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Original article

Radiological protection in the Neonatal Intensive Care Units (NICUs): a retrospective and observational audit at two teaching hospitals

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Abstract

Introduction: Portable chest and abdomen x-rays are the most common x-ray procedures performed during hospitalization in the Neonatal Intensive Care Units (NICUs). These x-rays contribute to radiation exposure to several radiosensitive tissues, causing increased concerns about patients' safety. This study aims to assess the status of radiological protection in the NICUs at two teaching hospitals supervised by Dezful University of Medical Sciences (DUMS), Dezful, Iran.

Methods: A retrospective and observational study was performed at two teaching hospitals of DUMS comprising three NICUs. Six radiologic technology students were invited and agreed to participate in this audit. The students were asked to attend as observers in the NICUs and record the radiation safety principle observances specified in the checklist. We also supplemented data from an observational study with a retrospective survey of the images at the picture archiving and communication system (PACS) database.

Results: 230 neonatal chest and abdomen x-rays from 65 hospitalized neonates were investigated during 57 work shifts in the observational survey. In all, 90.1%, 80% and 13% of the chest, abdomen and chest/abdomen x-rays had unsatisfactory beam restriction, respectively. The protective shielding tools were available; however, they were not commonly applied to the patients. Most of the personnel used fixed exposure parameters of 42 kVp and 3.2 mAs. In the retrospective study, 498 portable x-rays were retrieved from the PACS database, in which only 17.5% and 0.4% of images have adequate beam restriction and evidence of shielding, respectively.

Conclusion: Our study is commensurate with previous literature and emphasizes that neonates in the investigated hospitals are receiving avoidable excessive radiation exposure, mainly due to inappropriate beam restriction.

Keywords

Neonate, radiation protection, chest, abdomen, x-ray exposure, NICU.

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Introduction

In the past two decades, there has been a remarkable increase in the number of patients undergoing diagnostic x-ray procedures [1]. The rate of this scale is massive and continue to increase dramatically [2]. Although patients can benefit from medically indicated x-ray procedures, their use involves some potential health risks [3]. Indeed, the detrimental health effects, especially carcinogenesis, associated with exposure to ionizing radiations have been well established [4]. Several studies have emphasized that the radiation effects are inversely proportional to patients' age, suggesting the high radiation tissue sensitivity of neonates and pediatric patients [5, 6]. As a general rule, the radiosensitivity of tissue is directly proportional to the rate of proliferation [7, 8]. Hence, since neonate cells have high mitotic division rate, they are highly sensitive to radiation [7]. This rapid dividing rate of the cells can impair the repair process of the damaged cells from radiation exposure [6]. Neonates also have a smaller body size that places most organs in the radiation field, resulting in a higher effective dose compared with older children and adults [9]. Moreover, neonates have longer life expectancy than any other patient group, which allows more time for the expression of delayed detrimental health effects such as cancer and leukemia, in particular [6, 7].

Portable chest and abdomen x-rays are the most common x-ray procedures performed during hospitalization in the Neonatal Intensive Care Units (NICUs) [6]. They are contributing to radiation exposure of ionizing radiations to several critical tissues such as the thyroid gland, breast, colon, gonads and red bone marrow [10]. Moreover, consecutively exposing the neighbor neonates and nursery personnel from scatter radiation is an added concern. Therefore, it is imperative that radiation exposure be kept as low as reasonably achievable (ALARA) and all radiation dose optimization strategies be applied. Many dose optimization strategies can be applied to reduce patient and personnel radiation exposure and some authors have addressed these strategies [11-13]. Other studies have discussed the application of these strategies in clinical practice [10, 14]. In 2006, Soboleski et al. [15] assessed the status of radiological protection in terms of beam restriction during pediatric chest x-rays and reported that 45% of each radiograph consisted of unnecessarily imaged organs or tissues. Such similar findings have been reported by Bader et al. [16] during neonatal chest and abdomen x-rays. To the best of our knowledge, no study has previously been performed on the status of radiological protection in the NICUs in Iran; therefore, this study was aimed to assess the status of radiological protection in NICUs of two teaching hospitals supervised by Dezful University of Medical Sciences (DUMS), Dezful, Iran. The results of this study are expected to reduce the potential gaps between interest in patients' safety and implementation in clinical practice.

