Challenges in post-treatment Dose Calculations using image-based Quantification of Y-90 SPECT/CT Data

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- Motivation
- Study details
- Jaszczak & Body Phantom Measurements
- VOI Threshold Selection
- Total Activity & Volume
- Dose Calculations
- Conclusions & Outlook

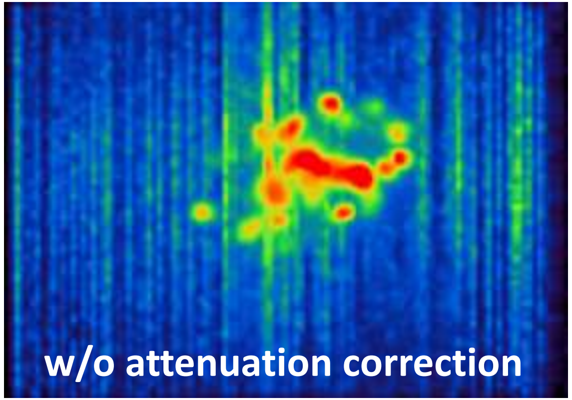
Cancer Treatment using Y-90

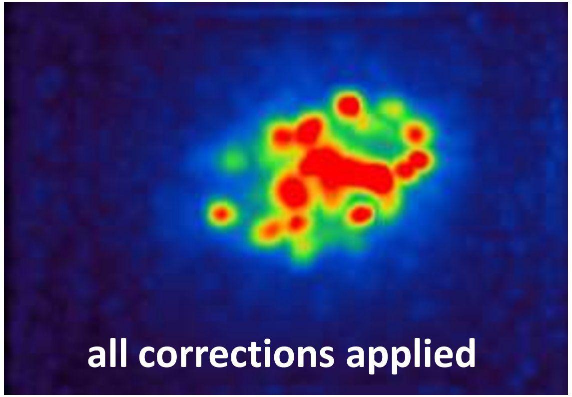
- Treatment of non-resectable liver cancer using Y-90 SIRT
- Applicable for primary carcinoma and metastasis
- Y-90: pure high-energy β-emitter, 64 h half-life
- Transarterial infusion of active microspheres (20 – 30 µm)
- Staying permanently in the patient's body
- Evaluation of doses to healthy liver and tumour
  → quantified post treatment imaging

SIRT post-treatment Imaging

- Low probability branch of e^{-} - e^{+} pair generation → PET
- SPECT possible, utilizing bremsstrahlung photons
- Continuous spectrum complicates reconstruction and quantification
- Software with Monte-Carlo based scatter and attenuation correction and collimator modelling

→ Quantification of SIRT SPECT/CT data





This study

- 17 SIRT patients treated at *AKH Vienna* between May 2017 and May 2018
- *Sirtex* resin-based *SIR-Spheres*
- Applied activities 0.58 – 2.77 GBq
- SPECT/CT using *Siemens Symbia Intevo* with ME-Collimator
- Reconstruction & Evaluation with *Hermes Medical Solutions' Hybrid Recon* 2.2 & *Hybrid Viewer* 3.0
- Measurement of Jaszczak and NEMA IEC Body Phantom

