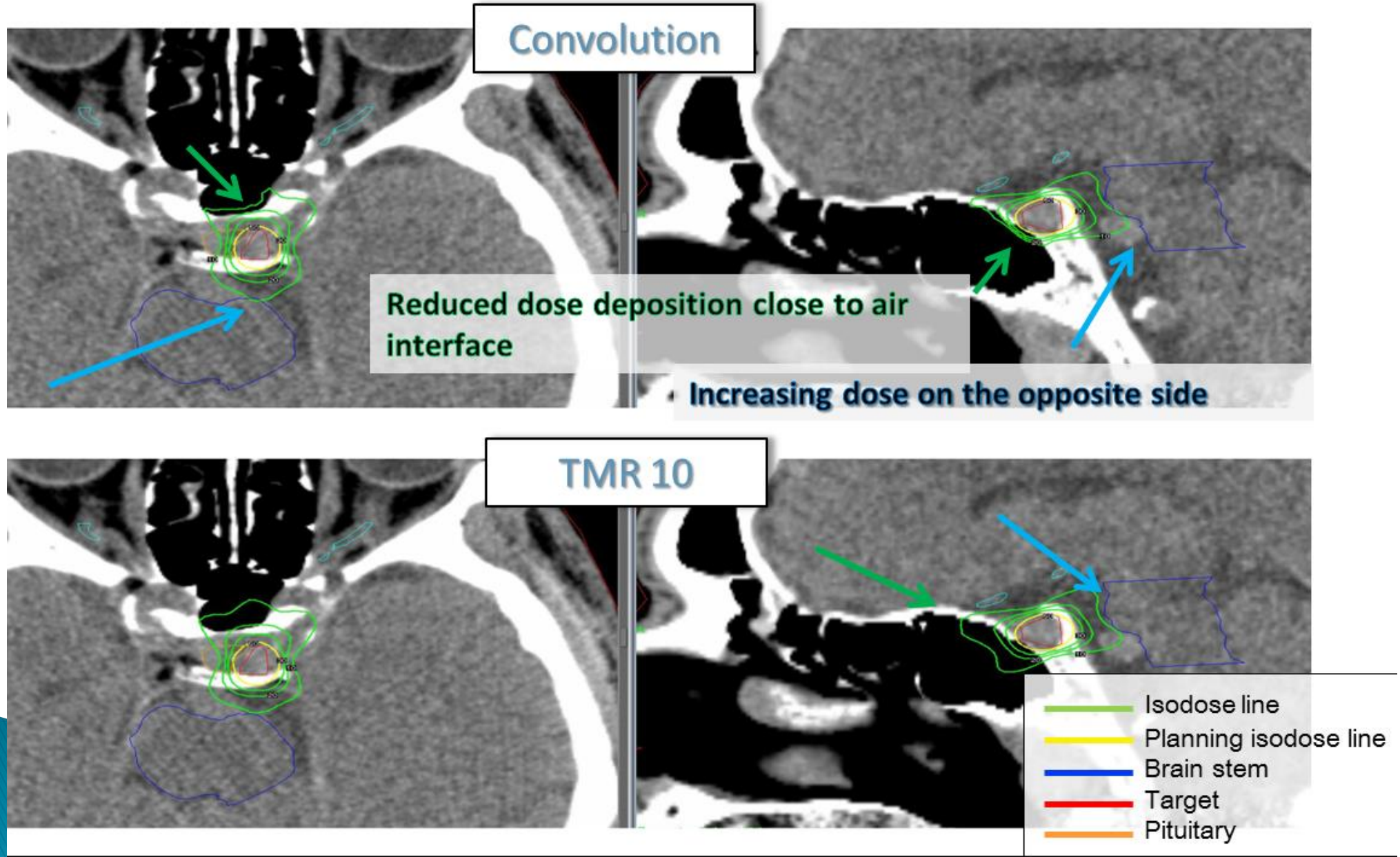








Convolution versus TMR 10 comparison example



Convolution algorithm

- For patients with targets located in homogeneous areas - minimal differences in dose distributions were observed
- For patients with target located close to heterogeneities (e.g. Pituitary adenomas, vestibular schwannomas) - clinically relevant differences in dose distributions were observed
- Differences mostly visible are for lower isodose lines e.g. 20 % isodose volume change 5.5 %
- Difference in max. dose in critical structures up to 15 %
- Treatment time increased typically in about 3 %

