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Quantification of the Effect of Respiratory Motion on Efficiency Calibration for Internal Dosimetry

Stefan Pölz[1]*, Thomas Schneider[1], Lars Hegenbart[2], Manfred Urban[2], Horst Geckeis[1]

[1] Institute for Nuclear Waste Disposal (INE), Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany
[2] Wiederaufarbeitungsanlage Karlsruhe, Rückbau- und Entsorgungs-GmbH, POB 1263, 76339 Eggenstein-Leopoldshafen, Germany
* Contact: stefan.poelz@kit.edu

1 Introduction

- Incorporation of radionuclides through accidental exposure
- In vivo measurement of activity with partial body counting
- Individual dose assessment for radiation protection purposes
- Measurements highly sensitive to detector configuration and anatomy
- Many calibration phantoms directly based on medical CT (typically assessed at full inspiration of heavy breathing)

2 Objectives

The goal is to quantify the systematic error introduced to numerical efficiency calibration for lung counting when disregarding respiratory motion in phantom development.

3 Methods and Materials

1. Anthropomorphic phantom with breathing motion:
   - 4DCT data captured with respiratory gating system (8 time frames, 0.7x0.7x2.0 mm^3)
   - Segmentation into seven basic tissues
   - Material densities and elemental compositions from [1]
2. Lung counting setup:
   - Two HPGe detectors of the local partial body counter [2]
   - Detector positions adjusted for full inspiration
3. Radiation transport simulations:
   - MCNPX

Fig. 1: Exemplary lung counting configuration with physical torso phantom of the local partial body counter.

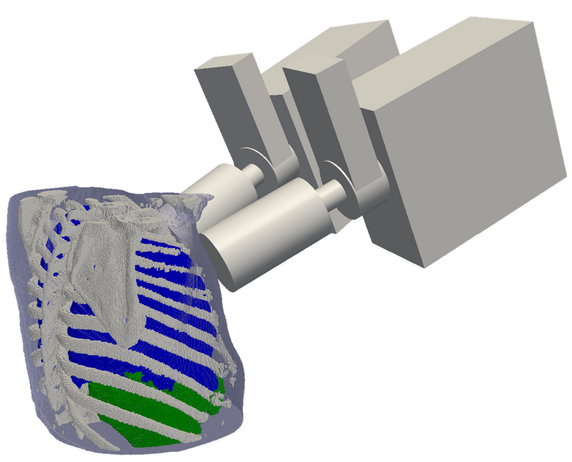

Fig. 2: Reconstructed phantom at full inspiration with two detectors in lung counting configuration. Only selected parts are visible: lungs (*blue*), bones (*grey*), and liver (*green*).

4 Results

- Correlation between respiratory motion and counting efficiency apparent

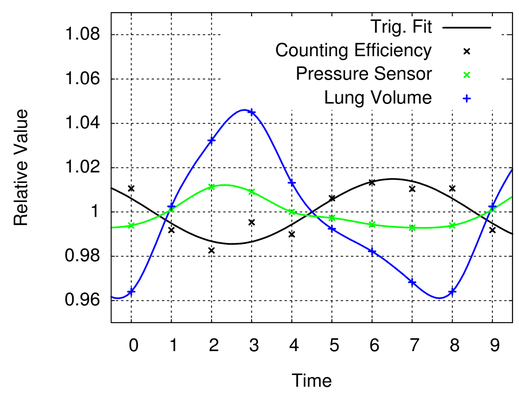

Fig. 3: Values over time relative to their averages for lung volume, pressure sensor, and calculated counting efficiencies at 122 keV for both detectors.

- Underestimation of counting efficiency over a full respiratory cycle of about 1 – 2%

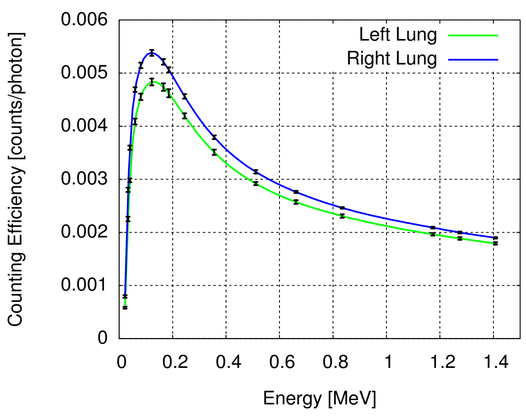

Fig. 4: Calculated counting efficiencies for both detectors averaged over time with standard deviation.

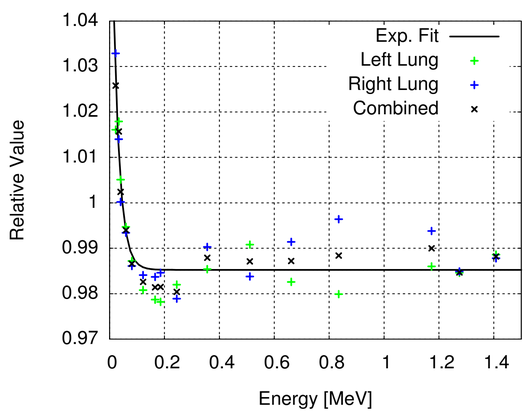

Fig. 5: Calculated counting efficiencies for both detectors for the breathing phantom relative to the phantom at full inspiration.

5 Discussion and Conclusion

The results show a slight overestimation of incorporated activity for lung measurements when using a calibration phantom at full inspiration of tidal breathing. However, when using single CT scans for phantom development, typically assessed at full inspiration of heavy breathing, the observed effect on efficiency calibration due to respiratory motion is expected to be larger.

6 Acknowledgements

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