Original

# Evaluation of Cumulative Radiation Dose in Neonates in Neonatal Surgery Ward of Alzahra Hospital of Isfahan

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## Abstract

**Introduction:** The purpose of this study, is evaluation of the average of cumulative radiation exposure in admitted neonates in neonatal surgery ward.

**Materials and methods:** Participants were all neonates consecutively admitted to the neonatal surgery unit of the study hospital for surgery and need one type of radiological study during hospitalization. Thermo luminescent dosimeters (TLD GR200) were used for evaluating absorbed dose of radiation on the body. For controlling of confounding variables, 130 admitted neonates who need no radiation were selected as control group.

**Results:** In this study, we evaluated 169 neonates.The most x -ray examination was on ribcage (338 cases). Total amount of bowel and backbone x-ray examinations were 117 and 11 respectively. Total amount of contrast enema, meal and swallow was 8, 9 and 5 respectively. The cumulative absorbed dose in 19 patients was more than 10 mSv. There was a significant differences between control group with other x ray examination groups (p=0.001). The mean of accumulated received dose for patients during admission period was 3.13±5.12 mSv.

**Conclusion:** The average of accumulated received dose for neonates was about 3.13 mSv. Although this dose is less than annual limit dose, but it is inacceptable in comparison with other medical centers.

## Keywords

- cumulative radiation exposure
- infant

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## Introduction

Neonates have the highest sensitivity to Radiation due to their high mitotic activity and their small size.[1] Although skin trauma and cataract are among the complications of excessive x-ray radiation, but the main complication is the increased risk of hematological and solid malignancy. Despite the actual low risk, it is increased with high exposure doses during life.[2] As neonatal intensive care units have become very advanced nowadays, the number of high risk neonates in NICU who need multiple x-rays for their complicated conditions such as neuro-developmental, respiratory and gastrointestinal diseases, have risen. Thus the risk of radiation exposure to other neonates in the NICU has become more prevalent. On the other hand, bedside neonatal radiological imaging can be challenging as the NICU ward makes it less than ideal for standard imaging protocols. Uncooperative neonate, monitoring devices, tubes and access lines are major limitations of imaging quality and safety. Also since neonatal tissues have a 10 times higher sensitivity to radiation, the risk is greater in them.[3] The related malignancy risk, at certain Levels of radiation in the first 10 years of life is reported to be more than[4,5] 30 to 40 and[6,7] in some studies as high as 50 times.[8] Many studies showed the importance of well-defined technical protocols and protection in NICU to decrease radiation doses with highest quality and safety as the concept of ALARA (as low as reasonably achievable) implies.[9]

Radiation exposure is the quantity of ionization in the air which is related to the level of radiation intensity. Radiation dose is the transfer of energy from radiation exposure to the body tissues which is affected by the amount of radiation energy, duration and area over which the radiation is exposed. Although the dose area product is a more accurate measure of radiation dose but the simplest method of measuring the radiation dose is the entrance skin dose, which measures the radiation incident upon the patient skin surface.[10]

According to Commission of EC report, the recommended radiation exposure limit for infants is 80 μ Gy, however this limitation is about 50 μGy for chest radiographs based on National Radiological protection Board report.[11]

The purpose of this study is to evaluate the average of cumulative radiation exposure in admitted neonates in surgical NICU, along with the diagnostic and therapeutic examinations which has been carried out in the admission period.

## Materials and methods

This is a cross sectional analytic study carried out in the surgical NICU of Al Zahra hospital, Isfahan university of Medical Sciences (IUMS) from March 2010 to September 2010. After obtaining approval from the hospital ethics committee, we consecutively included all neonates admitted to the neonatal surgery unit (NICU) of the study hospital for surgery who needed at least one type of radiological study during hospitalization. Patients with major metabolic or skin diseases, age>1 month and those who had previous surgery were excluded. Inform consent was obtained from the parents. Patient eligibility included age less than one month and the need for at least one type of X ray exposure during hospitalization.

