

Evaluation of DAP Values Obtained from Chest X-Rays in Children under 12 Years of Age Referred to Educational Hospitals of Birjand University of Medical Sciences in 2020

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Abstract

Purpose: Dose Area Product (DAP) is a quantity for radiation risk assessment in diagnostic X-ray tests. Children's tissues are up to 10 times more sensitive to radiation than adults, and life expectancy is higher in children than adults, as well as a higher risk of hematopoietic and mass malignancies in them. Therefore, this study aimed to measure DAP values for X-ray fields adjusted by Birjand radio-technologists in chest X-rays of children under 12 years of age.

Materials and Methods: 233 children from Birjand University hospitals who performed chest X-rays were included in the study. To collect data related to DAP, the DAP meter model KermaX® plus SDP was used. It should be noted that no intervention was performed in the patient's imaging method and at the time of radiation and measurement of the DAP values, there was no need for the patient's presence. In the end, the measured DAP values were compared with DAP values of other studies. Data were analyzed using SPSS software version 22 at 5% error level using Analysis of Variance (Anova), t-test, and Pearson correlation tests.

Results: Out of 233 patients who were included in the study, 134 males (57.5%) and 99 females (42.5%) participated in the study, it should be noted that there was no significant difference between the mean of DAP in male and female ($p = 0.52$). In our study, the average DAP was $5.78 \pm 3.54 \mu\text{Gy.m}^2$ and DAP values in the range of $0.55 \mu\text{Gy.m}^2$ to $15.54 \mu\text{Gy.m}^2$ that were higher than the average of other studies and there was a significant difference. There was a direct relationship between radiation field dimensions and DAP values so that as the dimensions of the radiation field increase, the DAP value increases. There was a significant difference between the mean DAP of the lowest and the highest age groups, lowest and the highest age groups, and lowest and the highest height groups of patients.

Conclusion: In our study, it was observed that there is a significant relationship between patients' weight, age, and height, radiation field dimensions with DAP values. The amount of DAP in the present study was significantly higher than in other studies. The most important effective parameter in DAP is the radiation field size and if sufficient optimization is done in imaging parameters (kVp, mAS, field size), the DAP values will be greatly reduced.

Keywords: Dose Area Product; Pediatric Radiography; Chest X-Ray; Radiation Risk.

1. Introduction

With the increasing advancement of science and technology, we are witnessing the widespread use of X-rays in the diagnosis and treatment of various diseases, including respiratory diseases, diagnosis, and treatment of tumor lesions or fractures of the skeletal system, etc. X-ray along with its numerous benefits also carries potential risks. The energy left by the radiation to the patient's body can lead to direct and indirect damage. It has been shown that ionizing radiation is carcinogenic and mutagenic. Due to cell irradiation and lack of complete repair, there is a possibility of cell death, and if it survives, depending on the cell type (somatic, sexual), there is a possibility of cancer or hereditary damage [1]. Therefore, performing radiological examinations requires the application of protective principles to reduce the potential risks of radiation. Since the size of the X-ray field affects both the image quality and radiation dose of the patient, so when performing radiography, the radiation field must be restricted by the radiology technologist. Collimating the X-ray field size, in addition to reducing the patient absorbed dose, due to reduced scatter rays, will also increase the image quality [2].

Studies showed that changes in the dose received by patients on a radiograph and for a radiographic device are sometimes changed by a factor of 100, which can be due to the operator inattention, the lack of X-ray machine calibration, and failure to select appropriate X-ray parameters (kVp, mAs) for each imaging method that increase the dose received by patients. This indicates that the use of appropriate devices and optimized methods can greatly reduce the dose received by the patient [3, 4].

Dose Area Product (DAP) is a quantity for radiation risk assessment in diagnostic X-ray tests. This quantity is defined as the product of the absorbed dose over the area of the X-ray field and is expressed in Gy·cm². Since DAP, in addition to the dose, takes into account the area of tissue that received the dose, it is a better indication of the overall risk of cancer incidence compared to the absorbed dose alone. Another advantage of DAP is the ease of measuring it and calculating the entrance skin dose using it [5].

After measuring these quantities for patients in different centers, it is necessary to compare these values with standard values or values of other studies. The International Commission for Radiological Protection (ICRP) has provided protocols for measuring the radiation dose of patients in diagnostic radiology [6].

