Radiation Physics and Chemistry 140 (2017) 271–274

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem

Medical and occupational dose reduction in pediatric barium meal procedures

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ARTICLE INFO

Keywords:
Pediatric fluoroscopy
Barium mealprocedure
Occupational exposure
Thermoluminescent dosimeter
Dose reduction

ABSTRACT

Doses received in pediatric Barium Meal procedure can be rather high. It is possible to reduce dose values following the recommendations of the European Communities (EC) and the International Commission on Radiological Protection (ICRP). In the present work, the modifications of radiographic techniques made in a Brazilian hospital according to the EC and the ICRP recommendations and their influence on medical and occupational exposure are reported. The procedures of 49 patients before and 44 after the optimization were studied and air kerma-area product ($P_{K,A}$) values and the effective doses were evaluated. The occupational equivalent doses were measured next to the eyes, under the thyroid shield and on each hand of both professionals who remained inside the examination room. The implemented modifications reduced by 70% and 60% the $P_{K,A}$ and the patient effective dose, respectively. The obtained dose values are lower than approximately 75% of the results from similar studies. The occupational annual equivalent doses for all studied organs became lower than the limits set by the ICRP. The equivalent doses in one examination were on average below than 75% of similar studies.

1. Introduction

The pediatric barium meal (BM) procedure is an examination that employs ionizing radiation and implies radiation exposure of children and staff with doses that can be rather high. It is possible to reduce the dose values optimizing the technical parameters of the equipment that usually is not configured for pediatric imaging. The recommendations of the European Communities (EC) and the International Commission on Radiological Protection (ICRP) for pediatric fluoroscopy can be used as a guideline for such optimization.

There are some studies dedicated to BM procedures in pediatric patients, in which air kerma-area product ($P_{K,A}$) and/or effective dose were determined (Servomaa et al., 2000; Yakoumakis et al., 2014; Canevaro et al., 2004; Chateil et al., 2004; Iacob and Diaconescu, 2004, ; Hiorns et al., 2006; Damilakis et al., 2006; Sorop et al., 2008; Hart et al., 2009; Dimitriadis et al., 2011; Emigh et al., 2013; Sulieman et al., 2014; Wambani et al., 2014). In Brazil, no diagnostic reference levels (DRLs) have been established for fluoroscopy-guided examinations and no experimental data are available for children (Canevaro et al., 2004).

Despite the importance of occupational exposure monitoring in pediatric BM procedures, the number of such studies is scarce (Damilakis et al., 2006; Coakley et al., 1997; Kemerink et al., 2000; Alejo et al., 2015; Ubeda et al., 2016). In Brazil, as well as for medical exposures, no data were found for occupational exposure.

The results of our previous work (Filipov et al., 2015) showed a significant difference between the radiographic techniques used in a Brazilian hospital and the recommendation based on the EC data. In the present work, the modifications of radiographic techniques made in the same hospital according to the EC recommendations and their influence on medical and occupational exposure are reported.

2. Materials and methods

This study was performed at the Pequeno Príncipe Hospital, one of the largest pediatric hospitals in Brazil, with 0–16 years old patients, in two phases: before (49 patients) and after (44 patients) the implementation of the optimization. The present study was done with the approval of the Hospital Ethical Committee.

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http://dx.doi.org/10.1016/j.radphyschem.2017.01.034
Received 30 September 2016; Received in revised form 25 January 2017; Accepted 27 January 2017
Available online 28 January 2017
0969-806X/

Table 1
Optimization of the technical parameters. "NSF" is the number of spot films; "FI" is the number of fluoroscopy images; "FT" is the fluoroscopy time; "FS" is the field size on patient. "kVp", "mAs" are the tube voltage and the current-time product, respectively, used for spot films.

Parameter	< 1			1–5 y			5–10 y			> 10		
	Before	After	Reduct. (%)	Before	After	Reduct. (%)	Before	After	Reduct. (%)	Before	After	Reduct. (%)
NSF	6.0 ± 1.1	5.5 ± 0.5	8	6.8 ± 0.7	6.4 ± 0.7	6	7.6 ± 0.5	6.3 ± 1.3	17	6.9 ± 0.6	5.7 ± 0.9	17
FI	6.2 ± 0.7	6.0 ± 1.5	3	5.0 ± 0.0	9.0 ± 0.0	−80	15.0 ± 3.0	8.8 ± 0.9	41	4.0 ± 0.0	10.0 ± 0.0	−150
FT (min)	1.6 ± 0.4	0.8 ± 0.1	50	1.4 ± 0.1	1.0 ± 0.1	29	1.2 ± 0.2	1.1 ± 0.2	8	1.6 ± 0.2	1.1 ± 0.1	31
FS (cm^2)	278 ± 46	225 ± 12	19	341 ± 27	234 ± 17	31	426 ± 63	318 ± 25	25	705 ± 99	360 ± 45	49
kVp	59.1 ± 0.4	71.2 ± 0.5	−20	60.6 ± 0.5	71.9 ± 0.7	−19	62.7 ± 1.0	70.0 ± 0.0	−12	68.8 ± 2.3	78.8 ± 2.0	−15
mAs	9.3 ± 1.3	4.8 ± 0.6	48	9.5 ± 0.5	4.3 ± 0.4	55	12.1 ± 0.8	5.2 ± 0.2	57	16.0 ± 2.0	5.7 ± 0.8	64

Table 2
$P_{K,A}$ and effective dose (E).

