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ON THE DOSE TO THE STOMACH WALL FROM INJECTED ^{99m}Tc PERTECHNETATE[1]

M. R. Ford, S. F. Dreis[2], and W. S. Snyder[3]

ABSTRACT

In estimating dose to the gastrointestinal tract (GIT) it has been assumed generally that the measured activity in the tract, i.e., in the walls, is present in the contents. This assumption has been necessary because absorbed fractions for photons were available only for the source in the contents. During the past year and a half, however, absorbed fractions, or specific absorbed fractions, have been estimated for photon emitters in the walls. These calculations were performed at the Instituto de Pesquisas Energéticas e Nucleares, São Paulo, Brazil, and they will be announced at the Health Physics Society meeting and presented subsequently for publication. The estimates are for the same twelve photon energies used in computing absorbed fractions in the GIT contents as given in MIRD Pamphlet No. 5. In the work presented here the new values are applied to estimate dose to the walls of the GIT from administration of ^{99m}Tc pertechnetate using data of Kubassi, 1973. The dose to the stomach wall from photons is found to be less than the dose from non-penetrating radiation, assuming complete absorption of energy. Thus, a correct estimation of average dose to the wall requires use of absorbed fractions of energy for electrons as well as for photons. The problem is discussed and values of absorbed fractions for electrons are given which are based on a uniform distribution of the activity. However, a final resolution of the problem will require further biological data on the fraction of activity in the wall and the fraction in the contents.

The purpose of this presentation is twofold; first to announce the availability of new sets of absorbed fractions—or specific absorbed fractions-for the walls of the gastrointestinal tract as source organs, and second to illustrate the problems which arise when one attempts to use them on the basis of the slender biological data now available. Hopefully, those interested in modeling may make an effort to provide biological data if they know that dosimetric factors are available to translate their data into doses.

The gastrointestinal tract is divided into four sections or regions for purposes of dosimetry, the stomach, the small intestine, an upper large intestine, consisting of the ascending and transverse colons, and the lower large intestine, consisting of the descending colon and sigmoid colon. The anatomical specifications of the sections are given in Table I. The data on the masses of the sections and their contents are reproduced from the ICRP Report on Reference Man[16], and the values for the thicknesses of the walls have been calculated on the basis of data given in that report.

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1 Publicated in "Radiopharmaceutical Dosimetry Symposium" — Proceeding of Conference Held at Oak Ridge, Tenn., April 26-28, 1976.

2 Employee, Instituto de Pesquisas Energéticas e Nucleares, São Paulo, Brazil. Presently assigned as a student to the Health Physics Division, ORNL.

3 Consultant.

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Table 1

Dosimetric Characteristics of the GI-Tract and Contents

Section of GI-Tract	Mass of Contents (g)	Mass of Walls (g)	Thickness of Walls (cm)
Stomach	250	150	0.6
Small Intestine	400	640	0.3 – 0.4
Upper Large Intestine	220	210	0.5 – 0.7
Lower Large Intestine	135	160	0.3 – 0.8

These fours sections have been programmed as a part of the phantom which is essentially that of MIRD Phamphlet No. 5[9] with some changes of which the substitution of a gastrointestinal tract with separate walls is an example. The source is assumed to be uniformly distributed in the walls of the stomach or the upper large intestine or the lower large intestine, and 60,000 photons were used for each Monte Carlo computer calculation. The calculation was repeated for each of the 12 monoenergetic sources of photons used in MIRD Pamphlet No. 5 and dose was recorded in all the body organs. No source was placed in the small intestine because results are already available for that section. This is true because in our phantom calculations for photons, the small intestine is indistinguishable from its contents since there is no fixed position of this portion of the tract except for the ends. The movement of the tract thus results in an averaging of dose from photons over both the walls and the contents, and this average dose is accepted for both the walls and for the contents. However, for electrons the dose is computed as with any other section, but one does not need the configuration of the small intestine to estimate dose. These data constitute the bulk of the data reported here whenever the coefficient of variation is sufficiently low to warrant its use. All of these 36 calculations were performed at the Instituto de Pesquisas Energéticas e Nucleares, São Paulo, Brazil, although the code was supplied from the Oak Ridge National Laboratory (ORNL) and several computer calculations were done to insure that the calculations were indeed comparable.