Dosimetry audit results

Státní ústav radiační ochrany, v. v. i.
National Radiation Protection Institute

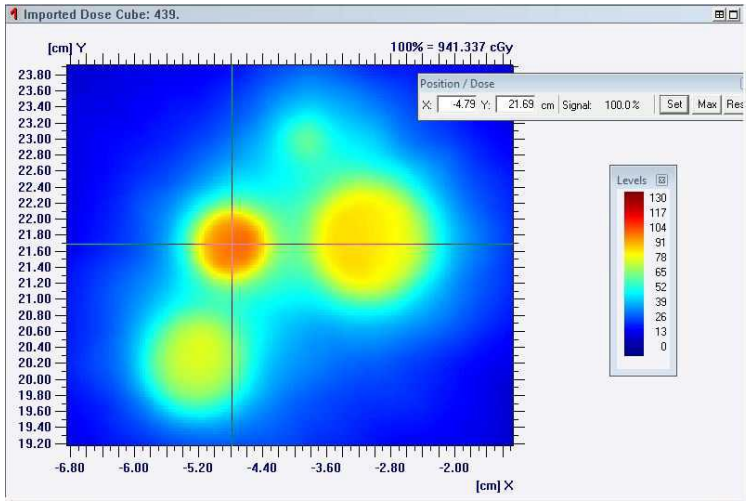
Verified parameter	Measured value	Reported value	Deviation	Tolerance
Dose rate in the ABS phantom	3.655 Gy/min	3.631 Gy/min	0.7%	±2%
Mean dose in target volume for TMR10 algorithm	8.014 Gy	8.100 Gy	-1.1%	±3%
Mean dose in target volume for Convolution algorithm	8.196 Gy	8.000 Gy	2.5%	±3%
Gamma analysis for film and TMR10 algorithm (4%/3mm)	98.5%	N.A.	N.A.	≥ 95%

$$\Delta\,[\%] = 100*(M_{measured} - M_{reported})/M_{reported}$$

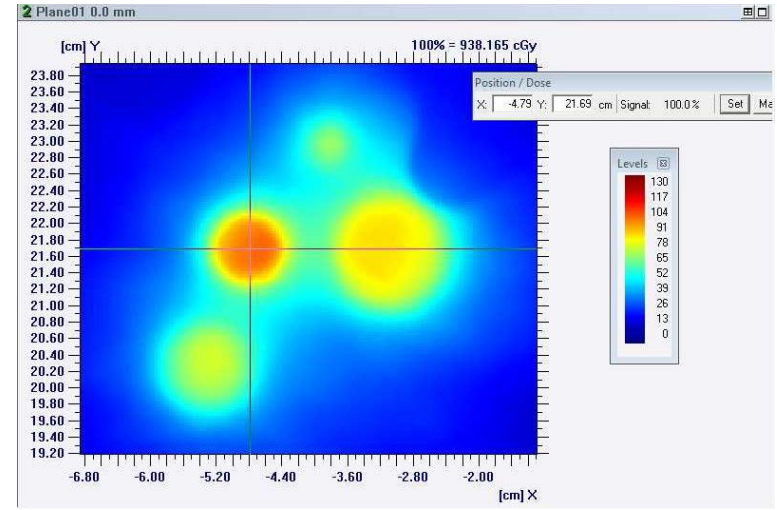
Dosimetry audit results

Státní ústav radiační ochrany, v. v. i.
National Radiation Protection Institute

Leksell GammaPlan TMR10 calculated dose distribution



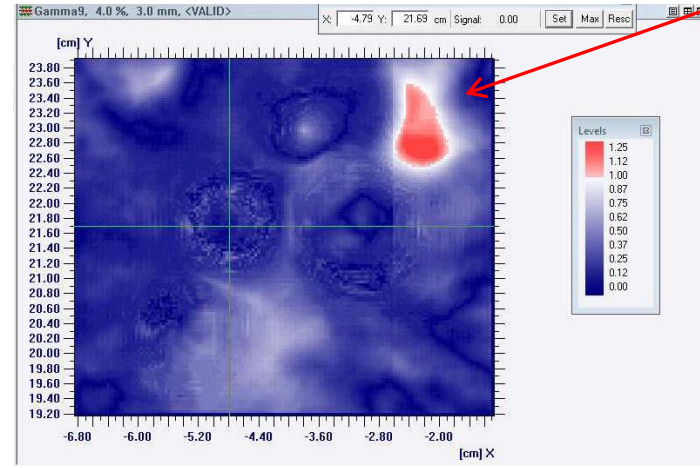
EBT3 Gafchromic film measured dose distribution

