Radiation Dose to the Upper Spine from Therapeutic Administrations of Iodine-131-Sodium Iodide

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Thyroid cancer patients sometimes receive conventional external irradiation to the neck in addition to radioactive iodine therapy. In these situations, knowledge of the radiation dose already received by the spine in the neck area from the radioiodine administration can be an aid in treatment planning. This paper gives an estimate of the radiation dose to the upper spine from administration of 3700 MBq of ^{131}I-sodium iodide. Monte Carlo codes used to estimate radiation dose from internal emitters usually give absorbed doses to the whole spine or marrow. One such code was modified to give a dose only to the upper spine region near the thyroid. Calculations assumed a thyroid uptake of 10% of administered activity and retention with a 35-hr effective half-time. Activity in the remainder of the body was assumed to clear with a 6-hr half-time to urine. Under these assumptions, the dose to this upper spine region was about 200 mGy.

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Thyroid cancer patients sometimes receive conventional external irradiation to the neck in addition to radioactive iodine therapy (*1*). In these situations, knowledge of the radiation dose already received by the spine in the neck area from the radioiodine administration can be an aid in treatment planning. Available dose conversion factors used in internal dosimetry give only the dose to the whole skeleton (*2*), whole marrow or all endosteal cells (*3*). However, absorbed doses for the upper spine may be estimated because the Monte Carlo software code (ALGAMP) (*4*), used to develop radiation dose estimates, can be modified to score photon absorption in user-defined subregions of the body.

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METHODS

The adult male human phantom (*3*) uses a right-handed coordinate system in which the z-axis is directed up, the x-axis is directed to the phantom's left and the y-axis is directed to the phantom's back. The thyroid in this phantom is located approximately between Z = 70 and Z = 75 cm. The spine runs from Z = 22 to Z = 80.54 cm, with subregions designated as lower, middle and upper ranging from Z = 22 to Z = 35.1, Z = 35.1 to Z = 70 and Z = 70 to Z = 80.54 cm, respectively (Fig. 1). When the transport code (*4*) scores photon interactions, it scores them separately in these three regions and reports results for each subregion as well as for the total spine and total skeleton. Target tissues include the total marrow, endosteal cells on the surfaces of growing bone and total skeleton.

The thyroid and total body are the two most important source regions for sodium iodide (*5*). Certainly urinary bladder is also important for some organs, but will be of limited importance to the thyroid region. Therefore, we ran the ALGAMP code, using thyroid and total body as source regions, and estimated the dose to the "upper spine" as defined in the code (Z = 70 to 80.54 cm). In addition, a separate calculation was made in which the dose was estimated only over the region where the thyroid is located (Z = 70 to Z = 75 cm) to obtain an indication of the maximum regional dose to the spine (Fig. 2). The mass of the spine in this region was assigned on the basis of the fraction of the entire spine included in this region.

Specific absorbed fractions were obtained for 12 discrete energies. The S-values (*6*) were then calculated using specific absorbed fractions obtained by interpolation between these discrete values using a linear interpolation in energy for the major photon decay energies of ^{131}I (*7*). The residence time (*6*) for the thyroid was calculated assuming an uptake of 10% of the administered iodine in the remaining thyroid tissue, which was retained with a 35-hr effective half-time. This assignment is somewhat arbitrary, but fairly realistic. If surgery has been performed, little thyroid tissue will remain and the clearance half-time will be decreased from normal values [the normal effective half-time is 168 hr (*5*)] as thyroid ablation proceeds. These values are typical of some values that have been reported to us in private communications; these parameters can be easily varied to estimate different residence times in different situations, if necessary. The residence time for the whole body was calculated (*5*) with the material not taken up by the thyroid being cleared with a 6-hr effective half-time. For purposes of calculation, an administration of 3700 MBq was assumed.

