

RESEARCH

Open Access



Evaluation of patient radiation doses using DAP meter in diagnostic radiology procedures in Birjand, Iran

Hassan Zarghani, Masoud Jabbari* and Sajjad Pandesh

Abstract

Background The concept of diagnostic reference level (DRL) is considered a regular method to optimize radiation protection in diagnostic imaging system. The objective of implementing a reference level for dose is to produce high-quality images by applying a minimum dose of radiation based on the As Low As Reasonably Achievable (ALARA) principle. Therefore, this study aimed to evaluate the status of radiation protection in diagnostic radiology wards of educational hospitals affiliated with Birjand University of Medical Sciences.

Methods This study was performed during a period of 11-months in the radiology center of the teaching hospital of Birjand University of Medical Sciences. The studied population included 477 patients who were referred to as clinically indicated x-ray radiography. In order to calculate local DRLs, dose area product (DAP) was measured by a DAP-meter (KERMAX-plus SPD, model 120–131 HS) for 11 devices at educational hospitals affiliated with Birjand University of Medical Sciences. The local DRL values was calculated as 75% of the mean DAP distribution for a specific patient trial at each center.

Results DAP for Chest PA examination was gained to be in the range from 0.12 Gy.cm² to 0.42 Gy.cm² with an average value of 0.23 Gy.cm² which is above the value of the reference level (0.12 Gy.cm²) for Chest PA. For Chest lateral the observed DAP was found to be in the range from 0.18 Gy.cm² to 1.48 Gy.cm² with an average value of 0.65 Gy.cm² and are therefore twice the reference value (0.3 Gy.cm²). The higher DRL values (average = 2.73) are for lumbar spine lateral radiography. It is observed that the DRL values of chest PA, abdomen AP and Lumbar spine AP are much lower with the earlier studies.

Conclusions The DRLs helps in understanding the current practices in radiographic examinations. Comparison with other hospitals, the scope of dose optimization and ultimately patient dose reduction in hospitals affiliated with Birjand University of Medical Sciences needs further investigation.

Keywords Diagnostic reference level, Dose area product, Radiation protection

Background

Diagnostic x-ray examinations as a basic tool for preserving and recovery of human health play an important role in helping the radiologist to discover a defect, monitor the improvement of diseases and assess the cure reaction. In the United States, medical radiation exposure is approximately the middle of whole radiation exposure from man-made and natural sources [1]. This is serious as the medical application of ionizing radiation over 95%

*Correspondence:

Masoud Jabbari

masoudjabbari@yahoo.com

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



© The Author(s) 2023. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

of all artificial radiation exposures and is the major radiation source after natural radiation [2]. Ionization radiation can both induce damaging consequences and supply a strong instrument for diagnostic goals. The relation has been demonstrated among radiation exposures and the occurrence of cancer. It is so important to evaluate the dose received at the x-ray examination. The dose assessment is used either as a representation for radiation risk or as a stage in the real approximation of the risk. There are three basic concepts for radiation protection that are justification, optimization, and dose limit. The optimization needs the usage of particular protocols to convince the remaining doses at a reasonably achievable low level (ALARA) [3]. One of the fundamental provisions for optimization is the perception of patient doses orderly; dosimetry is advised to appraise the dose of patients. Now measurement dose of the patient is considered as a perfect section of a quality assurance program. For optimization, the dose reference level (DRL) is one of the most useful means. DRL is described by two quantities of dose area product and entrance skin dose (ESD) [4]. In the United States, the dosimetry and quality control of x-ray instruments regularly have shown and the establishment of DRLs has played substantial roles in decreasing patient doses [5]. ESD for the 1964 to 2004 decrees 50–70%. A similar x-ray examination in various countries may have different values. As a result, DRLs can be just defined for a city or country as local diagnostic reference levels (LDRLs), while nationwide surveys make national dose reference levels (NDRLs) [6]. However, by comparison another diagnostic imaging patient dose in radiography is low, its quota to the collective dose is considerably caused to the repeated utilization of it. Dose-Area-Product (DAP) is a result of the area of a patient that is exposed multiplied by the radiation dose [7]. The unit of DAP is $\text{Gy}\cdot\text{m}^2$. Measurement of DAP is appropriate to achieve the optimum level of protection in radiological tests of patients. In utilization, the ionization chamber is located vertically to the beam central and in a position to totally cut off the total region of the x-ray beam. Compounding data of DAP with data on x-ray field size; can be applied to characterize the mean dose created by the x-ray. Then it must be located accurate reading. The reading from a DAP-meter can be varied by either changing the x-ray factors (kVp, mAs), or altering the field or both. Digital radiology over the last decade may demonstrate the major technological development in medical imaging. Although digital radiology has the potential to decrease patient doses, they also have the potential to notably enhance them. This study evaluated the patient dose with a DAP meter and LDRLs for common radiography examination by conventional and digital radiography in South Khorasan, Iran.