Pediatric tissues are up to 10 times more sensitive to radiation than adults, and life expectancy is higher in children than adults, and the risk of hematopoietic and mass malignancies is higher in children [7-9]. On the other hand, chest radiography is one of the most widely used X-ray imaging tests, with 20% in Australia and the Netherlands, 21% in Germany, 28% in Switzerland, Canada, Turkey, the United Kingdom, and the United Arab Emirates 29%, Kuwait 36%, and Japan 42%, Qatar 51% and Malaysia 63% of all X-ray imaging tests (plain radiographs, radiographs with contrast media, mammography, angiography, and Computed Tomography (CT) scan) [10].

Although patients' doses on chest radiographs are relatively low, because of the large number of people undergoing this test, the contribution of chest radiographs to the cumulative effective dose is important. Studies conducted in different countries show that the dose of patients in different centers in each country can be very different. This difference can be explained by a comprehensive study of the effective factors in this issue [11]. Therefore, the aim of this study was to measure the DAP values for the X-ray field sizes adjusted by radio-technologists in Birjand and compare them with other studies in chest radiographs of children under 12 years in 2020.

2. Materials and Methods

This study was a descriptive-analytical cross-sectional study. The study population was 233 children under 12 years old who referred to the imaging centers of educational hospitals of Birjand University of Medical sciences. The inclusion criteria were patients with chest radiographs and under 12 years of age.

The patients referred to educational hospitals of Birjand University of Medical Sciences were included in the study, if they had inclusion criteria and no exclusion criteria and had informed consent. The questionnaire was filled out by the researcher. In order to collect data related to DAP, DAP meter model KermaX® plus SDP Bought from the IBA company was used. For this purpose, first, questionnaires, including the patients' personal information (such as age, sex, weight, height, body thickness, etc.), radiation exposure parameters selected by the radio-technologist (kVp, mAs, and Focus to Film Distance (FFD)), and the size of the X-ray field were prepared. The prepared questionnaire did not include the name and surname. After collecting

the questionnaires, by installing the DAP meter to the output of the radiology machine and adjusting the radiation exposure parameters according to the information recorded in the questionnaires, DAP values were measured. It should be noted that no intervention was performed in the patient's imaging protocol and at the time of irradiation and measurement of DAP values, there was no need for the patient's presence and, therefore, the patient did not receive an additional X-ray dose.

3. Results

The results of this study were based on the data collected in a 10-month period in which the information of 235 patients referring to mentioned imaging centers was included in the study. Two patients were excluded from the study because of their unwillingness to continue. The data of the remaining 233 patients were evaluated. Among the 233 patients, 134 males (57.5%) and 99 females (42.5%) participated in the study. The average DAP in females (6.21 $\mu\text{Gy.m}^2$) was higher than the average DAP in males (5.46 $\mu\text{Gy.m}^2$) probably due to the fact that more girls were in the older age group. It should be noted that

there was no significant difference between the mean of DAP in male and female sex.

In the present study, the age distribution of patients was between 1 month and 12 years, which was compared with other studies with two types of age grouping. The age range of patients in our study was between 1 month and 12 years. The highest number of patients was in the age range of 1-5 years, which included 114 (48.9%) patients. The highest average DAP was for patients aged above 10 years, which was significantly higher than the average DAP of patients in group 1 ($p=0.00$). As shown in Tables 1 and 2, there is a direct relationship between the patient's age and DAP values, so that the DAP value increases with age.

Type A grouping: 1 (<1 year), 2 (1-5), 3 (5-10), 4 (10<). Type B grouping: 1 (<6 months), 2 (6 months – 2.5 years), 3 (2.5 -7.5 years), 4 (7.5-12.5 years). In this study, the average DAP value was $5.78 \pm 3.54 \mu\text{Gy.m}^2$ with a range of $0.55 \mu\text{Gy.m}^2$ to $15.54 \mu\text{Gy.m}^2$. The average DAP in our study was significantly higher than the average DAP in other studies. Tables 1 and 2 and Figure 1 compared the

Table 1. Comparison of the average DAP values from chest X-ray in children in the present study with other studies (Type A grouping)

Group	Age	Number of patients	DAP in this study (mean \pm SD) $\mu\text{Gy.m}^2$	DAP in UK (mean \pm SD) $\mu\text{Gy.m}^2$	Other studies (mean \pm SD) $\mu\text{Gy.m}^2$
1	<1	39	3.39 \pm 2.51	1.5 ($p=0.05$)	2.3 ($p=0.01$)
2	1-5	114	5.24 \pm 3.26	2.4 ($p=0.00$)	3.4 ($p=0.00$)
3	5-10	48	6.65 \pm 3.12	3.2 ($p=0.00$)	5.7 ($p=0.04$)
4	>10	32	9.79 \pm 3.43	6.4 ($p=0.00$)	-