Technique:

Thermo luminescent dosimeters (TLD GR200) were used to calculate absorbed doses of radiation on the body. TLD is a primary radial detector instrument which is used as a personal dosimeter. One peal was used specifically for each neonate until discharge or death. Each peal was placed in a safe plastic envelope in order to protect against dust and humidity. It was placed on the skin beneath the sternum by radiology technicians with the assistance of medical staff. The x rays taken in the ward by a portable device and those taken in the radiology department were included in study. Data such as name, file number, admission time, time of discharge or death, peal number and absorbed dose during the admission period were collected by a checklist. The cumulative absorbed dose by each patient was stored during the admission and separated after death or discharge from hospital. Stored dose was read by the TLD reader set in physic and medical engineering department of our medical school. TLD was calibrated based on two calibration factors: individual and batch. Individual calibration was used for inherent differences compensation among detectors. Batch calibration was used for determining calibration coefficient. To determine individual calibration factor, a 20 cGy dose was added to all the peals and they were read in the reader device. Individual calibration factor of each detector is equal to average ratio of readers in respect to reading each peal in every channel of the set. Determining batch calibration required 33 detectors to divide into 3 ×11 groups. The first group was baseline group and thus received no radiation. Certain dose equal to 1, 5, 10, 15, 20, 25, 30, 40, 45, 50 cGY were given to other groups respectively. Calibration curve show the given dose versus reading correct numbers. Calibration factors are then calculated from the slope of the curve. To evaluate calibration correctness, few numbers were selected from detectors in order to receive certain dose equal to 10 cGy. Then their correct computation was achieved by the reader device. The amount of dose was determined by multiplying numbers from the device and then deleting the base radiation from it. The difference between given dose and calculated dose should not be more than 5%. This formula was used for absorbed dose computation:

$$\text{Dose} = \{CC_{dose} \times BCF\text{-}BGD_{dose}\} \times ICF$$

$CC_{dose}$ is the corrected count of detector, $BGD_{dose}$ is calculated base dose $CC_{dose} \times BCF \times ICF$, and BCF is batch calibration agent of dose and ICF is personal corrected agent .

For controlling of confounding variables, 130 admitted neonates who needed no radiation were selected as the control group. Data was analyzed using SPSS (version 16). Quantitative and qualitative variables were expressed as mean (SD) and percentages respectively. Differences in mean scores were calculated using the Mann-Whitney test. P values less than 0.05 was considered significant.

**Results**

In this study, we evaluated 299 neonates consecutively referred to our center (169 patients as case group and 130 patients as control group). The length of hospitalization was 7.64±3.54 days. Forty eight percent of patients were preterm. The most common x-ray examination was on ribcage

(338 cases). Total amount of bowel and backbone x-ray examinations were 117 and 11 respectively. Total amount of contrast enema, meal and swallow examinations was 8, 9 and 5 respectively. The mean number of simple x-ray examination for each patient was 2.77±0.12 per admission.

Batch calibration factor was determined by drawing a corrected count diagram. Vertical axis illustrates the mean of corrected count in every group which is calculated through multiplying it by individual calibration coefficient. Horizontal axis illustrates dose **Figure 1 and 2.** Batch calibration factor was $3.28\times10^{-6}$ for channel A and $3.22\times 10^{-6}$ for channel B. Base dose was 0.011635 and 0.009352 cGy for channel A and B respectively.

