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Risks of radiographic procedures for neonates admitted to a public hospital in Belo Horizonte, MG, Brazil*

Riscos dos exames radiográficos em recém-nascidos internados em um hospital público de Belo Horizonte, MG

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Abstract **OBJECTIVE: The present study was aimed at: a) evaluating radiographic procedures and estimating entrance surface air kerma in preterm neonates submitted to chest and abdominal radiography at the unit of neonatology in a public hospital of Belo Horizonte, MG, Brazil; b) estimating the dose to organs and respective risks for cancer as a result from radiation exposure. MATERIALS AND METHODS: Records of patients admitted to the unit of neonatology of this hospital in the period between May and September 2004 were reviewed. Anthropometric data, admission/discharge dates and radiographic studies performed were recorded for each of the patients. The calculation of the entrance surface air kerma was based on the x-ray tube output and irradiation parameters adopted for examinations. Dose to organs was calculated with the aid of the software PCXMC, and the lifetime risk for cancer, with the software IREP. RESULTS: Mean entrance surface air kerma per examination was below the diagnostic reference levels recommended by the European Community. In the most severely irradiated patients, liver, breast and stomach were the organs at highest risk for cancer, with maximum excess relative risk of respectively 3.4%, 2.3%, and 1.7%. CONCLUSION: The present study demonstrated the need for optimization of radiographic procedures in order to reduce the risks for neonates that, in spite of being considered to be low as compared with the benefits, should be reduced to values as low as reasonably achievable.**

Keywords: Patient dosimetry; Radiological protection; Pediatric radiology; Cancer risk.

Resumo **OBJETIVO: Os objetivos deste trabalho são: a) avaliar os procedimentos radiográficos e estimar o valor do kerma no ar na superfície de entrada nos recém-nascidos prematuros submetidos a exames de tórax e abdome, realizados no setor de neonatologia de um hospital público de Belo Horizonte; b) estimar as doses nos órgãos e os respectivos riscos de ocorrência de câncer nesses órgãos em decorrência das exposições à radiação. MATERIAIS E MÉTODOS: Foram analisados os prontuários dos pacientes internados no setor de neonatologia desse hospital durante o período de maio a setembro de 2004, anotando-se os dados antropométricos, data de internação/alta, exames de raios X realizados. O kerma no ar na superfície de entrada foi determinado a partir do rendimento do tubo de raios X e dos parâmetros de irradiação utilizados nos exames. As doses nos órgãos foram estimadas com o *software* PCXMC e o risco, durante o restante da expectativa de vida, com o *software* IREP. RESULTADOS: O valor médio do kerma no ar na superfície de entrada por exame foi abaixo do nível de referência da publicação da Comunidade Européia. Para o paciente mais severamente irradiado, os órgãos mais suscetíveis à ocorrência de câncer foram fígado, mama e estômago, com valores máximos de *excess relative risk*, respectivamente, de 3,4%, 2,3% e 1,7%. CONCLUSÃO: Foi constatada a necessidade de otimização dos procedimentos radiográficos com vista à diminuição do risco para os recém-nascidos, que apesar de ser considerado baixo (comparativamente ao benefício), deve ser sempre diminuído para valores tão baixos quanto razoavelmente exeqüíveis.**

Unitermos: Dosimetria do paciente; Proteção radiológica; Radiologia pediátrica; Risco de câncer.

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INTRODUCTION

Diagnostic radiology is considered as the main artificial radiation source to which human beings are exposed, being responsible for about 14% of the total annual ab-

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sorbed radiation dose as a result of overall radiation exposure to the general population[1]. Considering that any radiation exposure can induce a risk for harmful effects, it is indispensable that a request for radiological examinations is preceded by a careful evaluation of risks versus benefits[2].

Special attention should be paid to radiographic examinations in children, considering their higher susceptibility to the harmful effects of radiation as compared with the rest of the population[3]. In units of neonatology, particularly in cases where the patients are typically found in adverse clinical circumstances, the request for a number of radiographic studies may represent a significant increase in the risk for these patients[4].

Studies developed in units of neonatology have demonstrated a great variation in radiographic technique conditions (voltage, filtration, load, screen-film combination, etc.) and, consequently, in the absorbed-dose to newborn patients[5–8]. In this sense, an optimization of radiographic procedures, particularly with the application of quality criteria recommended by the European Community[9,10], can significantly reduce dose to patients without impairing the quality of radiographic images.