Reference		< 1 y	1–5 y		5–10 y		> 10 y
		$P_{K,A}$ ($cGy\ cm^2$)	$P_{K,A}$ ($cGy\ cm^2$)	E (mSv)	$P_{K,A}$ ($cGy\ cm^2$)	E (mSv)	$P_{K,A}$ ($cGy\ cm^2$)
This work	Before	160 ± 10	160 ± 2	1.14 ± 0.18	280 ± 10	1.11 ± 0.02	610 ± 10
	After	50 ± 10	70 ± 10	0.6 ± 0.1	80 ± 10	0.3 ± 0.0	140 ± 30
Servomaa et al. (2000)		135.1	37.6		373.1		936.2
NRPB (2002)		70	200		325		560
Canevaro et al. (2004)		205 ± 116	319 ± 171		330 ± 335		
Chateil et al. (2004)		89 ± 39	136 ± 59		151 ± 56		
Iacob and Diaconescu (2004)			125 ± 43		270 ± 103		610 ± 272
Hiorns et al. (2006)		6.4 ± 8.6	9.5 ± 11.4		25 ± 26		25 ± 26
Damilakis et al. (2006)		78.6					
Sorop et al. (2008)		44 ± 37	151 ± 66	1.0 ± 0.4	310 ± 129	1.4 ± 0.5	515 ± 283
Hart et al. (2009)		75	130		240		640
Dimitriadis et al. (2011)		221.8	189.4	1.9			
Emigh et al. (2013)		18.2	82.5	0.77 ± 0.02	122.4	0.75 ± 0.02	
Sulieman et al. (2014)						0.3	
Wambani et al. (2014)		80	240	1.0	300	3.0	500
Yakoumakis et al. (2014)		173.9	284.9	2.8			

The fluoroscopy equipment used was the Philips Diagnost 93 overcouch system with a total nominal filtration of 2.5 mm Al. The LiF:Mg,Ti (for patient) and LiF:Mg,Cu,P (for staff) (RadPRO International GmbH, Wermelskirchen, Germany) thermoluminescent dosimeters (TLDs) were used for dose measurement.

For each examination there were recorded:

- Patient's anthropometric information: gender, age, body mass, upper-chest thickness (measured in the supine position).
- Technical information: kVp, mAs and exposure time of spot films; total fluoroscopy time; number of recorded images (for fluoroscopy and radiography); fluoroscopy mode (pulsed or continuous); use of antiscattering grid; field size on the table; focus-table and focus-detector distances.

The patient $P_{K,A}$ values were calculated from the entrance-surface air kerma (Filipov et al., 2015), obtained with the TLDs. To obtain effective doses, Monte Carlo simulations were performed with the software "CalDose" (Lima et al., 2011) that uses examination tube voltage, total filtration, focus-detector distance, field size and measured $P_{K,A}$ as the entrance parameters. This software has mathematical adult and pediatric human phantoms. In the case of pediatric BM examination, it is only possible to choose the phantoms that represent 5 or 10 years old patients.

The equivalent doses of the staff were measured with TLDs positioned on the temples (near both eyes), on the neck lead protector and on the hands. For the analysis of the doses received by the staffs' thyroids, the attenuation of the protector (with 0.5 mm lead equivalent) was determined and the TLD measurement on the protector was multiplied by the attenuation factor.

The equivalent doses per procedure (Ht_{Proc}) and the annual equivalent doses (Ht_{Ann}) for each investigated region was then estimated (Filipov et al., 2015).

3. Results and discussion

3.1. Optimization

Table 1 shows the changes made. Some essential in optimization of BM procedure factors (fluoroscopy pulsed mode, removal of antiscattering grid and additional filtration) were not considered. The used equipment did not allow such changes. Only the technical parameters were modified.

During the optimization, the X-ray tube was positioned at its maximum distance from the image intensifier (150 cm), which represents an increase of 24%. Regarding the number of images, it was found that the number of spot films could be lower if more medical physicians accepted the fluoroscopy images, even with its relative low quality.

Table 3
DRLs - $P_{K,A}$ 75th percentile. ($cGy.cm^2$).

Reference		< 1 y	1–5 y	5–10 y	> 10 y
This work	Before	150	190	190	610
	After	55	85	85	185
NRPB (2002)		70	200	325	560
Chateil et al. (2004)		170	220	240	240
Hiorns et al. (2006)		8	12	32	32
Hart et al. (2009)		75	130	240	640
Wambani et al. (2014)		120	300	400	700