MORE HANDBOOKS OF TISSUE DOSES IN DIAGNOSTIC RADIOLOGY

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ABSTRACT

An additional handbook for determining tissue doses from the upper gastrointestinal (GI) fluoroscopy examination is now available and a similar handbook addressing computed tomography (CT) examinations is being developed. Also, a complete recomputation of tissue-air-ratios is underway for revising the handbook currently available for common radiographic projections. All three efforts utilize a Monte Carlo radiation transport code and current anthropomorphic reference adult male and female phantoms.

COMPLETED HANDBOOK ON UPPER GI FLUOROSCOPY EXAMINATION

The handbook of tissue doses for the upper gastrointestinal fluoroscopic examination contains data for a set of discrete x-ray fields that can be used to simulate a dynamic upper GI examination. The handbook presents the absorbed dose to various tissues per unit entrance exposure (free-in-air) as a function of the x-ray fields and x-ray beam qualities typically used for the upper GI examination with $BaSO_4$ contrast material in the GI tract.

The dynamic upper GI fluoroscopic examination can be approximated with a set of discrete x-ray fields (1). The protocol for this involved videotaping the examination, while fluoroscopic technique factors, tube current and tube potential were simultaneously recorded on the audio track of the videotape. Subsequent analysis allowed the dynamic examination to be segmented into a series of discrete x-ray fields uniquely defined by field size, projection, and anatomical region. The anatomical regions associated with the upper GI examination were observed to be the upper, middle and lower esophagus, the gastroesophageal junction, the stomach, and the duodenum. The projections associated with each anatomical region are the left posterior oblique (LPO) and the right anterior oblique (RAO).

Once the discrete x-ray fields were identified, the technical specifications of each field could be used with mathematical anthropomorphic phantoms and a Monte Carlo radiation transport code to obtain tables of conversion factors (i.e. tissues doses per unit of entrance exposure, free-in-air). These phantoms and codes have evolved for use in medical x-ray dosimetry over a number of years. The conversion factors can then be used to estimate tissue doses for upper GI fluoroscopy.

The mathematical phantom used to represent the reference male patient was the ADAM phantom, developed at the Gesellschaft für Strahlen-und Umweltforschung (GSF) (2) by modification of the original MIRD-5 phantom of the Internal Radiation Dose Committee (3). The reference female patient was represented by GSF's EVA phantom (2).

Each table contains entries for male and female reference patients, giving the selected tissue doses per unit of entrance exposure, free-in-air. The values tabulated are for the average absorbed dose in the tissue (weighted over its entire mass). The user must take into consideration the actual entrance exposure at a give facility to estimate the absorbed dose for that facility.

An example of the type of data in the handbook is given in Table 1 for the duodenum anatomical region, LPO projection.

Table 1. Duodenum, LPO - tissue dose (mGy) per 1 mC/kg entrance exposure, free-in-air

Description of projection: The patient is oriented with the back to the x-ray table, the left posterior side against the table, angled at a nominal 30 degrees from a true posterior-anterior central ray. The distinguishing characteristic of the anatomical region is that it is centered on the duodenum. Field size: 11.4 cm x 11.4 cm at the image receptor. SID = 80 cm; SSD = 50 cm.

Note: Data entries apply to both single and double barium contrast procedures.

kVp	80		100		120	
HVL(mm Al)	4.0		5.0		5.5	
Tissue	Male	Female	Male	Female	Male	Female
Thyroid	+	+	+	+	+	+
Esophagus	0.02	0.02	0.04	0.03	0.04	0.03
Breast		+		0.02		0.02
Lung	0.02	0.02	0.03	0.03	0.04	0.03
Active Bone Marrow	0.63	0.81	0.82	1.01	0.90	1.09
Stomach	0.13	0.17	0.19	0.22	0.21	0.23
Colon	0.24	0.31	0.32	0.43	0.38	0.47
Bladder	0.01	+	0.02	0.01	0.02	0.01
Liver	0.18	0.27	0.25	0.39	0.30	0.43
Testis	+		+		+	
Uterus		0.04		0.06		0.06
Ovary		0.04		0.05		0.06
Trunk	0.35	0.34	0.39	0.39	0.43	0.43

+ Less than 0.01 mGy per mC/kg.

