# EFFECTIVE DOSE EQUIVALENT IN NUCLEAR MEDICINE INVESTIGATIONS

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When the concept of "effective dose equivalent" was introduced by ICRP (1,2) the intention was to use it for the radiation protection of workers. With this concept it is possible to make an assessment of the risk from radiation by a single figure, independent of the distribution of the absorbed dose within the body. To achieve this, different weighting factors for various organs, reflecting the relative risk from irradiation of that specific organ, is applied. The estimation of the radiation sensitivity of the various tissues is, however, very rough, but the weighting factors attempt to take into account lethal cancer, as well as genetic effects up to the second generation.

Even if the effective dose equivalent primarily was intended for occupationally exposed workers, it has been approved also for patients undergoing nuclear medicine or X-ray diagnosis. Since patients are not a representatitive part of the general adult population, the weighting factors used by the ICRP are not adequate in this case. For older persons, who are in great majority among nuclear medicine patients (about 3/4 is more than 50 years old (3)), the genetic risk is of no significance. Calculated somatically effective dose equivalents has therefore been published both for X-ray diagnosis (4). and for nuclear medicine investigations (5,6). In the latter case the calculations are based on the ICRP weighting factors, excluding the gonads. In all cases the normalized somatic weighting factors, $w_{S1}$, according to Table I, is used. However, since the gonads ofter recieve a relatively low absorbed dose, the resulting figure for the somatically effective dose equivalent, calculated in this way, is often higher than that for the effective dose eqiuivalent. This is due to the renormalization of the ICRP weighting factors, and gives a false impression of a higher risk for a population in which the genetic risks can be neglected. We therefore suggest to use the original weighting factors, except for the gonads, $w_{S2}$, in order to make a simple comparison with the total effective dose equivalent. Following our proposal the same risk figure, 0.0165 $Sv^{-1}$, can be applied both for the total and the somatically effective dose equivalent.

In Table 2, we give, for some commonly used radiopharmaceuticals, the effective dose equivalent, both including and excluding the contribution from the gonads, together with the mean absorbed dose in the total body. The figures in this table are derived from a compilation of absorbed doses from radiopharmaceuticals by Johansson, Mattsson and Nosslin (7). In some cases, however, calculations based on more recent biokinetic data, have been performed, using the MIRD formalism (8). Differences in the numerical value for the effective dose equivalent and the mean absorbed dose in the total body is due to an inhomogeneous distribution of the radiopharmaceutical. The greatest differences arise when the radiopharmaceutical is concentrated in an organ with a high weighting factor relative to it's mass. The magnitude of the ratio between the effective dose equivalent and the mean absorbed dsoe in total body is indicated in Table 2.

The effective dose equivalent is of great value in comparing the risk from various medical radiodiagnostic procedures. The concept is also useful in estimating the collective dose from various sources of radiation.

Table 1.

ICRP based weighting factor for calculation of the total effective ($w_T$) or somatically effective ($w_{S1}$ and $w_{S2}$) dose equivalent.

| Tissue | $w_T$ | $w_{S1}$ | $w_{S2}$ |
|---|---|---|---|
| Gonads | 0.25 | 0 | 0 |
| Breast | 0.15 | 0.20 | 0.15 |
| Red bone marrow | 0.12 | 0.16 | 0.12 |
| Lung | 0.12 | 0.16 | 0.12 |
| Thyroid | 0.03 | 0.04 | 0.03 |
| Bone surface | 0.03 | 0.04 | 0.03 |
| Remainder | 0.30 | 0.40 | 0.30 |
| Sum | 1.00 | 1.00 | 0.75 |

The weighting factor for the remainder is equally divided between the five remaining organs or tissues recieving the highest dose equivalent.

Table 2.

| Nuclide | Radiopharmaceutical | Total ($H_E$) effective dose equivalent (mSv/MBq) | Somatically* (mSv/MBq) | Mean abs. dose in total body ($\bar{D}_{TB}$) (mGy/MBq) | $\frac{H_E}{\bar{D}_{TB}}$ |
|---|---|---|---|---|---|
| H-3 | Water | 0.015 | 0.011 | 0.015 | ++ |
| C-14 | Aminopyrine | 0.0029 | 0.0022 | 0.0029 | + |
| F-18 | Fluoride ion | 0.016 | 0.016 | 0.013 | + |
| Na-22 | Sodium ion | 3.1 | 2.4 | 2.9 | + |
| Na-24 | Sodium ion | 0.34 | 0.26 | 0.29 | + |
| P-32 | Phosphate ion | 1.7 | 1.5 | 1.5 | + |
| Ca-47 | Calcium ion (oral) | 1.5 | 1.4 | 0.40 | ++ |
| Sc-47 | Scandium ion (oral) | 0.42 | 0.41 | 0.040 | ++++ |
| Cr-51 | Chromium (III) ion | 0.11 | 0.10 | 0.058 | + |
| Cr-51 | Chromate ion (oral) | 0.035 | 0.030 | 0.0063 | +++ |
| Cr-51 | Chromium labeled denat. erythrocytes | 0.40 | 0.39 | 0.049 | ++++ |
| Cr-51 | Chromium-EDTA | 0.0024 | 0.0021 | 0.00087 | ++ |
| Cr-51 | Chromium labeled erythrocytes | 0.21 | 0.20 | 0.099 | ++ |
| Fe-55 | Iron (III) ion, citrate | 1.3 | 1.2 | 0.62 | ++ |
| Fe-59 | Iron (III) ion, citrate | 13. | 11. | 7.9 | + |
| Co-57 | Vitamin B-12 (oral) | 2.9 | 2.9 | 1.5 | + |
| Co-58 | Vitamin B-12 (oral) | 5.9 | 5.7 | 3.1 | + |
| Ga-68 | Gallium-EDTA | 0.053 | 0.050 | 0.011 | +++ |
| Se-75 | l-Selenomethionine | 2.9 | 2.1 | 2.2 | + |
| Sr-85 | Strontium ion | 0.85 | 0.69 | 0.85 | + |