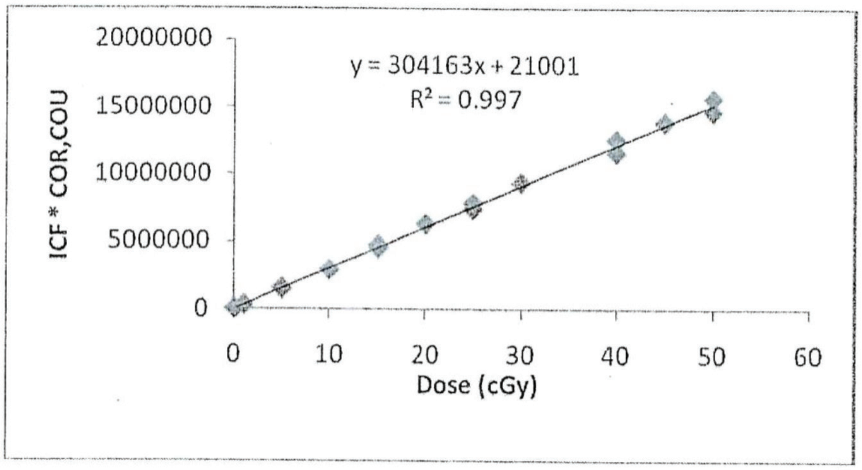


**Figure1:** Determination of batch calibration factor (channel A)

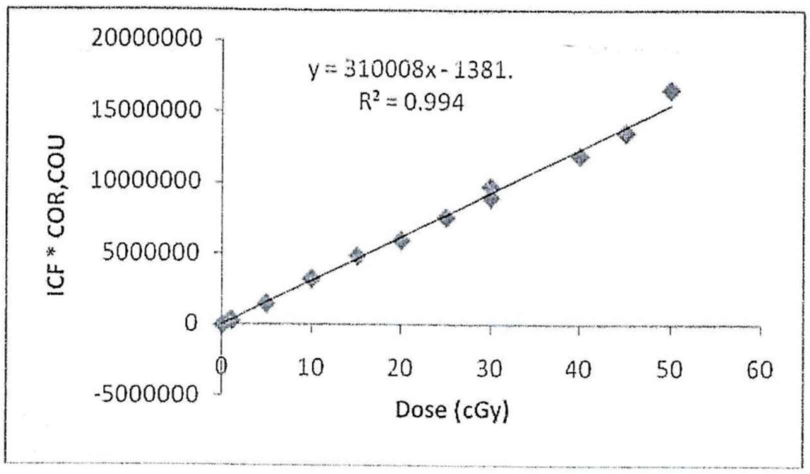


**Figure2:** Determination of batch calibration factor (channel B)

To evaluate calibration accuracy, 5 TLDs were chosen and received certain dose of 10 cGy. As it is shown in the **Table 1**, given and calculated dose differences were not more than 5%.

**Table 1:** Result of evaluation of calibration accuracy

| Percentage of difference | Calculated Dose (cGY) | Corrected Count | Base Dose (cGY) | BCF(cGy/cc) | ICF(cGY) | Number of TLD |
|---|---|---|---|---|---|---|
| 3.9 | 9.61 | 2584037 | 0.011635 | $3.28*10^{-6}$ | 1.134532 | 1 |
| 4.4 | 9.58 | 2950748 | 0.009352 | $3.22*10^{-6}$ | 1.005170 | 2 |
| 4.3 | 10.43 | 2905505 | 0.011635 | $3.28*10^{-6}$ | 1.109505 | 3 |
| 2.2 | 9.78 | 2967342 | 0.009352 | $3.22*10^{-6}$ | 1.022586 | 4 |
| 2.8 | 10.28 | 2700079 | 0.011635 | $3.28*10^{-6}$ | 1.159447 | 5 |

The mean of absorbed dose with regard to patients' diagnosis is shown in **Table 2**.

**Table 2:** The mean of absorbed dose with regard to patients' diagnosis

| Diagnosis (number of cases) | (Mean(SD | Range |
|---|---|---|
| Hypertrophic pyloric stenosis (6) | 3.8(8.1) | 0.03-18.32 |
| Imperforate Anus (18) | 1.31(4.16) | 0.01-17.43 |
| Bowel obstruction (29) | 4.94(6.32) | 0.01-23.84 |
| Abdominal mass (6) | 2.71(4.93) | 0.04-11.47 |
| Myelomeningocele (8) | 1.43(3.4) | 0.02-9.8 |
| Inguinal Hernia (20) | 0.37(0.77) | 0.01-3.11 |
| Omphalocele (8) | 1.98(4.36) | 0.03-11.83 |
| Diaphragmatic Hernia (12) | 3.19(3.34) | 0.32-10.21 |
| EA+TEF (20) | 5.67(5.32) | 0.22-22.34 |
| Gastroschisis (5) | 0.23(0.6) | 0.02-1.38 |
| Choanal Atresia (4) | 0.23(0.33) | 0.02-0.74 |
| Neck mass (3) | 0.48(0.76) | 0.04-1.37 |
| NEC (2) | 0.85(0.45) | 0.53-1.18 |
| Pneumothorax (21) | 5.69(4.76) | 2.03-13.83 |
| Others (7) | 0.34(0.45) | 0.02-1.56 |

The cumulative absorbed dose in 19 patients was more than 10 mSv. The mean of absorbed dose with regard to X-ray examination is shown in **Table 3**.

**Table 3:** The mean of absorbed dose with regard to X-ray examination

| Examination | Mean(SD) |
|---|---|
| Chest X ray | 0.313(0.24) |
| Abdominal X ray | 0.374(0.19) |
| Backbone X ray | 0.622(0.47) |
| Contrast studies | 12.6(3.58) |
| No Examination (controls) | 0.039(0.01) |

As shown in this table, there was a significant differences between control group with other x-ray examination groups (p=0.001). The mean of accumulated received dose for patients during admission period was 3.135.12± mSv.