The tissues for which data are tabulated are those for which the International Commission on Radiological Protection (ICRP) has provided risk coefficients for cancer mortality, genetic effects and in utero effects (4). For both the male and female patient these include: thyroid, esophagus, lung, active bone marrow, stomach, colon, bladder, liver and trunk tissue. The average absorbed dose in the trunk tissue is used as an indicator for the other tissues in the trunk of the body not specifically named. Trunk tissue excludes the lungs and skeletal tissues in the trunk. In addition, testis tissue is included for the male patient, and breast, uterus and ovary tissues are included for the female patient. The average absorbed dose in the uterus is used as the absorbed dose in the embryo, and is strictly applicable only in the first two months of pregnancy.

Data are given for the following three kVp and HVL combinations: 80 kVp, 4.0 mm Al HVL; 100 kVp, 5.0 mm Al HVL; 120 kVp, 5.5 mm Al HVL.

PLANNED HANDBOOK ON COMPUTED TOMOGRAPHY EXAMINATIONS

The handbook of tissue doses in computed tomography will contain data for the range of CT examinations observed in practice. The phantoms will be adapted to the geometrical and radiation exposure complexities of CT examinations. The handbook will present the absorbed dose to tissues from CT examinations per unit of computed tomography dose index (CTDI), a measurement manufacturers are required to provide to clinical users under the United States federal performance standard for CT equipment (5).

First, absorbed doses to tissues per unit CTDI will be calculated for contiguous one-centimeter slices of both the male (ADAM) and the female (EVA) phantoms, from the apex of the head to the base of the torso. (i.e. 24 head slices and 70 torso slices). The data will encompass kVp and filtration conditions that cover the range of design for current CT systems.

From the basic set of data for the contiguous one-centimeter slices, tissues doses per unit of CTDI will be computed and presented for specific head and body CT examinations, by accumulating the tissue doses from the required slices for each examination. The handbook user will be able to select the relevant values from the handbook and apply the values of CTDI provided by the CT system manufacturer or determined locally to obtain tissue doses for the examination.

UPDATE OF HANDBOOK ON COMMON PROJECTIONS IN DIAGNOSTIC RADIOLOGY

The revised handbook of selected tissue doses for common projections in diagnostic radiology will contain a complete and expanded recomputation of the data published in December 1988 (6). The expansion will consist of separate entries for a reference adult male and a reference adult female patient, additional oblique projections, an expanded list of tissues, and reformulation of a radiation detriment index.

Approximately 17,700 separate computer runs are underway. Tissue-air-ratios will be generated for appropriate tissues in each of two phantoms. The anticipated computer runs include: up to 8 different clinical projections (i.e. PA, LPO, LL, LAO, AP, RAO, RL, RPO) for each phantom; 160 to 320 4 cm x 4 cm plane parallel beams (grids) per clinical projection; and 4 to 7 monoenergetic energies per grid.

The expanded set of tissue-air-ratios will permit a much greater range of clinical conditions to be addressed than previously available, and the expanded set of tissue-air-ratios will be incorporated into the computer program for tissue doses in diagnostic radiology (7) now widely distributed and in use throughout the world.

REFERENCES

1. Suleiman, O.H., J. Anderson, B. Jones, G.U.V. Rao and M. Rosenstein. Tissue doses in the upper gastrointestinal fluoroscopy examination. Radiology,178:653 (1991).

2. Kramer, R., M. Zankl, G. Williams and G. Drexler. The calculation of dose from external photon exposures using reference human phantoms and Monte Carlo methods. Part I: The male (Adam) and female (Eva) adult mathematical phantoms. GSF-Bericht-S-885. Gesellschaft für Strahlen- und Umweltforschung mbH, München (1982).

3. Snyder, W.S., M.R. Ford, G.G. Warner, and H.L. Fisher, Jr. Estimates of absorbed fractions for monoenergetic phantom sources uniformly distributed in various organs of a heterogeneous phantom. Journal of Nuclear Medicine, Supplement Number 3, Pamphlet 5 (August 1989).

4. 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60. Annals of the ICRP, Volume 21, No. 1-3. Pergamon Press, Oxford (1991).

5. Food and Drug Administration, 21 CFR Part 1020, Diagnostic x-ray systems and their major components; amendments to performance standard; Final rule, Federal Register 49: 34698-34714 (1984).

6. Rosenstein, M. Handbook of selected tissue doses for projections common in diagnostic radiology. HHS Publication (FDA) 89-8031, Food and Drug Administration, Rockville, Maryland (1988).

7. Peterson, L.E. and M. Rosenstein, Computer program for tissue doses in diagnostic radiology (for VAX and IBM-compatible PC systems). Food and Drug Administration, Rockville, Maryland (1989).