Radiation dose in premature neonates undergoing radiography examinations in intensive care units

S. Pandesh, M. Jabbari*, H. Zarghani

Department of Radiology Technology, School of Allied Medical Sciences, Birjand University of Medical Sciences, Birjand, Iran

► *Short report*

***Corresponding author:**
Masoud Jabbari,
E-mail:
masoudjabari@yahoo.com

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ABSTRACT

Background: Evaluation of X-ray exposure biological effects in neonates are more important due to high radiosensitivity. This study aimed to evaluate the radiation doses of neonates undergoing x- ray radiography using portal machine in intensive care units (NICUs). ***Materials and Methods:*** We analyzed dose area product (DAP) values among 105 neonates with a gestational age less than 37 weeks admitted at our hospitals between 2021 and 2022. The number of radiographs was 154. DAP values were measured by DAP meter and compared in three category of weight (extremely low weight, low weight and normal weight) in two commonly radiographies (chest and abdomen). ***Results:*** DAP values ranged from 3.21 ± 0.1 to 5.65 ± 2.11 mGy.cm^2 and from 2.11 ± 1.98 to 4.38 ± 0.75 mGy.cm2 for patient weight from 920 to 2200 gr in chest and abdomen radiography respectively. These values were higher than the international criteria, standards in some cases. High significantly correlation was shown between technical settings of radiography (KV, CTP, field size) and DAP ($P < 0.05$ for all). ***Conclusions:*** It is recommended to use the proper collimation, kilovoltage and current time product during radiography of premature neonates to optimize patient protection.

INTRODUCTION

In the neonatal intensive care unit (NICU), newborns, especially premature neonates, often suffer from serious medical complications due to respiratory and cardiovascular diseases [1]. During hospitalization in these units, most of them require radiological tests in their chest and abdominal areas for diagnosis, follow-up and treatment.

The radiosensitivity of tissues is directly proportional to the rate of cell proliferation. Premature neonates are very sensitive to radiation due to the very meiotic state of their cells [2]. It is evidenced that in neonates the hematologic and mass malignancy risk of cancer per unit dose is 2-3 times higher than the mature population and 6-9 times higher than the risk of cancer at 60 years old people [3]. In addition, they are at risk of genetic aberrations caused by radiation transmitted to the next generation [4]. Due to their greater sensitivity to radiation, estimating radiation dose received by neonates with low birth weight undergoing radiographic tests is of great importance [5].

The number of radiographic examinations depends on many factors such as birth weight, gestational age (the length of pregnancy after the first day of the last menstrual period) and clinical symptoms of the newborn. Also, the radiation dose to the newborn depends on many parameters such as the size of the patient, filtration, focal point distance to the skin surface (SSD), tube voltage, collimation (field size), the irradiation time of the tube, tube current and *etc.* [6-8]. The aim of this study was to measure dose area product (DAP) values in premature infants and evaluate the relationship of patient and technical setting related variables on DAP. Since most of the radiographs are related to the chest, ribs and abdomen, we evaluated these examinations.

MATERIALS AND METHODS

In this descriptive-analytical and cross-sectional study, among the neonates hospitalized in the NICU department of our Hospital, infants with a gestational age of less than 37 weeks were included. This study was approved by the ethical committee of our university. Gestational age of infants at the birth was between 29 and 37 weeks. Another inclusion criteria were hospitalization in NICU and performing at least one radiography during the period of hospitalization.

Data such as sex, age, weight, height, the type of radiograph (anterior posterior (AP) radiograph of chest and abdomen region) and the number of radiograph for each patient were collected from the picture archiving and communicating system (PACS) records and documented. Physicians identified the type (anterior posterior (AP) radiograph of chest and abdomen region) and the number of radiographs. The mobile X-ray machine (MUX-100H; Shimadzu, Tokyo, Japan) and digital flat panel detector were used for recording all radiographic images in the NICU. Technical settings for each examination were selected based on the discussion with radiographers; besides, the standard protocol were collected where available. Tube voltage (kV), current time product (CTP), focal spot to patient skin distance (FSD) and field size were technical variables included in this study for examinations.