Phantom Measurements @ AKH Vienna

Jaszczak Phantom

A = 564 MBq

$t_{measurement}$ = 15, 30 min

Necessary for calibration

NEMA IEC Body Phantom

A = 465 MBq

$t_{measurement}$ = 15, 30 min, 8 h

Evaluation of reconstruction

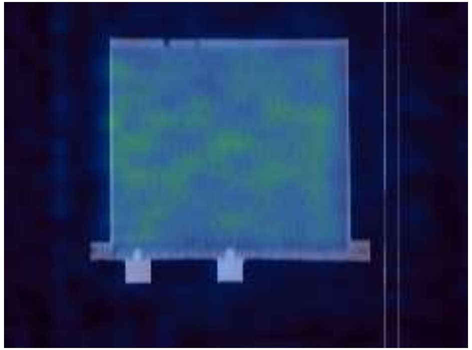
Phantom Measurements @ AKH Vienna

Jaszczak Phantom

For correct volume,
activity 3 % underestimated

Mean SUV ≈ 1.0

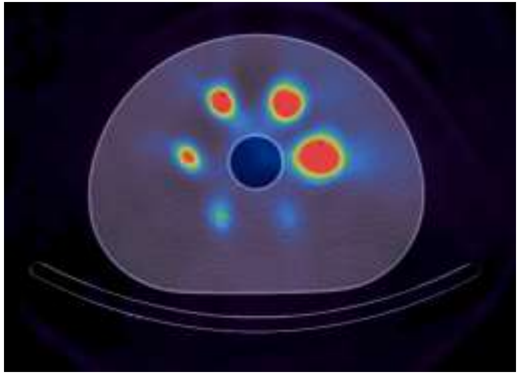
Very precise results



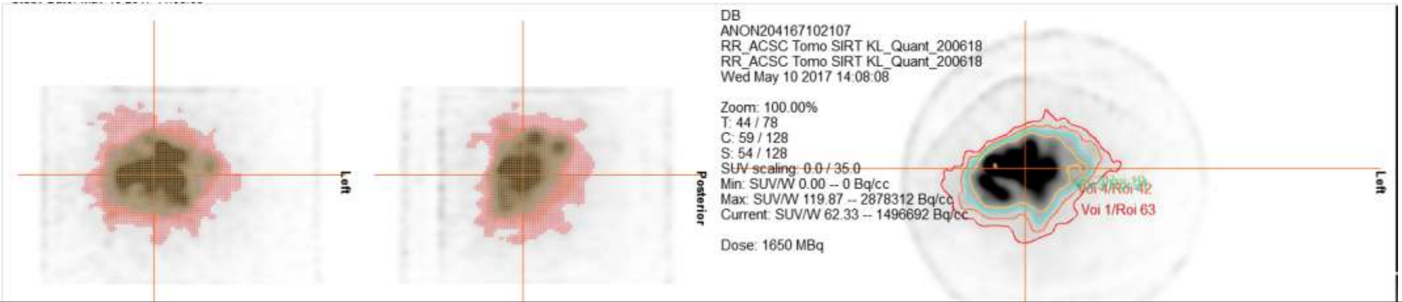
NEMA IEC Body Phantom

For spheres activity severely underestimated

Total activity correct,
but VOI definition arbitrary



Quantitative Evaluation



DB	SUV min	SUV max	Bq/cc	V (cm^3)	A tot(MBq)
Voi 1	3,16	119,87	266050,69	7335,08	1951,50
Voi 2	11,75	119,87	600625,69	1912,25	1148,55
Voi 3	8,39	119,87	491192,97	2741,41	1346,56
Voi 4	5,50	119,87	382051,22	4140,95	1582,05
applied			**V_{Liver} ca.**	2300,00	1650,00

→ Large impact of threshold selection for Volume of Interest (VOI)

Threshold Selection

- Stringent criteria necessary
- Evaluation of dataset with 4 different VOI thresholds
  - 20 % of max. SUV value (Shcherbinin et.al., 2008)
  - SUV = 4.0
- Thresholds with background corrections tested but discarded

