# Effect of respiratory motion on lung counting efficiency using a 4D NURBS-based Cardio-Torso (NCAT) phantom


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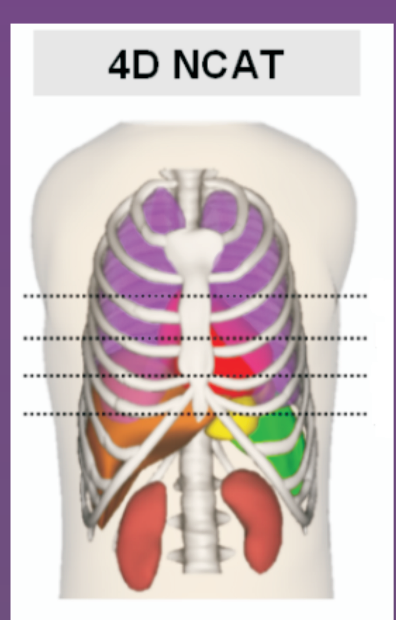
## Introduction

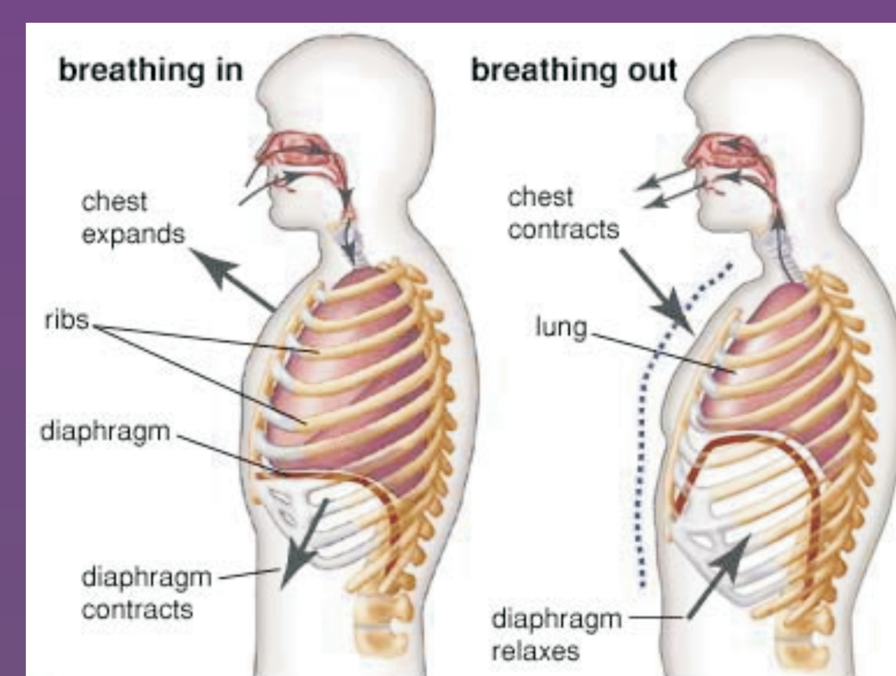
The Human Monitoring Laboratory (HML) of Health Canada has simulated the change in lung volume, the deformation of the chest, and the changes in the distance between the detector and the chest surface, due to breathing using a 4D non-uniform rational b-spline (NURBS)-based cardio-Torso (NCAT) phantom.

The impact of breathing during a measurement on the counting efficiency of the HML's lung counter, and the effect it will have on the lung burden, was determined and compared with a variety of parameters already shown to affect the counting efficiency.