In this study, to evaluate the dose received by patients, DAP values due to the diagnostic radiography were measured using DAP meter model KERMAX-plus SPD (IBA Dosimetry, Schwarzenbruck, Germany). DAP-meter was calibrated according to the NRPB protocol [9]. For each infant under radiation, DAP meter were placed on the surface of output port of x-ray tube. The DAP values were measured in cGy×cm^2 and then were converted to Gy × m^2 for all the chest and chest-abdomen examinations. Since technical exposure parameters settings are based on the patient size, radiographs are categorized according the patient weight: extremely low weight (less than 1000 gr), low weight (between 1000 to 2000 gr) and normal weight (more than 2000 gr). DAP values for each category classified and compared.

Statistical analysis was done using SPSS version 22. Quantitative variables were summarized as mean and standard deviation. Linear regression analysis was conducted to identify the factors affecting DAP. The correlation between variables such as tube voltage, field size gestational age and the neonate's weight with the amount of DAP values in chest and abdomen radiography was considered with the help of the Pearson's correlation coefficient with a significance level less than 0.05.

RESULTS

105 neonates hospitalized in NICU with a mean gestational age of 30 ± 1.3 weeks and the age range of 28 - 37 weeks were analyzed. The average duration of hospitalization was 6.20 ±9.52 days. For each premature neonate 1 to 3 radiography examination were done. Examination setting were collected for 143 radiography examinations including 93 (65%) radiography of chest and 52 (35%) radiography of abdomen. The total number of radiography examinations was the highest for infants with extremely low weight (n=75), followed by the group with birth weight 1000 to 2000g (n = 50) and >2000 g (n = 18) (p < 0.001 for trend). Table 1 gives the patient demographic data and ranges of examinations setting in chest and abdomen radiography. DAP values also compared in these examinations. As can be seen in table 1, the weight and height of the patients in these two groups are not statistically different (P_weight = 0.35 and P_height = 0.3), but the age of the patients who had chest radiography is significantly higher than those undergoing abdomen X-ray. There is no significant difference between tube voltage, FFD and DAP values of these two group of examinations. Fields size was variable and adjusted according to patient size. In the cases of chest radiography, field size is about 6×6 inches and in the cases of abdominal radiography was 10×12 inches.

Table 1. The patient demographic data, ranges of examinations setting and DAP in chest and abdomen radiography.

variables	Chest radiography	Abdomen radiography	p-value
Age (days)	4. 5 ± 4.25	3.5 ± 1.91	0.43
Weight(gr)	1570 ± 620	1540 ± 610	0.35
Height (cm)	40 ± 8.75	39.71 ± 6.31	0.3
Voltage (KV)	53.5 ± 4.91	56.6 ± 3.71	0.21
CTP(mAs)	2.5 ± 1.5	2.5 ± 1	0.86
Field size (inches)	7 ± 2 * 7± 2	8 ± 2 * 10 ± 2	0.08
FSD(cm)	89.05 ± 5.15	92.12 ± 5	0.34
DAP (mGy.cm^2)			
< 1000 gr	5.64 ± 2.11	4.38 ± 0.75	0.03*
1000-2000 gr	4.10 ± 1.68	3.82 ± 1.55	0.02*
>2000 gr	3.21 ± 0.10	2.11 ± 1.98	0.01*

The effect of different variables (age, weight, height, voltage, CTP, FFD and field size) on DAP is evaluated in table 2 for chest radiography. As shown in table 2, with one-day increase in age, the amount of DAP in infants who underwent chest radiography increases statistically significantly (r = 0.13, P-value = 0.02). There were reverse but not statistically significant correlation between newborn's weight and DAP (r = -0.12, P = 0.35). High significant correlations were seen between technical settings (KV, CTP, FFD and field size) and DAP.

Table 2. The Pearson's Correlation Between the variables and amount of DAP in chest radiography.