Methods

Initially, approval was obtained from the university ethic committee to proceed (approval number: IR.DUMS.REC.1397.033). A retrospective and observational study was conducted at two teaching hospitals of DUMS comprising three NICUs. A standard observational checklist comprising nine radiation protection items, recommended by the International Commission on Radiological Protection (ICRP), International Atomic Energy Agency (IAEA) and scientific literature [11-13], was designed for data collection (**Tab. 1**). The validity of the checklist was independently assessed and confirmed by three expert radiologists in the field. Six radiologic technology students were invited and agreed to participate in this study. After training, the students were sent to the NICUs in the morning and afternoon work shifts for two months (57 work shifts). The students were asked to attend as observers in the NICUs and record the observance of radiological protection specified in the checklist. The confidentiality of the study was respected. We also supplemented data from the observational study with a retrospective survey of the images at the picture archiving and communication system (PACS) database. We retrieved the portable neonatal chest and abdomen images from January 2018 to June 2018. Two expert radiologists independently reviewed each image for the probable evidence of protection such as appropriate beam collimation and shielding tools. According to the protocol, acceptable beam restriction was defined 2 cm out of perfect beam restriction from all sides. The need for x-ray repetition due to poor radiographic technique, patient rotation or movement was also investigated.

Results

In all, 230 neonatal chest and abdomen x-rays from 65 neonates (29 male and 36 female) were investigated during 57 work shifts. These x-rays were from the chest (n = 192), the abdomen (n = 15) and both the chest and abdomen (n = 23). It was observed that 173 (90.1%) chest x-rays, 12 (80%) abdomen x-rays and 3 (13%) chest/abdomen x-rays had unsatisfactory beam restriction. In all the NICUs, protective shielding tools were available; however, they were not commonly applied to the patients. Most of the personnel used the same exposure parameters (42 kVp and 3.2 mAs), and the appropriate exposure parameters (high kVp and low mAs) were used occasionally. The focus to film distance (FFD) was in the appropriate range of 40 to 80 cm. All the radiographers and most of the NICU personnel stood behind the lead-wall in posteroanterior position to the radiation source. In the retrospective study, 498 portable x-rays were retrieved from the PACS database, in which only 17.5% and 0.4% of images have adequate beam restriction and evidence of shielding, respectively (**Fig. 1**). It was estimated that at least 65 x-rays were needed to be repeated due to bad positioning of the neonate. A neonatal chest x-ray with poor beam restriction is presented in **Fig. 2**.

Table 1. Radiation safety items.

1.	Availability of the gonad/abdomen shield in the NICUs (in observational phase)
2.	Availability of the mobile-lead-wall in the NICUs (in observational phase)
3.	Application of the gonad/abdominal shield (in observational phase)
4.	Application of the gonad/abdominal shield (in retrospective phase)
5.	Application of the mobile-lead-wall when x-rays are used (in observational phase)
6.	Restricting the primary beam to the ROI (in the observational phase)
7.	Restricting the primary beam to the ROI (in retrospective phase)
8.	Observance of 150 cm between neighbor neonates (in observational phase)
9.	Use of optimum exposure factors (high kVp and low mAs) (in observational phase)

ROI: region of interest.

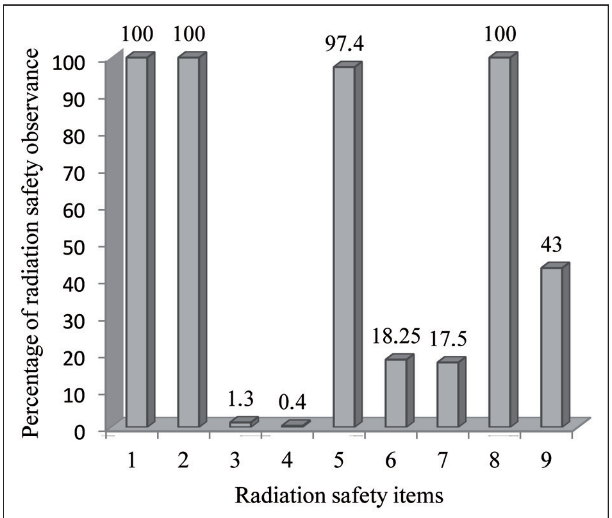

Figure 1. Radiation safety observance in neonatal portable chest/abdomen x-rays.

Radiation safety items are those defined in **Tab. 1**.

Discussion

Our data are commensurate with previous studies [10, 15-17]; however, they are inconsistent with others in some areas [18]. In agreement with the previous studies [10, 14-16], our study demonstrated that neonates had received unnecessary radiation exposure due to inappropriate beam restriction. This is of particular concerns as inadequate beam restriction could significantly increase patients dose and deteriorate image quality [19]. Increasing the primary radiation field from 6 × 6 to 8 × 10 inches could increase patients' dose by 50% [20]. Our data showed that 82.3% of all x-rays had inappropriate beam restriction.