Table 2. Comparison of the average DAP values from chest X-ray in children in the present study with other studies (Type B grouping)

Group	Age	Number of patients	DAP in this study (mean \pm SD) $\mu\text{Gy.m}^2$	DAP in France (mean \pm SD) $\mu\text{Gy.m}^2$	DAP in Germany (mean \pm SD) $\mu\text{Gy.m}^2$	DAP in Austria (mean \pm SD) $\mu\text{Gy.m}^2$
1	<6 m	23	3.09 \pm 2.56	1 ($p=0.01$)	0.8 ($p=0.00$)	1.7 ($p=0.02$)
2	6 m - 2.5 y	93	4.64 \pm 2.96	3 ($p=0.00$)	2 ($p=0.00$)	2.3 ($p=0.00$)
3	2.5y - 7.5y	73	6.99 \pm 5.57	5 ($p=0.00$)	3 ($p=0.00$)	2.6 ($p=0.00$)
4	7.5y – 12.5y	46	9.43 \pm 3.43	7 ($p=0.00$)	4 ($p=0.00$)	3.7 ($p=0.00$)

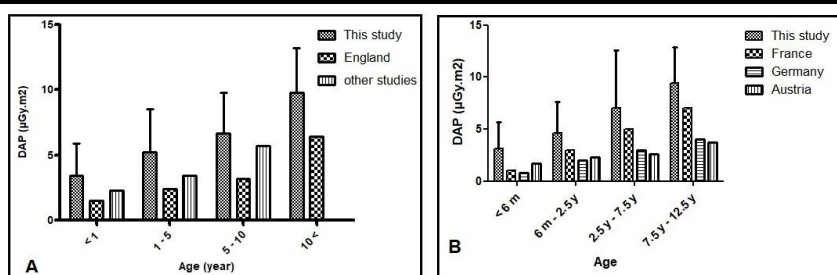


Figure 1. Comparison of the average DAP values from chest X-ray in children in the present study with other studies. A) Type A grouping and B) Type B grouping

mean DAP in each age group with the average DAP in other studies.

The weight of patients in our study ranged from 3 kg to 50 kg. The highest number of patients was in the weight group of 10-20 kg, which accommodated 90 (38.6%) patients, and the highest average DAP was for patients weighing more than 30 kg, which had a statistically significant difference with the average DAP of patients in the lowest weight group ($p = 0.00$). There was a direct relationship between patients' weight and the DAP, so that as the patient's weight increases, the DAP value also increases (Table 3, Figure 2).

Table 3. The relationship between DAP values from chest X-ray and the weight of the patients referred to educational hospitals of Birjand University of Medical Sciences

Weight (kg)	Number of patients	Percentage	DAP in this study (mean \pm SD) μ Gy.m ²
<10	76	32.6	3.59 \pm 2.61
10 – 20	90	38.6	5.69 \pm 3.04
20 – 30	31	13.3	7.45 \pm 3.40
30 <	36	15.5	9.20 \pm 3.14

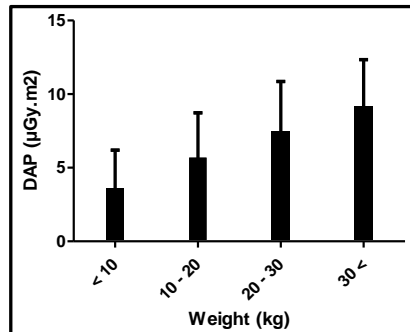


Figure 2. The relationship between DAP values from chest X-ray and patient weight for patients referred to educational hospitals of Birjand University of Medical Sciences

The height of the patients in our study was in the range of 50 to 158 cm. The highest number of patients was in the height group 50 to 75 cm, which accommodated 76 (32.6%) patients. The highest average DAP was for patients in the height group above 125 cm, which was significantly higher than the average DAP of patients in the lowest height group ($p = 0.00$) (Table 4, Figure 3). There was a direct relationship between patients' height and the amount of DAP, so that as the DAP values increase with the patient's height. As seen in Figure 4 there was a direct relationship between the radiation field size and DAP values so that the DAP value increases with the field size.