The estimation of the entrance surface air kerma rate (K_e) for inpatients of units of neonatology can be performed with the utilization of thermoluminescent dosimeters, dose-area product meters, or could be indirectly evaluated on the basis of radiographic technique parameters. This latter method, employing radiographic technique parameters in association with measurements of the x-ray equipment output is usually appropriate for this purpose[6].

Based on K_e, magnitudes related to risks, such as dose to organs, can be obtained with appropriate conversion coefficients shown in tables available in the literature[11,12] or by means of some softwares[13–16]. So, based on the dose to organ, the risk of an exposed individual for developing a determined type of cancer (in the irradiated organ) as compared with a non-exposed individual can be determined with the aid of appropriate models available in the literature[17].

The present study encompasses two objectives: a) to evaluate radiographic procedures and K_e in preterm neonates submitted to chest and abdominal radiography in the unit of neonatology (not ICU) of a public hospital in Belo Horizonte, MG, Brazil; b) to estimate dose to organs and respective risks for developing cancer in these organs as a result of the radiation exposure.

MATERIALS AND METHODS

Records of inpatients of the unit of neonatology in a public hospital of Belo Horizonte in the period between May and September 2004 were reviewed and the following individual data were recorded for the purposes of the present study: a) identification number; b) sex; c) weight; d) height; e) admission date; f) discharge date; g) chest and abdominal radiographic studies performed. Chest and abdomen account for 75% of radiographic procedures in neonates performed in this hospital.

The equipment utilized for radiographic images acquisition was a portable, monophase Movix 120 system with 1.5 mm aluminum filtration and full-wave rectification exclusively utilized in the unit of neonatology. All the images were acquired with the neonates in their respective incubators. Estimation of K_e values was based on the x-ray tube output. For this purpose, measurements of air kerma were performed with a MDH 10X5-6 ionization chamber (Radcal Corp.; Monrovia, USA) with an electrometer MDH 9015 (Radcal Corp.; Monrovia, USA), both previously calibrated. The ionization chamber was positioned on the center of the radiation field at a distance of 100 cm from the focus, and at 20 cm from the floor. Based on the x-ray tube output and irradiation parameters utilized in the examinations, the authors could estimate the incident air kerma (K_i) and K_e, by means of the following equations:

$$K_i = R_i \cdot Q \cdot (D_{ref} / DFP)^2 \quad (1)$$

$$K_e = K_i \cdot BSF \quad (2)$$

where: R_i = x-ray tube output for the radiographic technique employed, in mGy/mAs; Q = tube current (I) by exposure time (t) employed in the examination, in milliampere/second (mA.s); D_{ref} = distance where the output was measured (1 m); DFP = focus-skin distance, in meter, estimated by the difference between the focus-film distance (FFD) and the patient equivalent diameter (De) (equation 3)[18]; BSF = non-dimensional retroscattering factor. This is a function of the field size, equipment filtration and radiographic technique employed. A fixed value of 1.16 for BSF was adopted in the present study[19].

$$De = 2 \cdot [W / (H \cdot pi)]^{1/2} \quad (3)$$

where: H = patient's height in meter; W = patient's weight in grams.

Based on K_i, patient´s characteristics and radiographic techniques employed, the dose to the most exposed organs was evaluated by means of the software PCXMC[14], developed by Finnish Centre for Radiation and Nuclear Safety. So, the patient´s lifetime risk for developing cancer was estimated for some of the most exposed organs, by means of the software IREP (Interactive RadioEpidemiological Program)[17], developed by National Institute of Cancer in the United States of America. The IREP operation is based on risk models (excess relative risk – ERR; a measurement of change in the relative risk for cancer or death for a group of individuals exposed to a known radiation dose as compared with a non-exposed group), on a magnitude denominated assigned share (AS), defined by the equation 4, for a specific age where the cancer was diagnosed. In the present study, the AS was calculated by the IREP for the most severely irradiated individual at each year subsequent to the radiation exposure (totaling 50 years) and converted into ERR, a procedure similar to the one adopted by Thierry-Chef et al.[20].

$$AS = ERR / (1 + ERR) \quad (4)$$

RESULTS

Considering that, in the hospital evaluated, simultaneous irradiation of both regions (chest and abdomen) in a same examination is frequent, the results were jointly reported as a single chest/abdominal acquisition. So, dose to organs were estimated assuming an irradiation field covering both regions.

Table 1 presents the statistical analysis of weight, height, hospitalization period, number of chest/abdominal studies per patient, and K_e estimated for the newborn inpatients of the unit of neonatology. Mean parametric values (voltage, load, time, focus-film distance) usually adopted by the technicians for the chest/abdominal radiographic examinations of the neonates were, respectively: 53 kV, 1,5 mA.s, 50 ms, 95 cm.