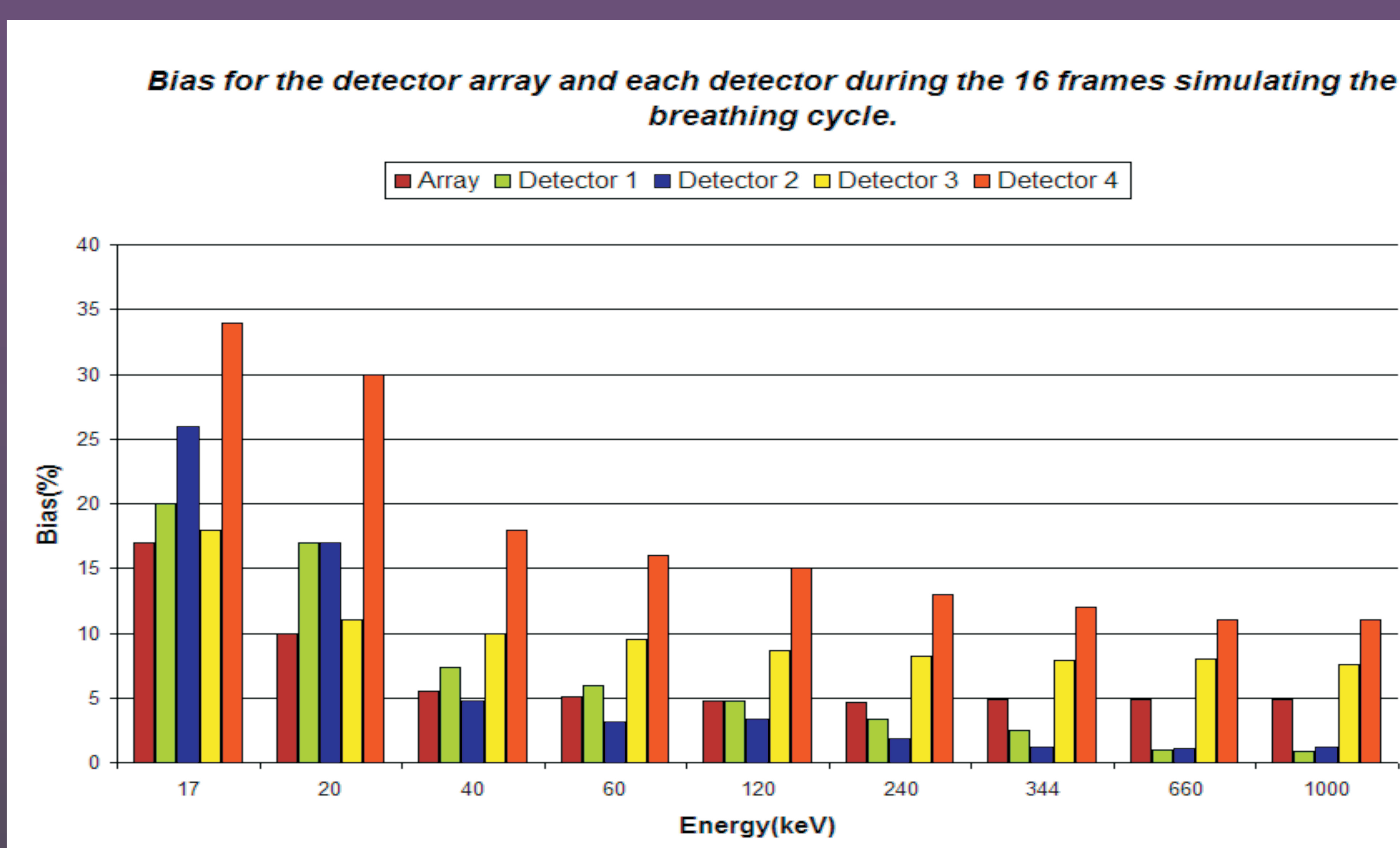



## The Simulations

Monte Carlo simulations (MCNPX version 2.6E) were performed using photon energies of 17, 20, 40, 60, 240, 344, 660 and 1000 keV. The inter-actions of these photons with the 4 germanium detectors comprising the HML's lung counter were tallied to obtain the changes in individual detector efficiency during the breathing cycle. The array was calculated by simply adding each efficiency for a given energy.




The 4D NURBS-based Cardio-Torso (NCAT) phantom used in this study to simulated the breathing cycle, was developed by Paul Segars and its team at the Department of Biomedical Engineering and Department of Radiology, University of North Carolina .




## Results and Discussion

The uncertainty introduced into the lung count due to the breathing motion was estimated by calculation of the bias. The maximum efficiency was used as a reference value to calculate the bias as it best represents the calibration efficiency obtained using a physical phantom.

- The bias values for the array and individual detectors are highest at low energies as expected due to attenuation and geometry effects.
- The gross difference between each individual detector efficiency show that the use of individual detectors to determine whether a deposition is heterogenous or homogeneous may be problematic.
- The bias results obtained for the array are considerably smaller than the values for an individual detector. This confirms the fact, as already stated in previous studies, that the accuracy of measurement depends on the positioning of the detectors relative to the physical phantom or the person counted.
- The data show that the use of a detector array will minimize the uncertainties arising from the positioning of the detectors, the geometry of the lung deposition and from respiratory motion.

## Conclusion

The impact of respiratory motion on the counting efficiency of the HML's lung counting system is negligible compared with other parameters like the deposition patterns and the chest wall thickness profile. Thus, the use of a 4D NCAT phantom to simulate the respiratory motion is considered by the HML as unnecessary when developing calibrations factors for a lung counting system; however, it is worth remembering that the close geometry used during the calibration process introduces a systematic bias that results in all lung burdens being underestimated by few percent. For instance, at 17 and 60 keV an underestimation of 17% and 5%, respectively, should be taken into consideration when evaluating the internal deposited radioactivity in the lungs.