Methods

This study was performed in South Khorasan, Iran in the departments of radiology at the educational hospitals affiliated with Birjand University of Medical Sciences department during the period September 2019 to October 2020. There were four active radiology rooms in three educational hospitals of Birjand city (Emam reza, Valias and Razi). The technical specifications of the devices are shown in Table 1. They were chosen from patients randomly who had been referred to the radiographic department of hospitals in South Khorasan. Data were accumulated from physical parameters such as kVp, mAs, and patient data (age, sex, and weight), and type of projection which are as follows: neck (AP), lumbar spine (AP and Lat), skull (AP and Lat), abdomen (AP), pelvis (AP) and CXR. All unite used were conventional and digital radiography (Table 1). All projections and measurements were performed on four different x-ray machine models. The first step for the examined x-ray machine performed a quality control test. Total filtration for all units was 3.5 mm aluminum at 80 kV. Also, the DAP-meter for each type of x-ray projection registers by itself.

DAP was measured by a DAP-meter (KERMAX-plus SPD, model 120–131 HS). It is capable of measuring output X-ray tubes, with an energy range of 40–150 kVp (less than 3 mm Al). The condition recommended is as followed: temperature between +10 °C and +50 °C, humidity between 30 and 75% without condensation, and pressure between 700 and 1060 hPa. It transfers data to a connected computer every 5 ms.

DAP-meter must be calibrated before being used. Calibration process was done according to the method suggested by NRPB protocol, to achieve DAP values [8]. The DAP had a monitor and a detector. The detector was fixed under the beam collimator. A calibrated X-ray test device piranha model was used to measure the performance of the examined X-ray machine and for quality control. The X-ray machines were calibrated. Digital images were acquired by the complete automatic system. An essential quality control test for all x-ray machines including accuracy of the timer, kVp, mA linearity, mAs reciprocity, half value layer (HVL) check, and output check) was done to ensure the high accuracy. The absorbed dose (in unit of Gy) multiplied by the area of tissue irradiated is defined as DAP which reflects dose in the radiation field [9] The DAP values were measured in $\text{cGy}\cdot\text{cm}^2$ and then were converted to $\text{Gy}\cdot\text{m}^2$. Average DAP values were calculated from the measurements for each device for the 8 conventional examinations considered in this study: Neck(AP), Skull(lat), Skull(AP), Abdomen, CXR, Lumbar(Lat), Lumbar(AP), Pelvic. The third quartile DAP values were then calculated from the results for each radiographic examination type and view and adopted as the LDRL in Birjand.

Table 1 The technical specifications of the devices

Device	Manufacture	Maximum KV	Year of installation	AEC system	Total filtration thickness (mm Al)
1	TOSHIBA	150	2018	Yes(not used)	2.4
2	SEMENS	150	2018	NO	1
3	SHIMADZU	150	2019	NO	2.5
4	Varian	150	2019	NO	2.7

Table 2 The radiological and patient parameters (weigh of patient, height of patient, kVp, mAs)

