

### Background

As ionizing radiation has enabled great progress in the diagnostic and therapeutic aspects of medicine, its use is in most cases easily justifiable. General radiation protection principles require additionally that radiation doses of the patients should be as low as reasonably achievable within the medical purposes. In Europe this is stipulated in the directive 97/43/Euratom. This directive also requires that special attention should be given to the patient doses in pediatric examinations, of which premature babies constitute an important sub-group.

All babies born before 37 weeks of gestation are defined as being prematurely born. Newborn and prematurely born babies are particularly sensitive to the detrimental effects of X-rays. Risk of cancer induction is believed to be 2–3 times higher than that of the average population and 6–9 times higher than the risk from an exposure at 60 years of age, for equal dose.

A premature born child may be exposed to a large number of diagnostic X-ray examinations. Several of these infants may have underdeveloped lungs, which may lead directly to the respiratory distress syndrome (RDS) or to (lethal) lung hypoplasia/hypertension. Diagnosis and follow-up of the respiratory distress syndrome by means of chest radiography is justified. Risks associated with X-ray examinations are low compared to the other medical risks that these patients face, but even in this case the radiation dose should be kept as low as possible. Knowledge of the radiation dose is a first step in the optimization process. A recent study on 255 premature children in the University Hospital of Gasthuisberg found that they undergo 10 X-ray examinations, on the average. In this sample, the maximum was 78 X-ray examinations.

### Objectives

Radiation risk estimates are based on the doses in various organs and tissues of the body. In practice, direct measurement of the organ doses is not possible and therefore organ doses must be estimated otherwise, most often by means of Monte Carlo simulations.

To calculate doses in the entire body and in specific organs, computational models of the human anatomy are needed. Mathematical (equation based) phantoms resemble the human anatomy only roughly (figure a). More realistic human phantoms have become available based on medical imaging techniques, such as computed tomography (CT) or magnetic resonance imaging (MRI). These so called voxel phantoms provide a more realistic representation of the anatomical structures.

While much effort has been devoted towards the creation of adult phantoms, only few research studies have proposed phantoms for pediatric radiology. As far as we know, specific voxel phantoms for premature babies have not been presented earlier. In this study two voxel phantoms (figure b and c), representing prematurely born babies, were created from CT- and MRI-images.

### Results

The phantoms described in this study are useful for calculating conversion factors from entrance air kerma to organ doses. For a chest radiograph the doses typically are low. For example, in the University Hospital of Gasthuisberg the lung dose in a 2 kg premature baby who is exposed to the average of 10 chest radiographs is of the order of 250  $\mu$ Gy. If 80 radiographs are required, the dose to the lung will be approximately 2 mGy.

### Future work

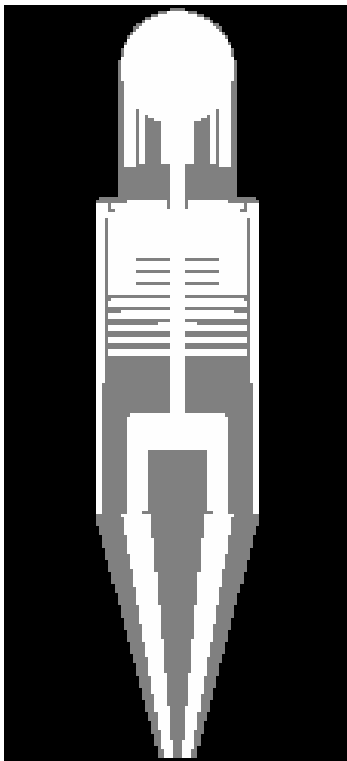
The development of a voxel phantom in this age group was considered a first step towards optimization studies in the neonatal unit. MCNPX is not limited to calculating organ doses, but can also be used to assess image quality (figure d). In further work, the voxel phantoms will be used to link patient doses and image quality.

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### Main reference

K. Smans, M. Tapiovaara, M. Cannie, L. Struelens, F. Vanhavere, H. Bosmans, Calculation of organ doses in X-ray examinations of premature babies, Medical Physics, to be published (februari 2008).



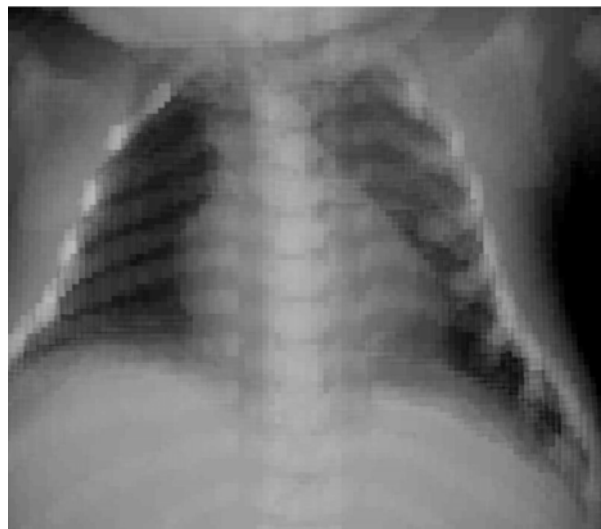
(a)



(b)



(c)



(d)

*(a) Mathematical phantom: model resembles human anatomy only vaguely  
(b) and (c) Voxel phantom: realistic representation of anatomical structures  
(d) Chest radiography created with MCNPX*