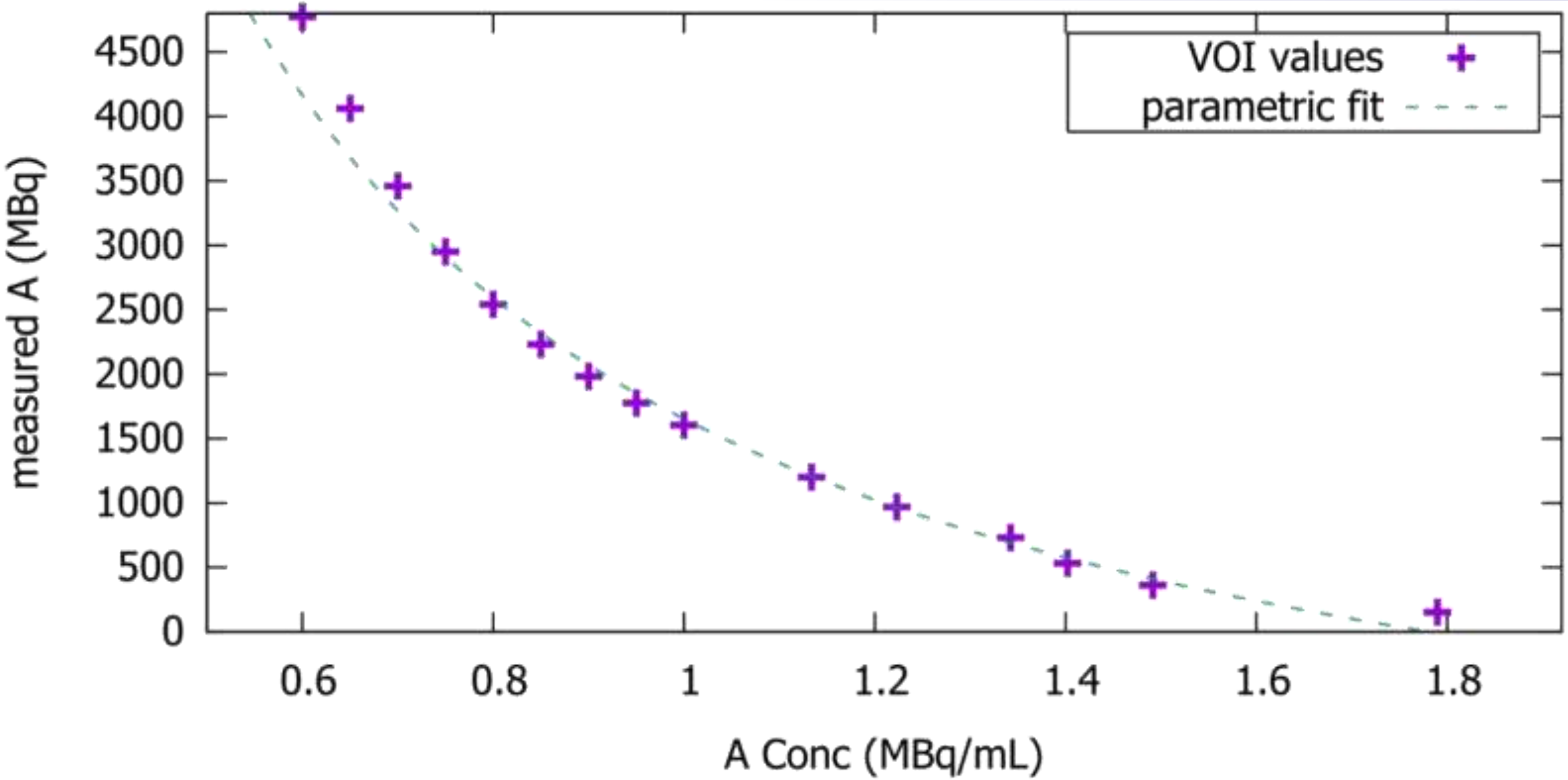
Relation between Threshold and Activity

- Mathematical relation between VOI threshold (MBq/mL) and VOI total activity investigated
- Best guess $A_{tot} = \frac{a}{A_{Conc}} * b$
- Fit using nonlinear least-squares Marquardt-Levenberg algorithm; parameters a, b