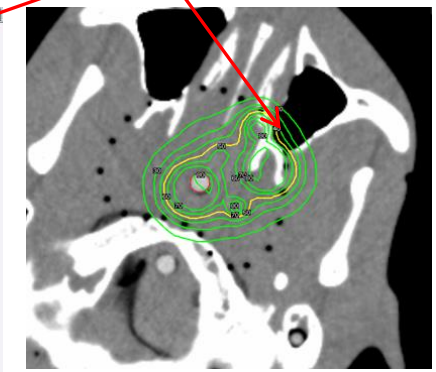


Comparison of dose profiles

Results of gamma analysis

Not passing

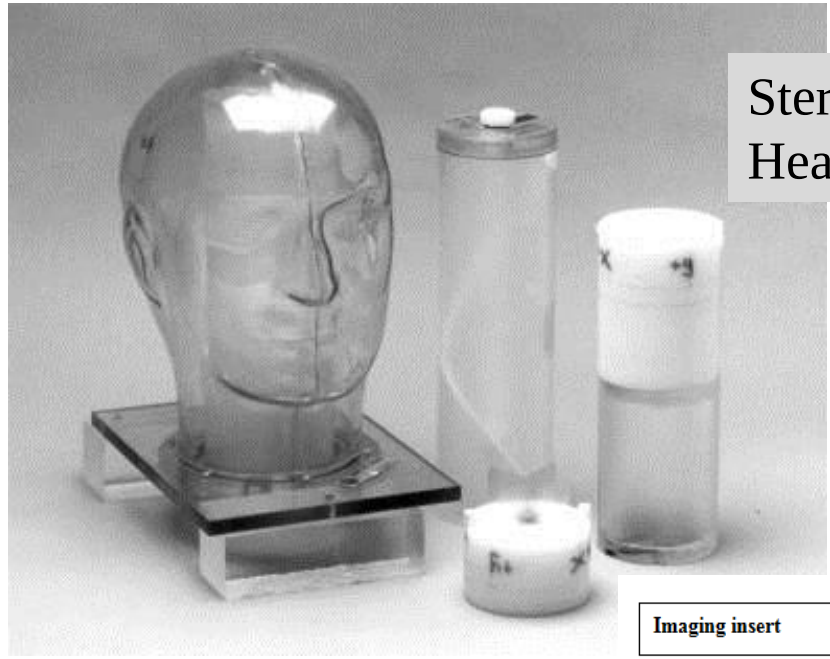




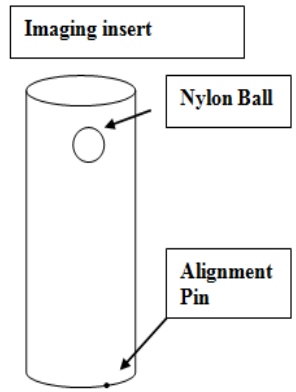
The MD Anderson Dosimetry Laboratory audit

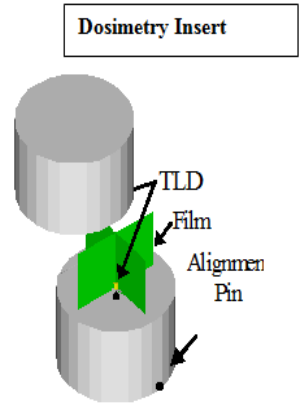
The MD Anderson Dosimetry Laboratory

- Assess accuracy of the entire process:
  - CT/MRI scan
  - Contouring
  - Dose calculation
  - Radiation delivery



