TM-1221
1183.000
11/8/83

ABOUT PHANTA FOR CLINICAL NEUTRON DOSIMETRY.

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At the neutron dosimetry workshop that took place in Seattle, Washington, October 26-27, 1983, the decision was reached without justification to use a muscle tissue equivalent solution with a density of 1.030 g cm^{-3} for phanta. Here, the selection of muscle TE solution is supported but having a density of 1.040 g cm^{-3}.

Tissues and Densities.

A few tissue densities are quoted below from ICRP 23 (Report of the Task Group on Reference Man, NY, Pergamon Press, 1975). Note that ICRU 26 does not give tissue densities.

Tissue	Densities (g cm^{-3})	Tissue	Densities (g cm^{-3})
Whole blood	1.06	Lungs (condensed)	1.05
Bone, cortical	2.20	Red marrow	1.03
Bone, trabecular	1.08	Yellow marrow	0.98
Bone, whole skeleton	1.40	Muscle	1.04
Brain	1.03	Pancreas	1.05
Esophagus	1.04	Prostate	1.05
Fat	0.92	Rectum	1.04
Heart	1.03	Salivary gland	1.05
Intestine	1.04	Skin	1.10
Kidneys	1.05	Spinal cord	1.01
Larynx	1.08	Stomach	1.05
Liver	1.05		

It is clear that most soft tissues have densities between 1.03 and 1.05 g cm^{-3}. Therefore, it would seem more appropriate to select an average tissue density of 1.04 g cm^{-3} than 1.03 g cm^{-3} for soft tissue.

The range of chemical compositions of the soft tissues is rather narrow. Thus ICRU muscle is not significantly different from the other soft tissues. The parameter of interest in this assessment is the kerma weighted mean free path. Hence, the use of muscle-TE solution is an acceptable choice.

Therefore, it is now proposed that neutron beam characterizations be made in a phantom filled with muscle tissue equivalent solution having a density of 1.040 g cm^{-3}. However, measurements could still be made in other media (water, TE solution of any density, etc.) and then scaled to muscle-TE solution with density 1.040 g cm^{-3}.

Muscle TE Solutions.

At the above mentioned workshop it was further recommended that a suitable muscle-TE solution could be obtained mixing in appropriate proportions, Frigerio's low (1.011 g cm^{-3}) and medium (1.078 g cm^{-3}) density muscle-TE solutions (Phys. Med. Biol. 17, 792, 1972). An unsuccessful effort was made to find the chemicals to mix the low density solution. We could not find one of them

anywhere: malonomononitrile (C_3 HON·$H_2$0). Attempts to contact Frigerio about possible substitutions revealed he has died. Therefore, we have looked at other muscle-TE solutions.

Constantinou's Solutions. Conversing with him by telephone, he told us that, at Hammersmith, he had done characterizations of their neutron beam using muscle-TE solutions with and without trace elements but having the same densities. The two isodose distributions were undistinguishable from each other. Under the circumstances, one could mix a half muscle and half total soft tissue solution using the following Constantinou recipes:

A - muscle TE without trace element, ρ = 1.05 g cm^{-3}

water	63.84 % by weight
urea	7.50
ethylene glycol	28.6

B - total soft tissue equivalent solution, ρ = 1.03 g cm^{-3}

10 components: BJR 55, 217 (1982).

G.K.Y. Lam Solutions. Lam has published a series of recipes for muscle-TE solutions ranging in density from 1.00 to 1.13 g cm^{-3}, Med. Phys. 8, 894 (1981). The recipe for the one having a ρ = 1.040 $\pm$0.005 g cm^{-3} is,

water	72.64 % by weight	malonoitrile	4.60
glycerol	18.18	glucose	0.069
acetonitrile	4.51		

If the glucose were to be omitted from the recipe, the elemental

compositions would change as follows:

	ICRU Muscle	Lam's solution w/o glucose
H	10.2 % by weight	10.2 - 0.004 % by weight
C	12.3	12.3 - 0.028
N	3.5	3.5
O	72.9	72.9 - 0.037

Therefore, it is recommended that

1) Neutron beam characterizations be made in phanta having muscle TE solution with a ρ = 1.040 g cm^{-3}. As an alternative, measurements may be made in other liquid media and the results scaled to muscle TE, ρ = 1.040 g cm^{-3}.

2) That the modified Lam solution (no glucose) be used as the standard phantom filling medium,

water	72.64% by weight	acetonitrile	4.51
glycerol	18.18	malonoitrile	4.60

3) The density of the muscle-TE solution must be checked each time before using it. Suitable hydrometers are the Fisher precision hydrometers. There are two models, both have a density range of 1.000 to 1.070 g cm^{-3},

11-555 G - 32.5 cm long - scale smallest division 0.0005

11-556 F - 15.0 cm long - scale smallest division 0.001

Their prices are in the $10-15 range.