→ Calculation of threshold yielding correct total activity

→ Investigation of common behaviour

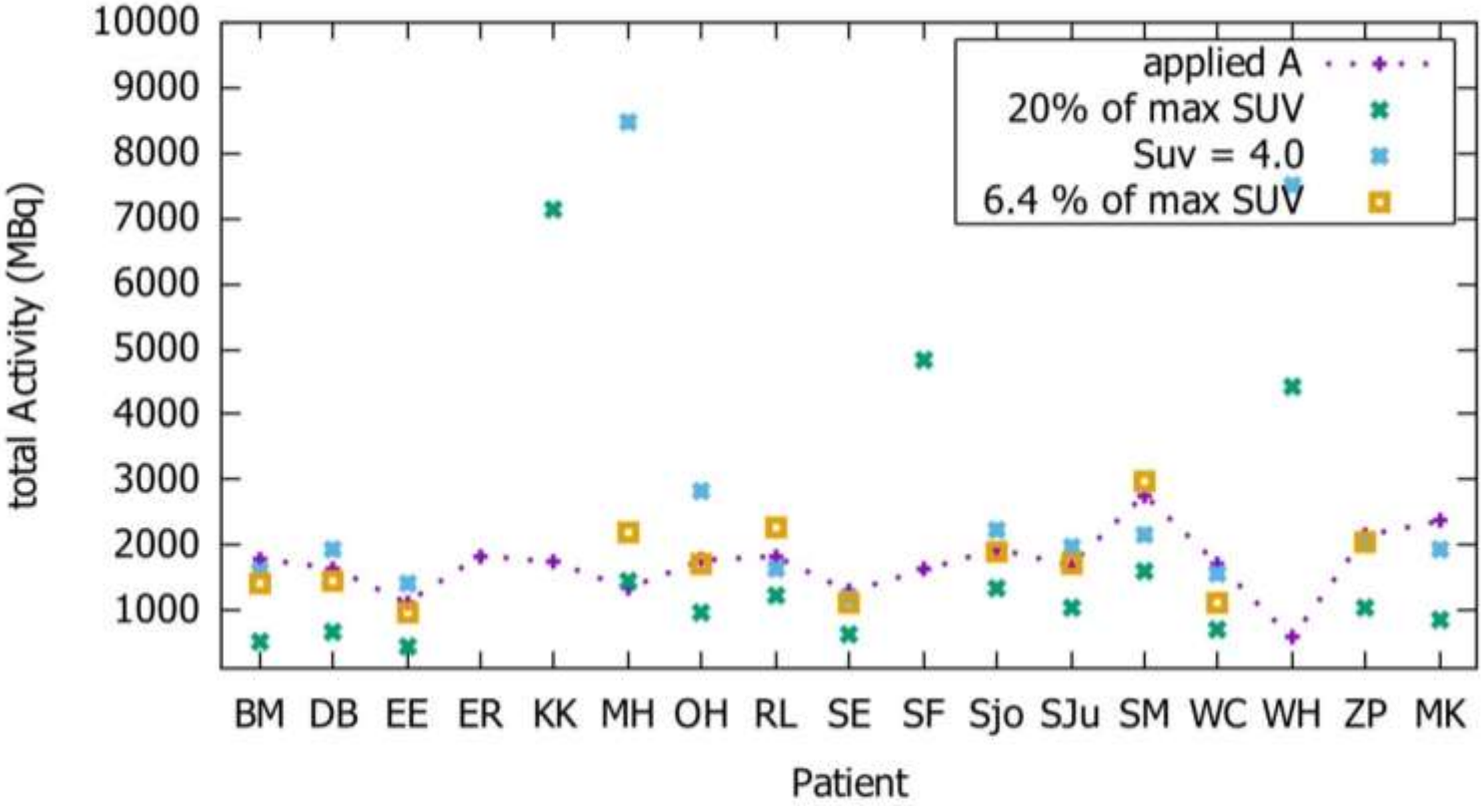
Relation between Threshold and Activity - SF



Threshold Selection

- Stringent criteria necessary
- Evaluation of dataset with different VOI thresholds
  - 20 % of max. SUV value (Shcherbinin et.al., 2008)
  - SUV = 4.0
- Thresholds with background corrections tested but discarded
- Excluding outliers best common threshold is
  6,4 % of max. SUV value

Total activity



Activity → Dose ?

