

MATHEMATICAL PHANTOMS FOR EVALUATION OF AGE-SPECIFIC INTERNAL DOSE\*

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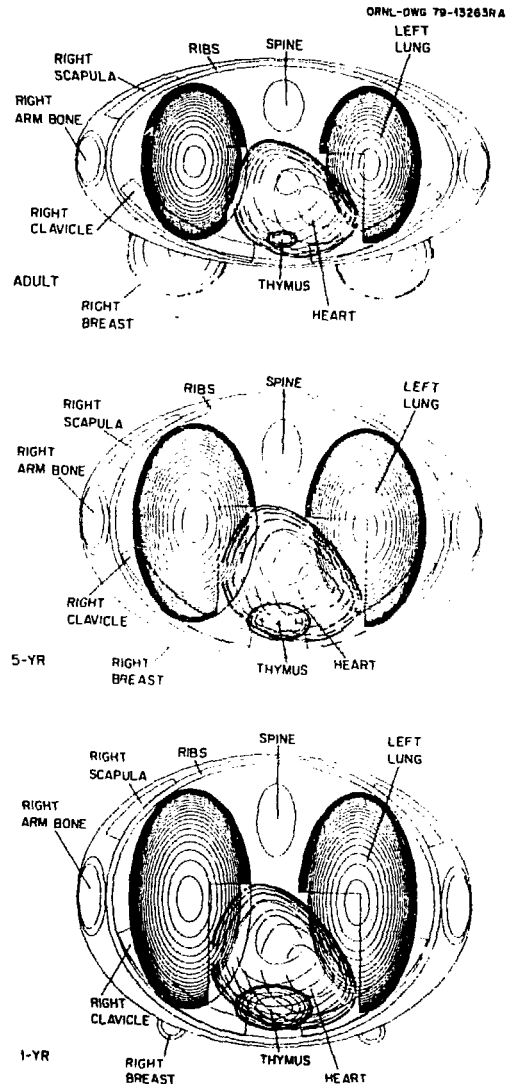
**MASTER**

A series of mathematical phantoms representing children has been developed for use with photon transport codes. These phantoms, patterned after the Fisher-Snyder adult phantom,<sup>1</sup> consist of simple mathematical expressions for the boundaries of the major organs and body sections. The location and shape of the organs are consistent with drawings depicting developmental anatomy, with the organ volumes assigned such that the masses at the various ages conform closely with the data presented in *Reference Man*.<sup>2</sup> The explicit mathematical expressions for the various ages overcome the potential misrepresentation of organ sizes that occurred in phantoms derived from simple mathematical transformations of the adult phantom. Female breast tissue has been added to the phantoms, including the adult, now allowing assessment of doses to this organ.

The figure to the right illustrates the cross-sectional anatomy of the phantoms: superimposed cross-sections of the upper trunk of the adult phantom and the 5- and 1-year-old phantoms are shown. For the adult, cross-sections are drawn at intervals of 1 cm. For the other two phantoms, cross-sections are drawn at intervals which yield the same number of sections as for the adult.

The distribution of active marrow has been developed for each phantom of the series. These distributions are based on a refinement of Atkinson's method.<sup>3</sup> The refined method predicts that, in the newborn, 27.8% of the active marrow of the body resides in the skull with 20.7% in the lower limbs. Atkinson's method predicts 7.0 and 38.9%, respectively. Experimental data of Hudson<sup>4</sup> involving 16 late-term fetus and newborns indicate that 29.5% and 23.7% of the active marrow resides in the skull and lower limbs, respectively. Hence the values estimated by the refined method are in better agreement with the experimental data than the earlier values.

Calculations of specific absorbed fractions for various source-target organ combinations at a range of energies were performed using a Monte Carlo radiation transport code, with the phantoms having different densities for lungs, bone, and soft tissues, and embedded in air. The specific absorbed fraction increases with



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decreasing age, with the greatest rate of increase occurring between age 5 and newborn. For assessment of the significance of this trend, the ratio of the specific absorbed fraction of a source-to-a-target organ,  $\phi(Y+X)$ , to the specific absorbed fraction of the source organ-to-itself,  $\phi(X+X)$ , for several source-target pairs at selected photon energies and at three ages are given in the tables below.

The first table gives an example of a discrete (i.e., not widely distributed) target organ, the ovaries. For discrete targets, the ratio of the photon dose absorbed by a target organ to the source organ self-dose increases with decreasing age, with the relative increase depending on the energy of the photons and the distance of separation of the source and target organs. These calculations support earlier suggestions that cross-organ irradiation is of increased importance in children.

| Energy (MeV) | $\phi(Y+X)/\phi(X+X)$ in percent |       |       | Target - Source                           |
|--------------|----------------------------------|-------|-------|---|
|              | Newborn                          | 5-yr  | Adult |   |
|              |                                  |       |       | Ovaries - Liver                           |
| 0.075        | < 0.1                            | < 0.1 | < 0.1 |   |
| 0.05         | 9.9                              | 4.5   | 0.9   |   |
| 0.2          | 10                               | 7.1   | 3.1   |   |
| 1.0          | 8.3                              | 5.8   | 3.1   |   |
|              |                                  |       |       | Ovaries - Urinary bladder contents*       |
| 0.015        | 0.5                              | 0.1   | 0.1   |   |
| 0.05         | 16                               | 14    | 8.4   |   |
| 0.2          | 14                               | 13    | 11    |   |
| 1.0          | 12                               | 11    | 8.8   |   |
|              |                                  |       |       | Ovaries - Lower large intestine contents* |
| 0.015        | 19                               | 9.5   | 3.9   |   |
| 0.05         | 43                               | 40    | 35    |   |
| 0.2          | 41                               | 38    | 34    |   |
| 1.0          | 39                               | 35    | 42    |   |

\*For walled organs,  $\phi(X+X)$  is defined here as  $\phi(\text{wall-contents})$ .

The second table gives an example of a distributed target organ, the active marrow, whose distribution changes substantially with age. For the brain as source organ, the results are similar in trend to those above. For the lower large intestine contents, however, the pattern is reversed at the higher three energies, i.e., the ratio is higher in the adult than in the children. For the urinary bladder contents the pattern is intermediate, i.e., the ratio changes little with age.

| Energy (MeV) | $\phi(Y+X)/\phi(X+X)$ in percent |      |       | Target - Source                                 |
|--------------|----------------------------------|------|-------|---|
|              | Newborn                          | 5-yr | Adult |   |
|              |                                  |      |       | Active marrow - Brain                           |
| 0.015        | 12                               | 3.7  | 0.6   |   |
| 0.05         | 20                               | 9.1  | 1.7   |   |
| 0.2          | 19                               | 9.8  | 4.3   |   |
| 1.0          | 19                               | 9.7  | 4.0   |   |
|              |                                  |      |       | Active marrow - Lower large intestine contents* |
| 0.015        | 0.6                              | 0.6  | 0.3   |   |
| 0.05         | 3.4                              | 4.7  | 5.4   |   |
| 0.2          | 3.3                              | 4.9  | 6.1   |   |
| 1.0          | 2.9                              | 4.3  | 5.5   |   |
|              |                                  |      |       | Active marrow - Urinary bladder contents*       |
| 0.015        | < 0.1                            | 0.1  | 0.1   |   |
| 0.05         | 1.6                              | 1.7  | 1.1   |   |
| 0.2          | 1.7                              | 2.1  | 2.0   |   |
| 1.0          | 1.4                              | 1.7  | 1.7   |   |

\*For walled organs,  $\phi(X+X)$  is defined here as  $\phi(\text{wall-contents})$ .

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