Gastroesophageal Scintiscanning in a Pediatric Population: Dosimetry

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The dosimetry associated with orally administered [^{99m}Tc]sulfur colloid for the diagnosis of gastroesophageal reflux has not been adequately described for the pediatric populations. Standard MIRD methodology was performed for the following: newborn, 1, 5, 10, and 15 yr old, and adult standard man. The critical organ for all pediatric groups was the lower large intestine with absorbed dose of 0.927, 0.380, 0.194, 0.120 and 0.0721 rad/100 μCi, respectively. For the adult the critical organ was the upper large intestine with an absorbed dose of 0.0518 rad/100 μCi. These data should be considered when administering [^{99m}Tc] sulfur colloid orally in a pediatric population.

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In an effort to more accurately diagnose the etiology of gastroesophageal reflux in children, a radiopharmaceutical method using orally administered technetium-99m (^{99m}Tc) sulfur colloid was developed to measure gastric emptying time (*1–5*). While this test has become widespread in the literature, a detailed dosimetric analysis for the pediatric population has been lacking. The published radiation doses associated with this test, as summarized in Table 1, are inadequate since the dosimetry reported ignores the lower segments of the gastrointestinal tract (*1–2*). The purpose of this report is to more accurately define the radiation burden from [^{99m}Tc]sulfur colloid to various segments of the pediatric gastrointestinal tract.

TABLE 1
Published Dosimetric Values for [^{99m}Tc]Sulfur Colloid Gastroesophageal Scanning in Children

Organ	mrad/μCi	Patient	Ref. no.
Whole body	0.20	Adult	*1*
Whole body	0.22	Newborn	*4*
Whole body	0.065	1 yr	*4*
Stomach	2.0	Newborn	*4*
Stomach	0.5	1 yr	*4*
Gonads	0.113	Newborn	*4*
Gonads	0.038	1 yr	*4*
Stomach	0.093	Adult	*10*
Small intestine	0.27	Adult	*10*
Upper large intestine	0.82	Adult	*10*
Lower large intestine	0.32	Adult	*10*

MATERIALS AND METHODS

In order to calculate the absorbed dose to various segments of the gastrointestinal tract accurately, "times of entry" and "mean resident times" of the radioactive material are needed. For adults these values are easily obtained, as shown in Table 2 (*6*). In the pediatric population, however, variations in these values exist in the literature and average values were therefore chosen, as shown in Table 3 (*7*).

The methodology employed for the radiation dose determinations was that of the MIRD "S" method (*8*). Pediatric "S" values were supplied by the Radiopharmaceutical Internal Dose Information Center at Oak Ridge (*9*). Calculations were performed for the following: newborn, 1, 5, 10, and 15 yr old. In addition, similar calculations were completed for an adult standard man.

The theory associated with the calculation of the mean absorbed dose, D, from a specified radionuclide to target organ, t, from source organ, s, is adequately described elsewhere (*8*).

$$D_t[\text{rad}] = A_s[\mu\text{Ci-hr}]S_{t\leftarrow s}[\text{rad}/\mu\text{Ci-hr}].$$

Determination of Cumulative Activity (A)

For our purposes the cumulated source activity in organ s would be a function of the time of entry and effective half-time ($T_{1/2_e}$) of the [^{99m}Tc]sulfur colloid in each segment of the gastrointestinal tract (GIT).

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TABLE 2
[^{99m}Tc]Sulfur Colloid Gastrointestinal Transit in Adults (*6*)

Section of GI tract	$T_{1/2b}$ (hr)	Time of entry (hr)	$T_{1/2e}$* (hr)
Stomach (S)	1	0	0.857
Small intestine (SI)	4	1	2.4
Upper large intestine (ULI)	13	5	4.11
Lower large intestine (LLI)	24	13	4.80

$$^{*}T_{1/2_e} = \frac{(T_{1/2b})(T_{1/2p})}{(T_{1/2b})+(T_{1/2p})}.$$

$$A = (1.44)(\text{activity administered orally}) (T_{1/2_e})(e^{-0.1151t})\mu\text{Ci-hr}.$$

Using the above formula and the data contained in Tables 2 and 3, cumulative activity (A) values for adult and pediatric populations were determined (Table 4).

