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ESTIMATION OF CONVERSION COEFFICIENTS FROM DOSE-AREA PRODUCT TO EFFECTIVE DOSE FOR BARIUM MEAL EXAMINATIONS FOR ADULT PATIENTS

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Abstract

The aim of the current study was to establish conversion coefficients (CCs) from dose-area product to effective dose for most common barium meal (BM) fluoroscopic examination. The study was based on data collection in two X-ray rooms in a major university hospital in St-Petersburg, Russia that allowed evaluating a structure of BM fluoroscopic examinations and developing a computed model of effective dose estimation using PCXMC 2.0 software. Results indicate that effective doses and the CCs were mainly influenced by the structure (contribution of different projections) and by the parameters (field size and energy characteristics of the X-ray beam) of the fluoroscopic examination. Resulting values of CCs estimated in the study were comparable with the published data for BM examinations.

1. INTRODUCTION

Justification and optimization are necessary and efficient ways to reduce both individual patient and collective risk from fluoroscopic examinations, that are associated with relatively high patient doses. Barium meal examinations (BM) are among most common fluoroscopic examinations, corresponding to 38% contribution to the collective dose from fluoroscopic examinations in Russia [1]. It is necessary to assess and optimize the level of exposure of the patients from these types of examinations.

Effective dose (E, mSv) was selected as the most practically suitable dose quantity for the issues of justification and optimization. Effective dose is estimated using conversion coefficients (CCs) that relate effective dose with dose-area product (DAP, cGy*cm^2). CCs are highly dependent on the exposure conditions (energy spectra of an X-ray beam, exposure geometry and examined anatomic area) [2]. Usually only a limited set of CCs for certain exposure conditions is available [2].

Hence, the aim of the current study was to calculate conversion coefficients (CCs), relating E with DAP for BM fluoroscopic examinations. That required to evaluate the structure of the selected fluoroscopic examinations, to collect the relevant patient dose and clinical protocol data, and to develop a computational model of patient exposure.

2. MATERIALS AND METHODS

Data for E estimation was collected on the base of two X-ray rooms, belonging to surgical (SD) and therapy (TD) departments in St-Petersburg State Mariinsky hospital. Fluoroscopic protocols significantly varied between these X-ray rooms. Examination data was collected for two samples of 20 and 26 typical patients in SD and TD departments correspondingly.

All the examinations were performed on two digital KRT-Electron (JSC "NIPK "Electron", Russia) X-ray units. These remotely guided X-ray units with an over-couch X-ray tube and a CCD-matrix detector are commonly used for fluoroscopic examinations and compose up to 70% of all fluoroscopic X-ray units in St-Petersburg. Both X-ray units were installed in 2005-2007 period and have identical settings (focal-image distance 115 cm; grid 110 lines/inch, R=13:1, F=180 cm; total filtration of 5 mm Al), varying only by a detector size (12' and 16' for SD and TD departments correspondingly). Imaging was performed using default vendor protocols with automated brightness control (ABC) without the digital image intensification.

The preliminary structure of BM examinations was estimated based on the existing clinical protocols and information from the radiologists. Patient positioning, examination structure, irradiation speed and total time of irradiation were selected by the radiologists individually for each patient based on their personal experience or preferences, patient condition and preliminary diagnosis. Each examination was divided into a set of standardized fluoroscopy phases and X-ray images, specified by the examined anatomic region and the projection of patient exposure. The following data was collected for each fluoroscopy phase and for each X-ray image taken for each patient: patient position (standing, supine, prone, recumbent), projection, total fluoroscopy time (s), fluoroscopy speed (frames/s), field size (cm*cm), average tube voltage (kV), total DAP (cGy*cm^2). Data was collected manually by the authors using dedicated spreadsheets. All examinations were digitally recorded in a DICOM format and exported from PACS; these records were used for computational modelling the exposure of the patients.

Effective dose calculation was performed using a PCXMC 2.0 software (STUK, Finland) [3]. Each fluoroscopic phase, in turn, was described by a set of discrete irradiation fields, corresponding to the locations of the relevant organs and tissues. If there was no significant movement of an X-ray tube and only the single organ as irradiated (i.e. fluoroscopy of the stomach with contrast), the phase consisted of a single irradiation field. On the other hand, if different organs were exposed and the tube movement was significant (i.e. survey fluoroscopy of the oesophagus), the phase consisted of several irradiation fields, each corresponding to a certain relevant anatomic location. Exposure parameters for each irradiation field within a single phase were considered to be constant.

Coordinates for the selected irradiation fields were determined for each projection. A total of 8 projections were selected to describe the exposure of the patient: anteroposterior (AP), posteroanterior (PA), left lateral (LATL), right lateral (LATR), left posterior oblique (LPO), right posterior oblique (RPO), left anterior oblique (LAO), right anterior oblique (RAO). For the simplicity of modelling the exposure in oblique projections it was assumed that all of them were 45°-fold.

Effective doses and CCs for each geometry of exposure were estimated using the standard adult (PCXMC default, 178.6 cm height and 73.2 kg body mass) parameters. Effective dose per phase was calculated as a sum of effective doses for each irradiation field. CCs were estimated for each phase for all projections.