Stereotactic Radiosurgery Head Phantom

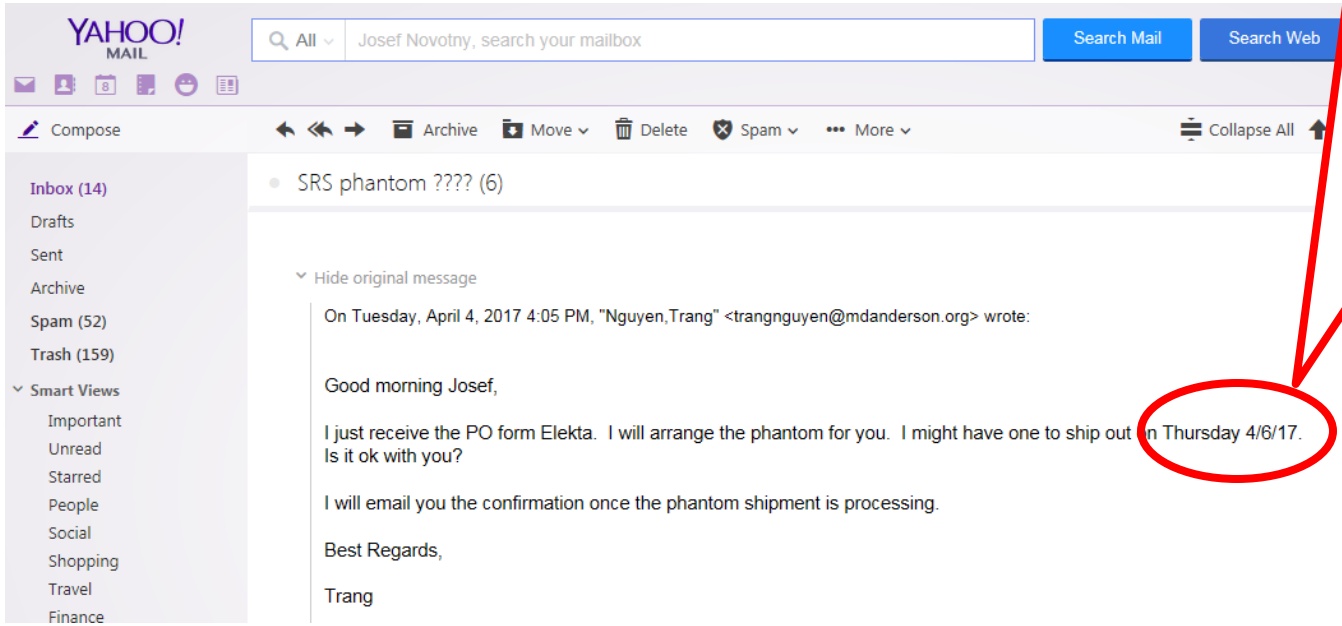




The MD Anderson Dosimetry Laboratory audit

The MD Anderson Dosimetry Laboratory

After approximately 30 e-mails, many phone calls and five months, phantom is finally being shipped!



Conclusions and summary

- Deviation between measured and reported calibration dose rate in the ABS plastic phantom was 0.7 %.

- Deviations in mean doses measured by ion chamber positioned within target volume in heterogeneous anthropomorphic head phantom were -1.1 % and 2.5 % for TMR 10 and Convolution algorithms, respectively.

- Convolution algorithm generally calculated longer irradiation times by 2-3 % on average compared to TMR10.This fact was also supported by measurement results. Based on results from this experimental study the statement that Convolution algorithm provides more accurate calculation is not supported.

Conclusions and summary

- Audit from The MD Anderson Dosimetry Laboratory is still work in progress.
- Mandatory dosimetry audits required by law would improve safety and make all administrative and logistic issues much easier for a physicist performing commissioning of the system.
- Including budget for dosimetry audit in a contract with vendor should make things much easier.

Do we really have a bullet proof system in a quality control?

- Joint Commission International (JCI) accreditation

- Annual inspections by State Office for Nuclear Safety

- Internal clinical audits required by Ministry of Health of the Czech Republic and performed annually by small team of hospital employees

- External clinical audits required by Ministry of Health of the Czech Republic and performed every five years by specially licensed organizations and independent consultants

“I write differently from what I speak, I speak differently from what I think, I think differently from the way I ought to think, and so it all proceeds into deepest darkness.”

Franz Kafka

Acknowledgements

- Elekta Services s.r.o. for complete financial coverage of both dosimetry audits

- National Radiation Protection Institute, Prague, Czech Republic for their helpful and personal involment in this study

Thank you!