Although data from these calculations have supplied most of the data reported here, there were many organ pairs whose coefficient of variation indicated considerable unreliability. In such cases a calculation involving the build-up factor of Berger[11] was substituted. The calculations for the build-up factor were also done at the Instituto de Pesquisas Energéticas e Nucleares, using a computer code from Oak Ridge, and as before calculations were done at ORNL to check that the programming and running of the code were correctly performed. Previous studies[10] have indicated that values obtained by use of the build-up factor are almost certainly within a factor of 2, and a value obtained by a Monte Carlo calculation with a coefficient of variation in excess of 50% can hardly claim this much. It is planned to use all these values in future calculations at our laboratory and they will be published soon.

To illustrate the use of these new specific absorbed fractions we shall consider ^{99m}Tc pertechnetate. ^{99m}Tc has a decay scheme given in MIRD Pamphlet No. 10[3] which is, with some grouping of the data, equivalent to that shown in Table II. Most of the energy is emitted in the form of photons, but there is sufficient energy in the form of electrons that when one assumes all this energy is absorbed the dose from electrons is the major contributor to dose. After some consideration we have adopted the metabolic model proposed by Kubassi[5]. This model is quite detailed since it lists

15 source organs. Unfortunately it is the result of a thesis and so has not been available to the authors in its original form.

Table II

Simplified Decay Data for Technetium-99m (Half life = 6.03 hr)

Radiations	Mean Number per Desintegration	Mean Energy per Particle (MeV)
Gamma	0.88	0.14
X-Ray	0.077	0.018
Internal Conversion Electron	0.12	0.12
Auger Electrons	0.021	0.016

However, our principal interest is centered in the gastrointestinal tract and the model does list the stomach and the colon as source organs. We must interpret this as meaning that the activity is in the sections and not merely in the contents of these sections. The time sequence somewhat reinforces this view. Moreover in a review by Smith[7] published in 1965 he mentions that even when pertechnetate is injected there is considerable activity present in the gastric mucosa and he cites studies of McAfee et al.[6] and Harper et al.[4].

Unfortunately these references do not make it clear how extensively the stomach wall was sampled. The reference for Kubassi does not mention the gastric mucosa but only the stomach. Thus, our first dilemma is that of whether we should use the source as uniform in the wall or only in the gastric mucosa. We would not expect a great difference in dose due to the photon irradiation but the beta radiation will differ more. In fact, taking the activity in the stomach as being uniform in the contents we obtain the data shown in the top line of Table III, but if we suppose it is uniform in the stomach wall we get the data in the second line. It makes a difference of about 50% in the photon dose but there is a difference of about a factor of 3 in the electron dose. These values are only for the activity in the stomach contents, or in the stomach wall, and these doses are shown in the first two lines of the table. Of course, dose from other organs outside the stomach will be the same for either model and when these are included the last two lines of the table are obtained. Here the difference in the total dose received is only a factor of 2.

If the activity is assumed to be all in the gastric mucosa, the difference in dose is much greater than if it is assumed to be in the stomach wall or in the stomach contents. The stomach wall is programmed as having a total thickness of about 0.6 cm. The first millimeter contains the gastric pits, a second strip of about 1 mm thickness is the gastric mucosa, and the third 1 mm thick division contains the proliferating cells which produce the cells that move upward to the surface and are lost. Of course, none of this detail is really present in the phantom except for the total thickness. As a separate calculation, we have programmed a slab model of total thickness 0.6 cm, and this is subdivided as suggested above, i.e., an outer strip or layer, a second layer, as the gastric mucosa, etc., each layer being 1 mm in width with the gastric mucosa containing the source. Perhaps this would be the place to acknowledge that our discussions with Dr. Lushbaugh and the references he has supplied have been very helpful, although the crudeness of the model is our own responsibility.