Table 2, cont.

| | | | | | |
|---|---|---|---|---|---|
| Tc-99m | Pertechnetate | 0.011 | 0.0090 | 0.0038 | ++ |
| Tc-99m | Insoluble compunds (oral) | 0.025 | 0.023 | 0.0048 | +++ |
| Tc-99m | Technetium labeled albumin | 0.0064 | 0.0048 | 0.0043 | + |
| Tc-99m | Technetium labeled denat. erythroc. | 0.053 | 0.053 | 0.0052 | ++++ |
| Tc-99m | Technetium labeled DMSA | 0.016 | 0.015 | 0.0046 | ++ |
| Tc-99m | Technetium DTPA | 0.0065 | 0.0057 | 0.0030 | ++ |
| Tc-99m | Technetium labeled erythrocytes | 0.0076 | 0.0066 | 0.0049 | + |
| Tc-99m | Technetium labeled phosphorus comp. | 0.0061 | 0.0049 | 0.0024 | ++ |
| Tc-99m | Technetium labeled gluconate compl. | 0.0091 | 0.0083 | 0.0027 | ++ |
| Tc-99m | Technetium lab. liver-biliary subst. | 0.020 | 0.019 | 0.0034 | +++ |
| Tc-99m | Technetium labeled colloids | 0.013 | 0.012 | 0.0051 | ++ |
| Tc-99m | Technetium lab. makroaggr./microsph. | 0.012 | 0.012 | 0.0031 | ++ |
| Tc-99m | Technetium labeled plasmin | 0.0080 | 0.0075 | 0.0033 | ++ |
| In-111 | Indium DTPA | 0.026 | 0.023 | 0.0082 | ++ |
| In-111 | Indium labeled leukocytes | 0.63 | 0.62 | 0.17 | ++ |
| In-111 | Indium labeled lymphocytes | 0.65 | 0.63 | 0.17 | ++ |
| In-111 | Indium labeled thrombocytes | 0.74 | 0.72 | 0.17 | +++ |
| In-113 | Indium ion | 0.012 | 0.011 | 0.0047 | ++ |
| I-123 | Iodide ion (thyroid uptake: 35%) | 0.17 | 0.17 | 0.0087 | +++++ |
| I-123 | Iodide ion, blocked thyroid | 0.013 | 0.011 | 0.0077 | + |
| I-123 | Iodine labeled albumin | 0.021 | 0.016 | 0.015 | + |
| I-123 | Iodine labeled fatty acids | 0.11 | 0.11 | 0.011 | ++++ |
| I-123 | Orthoiodohippuric acid | 0.015 | 0.014 | 0.0015 | ++++ |
| I-125 | Iodide ion (thyroid uptake: 35%) | 10. | 10. | 0.19 | ++++++ |
| I-125 | Iodide ion, blocked thyroid | 0.014 | 0.012 | 0.0073 | + |
| I-125 | Iodine labeled albumin | 0.29 | 0.22 | 0.22 | + |
| I-125 | Iodine labeled fibrinogen | 0.11 | 0.10 | 0.063 | + |
| I-125 | Orthoiodohippuric acid | 0.011 | 0.011 | 0.0015 | +++ |
| I-131 | Iodide ion (thyroid uptake: 35%) | 16. | 16. | 0.26 | ++++++ |
| I-131 | Iodide ion, blocked thyroid | 0.077 | 0.065 | 0.040 | + |
| I-131 | Iodine labeled albumin | 0.68 | 0.51 | 0.48 | + |
| I-131 | Iodine labeled albumin, microaggr. | 0.037 | 0.035 | 0.017 | ++ |
| I-131 | Orthoiodohippuric acid | 0.065 | 0.062 | 0.0062 | ++++ |
| I-131 | Iodine labeled makroaggr./microsph. | 0.39 | 0.37 | 0.051 | +++ |
| I-131 | 6-Iodomethylnorcholesterol | 1.0 | 0.65 | 0.35 | ++ |
| Xe-133 | Xenon gas (inhal., with rebreathing 5 min) | 0.00069 | 0.00057 | 0.00038 | + |
| | (inhal., single breath, hold 30 s) | 0.00024 | 0.00024 | 0.00012 | ++ |
| Xe-133 | Xenon gas in solution (breathhold 30 s, rebreath 5 min) | 0.0010 | 0.00083 | 0.00057 | + |
| | (wait 10 s, breathhold 30 s) | 0.00043 | 0.00036 | 0.00024 | + |
| Yb-169 | Ytterbium DTPA | 0.048 | 0.044 | 0.013 | ++ |
| Tl-201 | Thallium ion | 0.094 | 0.058 | 0.035 | ++ |

* With the genetic contribution (0.25x(Absorbed dose to the gonads)) subtracted.

** The following intervals for the ratio $\frac{H_E}{D_{TB}}$ are indicated:

+: 1 - 2, ++: 2 - 4, +++: 4 - 8, ++++: 8 - 16, +++++:16 - 32, ++++++: 32 - 64.

## REFERENCES

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