Variables	*r*	T	P-Value
Age	0.13	2.40	0.02*
Weight	-0.12	-1.05	0.35
Height	0.11	1.03	0.31
Voltage	0.40	6.28	<0.001*
FSD	-0.48	-8.58	<0.001*
CTP	0.59	10.05	<0.001*
Field size	0.45	8.31	<0.001*

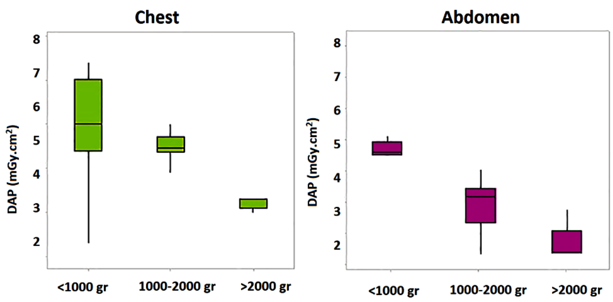

Figure 1. DAP values for chest and abdomen radiography for extremely low weight infants (< 1.000 g), low weight infants (1.000 – 2.000 g) and normal weight infants (> 2.000 g).

DISCUSSION

Nowadays due to the continuous improvement of neonatal intensive care practices and advances in x-ray diagnostic radiography examinations, more preterm neonates can survive than before. Some neonates may need multiple x-rays examinations during care. Knowing the present state of radiologic procedures and dose optimization strategy is necessary to manage the risk of biological risk of exposure. Optimization and reducing the radiation dose received in neonates due to diagnostic radiography are extremely important.

In this study, DAP values were measured for neonates undergoing diagnostic radiology. Comparison to standard DAP values, DAP values reported in our study were higher than those published by the National Radiological Protection Board [10-11] for neonatal chest X-ray examination, but lower than those proposed by the guidelines of the European Commission [12]. Also, in the comparison of our study with the values of the federal office for radiation protection (FORP) in Germany, which were stated in the study of Gerhard Alzen *et al*., the value of DAP was statistically significantly lower [13]. Also, regarding abdominal radiography, the amount of DAP values in our study was not significantly different from the level of DAP reported by FORP. In this study, the amount of DAP in the group that underwent abdominal radiography was significantly higher than the group that underwent chest radiography ($P < 0.05$).

There may be a wide range of received doses for different patients. The important point is that this range is variable even for one device and one operator and one imaging area. Factors related to changes in patient age (up to 1 year), equipment and radiographic technique may change this range. Generally, the tube voltage (41 – 62 kVp) and CTP (0.5 – 4 mAs) used vary widely across centers [21]. The analysis of radiographic technical settings in the present study showed that in most cases, the X-ray tube voltage (kV) used for common radiography of neonates was lower than standard protocol suggested by the Commission of the European Communities, at between 60 and 65 kVp.

Results of this study indicated that tube voltage and CTP variables have high significantly direct correlation with DAP value, but DAP value has experienced a significant reverse correlation with FSD. It was also shown that weight and height variables were not significant factors in DAP estimation. In a similar study conducted by Wraith et al., a clear relationship between DAP values and the weight of patients was found [22]. According to the results of this study, the amount of DAP in all infants (1000 g, between 1000-2000 g, and above 2000 g) was significantly lower than the standard DAP values. The amount of DAP received in the chest radiograph of infants who weighed less than 1000 grams and 1000 - 2000 grams was significantly lower than the Belgian diagnostic reference levels, and in infants who weighed more than 2000 grams, the amount of DAP received by them There was no significant difference with the Belgian diagnostic reference levels. Received doses in most newborn range widely due to differences in birth weight or patient size.

CONCLUSIONS

Training the staff for portable radiography in NICU is necessary to avoid wrong radiography techniques especially choosing the inappropriate field size.

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Author contribution: MJ (the corresponding author) is responsible for ensuring that the descriptions are accurate and agreed by all authors. All authors approved the revised version. All authors read and approved the final manuscript.