Table III

Dose to Stomach Wall by Two Models From Injection of ^{99m}Tc Pertechnetate

Source location	Dose (rads/mCi)		
	Photons	Electrons	Total
Stomach contents	9.78×10^{-3}	1.43×10^{-2}	2.41×10^{-2}
Stomach wall	1.45×10^{-2}	4.97×10^{-2}	6.45×10^{-2}
All source tissues including stomach contents	1.93×10^{-2}	1.73×10^{-2}	3.66×10^{-2}
All source tissues including stomach wall	2.43×10^{-2}	5.26×10^{-2}	7.69×10^{-2}

Using this slab model, we have computed absorbed fractions for 20 monoenergetic electrons with energies from 0.01 to 3 MeV, and these are shown in Table IV. The electron energies are listed in the first column, and the next column contains absorbed fractions in the gastric mucosa, which is the second division of the slab and which contains all the activity. The values in the third column are absorbed fractions for the adjacent strips, that is, the values in this column could apply to either strip bordering the source region. The fourth column contains absorbed fractions for the entire wall as represented by the six strips or divisions, and the range in tissue including straggling which Berger[2] estimates to be 1.2 times the continuous slowing down approximation (CSDA) range is shown in the last column. The values in this table were computed using the new point kernel of Berger for a point source of electrons.

Of course, these data can be applied to any radionuclide, but for beta particles they will need considerable averaging. Here we are interested in ^{99m}Tc, and this gives a total absorbed fraction for electrons of 95.6%, that is, if the activity is uniformly distributed in the gastric mucosa, over 95% of the electron energy would be absorbed there. This means that if the activity is entirely in the gastric mucosa and no activity is present elsewhere in the stomach wall, the electron dose to the gastric mucosa would be multiplied by essentially a factor of 5 (the ratio of the concentrations) above what was shown in Table III for electrons assumed to be distributed uniformly in the stomach wall. We offer this example only to stress that if the nuclear clinician demands realistic dose levels, he must be prepared to supply data on the distribution of activity which is equally realistic. Thus, the new absorbed fractions for activity distributed uniformly in the walls of the tract will require rather detailed information on the distribution of the activity if they are used to produce doses, and any departure from uniformity may produce doses which vary considerably from the doses computed. But this is true generally for other organs as well as for the gastrointestinal tract.

Thus, it seems clear that no amount of purely dosimetric data will resolve the question of the dose being received by the tissues of the body. It does emphasize the importance of good metabolic models. Is the activity only in the gastric mucosa or is it fairly uniform throughout the stomach wall, or is it largely in the contents of the stomach? The dose to the stomach wall will depend largely on the

Table IV

Ranges and Absorbed Fractions of Electron Energy in the Gastric Mucosa and Adjacent Tissue

Electron Energy (MeV)	Absorbed Fractions in the Target Regions			Range in Tissue (cm)
	Source Region 1 mm layer (Gastric Mucosa)	1 mm Layer Adjacent to Source	Total Wall	
0.01	~ 1	3.25×10^{-4}	~ 1	3.05×10^{-4}
0.015	~ 1	6.66×10^{-4}	~ 1	6.21×10^{-4}
0.02	9.98×10^{-1}	1.11×10^{-3}	~ 1	1.03×10^{-3}
0.03	9.95×10^{-1}	2.28×10^{-3}	~ 1	2.11×10^{-3}
0.04	9.92×10^{-1}	3.78×10^{-3}	~ 1	3.51×10^{-3}
0.05	9.89×10^{-1}	5.59×10^{-3}	~ 1	5.20×10^{-3}
0.06	9.85×10^{-1}	7.68×10^{-3}	~ 1	7.15×10^{-3}
0.08	9.75×10^{-1}	1.26×10^{-2}	~ 1	1.18×10^{-2}
0.10	9.63×10^{-1}	1.84×10^{-2}	~ 1	1.72×10^{-2}
0.15	9.28×10^{-1}	3.61×10^{-2}	~ 1	3.48×10^{-2}
0.2	8.85×10^{-1}	5.73×10^{-2}	~ 1	5.42×10^{-2}
0.3	7.87×10^{-1}	1.07×10^{-1}	~ 1	1.02×10^{-1}
0.4	6.78×10^{-1}	1.62×10^{-1}	~ 1	1.56×10^{-1}
0.5	5.73×10^{-1}	2.05×10^{-1}	9.92×10^{-1}	2.14×10^{-1}
0.6	4.83×10^{-1}	2.24×10^{-1}	9.70×10^{-1}	2.74×10^{-1}
0.8	3.85×10^{-1}	2.14×10^{-1}	9.07×10^{-1}	4.00×10^{-1}
1.0	3.18×10^{-1}	1.92×10^{-1}	8.50×10^{-1}	5.29×10^{-1}
1.5	2.26×10^{-1}	1.48×10^{-1}	7.34×10^{-1}	8.56×10^{-1}
2	1.78×10^{-1}	1.23×10^{-1}	6.27×10^{-1}	1.18
3	1.27×10^{-1}	9.34×10^{-2}	4.85×10^{-1}	1.83