RESULTS

The GIT radiation absorbed doses for the oral model systems described above were calculated for the various age groups using the S values in Table 5 (*9*). The methodology used has been described previously and is illustrated for the stomach as follows (*8*):

$$D_{STO} = A_{STO}S_{STO \leftarrow STO} + A_{SI}S_{STO \leftarrow SI} + A_{ULI}S_{STO \leftarrow ULI} + A_{LLI}S_{STO \leftarrow LLI}.$$

Similar calculations were performed for children ages 1, 5, 10 and 15 yr old, and for the adult standard man. These data are summarized in Table 6 for an oral dose of 100 μCi [^{99m}Tc] sulfur colloid.

DISCUSSION

Orally administered [^{99m}Tc]sulfur colloid for the diagnosis of gastroesophageal reflux is a much quoted procedure in the literature (*1–5*). The dosimetry asso-

TABLE 3
[^{99m}Tc]Sulfur Colloid Gastrointestinal Transit in Pediatric Population (*7*)

Sections of GI tract	$T_{1/2b}$ (hr)	Time of entry (hr)	$T_{1/2e}$* (hr)
Stomach (S)	1.0	0	0.857
Small intestine (SI)	3.0	0.5	2.0
Upper large intestine (ULI)	6.5	3.5	3.12
Lower large intestine (LLI)	18	6.5	4.5

$$^{*}T_{1/2_e} = \frac{(T_{1/2b})(T_{1/2p})}{(T_{1/2b})(T_{1/2p})}.$$

TABLE 4
[^{99m}Tc]Sulfur Colloid Cumulative Activity Values for Adult and Pediatric Population

Organ	Adult (μCi-hr)	Pediatric (μCi-hr)
Stomach	1.23	1.23
Small intestine	3.08	2.72
Upper large intestine	3.33	3.0
Lower large intestine	1.55	3.07

TABLE 5
Pediatric "S" Values (rad/μCi-hr) for ^{99m}Tc (*9*)