REFERENCES

1. Bouaoun A, Ben-Omrane L, Hammou A (2015)Radiation doses and risks to neonates undergoing radiographic examinations in intensive care units in Tunisia. *Int J Cancer Ther Oncol, **3(4)**: 342-347*.
2. Minkels TJ, Jeukens CR, Andriessen P, *et al.*)) 2017Dose evaluation for digital X-ray imaging of premature neonates. *Radiation Protection Dosimetry, **177(4)**: 440-449*.
3. Smans K, Struelens L, Smet M, Bosmans H, Vanhavere F (2008) Patient dose in neonatal units. *Radiation protection dosimetry, **131 (1)**: 143-147*.
4. Hall EJ) (2009Radiation biology for pediatric radiologists. *Pediatric Radiology, **39**: 57-64*.
5. Sanchez R, Khong PL, Ringertz H) (2013Radiologic protection in pediatric radiology: ICRP recommendations. *Pediatric Radiology, **43**: 920-921*.
6. Olgar T, Onal E, Bor D, Okumus N, Atalay Y, Turkyilmaz C, Ergenekon E, Koc E)) 2008Radiation exposure to premature infants in a neonatal intensive care unit in Turkey. *Korean Journal of Radiology, **9(5)**: 416-419*.
7. Gislason-Lee AJ)) 2021Patient X-ray exposure and ALARA in the neonatal intensive care unit: global patterns. *Pediatrics & Neonatology, **62(1)**: 3-10.*
8. Ono K, Akahane K, Aota T, Hada M, Takano Y, Kai M, Kusama T) (2003Neonatal doses from X ray examinations by birth weight in a neonatal intensive care unit. *Radiation protection dosimetry, **103(2)**: 155-162*.
9. Hart Hart D, Hillier MC. Doses to patients from radiographic and fluoroscopic X-ray imaging procedures in the UK-2005 review. *Health Protection Agency, Radiation Protection Division; 2007.*

[DOI: 10.61186/ijrr.22.4.1091]

10. Hart D, Wall BF, Shrimpton PC, Dance DR (2000) The establishment of reference doses in paediatric radiology as a function of patient size. *Radiation protection dosimetry, **90(1-2):** 235-238.*
11. Hart Hart, D. W. B. F., Wall, B., & Shrimpton, P. (2000). Reference doses and patient size in paediatric radiology (No. NRPB-R--318). *National Radiological Protection Board.*
12. European Union. European Commission. Directorate-General XII-Science, Research and Development. European guidelines on quality criteria for diagnostic radiographic images in paediatrics. *Office for Official Publications of the European Communities; 1996. UK.*
13. Alzen G, Benz-Bohm G (2011) Radiation protection in pediatric radiology. *Deutsches Ärzteblatt International, **108(24):** 407.*
14. Ono K, Akahane K, Aota T, Hada M, Takano Y, Kai M, Kusama T (2003) Neonatal doses from X ray examinations by birth weight in a neonatal intensive care unit. *Radiation protection dosimetry, **103(2):** 155-162.*
15. Donadieu J, Zeghnoun A, Roudier C, Maccia C, Pirard P, André C, Adamsbaum C, Kalifa G, Legmann P, Jarreau PH (2006) Cumulative effective doses delivered by radiographs to preterm infants in a neonatal intensive care unit. *Pediatrics, **117(3):** 882-888.*
16. Bader D, Datz H, Bartal G, Juster AA, Marks K, Smolkin T, Zangen S, Kugelman A, Hoffmann C, Shani G, Ben–Shlomo A (2007) Unintentional exposure of neonates to conventional radiography in the neonatal intensive care units. *Journal of Perinatology Sep, **27 (9):** 579-585.*
17. Puch-Kapst K, Juran R, Stoever B, Wauer RR (2009) Radiation exposure in 212 very low and extremely low birth weight infants. *Pediatrics, **124(6):** 1556-1164.*
18. Scott MV, Fujii AM, Behrman RH, Dillon JE (2014) Diagnostic ionizing radiation exposure in premature patients. *Journal of Perinatology, **34(5):** 392-395.*
19. Bahreyni Toossi MT, Malekzadeh M (2010) Diagnostic reference levels in neonatal units. In: International symposium on standards, applications and quality assurance in medical radiation dosimetry (IDOS), Nov 9–12, Austria, Vienna: International Atomic Energy Agency, pp. 175–176.
20. Wraith CM, Martin CJ, Stockdale EJ, McDonald S, Farquhar B (1995) An investigation into techniques for reducing doses from neo-natal radiographic examinations. *The British Journal of Radiology, **68(814):** 1074-1082.*
21. Donadieu J, Zeghnoun A, Roudier C, Maccia *et al.* (2006) Cumulative effective doses delivered by radiographs to preterm infants in a neonatal intensive care unit. *Pediatrics. **117(3):** 882-8.*
22. Wraith CM, Martin CJ, Stockdale EJ, McDonald S, Farquhar B. (1995) An investigation into techniques for reducing doses from neo-natal radiographic examinations. *The British journal of radiology. **68(814):** 1074-82.*