Table 2 shows a comparison between radiographic technique parameters and mean values for K_e, per study found for the neonates in the present study and those reported in the literature.

Table 1 Statistical analysis of weight, height, hospitalization period, number of studies per patient and estimated K_e for neonates in the Unit of Neonatology of a hospital in Belo Horizonte.

	Weight (kg)	Height (cm)	H.P. (days)	*n*	K_e (mGy)
Mean	2.26	44.5	16.0	3.9	0.075
Minimum	0.53	30.0	1.0	0.0*	0.070*
1st quartile	1.69	42.0	4.0	0.0*	0.074
Median	2.25	45.0	10	2.0	0.075
3rd quartile	2.84	48.0	21.5	5.0	0.077
Maximum	4.80	62.0	137	50.0	0.080

n, number of studies per patient; H.P., hospitalization period.
* Minimum K_e corresponds to the lowest kerma rate among the patients admitted to the hospital and submitted to examinations. The patients who had not been submitted to examinations and therefore were not exposed to radiation were not included in the statistical analysis of K_e.

Table 2 Mean values for irradiation technique parameters and K_e, per examination in the present study and in other studies in the literature.

Reference	Study	Mean values per examination		
		Voltage (kV)	Load (mA.s)	K_e (mGy)
The present study	Chest/abdomen	53	1.5	0.075
Chapple et al.[6]	Not available	Not available	Not available	0.055
Wraith et al.[7]	Chest	60	1.0–2.0	0.036
	Abdomen	60	1.0–2.0	0.038
McParland et al.[4]*	Chest	52–60	0.8	0.020
	Abdomen	52–60	0.8	0.020
	Chest	62–70	0.4–0.5	0.016
	Abdomen	62–70	0.4–0.5	0.015
Jones et al.[21]	Chest	62	2.0	0.057
	Abdomen	62	2.5	0.074
Armpilia et al.[19]	Chest	53	2.0	0.036
	Abdomen	53	2.0	0.039
Brindhaban e Al-Khalifah[22]†	Chest	52	1.6	0.102
	Abdomen	52	1.6	0.102
	Chest	57	1.6	0.060
	Abdomen	57	1.6	0.060
	Chest	60	0.5	0.051
	Abdomen	60	0.5	0.058

* Results with the conventional technique and with the optimized technique; † Results obtained in three hospitals in Kuwait.

Table 3 Estimated minimum, mean and maximum values for doses (D_T) to some of the most exposed organs of neonates in a public hospital of Belo Horizonte.

Organ	D_T (mSv)		
	Minimum	Mean	Maximum
Stomach	0.040	0.045	0.049
Lung	0.028	0.031	0.037
Ovary	0.020	0.022	0.025
Testicle	0.032	0.049	0.065
Breast	0.050	0.056	0.078
Liver	0.035	0.037	0.042
Thyroid	0.010	0.027	0.055

Table 3 presents minimum, mean and maximum doses to some of the most exposed organs, estimated per study.

Figure 1 shows ERR variation with the time subsequent to the exposure estimated for some of the organs of the most severely exposed neonate (i.e. the patients submitted to 50 examinations).

DISCUSSION

The statistical analysis of weight and height of the neonates, as well as hospitalization period presented on Table 1, corroborates the preterm condition of the inpatients in the unit of neonatology and the necessity of special care to be provided to these neonates. Such special care is translated into a significant number of radiographic studies per patient. On average, the neonates were submitted to 3.9 chest/abdominal radiographic examinations, over a mean 16-day hospitalization period. It is important to note that one of the patients was submitted to an exceptionally high number of examinations (50) over a 137-day hospitalization period.

The analysis of radiographic technique parameters demonstrates that the x-ray tube voltage (kV) utilized for chest examination is below that recommended by the European Community (60–65 kV). On the other hand, the exposure time utilized is higher than recommended (4 ms), and the focus-film distance is shorter than recommended by the European Community (100–150 cm). Also, additional copper filters have not been utilized during the procedures as recommended by the European Community[10].

The analysis of Table 2 demonstrates that the mean K_e per examination found in the present study is below the reference level suggested by the European Community[10] (0.080 mGy). However, this value is higher than the mean values reported by the majority of studies in the literature[4,6,7,18,20].