Target organs	Source organs: STO	SI	ULI	LLI
Newborn				
STO	2.9E-03	2.89E-05	3.82E-05	2.10E-05
SI	2.82E-05	1.13E-03	1.25E-04	7.55E-05
ULI	3.40E-05	1.40E-04	1.8E-03	4.13E-05
LLI	1.62E-05	6.79E-05	3.43E-05	2.92E-03
Ovaries	1.20E-05	1.04E-04	7.60E-05	1.51E-04
Testes	3.45E-06	9.37E-06	8.31E-06	2.69E-05
Thyroid	2.84E-06	1.15E-06	2.21E-06	1.03E-06
Whole body	1.62E-05	2.21E-05	1.93E-05	2.02E-05
1 yr old				
STO	6.8E-04	1.52E-05	1.96E-05	1.01E-05
SI	1.45E-05	4.67E-04	6.77E-05	4.09E-05
ULI	1.81E-05	7.25E-05	7.89E-04	2.22E-05
LLI	7.53E-06	3.54E-05	1.66E-05	1.19E-03
Ovaries	5.66E-06	5.50E-05	4.2E-05	7.71E-05
Testes	1.25E-06	4.36E-06	4.2E-06	1.22E-05
Thyroid	1.37E-06	4.03E-07	5.88E-07	9.63E-06
Whole body	7.25E-06	1.17E-05	9.40E-06	3.18E-07
5 yr old				
STO	3.5E-04	8.9E-06	1.14E-05	5.74E-06
SI	8.65E-06	2.5E-04	4.33E-05	2.52E-05
ULI	1.10E-05	4.6E-05	4.90E-04	1.29E-05
LLI	4.14E-06	2.1E-05	1.03E-05	6.05E-04
Ovaries	3.32E-06	3.32E-05	2.69E-05	4.71E-05
Testes	3.01E-07	2.28E-06	1.97E-06	6.80E-06
Thyroid	5.62E-07	1.18E-07	1.94E-07	9.29E-08
Whole body	5.19E-06	6.67E-06	5.95E-06	5.99E-06
10 yr old				
STO	2.11E-04	5.71E-06	7.47E-06	3.53E-06
SI	5.59E-06	1.59E-04	3.03E-05	1.75E-05
ULI	6.97E-06	3.36E-05	2.57E-04	8.27E-06
LLI	2.51E-06	1.5E-05	6.32E-06	3.72E-04
Ovaries	1.91E-06	2.30E-05	1.83E-05	3.32E-05
Testes	1.45E-07	1.22E-06	1.02E-06	4.49E-06
Thyroid	1.85E-07	5.73E-08	7.64E-08	2.88E-08
Whole body	3.49E-06	4.45E-06	3.98-06	4.04E-06
15 yr old				
STO	1.53E-04	3.7E-06	5.2E-06	2.34E-06
SI	3.53E-06	9.56E-05	2.05E-05	1.16E-05
ULI	4.40E-06	2.28E-05	1.52E-04	5.14E-06
LLI	1.53E-06	1.04E-05	4.01E-06	2.21E-04
Ovaries	1.12E-06	1.52E-05	1.27E-05	2.21E-05
Testes	5.01E-08	6.05E-07	4.71E-07	2.56E-06
Thyroid	9.90E-08	1.77E-08	2.04E-08	7.36E-09
Whole body	1.96E-06	2.95E-06	2.39E-06	2.46E-06

TABLE 6
Dosimetry Associated with Oral Administration of 100 μCi [^{99m}Tc]Sulfur Colloid for Several Age Groups

Organ	rad/100 μCi					
	Newborn	1 yr	5 yr	10 yr	15 yr	Adult
STO	0.383	0.093	0.0507	0.0308	0.0221	0.0187
SI	0.372	0.164	0.0901	0.0583	0.0361	0.0315
ULI	0.596	0.267	0.164	0.0896	0.0539	0.0518
LLI	0.927	0.380	0.194	0.120	0.0721	0.0329
Ovaries	0.0993	0.0420	0.033	0.0722	0.00149	0.0102
Testes	0.0176	0.00717	0.00334	0.0108	0.0011	0.00029
Thyroid	0.00164	0.00062	0.000215	0.00007	0.00003	0.00002
Whole body	0.0200	0.0107	0.00633	0.00407	0.00268	0.00185

ciated with this test has been inadequate and not truly representative of the radiation burden to a pediatric population. Adult dosimetric values published previously (Table 1) for this test essentially agree with the values reported above except for the stomach and whole body doses which are a factor of two higher and 10.8 lower in Table 6. This difference could be accounted for by the variable organ retentions of the [^{99m}Tc]sulfur colloid in our dosimetric assumptions. Published values for the pediatric population, however, are either lacking or incomplete relative to reporting the radiation burden along the entire gastrointestinal tract (*2*).

It should be emphasized that the dosimetry reported above assumes normal handling of the colloidal material. A pathologic state may alter the transit times through the gastrointestinal tract and thus affect the dosimetric values. Even positioning of the child is important. For example, in a barium roentgenographic study 40–50% retention was observed for the stomach 10 hr after the meal. It was concluded that this increased stomach retention was due to accumulation of air on the distal end of the stomach when the child was kept lying posteriorly (*11*). Whether this type of behavior is similar for [^{99m}Tc]sulfur colloid is presently unknown.

This report more accurately defines the dosimetry associated with a pediatric population receiving [^{99m}Tc] sulfur colloid orally for the diagnosis of gastroesophageal reflux. The values reported are significantly higher than those for an adult and should be considered whenever this test is indicated for a pediatric case.

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