Moreover, 16 neonates were radiographed as babygram (exposure to all body). The cervical and gonads were unnecessarily included in the primary beam in 93% and 40% of chest x-rays, respectively. In a similar study, Bader et al. [16] reported a similar concern for accidental exposure during neonatal chest and abdominal x-rays. Such findings have raised a concern about the unnecessary irradiation of radiosensitive tissues such as thyroid gland, gonads, and red bone marrow. It seems that the transition from analog to digital radiography has reduced motivations toward appropriate beam restriction [21] and needed to be considered, especially in neonatal imaging.

Increasing the FFD is an effective method to reduce patient radiation exposure during a radiological examination [11, 22]. Several studies have recommended the use of an updated FFD of 130 cm instead of the conventional FFD of 100 cm during pediatric [23] and adult x-ray examinations [23]. This can decrease patients' dose by 22-35% in pediatric x-ray imaging [23]. However, due to practical limitations in the portable radiography, it is recommended the FFD should not be lower than 35 cm. Our study coupled with the study by Tohidniya et al. [14] indicated that the FFD was in the permissible range.

Figure 2. A neonatal chest x-ray with poor beam restriction. There is no evidence of any protective tool.

The use of high tube voltage (kVp) and low current-time product (mAs), as long as not affecting optimal image contrast, could result in a reduction in patient dose [11]. However, our study along with other studies [7] reflects the lack of standardization of the applied exposure parameters in the neonatal chest and abdomen x-rays. Evidence suggests that 60 kVp is preferable for the neonatal chest x-rays [7]; however, our data demonstrated that the majority of the radiographers used fixed exposure parameters of 42 kVp and 3.2 mAs for neonatal x-rays, which needed to be corrected.

Shielding is one of the primary methods recommended to reduce the patients' radiation exposure during a radiological procedure [10, 11]. Evidence showed that application of 1 mm lead shield could decrease patients' dose by 97-99% [10, 24]. Although the effectiveness of shielding has been highlighted in the literature, our study showed that shielding was neglected in clinical practice in both the observational (1.3%) and retrospective (0.4%) phases of the study. The inferior status of shielding in Iranian hospitals has been previously reported in other studies [10, 14]. To the best of our experience, the key to the implementation of radiation safety issues is strict advice and supervision of medical health physicist. However, there are limitations in this regard. For example, it was reported that "pediatricians and radiologists believe that it is not necessary to have the advice of a medical physicist in pediatric radiology" [7].

Although portable x-ray exposes neonates to very low radiation, due to full frequency, it should not be underestimated. Moreover, during the use of portable x-rays in the NICU, the nursery personnel and parents usually leave the room or stand behind a mobile-lead-wall, next to the radiographer who is wearing the lead apron. Parents and nursery personnel worry for the radiation risk associated with irradiation of the neighbor neonates from scatter radiation. Several studies have addressed these exposures and suggested that the neighbor neonates and other persons in the room have received negligible radiation dose and it is not necessary to leave the room. However, the distance from the central beam should be kept at 150 cm or more, when the radiograph is taken in the vertical beam [25, 26]. The use of mobile-lead-wall is also an effective method to protect the radiographers and personnel from scatted radiations in the room. In our study, the mobile-lead-wall was available in all NICUs, and the personnel either left the room or stayed behind the mobile-lead-wall when the neonate was being x-rayed. In agreement with Tohidniya et al. [14], our data showed that the status of radiological protection seems to be appropriate for the radiographers and nursery personnel; however, neonates receive unnecessary and avoidable radiation exposure. It is known that changes in skills, knowledge, and attitudes of learners are mainly influenced by the change in behavior or practice [27]. Therefore, increasing the knowledge of radiographers may play an essential role in the implementation of radiation safety issues. We believe that our data are more reliable than data from those studies using questionnaires for data collection. However, the main limitation of the current study was the time-consuming process of data collection and also practical limitations of this process in the night work shifts, considering the personnel's fatigue and its probable influence on observing protection issues.

Conclusion

Our study was commensurate with previous studies and emphasized that neonates in the hospital investigated are receiving avoidable excessive radiation exposure, mainly due to inappropriate beam restriction. Although the status of radiological protection seems to be appropriate for the radiographers and nursery personnel, the neonates require further attention from the radiation protection point of view. Providing educational pamphlets and in-service training programs may help implement radiation safety issues. However, it is pertinent to note that this is not easy to have a sudden change in practice following changes in educational environments.

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Declaration of interest

The Authors declare that there is no conflict of interest.

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