Main challenge: activity very inhomogeneously distributed

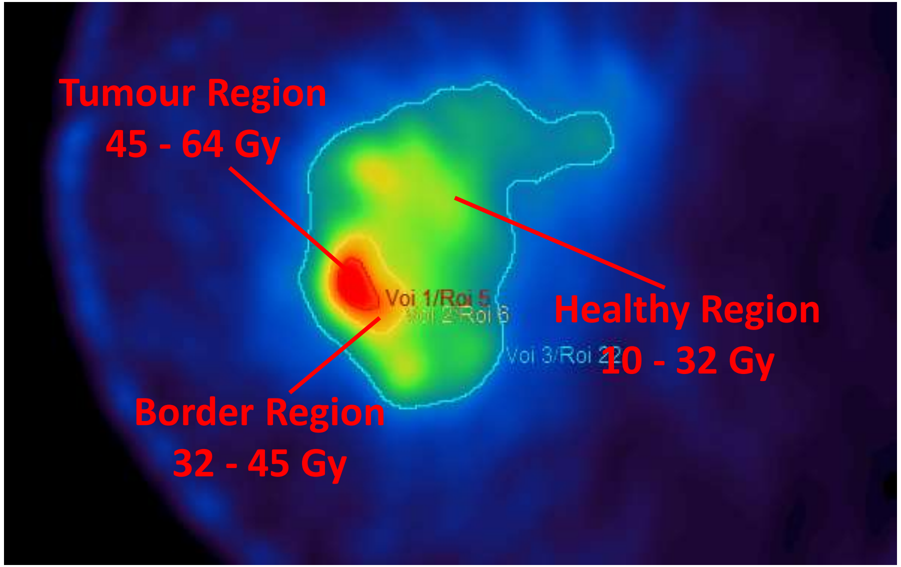
Constant dose:

