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Technical Note

Tissue weighting factor and its clinical relevance*

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Since 1977, the International Commission on Radiological Protection (ICRP) published, revised and updated tissue weighting factors (TWFs) in human tissues/organs.[1–3] TWFs are based on estimates of the radio-sensitivity of each organ. However, TWFs change every decade or so as if it is a variable quantity (Table 1). TWFs are used in the calculation of the effective dose that is not a real quantity[4] but a conceived quantity proposed by ICRP. In computing TWFs, ICRP did not take into account the body weight, organ weight and gender difference. The value of TWFs ICRP provided: it is interesting to note that not a single biophysical factor correlate with TWFs.

Radiation sensitivity of human organs varies as a function of organ weight.[5] Smaller organs have lower radiosensitivity and in turn higher radiation tolerance dose (TD_{50}).[5] As the organ increases in size and weight by assembling many cells of different functions, TD_{50} decreases.

TWFs calculated in Tables 2 and 3, provide a new perspective. First of all, all the variables such as gender difference, organ weight and body weight are taken into account.

As Woodward and White eloquently wrote: 'The need for reliable composition and density data of human organs is a prerequisite in theoretical dosimetry involving radiation interactions in human tissues. Uncertainties in elemental compositions and mass densities of the body tissues will lead to reduced confidence in the relevance of the calculated and measured doses. Uncertainties in the elemental composition of each organ of a human body may affect the dosimtery of low- and high-energy photons. The concentrations of high atomic number elements in a tissue will strongly influence photoelectric absorption, while hydrogen content will affect the Compton scattering'.[7] ICRP did not take these factors into account in computing the TWFs and therefore effective dose (ED) cannot be relied upon. ICRP also assume that there is no difference between kV and MV energies nor there is any difference in electron density or mass density[6] in different organs. The ratio of organ weight to body weight is a close approximation of all the factors given in Table 2.

The TWFs in the present case is calculated as

$$\mathrm{TWF} = \frac{\text{Organ weight}}{\text{Body weight}} \times \frac{\dfrac{\text{Electron density}}{\text{kg} \times 10^{26}}}{\dfrac{\text{Electron density}}{\text{m}^3 \times 10^{26}}} \times \mathrm{P}\ (\text{kg/m}^3)$$

This equation takes into account all the factors that ICRP ignored.

Table 3 provides the organ weights of both male and female and the ratio of organ weight to

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body weight is calculated. In Table 3, we have taken 73 kg reference man and height of 176 cm and reference female body weight is 60 kg and height of 163 cm and their organ weight.[9] In clinical settings, the situation is different. In order to compute the organ weight of different body weight, two methods can be used to compute organ weight.

First, the organ weight and body weight of 73 kg reference man and height of 176 cm, multiply by body weight and height of the human in question. For female, body weight of 60 kg and height of 163 cm. This will provide an estimate of organ weight. The second method is to perform the CT scan of the patient and compute the volume and multiply the volume by physical density that will yield the organ weight.

Table 1. *ICRP TWF proposed in 1990 and 2007*

Organs	TWF (1990)	TWF (2007)
Bone marrow, colon, lungs, stomach	0·12	0·12
Breast	0·05	0·12
Gonads	0·20	0·08
Bladder, oesophagus, liver, thyroid	0·05	0·04
Brain		0·01
Salivary glands		0·01
Remainder tissues	0·05	0·12

Abbreviations: ICRP, International Commission on Radiological Protection; TWF, tissue weighting factor.

Table 2. *The densities of human organs along with their OW and BW of 70 kg reference man and computation of new TWF*

Organs	OW (8) (g)	Ratio of OW/BW	Electron density (7) per kg $\times 10^{26}$	Electron density (7) per $m^3 \times 10^{26}$	Physical (6,7) density (kg/m^3)	ICRP (2) TWF	New TWF
Adrenals	14	0·0002	3·324	3,424	1,030	0·05	0·0002
Bladder	45	0·0006	3·330	3,430	1,030	0·05	0·0006
Brain	1,400	0·0200	3·327	3,460	1,040	0·05	0·0197
Heart	330	0·0047	3·319	3,485	1,050	0·05	0·00476
Ovaries	11	0·00016	3·312	3,487	1,050	0·20	0·00016
Testis	17	0·00024	3·324	3,457	1,040	0·20	0·00024
Kidney	310	0·0044	3·318	3,481	1,050	0·05	0·00440
Liver	1,800	0·0257	3·312	3,511	1,060	0·05	0·02569
Lungs	1,000	0·0143	3·315	3,481	1,050	0·12	0·01429
Pancreas	100	0·0014	3·324	3,457	1,040	0·05	0·0014
Prostate	20	0·0002	3·322	3,455	1,040	0·05	0·0002
Spleen	180	0·0026	3·315	3,514	1,060	0·05	0·0026
Thyroid	20	0·0002	3·322	3,484	1,050	0·05	0·0002

Notes: numbers in parenthesis refer to the reference list. OW/BW is the ratios of OW to BW in reference man.
Abbreviations: OW, organ weight; BW, body weight; TWF, tissue weighting factor; ICRP, International Commission on Radiological Protection.