## Discussion

Findings of this study show that the mean of accumulated radiation dose for neonates during admission period was about 3.13 mSv. Although this dose is less than annual limit dose (50 mSv each year)[7], but it is unacceptable in comparison with other medical centers in the world.[8, 11-17] **Table 4.**

In a study by Donadieu et al.[8] in evaluation of four hundred fifty patients the median number of

**Table 4:** Results of mean of cumulative absorbed dose in other studies

| Author | Mean(mSv) |
|---|---|
| Donadieu J (8) | 0.138 |
| Wilson-Costello D(11) | 0.72 |
| Armpilia CI(12) | 0.14 |
| Brindhaban A (13) | 0.9 |
| Puch-Kapst K (14) | 0.071 |
| Ana Cecilia Pedrosa de Azevedoa(15) | 0.25 |
| Makri T (16) | 0.44 |
| Brindhaban A(17) | 0.73 |

radiographs for each neonate was 10.6 and the median cumulative effective dose (CED) was 138 μSv (range: 0-1450 μSv). The cumulative dose was more than 500 μSv in 7.6% of the neonates. He concluded that exposure of neonates in the NICU was relatively low compared with doses they are exposed to in the environmental and compared to international recommendations. In 1996 Wilson-Costello et al.[11] showed that organs such as skin, breast, and thyroid which are on the surface receive most of the radiation doses. The effective dose equivalent for each baby considering all radiographs was 0.72 mSv (using the modified method) and the total-body dose was 0.40 mSv (with the standard method). They concluded that neonates with a birth weight under 750 g receive radiation doses that are minute compared with doses that might increase the risk of cancer. In Armpilia et al.[12] study using quality control measurements on the X-ray unit, entrance surface dose (ESD) of radiation to neonates from diagnostic X-rays was determined. ESD resulting from 95 examinations had a range from 28 μGy to 58 μGy, with a mean ESD per radiograph of 36+/-6 μGy.

In a study by Brindhaban et al.[13] in Kuwait it was shown that entrance surface dose (ESD) and effective dose to premature neonates in NICU was the highest for skull examinations (between 58 and 145 μGy) compared with abdominal X rays (between 58 and 102 μGy) and chest X rays (between 51 and 102 μGy) which was comparable other studies.

In a study by Puch-Kapst et al.[14] ESD varied between 11.8 and 15.0 μGy and effective dose was 71.5 μSv for each neonate for the entire hospitalization. Newborns with birth weight ≤750 g, length of stay ≥16 weeks, congenital malformations, or oxygen dependence for ≥36 weeks were more likely to receive high numbers of radiographs and high radiation doses. By their estimation only 1 in 60000 NICU-treated VLBW neonates might grow up to have a fatal malignancy by the age of 15. Macri et al.[16] in a study using thermo-luminescence dosimetry calculated ESD in 60 neonates to be 44 ± 16 μGy for AP chest and 43 ±19 μGy for AP combined chest-abdominal exposures. He concluded that the risk caused by each radiograph was relatively low (between 1.7 and 2.9 per million neonates) and is to some extent higher in females.

Comparing the mean cumulative dose of fluoroscopic examination with cumulative dose in patients with no examination or just simple x-ray examination showed that the fluoroscopic examination had a major role in increasing the mean cumulative dose in neonates. Regarding risk of malignances fluoroscopic examination increases the risk to about 1 in 1000 (as a result of receiving a dose of more than 10 mSv) thus it is a considerable risk factor. Nineteen patients who received a dose of more than 10 mSv, had this risk.

The mean absorbed dose in 130 patients with no examination or just simple x-ray examination was very high in comparison with other world centers. This amount was achieved by only 2.58 examination, whereas, lower cumulative dose was achieved with more examinations in other studies. There for in our study despite the acceptable range of x-ray examination for each person, the average radiation exposure is high. The average range of radiation in ribcage examination was very high in comparison with the standard range (80 μGy) declared by European commission for diagnostic examination of neonates.[2] The average received radiation in neonates with no examination was very low. It is clear that in addition to improvement of our radiologic setting the fluoroscopic setting should improve too and since the average radiation of fluoroscopy depends on the radiologist's skills and speed, more attention should be paid to this matter by radiologists. We also recommend a more dedicated use of protective walls in order to reduce the effect of this high radiation exposure to NICU staff.

## Ethics Approval

This study was approved with ethical code number of 387349.

## Conflict of Interest

There is no conflict of interest.

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