Projection	Number	Patient age	Patient weight (kg)	Patient height (cm)	Tube voltage (kvp)	mAs
Conventional						
Neck(AP)	21	53.25 (18–88)	75.6 (51–97)	170.6 (149–203)	61.75 (60–70)	14.4 (12–20)
Skull(lat)	21	44.15 (18–85)	67.2 (41–95)	161.95 (135–187)	66.2 (60–72)	15.4 (12–20)
Skull(AP)	21	49.9 (20–87)	67.35 (43–95)	162.7 (140–187)	69.5 (65–75)	19.2 (16–20)
Abdomen	41	50.31 (22–82)	72.05 (55–99)	165.76 (146–189)	74.2 (70–78)	6.36 (5–8)
CXR	41	44.43 (18–74)	69.84 (46–103)	166.76 (145–188)	99.87 (90–110)	3.32 (3.2–4)
Lumbar(Lat)	21	50.45 (19–87)	78.3 (48–123)	166.35 (145–189)	84.6 (79–90)	31.3 (25–32)
Lumbar(AP)	21	53.1 (19–90)	70.75 (44–98)	169.3 (145–189)	70.65 (65–78)	21 (20–225)
Pelvic	41	55.2 (18–89)	67.25 (49–94)	166.25 (143–195)	72.5 (65–80)	17 (16–20)
Digital						
Neck(AP)	21	67.95 (27–90)	67.85 (45–103)	165.9 (144–199)	61.75 (60–65)	16.4 (12–20)
Skull(lat)	21	51.8 (18–86)	73.4 (47–98)	163.45 (130–190)	63.55 (60–70)	18.2 (16–20)
Skull(AP)	21	45.8 (18–86)	74.15 (48–94)	168.75 (142–192)	70.75 (65–75)	19 (16–20)
Abdomen	41	57.3 (23–88)	75.2 (52–97)	161.95 (140–188)	74.7 (70–78)	7.53 (5–8)
CXR	41	55.3 (24–82)	71.05 (45–123)	162.9 (140–194)	100 (95–108)	3.32 (3.2–4)
Lumbar(Lat)	21	53.85 (21–87)	64.4 (45–89)	161.45 (143–190)	84 (80–85)	28.85 (25–32)
Lumbar(AP)	21	44.55 (21–86)	68.4 (49–95)	168.05 (144–195)	75.5 (70–80)	23 (20–25)
Pelvic	41	60.85 (23–84)	76.35 (47–98)	169.7 (140–190)	81.95 (80–87)	19 (16–20)
neck(Lat)	21	46.85 (19–87)	72.85 (46–97)	168.95 (142–194)	63 (60–65)	17.8 (16–20)

Results

In this study radiographic and demographic information of 477 patients was collected. Table 2 shows the radiological and patient parameters (weigh patient, high patient,

kVp, mAs). Table 3 displays the average, minimum, maximum, mean, median, first quartile, third quartile of DAP for X-ray examination. Observed DAP for CXR was Minimum of average and quartile3th DAP is CXR of

Table 3 Shows the average, minimum, maximum, mean, median, first quartile, third quartile of DAP for X-ray examination

	Mean	Min	Max	First quartile	Median	Third quartile
Digital						
Neck(Lat)	0.13559	0.0813	0.1603	0.1272	0.1415	0.1581
Neck(AP)	0.11583	0.0728	0.1435	0.0903	0.11495	0.14115
Lumbar(Lat)	2.696855	2.4213	3.0849	2.431175	2.68355	3.0423
Lumbar(AP)	2.044285	1.9699	2.1263	1.9789	2.02165	2.120075
Skull(Lat)	0.29328	0.2318	0.4298	0.256375	0.2863	0.315425
Skull(AP)	0.29574	0.1748	0.4215	0.1901	0.283	0.380175
Skull(AP)	0.5211	0.5005	0.5053	0.5198	0.503110256	0.4611
Pelvic	1.6178	1.4498	1.5322	1.5712	1.496433333	1.2528
CXR	0.1128	0.0922	0.0934	0.0975	0.096048718	0.0868
Conventional						
Pelvic	1.3405	0.801775	0.9365	1.09705	0.963776316	0.7812
Lumbar(AP)	2.73039	0.3509	42.11	0.419725	0.62625	0.934375
Lumbar(Lat)	2.491505	1.6411	3.0821	2.3871	2.6719	2.7394
CXR	0.091282	0.0632	0.1435	0.0789	0.092	0.0945
Abdomen	0.372174	0.234	0.5428	0.32525	0.35775	0.461
Skull(AP)	0.26941	0.0449	0.4047	0.23865	0.25255	0.3029
Skull(Lat)	0.20284	0.1497	0.2771	0.1863	0.1961	0.2133
Neck(AP)	0.11606	0.0745	0.2089	0.093375	0.10215	0.135275