Table 3. *Human organs along with their OWs and BW (9) and computation of new tissue weighting factor*

Human organs	TD50 (Gy)	Male [OW (g)]	Female [OW (g)]	Ratio of OW/BW in male	Ratio of OW/BW in female
Bladder	80	45	34	0·0006	0·00056
Brain	60	1,400	1,257	0·0197	0·0209
Colon	55	12	96	0·0016	0·0016
Oesophagus	68	40	30	0·0005	0·0005
Heart	48	330	278	0·0045	0·0046
Kidney	28	310	271	0·0042	0·0045
Larynx	80	28	21	0·00038	0·00035
Liver	40	1,800	1,575	0·02460	0·02460
Lung	24·5	1,000	758	0·01369	0·01263
Parotid	46	50	38	0·0068	0·00063
Small intestines	55	640	488	0·00876	0·00813
Spinal cord	66·5	30	30	0·0004	0·0005
Stomach	65	150	118	0·0020	0·0019
Thyroid	80	20	18	0·00027	0·0003

Abbreviations: OW, organ weight; BW, body weight (173 kg for male and 160 kg for female); TD50, radiation tolerance dose.

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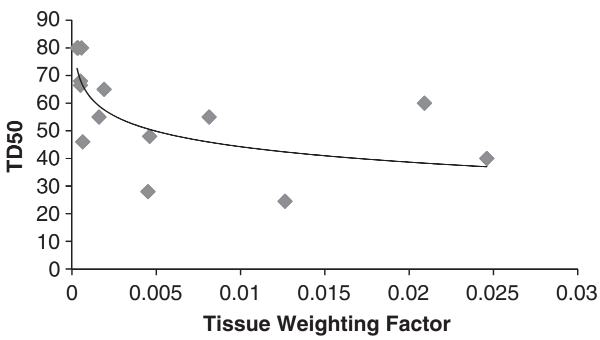

Figure 1. Correlation between ratios of organ weight to body weight (TWFs) in reference female with TD_{50}.
Abbreviation: TWF, tissue weighting factor.

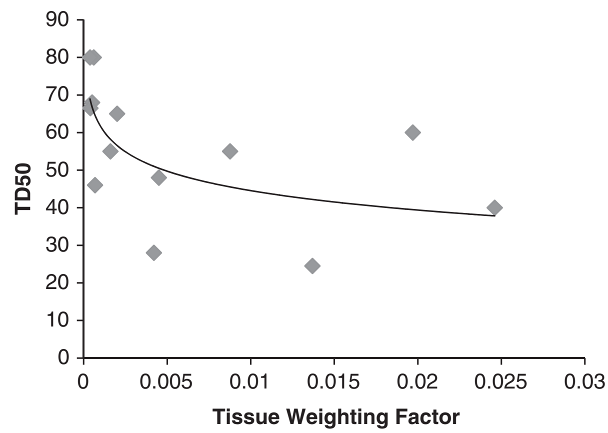

Figure 2. Correlation between ratios of organ weight to body weight (TWFs) in reference male with TD_{50}.
Abbreviation: TWF, tissue weighting factor.

The interesting aspects of TWFs are the ICRP requirement to sum to unity and individual organ risk is indeed dependent on other organs. In the present assessment TWFs are indeed sum to unity, however, they are independent of one another. The proper way to interpret TWFs is that they are an indication of organ risk, which in the present case is based on the ratio of organ weight to body weight. In the present case we preserve the sum of unity as suggested by ICRP and individual organ risk is independent of other organs. Whereas ICRP claim that their TWFs are based on the radio-sensitivity of the organ. If this is the case than how come ten organs (Table 2) have the same TWFs of 0·05, meaning that they have the same radio-sensitivity. In these ten organs the organ weight varies from 20 g to 1,800 g but the TWFs is the same? For example, the thyroid blood content is 3.6 mL and weighs only 20 g: whereas the TD_{50} is 80 Gy. Liver on the other hand, blood content is 250 mL and weighs 1,800 g and the TD_{50} is 40 Gy. The blood flow in thyroid is 50 and 350 mL/minute for liver. Is the radiation sensitivity of the two organs are the same?

Shimizu et al.[10] reported the radiation dose response of cancer mortality by site in both males and females of all ages of atomic bomb survivors. Using the constant relative risk model that assumes the risk to be of constant proportion of the background radiation at 1 Gy of different human organs for the induction of cancers, the relative risk is indeed independent of each other (organs).

One of the significance of TWFs is to calculate ED. ED is a dose quantity of health determinant due to scholastic effects from exposure to low doses. ED is a flawed concept[4] given it is based on erroneous TWFs.

The present methodology provides a convenient way to compute ED both in the KV range as well as in MV range as the ratio of organ weight/body weight is a close approximation of all the factors given in Tables 2 and 3.

To test the present theory, we abstracted the TD_{50}[11] values of several organs and using the ratio of organ weight/body weight, given in Table 3, we plotted the data. It is interesting to note that TD_{50} yield's a nice correlation with TWFs both in male and female (Figures 1 and 2) unlike ICRP TWFs.

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