The fact that the mean K_e per examination has been higher than the reference level recommended by the European Community, despite the non-optimization of the irradiation parameters. Can be partially explained by the low x-ray equipment output. Previous results of quality control tests

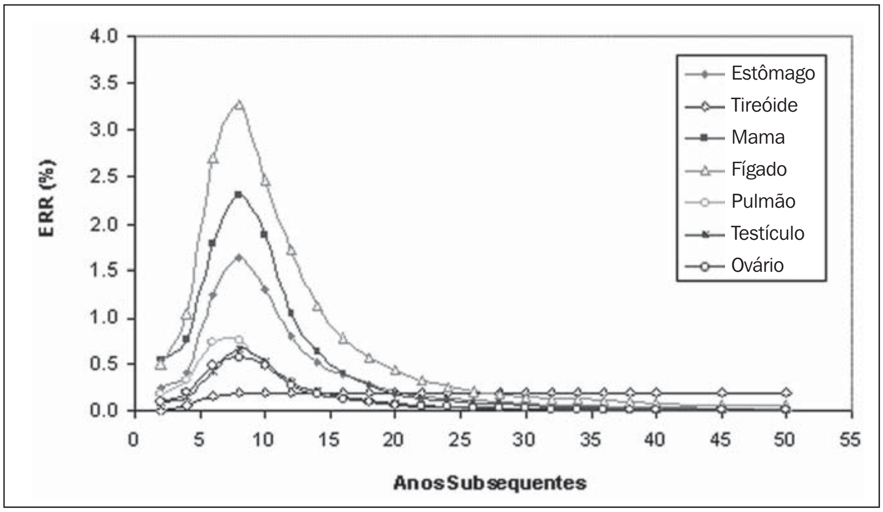

Figure 1. ERR variation with the time subsequent to the radiation exposure estimated for some of the organs of the most severely exposed neonate.

have shown that the equipment time and voltage accuracy and reproducibility are in compliance with the technical performance standards established by the Brazilian authorities[23]. However, the half-value layer at 80 kV (1.75 mm of Al) was significantly below of the minimum value established by the mentioned technical standard (2.3 mm of Al); that is to say, the x-ray tube output is low, even with the utilization of inadequate filtration. Considering that the hospital technicians already operate with minimum values for time and current, it may be concluded that besides the x-ray equipment inappropriateness for examining neonates, the optimization of the radiographic techniques in compliance with European Community recommendations is not feasible. This fact demonstrates that, probably, the quality of radiographic images is currently impaired. But this latter assertion only could be confirmed by further studies involving a joint evaluation of dose and image quality[24].

Table 3 demonstrates that mean doses to the gonads (testicles and ovaries) and thyroid were relatively high. This fact demonstrates that an accurate collimation of the x-ray field, limiting the irradiated area to the chest and abdomen (provided it is clinically acceptable), and the utilization of lead shielding in the incubators or collimator lead shields would certainly reduce the dose to at least one of these organs.

The analysis of Figure 1 demonstrates that liver (maximum ERR = 3.4%), breast (maximum ERR = 2.3%) and stomach (maximum ERR = 1.7%) are most susceptible to the development of cancer. In the case of the liver, this ERR value represents an increase in the risk for cancer from 89/10.000 (baseline)[25] to 92/10.000. The maximum ERR is typically observed eight years after the exposure. In the case of the thyroid, this maximum ERR persists over the patient´s lifetime. In the other organs, the ERR tends to decrease to values near zero over the patient´s lifetime. Considering that these results refer to the most severely exposed patient, who was submitted to a number of examinations 12 times higher than the average for the unit (~ four examinations/patient), it may be concluded that the neonates' risk for developing several types of cancer in the future as a result of these examinations is relatively low as compared with the benefits from the appropriately justified radiographic examinations. That is to say that the extremely adverse conditions of some neonates and the relevance of the radiodiagnosis as an essential clinical tool in the improvement of the management of the patient could justify this higher risk.

CONCLUSIONS

Doses and risks for preterm neonates admitted to a public hospital in Belo Horizonte were investigated. The authors observed that the mean K_e/examination found in the present study is below the reference level suggested by the European Community[10] and above the mean values found in a considerable number of studies in the literature. However, the adoption of non-optimized radiographic technique parameters imposed by the utilization of a x-ray equipment with low output and inappropriate for examination of neonates, is probably impairing the radiographic images quality. But this hypothesis could only be confirmed by further studies involving a joint evaluation of dose and image quality.

It was suggested that an appropriate collimation of the x-ray field and/or the utilization of lead shielding (as clinically acceptable) for reducing the doses to the thyroid and/or gonads. Liver, breast and stomach were most susceptible to the development of cancer. The optimization of radiographic procedures is essential for reducing the risk for neonates that, in spite of being considered to be low as compared with the benefits, should be reduced to values as low as reasonably achievable.

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