Table 4 Displays DRLs for different projection radiographies in this study, and our results were check with DRLs of other study

Projection	This study by convolution	This study Digital	Zarghani [10]	Shandiz [11]	Iran [12]	Japan	NRPB
Dose							
Chest(AP)	0.09	0.08	0.64	0.25	0.97	–	1
Chest (PA)	–	–	0.54	0.22	0.41	0.3	0.2
Abdominal	0.46	0.46	2.15	1.29	4.06	3	6
Pelvic	0.78	1.25	1.47	1.09	3.15	4	4
Lumbar(PA)	0.93	2.12	1.99	0.7	3.43	11	6
Lumbar(Lat)	2.73	3.04	3.83	1.52	8.41	–	14
Skull pa	0.30	0.38	1.22	0.42	2.85	–	3
Skull Lat	0.21	0.31	1.01	0.39	1.93	–	1.5
cervical PA	–	–	0.58	0.15	1.83	0.9	–
Cervical Lat	–	–	0.74	0.16	0.93	3	–
Neck(AP)	0.13	0.14	–	–	–	–	–

conventional radiography. DAP for Digital radiography for CXR is 0.11. The observed DAP for Chest PA examination was gained to be in the range from 0.12 Gy.cm² to 0.42 Gy.cm² with an average value of 0.23 Gy.cm² which is above the value of the reference level (0.12 Gy.cm²) for Chest PA given in Table 3. For Chest lateral the observed DAP was found to be in the range from 0.18 Gy.cm² to 1.48 Gy.cm² with an average value of 0.65 Gy.cm² and are therefore twice the reference value (0.3 Gy.cm²) given in Table 3.

Table 4 displays DRLs for different projection radiographies in this study, and our results were checked with DRLs reported by NRPB, Japan, and NDRL. According to Table 4, the 3rd quartile of the measured by digital radiography is upper than convolution radiography. The dose of all projection is lower than in other studies. Figure 1 shows the different means of dose obtain by digital and convolution radiography. DRL for digital radiography is upper than convolution radiography.