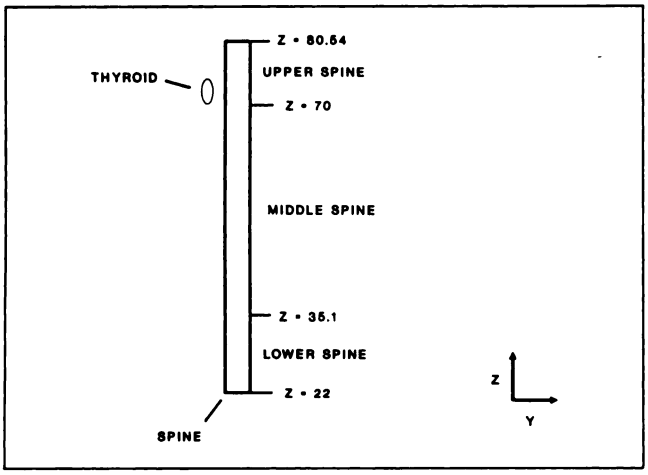

FIGURE 1. Diagram showing approximate geometries of spine and thyroid in adult male phantom.

RESULTS

The "upper spine" is normally defined in the phantom within the ALGAMP code between Z = 70 and Z = 80.5 cm. The S-value from the thyroid to this "upper spine" region for ^{131}I is calculated to be 1.15×10^{-6} mGy/MBq-sec; the S-value for the total body to the upper spine is 7.5×10^{-7} mGy/MBq-sec. The estimated residence times for thyroid and total body were 5.05 hr and 12.7 hr, respectively. The dose to the upper spine from the thyroid under these assumptions is therefore:

$$5.05 \text{ hr} \times 3600 \frac{\text{sec}}{\text{hr}} \times \left(1.15 \times 10^{-6} \frac{\text{mGy}}{\text{MBq-sec}}\right) \times 3700 \text{ MBq} = 80 \text{ mGy}.$$

The dose from the remainder of the body is:

$$12.7 \text{ hr} \times 3600 \frac{\text{sec}}{\text{hr}} \times \left(7.5 \times 10^{-7} \frac{\text{mGy}}{\text{MBq-sec}}\right) \times 3700 \text{ MBq} = 130 \text{ mGy}.$$

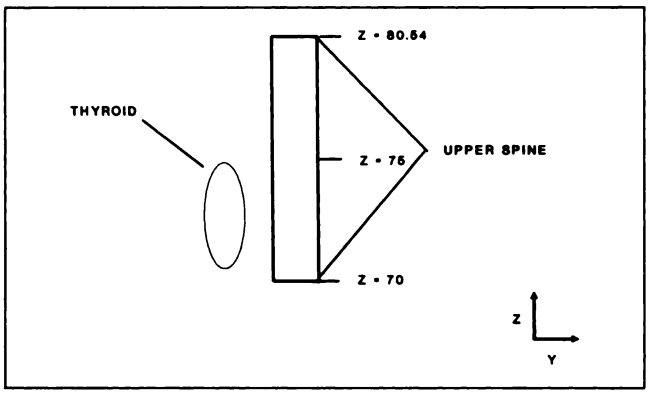

FIGURE 2. Diagram showing approximate geometries of upper spine and thyroid in adult male phantom and location of restricted region (Z = 70 to 75 cm) used in dosimetry calculation.

This gives a total of 210 mGy. By restricting the target region to only between Z = 70 and 75 cm (the approximate upper and lower limits of the thyroid region), the S-value for the thyroid to this restricted region is 1.32×10^{-6} mGy/MBq-sec. The dose to this region from the thyroid under this assumption is 90 mGy for a total of 220 mGy (the dose from the remainder of the body will be approximately the same as before for the restricted region). The S-value from thyroid to the spine is for the total skeleton (bone plus marrow) within this region. The S-values for thyroid irradiating the red marrow and bone surface cells in the restricted (Z = 70 to 75 cm) region are 1.14×10^{-6} and 1.74×10^{-6} mGy/MBq-sec, respectively.

DISCUSSION

The dose to the upper spine from therapeutic administrations of ^{131}I is about 200 mGy, assuming that the thyroid tissue takes up only 10% of the injected activity and clears it within a 35-hr effective half-time. If more activity is taken up by the thyroid, the radiation dose received by the spine from the thyroid will be greater, but less will be received from the remainder of the body. If the effective half-time for retention in the thyroid is significantly increased, the dose from the thyroid will increase proportionately and the dose from the remainder of the body will not change. Therefore, the dose to the upper spine will be about 200 mGy if the effective half-time for retention in the thyroid is 35 hr and perhaps higher if the half-time is longer.

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