$$\bar{D}(Gy) = \frac{49.67 * A_0\,(GBq)}{M(kg)}$$

Example: A= 1.12 GBq

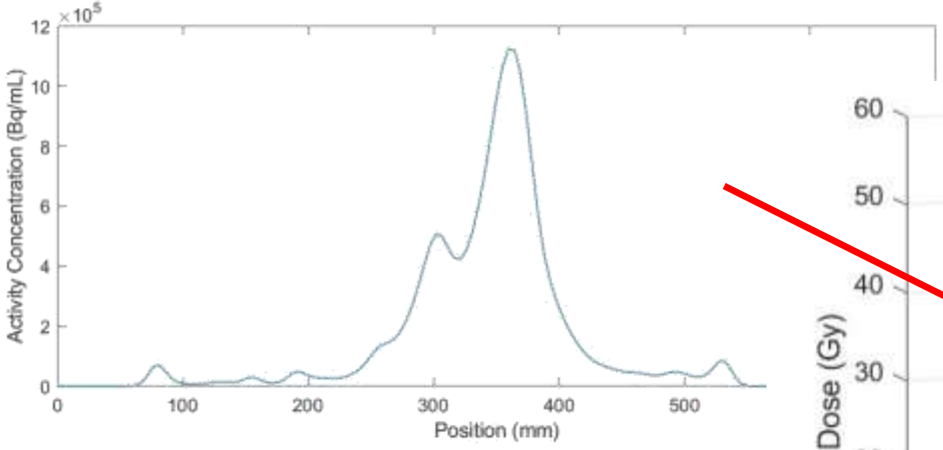
D= 36 Gy

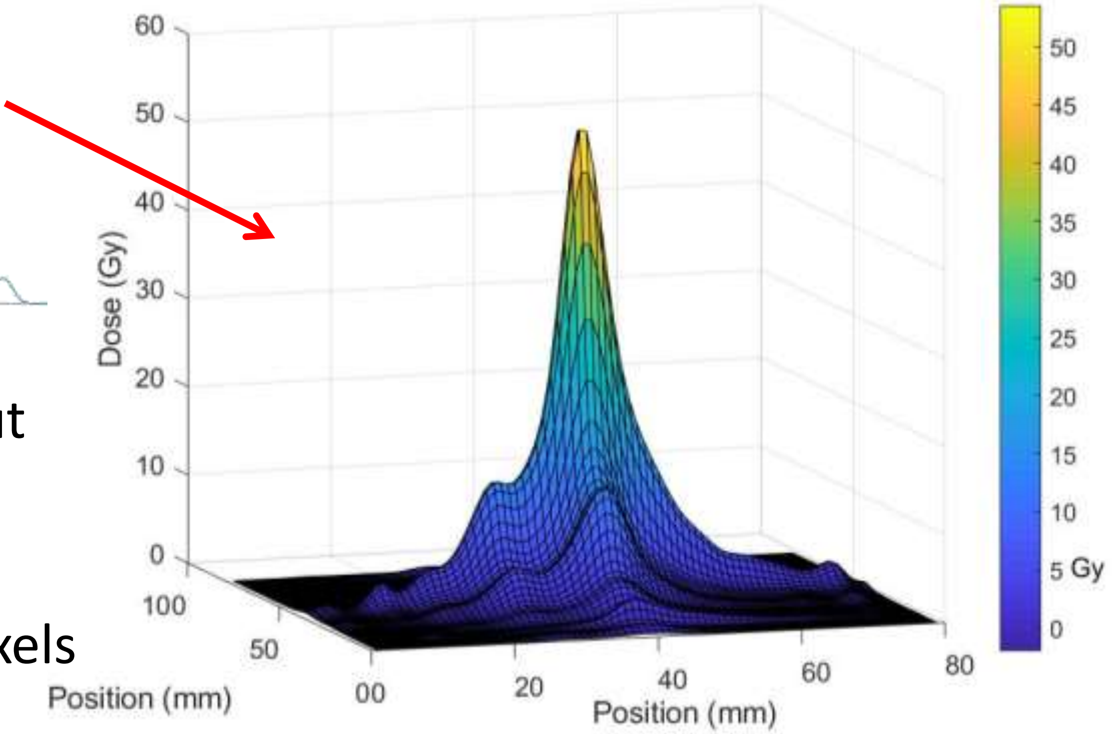
$$D(Gy) = \frac{49.67 * 10^{-6}}{1.04} * c(Bq\,cm^{-3})$$



Formulae from:
Dieudonne, A., Hobbs, R., et al.,
Clin. Transl. Imaging (2016) 4:273-282

More refined approach





Calculating a dose profile out of the activity distribution

But: only for one layer
and interaction between voxels is not taken into account

Conclusions & Outlook

- Quantitative reconstruction yields reasonable results
- Criteria for VOI thresholds improve reproducibility
  - 20% of max SUV for most accurate volumes as in *Shcherbinin et.al.*
  - Mathematical relation for best threshold value found
    → use beyond this study needs to be investigated
- Rough estimation of dose possible, but interactions between microspheres should be modelled

Outlook:

- Monte-Carlo based dose evaluation, yielding 3D dose model and values for tumour doses and healthy liver doses

Thank you for your attention!

References

- **Dieudonne, Arnaud, et al.** Absorbed-dose calculation for treatment of liver neoplasms with Y-90 microspheres. *Clin. Transl. Imaging.* 4:273-282, 2016.
- **Shcherbinin, S., et al.** Accuracy of quantitative reconstruction in SPET/CT imaging. *Phys. Med. Biol.* 53: 4595-4604, 2008.
- **Porter, Charlotte A., et al.** Phantom and clinical evaluation of the effect of full Monte Carlo collimator modelling in post-SIRT yttrium-90 Bremsstrahlung SPECT imaging. *EJNMMI Research.* 8:7, 2018.
- **Sohlberg, Antti O. und Kajaste, Markus T.** Fast Monte Carlo-simulator with full collimator and detector modelling for SPECT. *Ann. Nucl. Med.* 26:92-98, 2011.