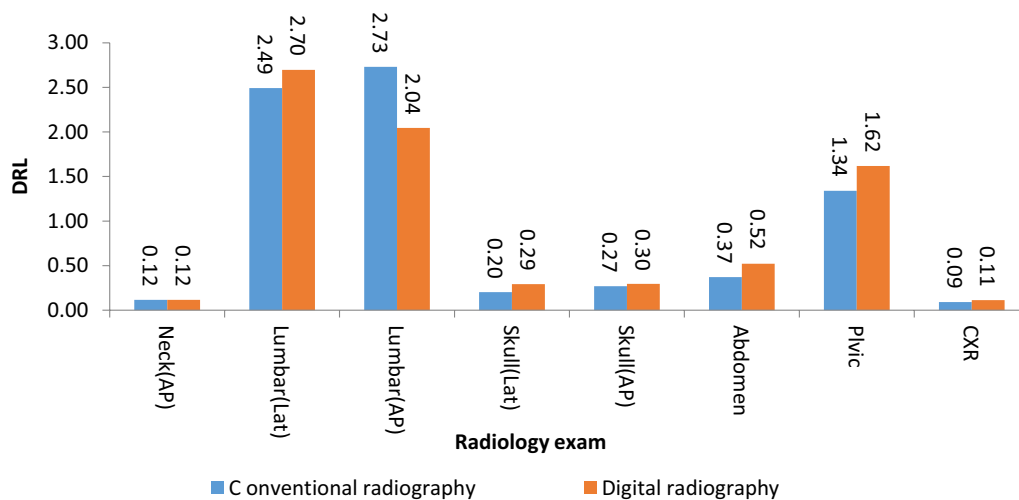


Fig. 1 DRL values for different radiology examinations

Discussion

The linear no-threshold theory says that low dose of ionizing radiation is also not safe. Therefore, decrease of the doses from medical exposures is a serious stage into radiation protection. Measurement of radiation dose in patients is crucial to optimize radiological protection in x-ray centers. This study presents useful information about the radiation dose received by patients undergoing common radiology procedures at hospitals affiliated to Birjad university of medical sciences. It can be used for comparing patients' dose with the established DRL values in order to refuse unnecessary radiation exposure than needed. Table 3 shows a wide range of DAP values for radiographic procedures. These variations were also observed in a same device, for a specific procedure for different patients and in different devices for similar procedures. For instance, the maximum-to-minimum ratio of DAP for individual patients varied from 0.1 for chest LAT to 42 for skull AP/PA. Other studies also have reported such wide variations in diagnostic radiography practice [13, 14]. According to our results, the average DAP value for patients are consistent with reported by many studies have been done in Iran [10, 15–21]. The DAP value measured in this study for the CXR is consistent with the values reported by Faghihi et al. [22] and Smans et al. [12] for neonatal chest x-rays, whereas, it was lower than values reported by Bahreyni Toossi et al. [23]. Both agreement and discordance were present between our study and other study performed by chest x-rays in Iran. Similarly, our results are inconsistent with DAP value reported by Zewdu et al. for patients during chest x-rays [22]. Variation in the applied film to source distance (FSD) and exposure parameters (kVp

and mAs), patient habitus, use or not use of anti-scatter grid and x-ray units used in these studies are major reasons for the variation of data. We found no significant correlation between patients' sex and weight with DAP values, whereas, a significant correlation was seen for the applied kVp and mAs. These results are consistent with the literature [6]. Variation in typical doses delivered by different x-ray rooms and departments is still substantial, indicating that there is further scope for patient dose reduction in those departments at the top end of the dose range. This verifies the continuing usefulness of reference doses for identifying them. Digital devices have revolutionized medical imaging. Digital radiography can help reduce the patient's dose as long as the operator is trained. There are solutions to reduce the dose and increase the quality of the image, which can be improved by training technologists. As mentioned, improper use of digital radiography can lead to an increase in the dose. What was also shown in this study was that the dose from radiographic convolution imaging was lower than from digital radiography. This is a sign of poor training for technologists. On the other hand, the dose range and the difference between the lowest and highest doses are very high, and this shows that it is possible to provide a suitable image in a specific projection by reducing the dose. Therefore, we need to work hard to reduce the dose.

Conclusions

Variation in typical doses delivered by different x-ray rooms and departments is still substantial, indicating that there is further scope for patient dose reduction in those departments at the top end of the dose range. Training radiation workers and implementing a QA program for

devices are necessary for lower patient doses and lower costs for medical health services.

Abbreviations

DRL	Diagnostic reference level
DAP	Dose area product
QA	Quality assurance
AP	Anterior posterior
PA	Posterior anterior
LAT	Lateral
CXR	Chest x-ray

Acknowledgements

I am grateful to all of those with whom I have had the pleasure to work during this and other related projects.

Author contributions

MJ (the corresponding author) is responsible for ensuring that the descriptions are accurate and agreed by all authors. All authors had made substantial contributions to all of the following: (1) the conception and design of the radiological work, (2) the measurement, analysis and interpretation of data; (3) drafting the work and revising it; (4) conduction of revision and corrections as per reviewers' comments. All authors have agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature. All authors approved the revised version. All authors read and approved the final manuscript.

Funding

No funding was obtained for this study.

Availability of data and materials

The data that support the findings of this study are available on request from the corresponding author.

Declarations

Ethics approval and consent to participate

The medical ethics were considered and respected. The study was approved by Institutional Ethics Committee in Birjand University of Medical Sciences.

Consent for publication

Not applicable.

Competing interests

None of the authors has competing interests.

Received: 16 September 2022 Accepted: 10 March 2023

Published online: 22 March 2023

References

- Shahbazi-Gahruei D (2005) The rate of exposure of patients in common X-ray examinations in radiology centers of Chaharmahal & Bakhtiari province. *J Shahrekord Univ Med Sci* 7(2):57–63
- Nowak B, Jankowski J (1991) Occupational exposure in operational radiology. *Pol J Occup Med Environ Health* 4(2):169–174
- Bevelacqua JJ (2010) Practical and effective ALARA. *Health Phys* 98(2):S39–47
- Marshall NW, Chapple CL, Kotre CJ (2000) Diagnostic reference levels in interventional radiology. *Phys Med Biol* 45(12):3833
- Seeram E, Brennan PC (2006) Diagnostic reference levels in radiology. *Radiol Technol* 77(5):373–388