To estimate the CCs for the whole BM fluoroscopic examinations, the following method was used:

— Estimation of the effective doses and CCs for each fluoroscopic phase and X-ray image for each projection;
— Estimation of DAP contribution of each projection into the total DAP for the examination for the whole patient sample for BM fluoroscopic examination;
— Estimation of mean CC for the selected type of the fluoroscopic examination using the following equation:

$$CC_{60} = \sum^{projection} \frac{DAP_{projection}}{DAP_{total}} \times CC_{60projection}, \frac{\mu Sv}{cGy \cdot cm2}$$

where:

CC_{60} – mean CC for the selected type of the fluoroscopic examination estimated using tissue weighting coefficients from ICRP Publication 60;

$DAP_{projection}$ –DAP for all fluoroscopic phases and X-ray images for the selected projection for BM fluoroscopic examination, cGy·cm^2;

DAP_{total} –total DAP for all fluoroscopic phases and X-ray images for the whole patient sample for BM fluoroscopic examination, cGy·cm^2;

$CC_{60projection}$ – CC for the selected projection for the whole examination, estimated using tissue weighting coefficients from ICRP Publication 60.

3. RESULTS

Data on the structure, relevant examination parameters, total DAP and E for BM examinations in surgical and therapy departments is presented in Table 1.

TABLE 1. DATA ON BM EXAMINATIONS

Department	Number of fluoroscopic phases	Number of X-ray images	Tube voltage, kV	Typical irradiation field size, cm·cm	Total DAP for the examination, cGy·cm^2	Total E for the whole examination (ICRP Pub 60), mSv
Surgical department	8.7±3.4* (3-16)	7±4 (0-15)	89±10 (61-127)	28·28	3392±2340 (316-10309)	8.7±6.4 (0.7-27.5)
Therapy department	17±5.5 (6-28)	6.3±1.9 (4-12)	90±11 (59-125)	35·30; 15·25**	508±371 (228-2157)	1.9±1.4 (0.7-7.9)

* mean±SD (min-max).

** For all patients 35·30 field was used only for the survey of UGIT without contrast; 15·25 field was used for all other phases.

Data on the CCs for individual projections and the contribution of different projections to the BM examinations for two X-ray rooms is presented in Table 2.

TABLE 2. CONTRIBUTION OF DIFFERENT PROJECTIONS TO THE TOTAL DAP FOR BM EXAMINATION AND CONRRESPONDING MEAN CONVERSION COEFFICIENTS

Projection	AP	PA	LATL	LATR	LPO	RPO	LAO	RAO
Contribution for SD	52%	12%	13%	6%	-	-	8%	8%
Mean CC, SD	3.1	1.9	1.9	1.0	-	-	1.8	1.7
Contribution for TD	26%	10%	1%	1%	35%	26%	-	1%
Mean CC, TD	3.9	2.4	2.5	1.5	3.2	5.1	-	2.4

Resulting CCs for BM examinations for both departments and comparison with the existing CCs from other studies are presented in Table 3.

TABLE 3. COMPARISON OF THE CONVERSION COEFFICIENTS FROM DAP TO EFFECTIVE DOSE (ICRP 60) FOR BM EXAMINATIONS

Source	Current study	Methodical guidance 2.6.1.2944-11 [4]	Delichas et al. [5]	Geleijns et al. [6]	Hart et al. [7]	Ciraj et al.[8]	Gyekye et al. [9]
CC for BM examination, $\frac{\mu Sv}{cGy*cm2}$	SD: 2.6 TD: 3.7	2.0	3.4	3.2	2.0	1.9-2.4	3.2

4. DISCUSSION

The proposed approach for the estimation of the effective dose considers important features of fluoroscopic examinations: non-uniform examination composition, significant movement of the X-ray tube within a single phase and the variety of exposure geometries. Using standardized structure of fluoroscopic examination allows a uniform approach to the effective dose estimation regardless of structure of the

examination. In the current study the differences in CC values between two X-ray rooms (Table 3) can be explained by two main factors: differences in irradiation field size and different contribution of different projections into a total DAP for examinations (see Table 1 and 2).

It is visible from Table 3, that estimated CCs (SD) are higher (up to 30%) compared to the existing Russian CCs [4] results published in [7,8], and comparable (TD) with the published CCs [5,6,9] for BM examinations.

To allow accurate effective dose estimation, CCs should consider the structure of the examination, geometry of patient exposure and the parameters of examinations. The use of single CC for a selected fluoroscopic examination would lead to over- or underestimation of the effective dose. Hence, it is proposed to establish sets of conversion coefficients for different exposure geometries and energy characteristics of the X-ray beam for each common fluoroscopic examination. In this case it would be possible to increase the accuracy of the effective dose estimation by applying a corresponding CC for each fluoroscopic phase of the complex examination, or establishing X-ray room specific CCs based on the relative contribution of different phases and projections into a total DAP for the examination.

5. CONCLUSIONS

Effective doses and the corresponding CCs relating effective dose with dose-area product for the BM fluoroscopic examinations were estimated by calculations using PCXMC 2.0 software based on the input data collected from two X-ray rooms in a major St-Petersburg university hospital. Effective doses and the CCs would be mainly influenced by the structure (number of fluoroscopic phases and selection of the projections of irradiation of the patient) and by the parameters of the fluoroscopic examinations (field size and energy characteristics of the X-ray beam).

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