answer to this question. It would make a difference of about a factor of 10 in the answer if the activity were largely in the gastric mucosa rather than in the contents of the stomach.

DISCUSSION

LATHROP: We did a study on a dog that had a Heidinhein pouch, which is a small portion of the stomach that has been isolated from the rest of the stomach and has an opening to the outside. I'm the first to admit that dogs aren't people but maybe it's a little helpful in this situation. We found that essentially all of the radioactivity was in the washings from the pouch and that very little was in the walls of the pouch.

FORD: That's very interesting. We suspect that there is activity in the contents, walls and mucosa.

RESUMO

Na estimativa da dose no trato gastro-intestinal (TGI) foi suposto que a atividade medida no trato, isto é, nas paredes do sistema gastro-intestinal, está presente no conteúdo do TGI. Esta suposição foi necessária porque as frações absorvidas para fótons só são disponíveis quando a fonte está no conteúdo do TGI. Contudo, há um ano e meio atrás, frações absorvidas ou frações absorvidas específicas, foram estimadas para emissores gama contidos nas paredes do TGI. Estes cálculos foram feitos no Instituto de Pesquisas Energéticas e Nucleares, São Paulo, Brasil, e serão apresentados na reunião anual da Health Physics Society e subsequentemente publicados. As estimativas são para as mesmas doze energias gamas usadas nos cálculos das frações absorvidas no conteúdo do TGI como mostrados no MIRD Pamphlet Nº 5. No trabalho aqui apresentado os novos valores das frações absorvidas específicas foram usados para estimar a dose nas paredes do TGI em consequência da administração de pertecnetato-^{99m}Tc, usando dados de Kubassi, 1973. A dose nas paredes do estômago, devido aos fótons são menores que a dose devido à radiação não penetrante, supondo absorção completa da sua energia. Desse maneira, uma estimativa correta da dose média nas paredes requer o uso da fração absorvida de energia tanto para os elétrons como para os fótons. O problema é discutido e os valores das frações absorvidas para elétrons são apresentados e se baseiam numa distribuição uniforme de atividade. Contudo, uma solução final do problema requer mais dados biológicos sobre a fração de atividade nas paredes e a fração no conteúdo.

Os objetivos desta apresentação são dois: primeiro, anunciar a disponibilidade do novo conjunto de frações absorvidas — ou frações absorvidas específicas — para as paredes do TGI como órgãos fontes, e, segundo, para ilustrar os problemas que se apresentam quando se tenta usá-los com base nos dados biológicos escassos, disponíveis no momento.

Espera-se que aqueles interessados em desenvolver modelos possam prover dados biológicos assim que souberem que fatores dosimétricos são disponíveis para converter os seus dados em dose.

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INSTITUTO DE PESQUISAS ENERGÉTICAS E NUCLEARES
Caixa Postal, 11 049 – Pinheiros
CEP 05508
01000 – São Paulo – SP

Telefone: 211-6011
Endereço Telegráfico – IPENUCLEAR
Telex – (011) 23592 - IPEN - BR