- Ruiz-Cruces R, Vano E, Carrera-Magariño F, Moreno-Rodríguez F, Soler-Cantos MM, Canis-Lopez M, Hernández-Armas J, Diaz-Romero FJ, Rosales-Espizua F, Fernandez-Soto JM, Sanchez-Casanueva R (2016) Diagnostic reference levels and complexity indices in interventional radiology: a national programme. *Eur Radiol* 26(12):4268–4276
- Brambilla M, Marano G, Dominiotto M, Cotroneo AR, Carriero A (2004) Patient radiation doses and references levels in interventional radiology. *Radiol Med (Torino)* 107(4):408–418
- Hart D, Hillier MC, Wall BF. Doses to patients from radiographic and fluoroscopic X-ray imaging procedures in the UK—2005 review. HPA-RPD-029. Chilton, UK: HPA;2007.
- Kisielewicz K, Truskiewicz A, Wach S, Wasilewska-Radwańska M (2011) Evaluation of dose area product vs patient dose in diagnostic X-ray units. *Physica Med* 27(2):117–120
- Zarghani H, Bahreyni Toossi MT (2015) Evaluation of organ and effective doses to patients arising from some common X-ray examinations by PCXMC program in Sabzevar, Iran. *Iran J Med Phys* 12(4):284–291
- Shandiz MS, Toossi MB, Farsi S, Yaghobi K (2014) Local reference dose evaluation in conventional radiography examinations in Iran. *J Appl Clin Med Phys* 15(2):303–310
- Smans K, Struelens L, Smet M, Bosmans H, Vanhavere F (2008) Patient dose in neonatal units. *Radiat Prot Dosimetry* 131(1):143–147
- Brennan PC, Johnston D (2002) Irish X-ray departments demonstrate varying levels of adherence to European guidelines on good radiographic technique. *Br J Radiol* 75(891):243–248
- Rainford LA, Al-Qattan E, McFadden S, Brennan PC (2007) CEC analysis of radiological images produced in Europe and Asia. *Radiography* 13(3):202–209
- Bouzarjomehri F (2004) Patient dose in routine X-ray examinations in Yazd state. *Iran J Radiat Res* 1(4):199–204
- Aliasgharzadeh A, Mihandoost E, Masoumbeigi E, Salimian M, Mohseni M (2015) Measurement of entrance skin dose and calculation of effective dose for common diagnostic X-ray examinations in Kashan. *Iran. Global Journal of Health Science* 7(5):202
- Schauer DA, Linton OW (2009) NCRP report no. 160, ionizing radiation exposure of the population of the United States, medical exposure—are we doing less with more, and is there a role for health physicists? *Health Phys* 97(1):1–5
- Toosi MT, Asadinezhad M (2007) Local diagnostic reference levels for some common diagnostic X-ray examinations in Tehran county of Iran. *Radiat Prot Dosimetry* 124(2):137–144
- Bijari S, Banaei A, Kanani M (2016) Assessment of entrance skin doses and effective dose for common X-ray diagnostic examinations. *Paramed Sci Mil Health* 11(3):1–5
- Monfared AS, Mozdarani H, Amiri M (2003) Natural background radiation induces cytogenetic radioadaptive response more effectively than occupational exposure in human peripheral blood lymphocytes. *Czech J Phys* 53(1):A791–A795
- Barquinero JF, Barrios L, Caballín MR, Miró R, Ribas M, Subias A et al (1993) Cytogenetic analysis of lymphocytes from hospital workers occupationally exposed to low levels of ionizing radiation. *Mutat Res* 286(2):275–279
- Faghihi R, Mehdizadeh S, Sina S, Alizadeh FN, Zeinali B, Kamyab GR et al (2011) Radiation dose to neonates undergoing X-ray imaging in special care baby units in Iran. *Radiat Prot Dosimetry* 150(1):55–59
- Toossi MTB, Malekzadeh M (2012) Radiation dose to newborns in neonatal intensive care units. *Iran J Radiol* 9(3):145–149

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.