Table 4. The relationship between DAP values from chest X-ray and patient height for patients referred to educational hospitals of Birjand University of Medical Sciences

Height (Cm)	Number of patients	Percentage	DAP in this study mean \pm SD μ Gy.m ²
50 – 75	76	32.6	3.58 \pm 2.62
75 – 100	73	31.3	5.83 \pm 3.16
100 – 125	35	15	6.24 \pm 2.88
125 <	49	21	8.80 \pm 3.42

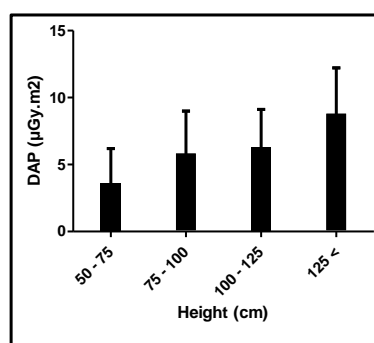


Figure 3. The relationship between DAP values from chest X-ray and patient height for patients referred to educational hospitals of Birjand University of Medical Sciences

4. Discussion

In the present study, the average DAP in females was higher than the average DAP in males, which seems to be due to the higher number of females at older ages. The radio technologist uses both the higher radiation exposure parameters (kVp and mAs) and the larger size of the radiation field to capture images of older patients. The higher radiation parameters are selected so that the beam

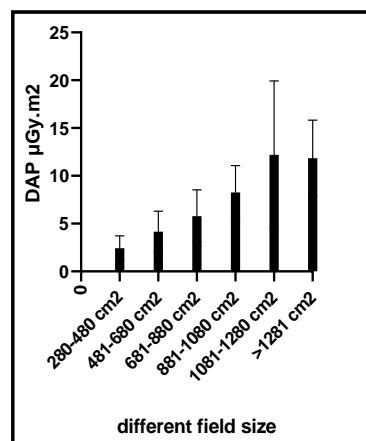


Figure 4. The relationship between DAP values from chest X-ray and patient height for patients referred to educational hospitals of Birjand University of Medical Sciences

can pass through the greater thickness of the older patient's body. The field size is chosen to be larger due to the patients' larger anatomy. The result of these two factors has been to increase the amount of DAP for girls. It should be noted that there was no statistically significant difference between the averages DAP in females and males ($p=0.52$).

The average DAP in our study was higher than the average DAP in other studies in England, France, Germany, and Austria and was statistically significant. It should be noted that because there is no standard value for DAP, comparisons were made with other studies in the same age group. The DAP value varies in different patients and it is similar to other studies. This is due to variations in the patient's anatomy such as height, weight, body size, or different radiation exposure parameters (field size, kVp, mA, S) selected by different radiotechnologists. It is highly recommended to reduce the radiation dose to the extent that the image quality is not reduced unacceptably.

The higher average DAP in this study compared to other studies indicates a lack of radiographic optimization, and it is expected that DAP can be reduced by optimizing radiation exposure parameters. Also, since in this study in most of the time the grid was in the x-ray path and in this condition the radio technologist has to increase the radiation exposure parameters, it will naturally increase the DAP values. So it is recommended to use the grid only in high kVp and high FFD techniques. Another point that can be mentioned is the difference in the type of devices used in our study compared to other countries.

The X-ray machines used in our study were digital and the devices used in other countries may be analog. Radiation exposure parameters in digital radiographs are a little higher than analog devices and will result in higher DAP in our study. In addition, the higher DAP values in this study could also be due to the use of poor radiographic techniques, or non-compliance with standard guidelines (such as guidelines on the amount of FFD, mAs, kVp, grid ratio, total filtration, etc.).

In the present study, it was observed that as the radiation field size increases, the amount of DAP increases, which was similar to the results obtained in the studies of Kisielewicz [12], Fauber [13] and Karami [14]. In the studies of Namdi [15] and Okeji [2] in most cases the field size collimations were insufficient and the results of both studies were consistent with our study. In the study of Kisielewicz [12] it was observed that the amount of DAP increases with increasing field size under constant

radiation exposure parameters. According to our study and similar studies, reducing the size of the radiation field will lead to a significant reduction in the DAP values [12-15].

In our study, it was found that there is a direct relationship between DAP and age, height and weight of the patient, which was similar to the results in the studies of Billinger [16], Roch [17], and McDonald [18]. In the study of Chida [19], the correlation between DAP values in fluoroscopy and weight of patients was evaluated. The results showed that there was a good correlation between DAP values and children's weight. In the study of Okeji *et al.* [2], it was observed that DAP increases with children's weight, which was in line with the results of our study, so the weight of children was suggested as a very important factor in determining DAPs.

5. Conclusion

The results of this study showed the current status of the dose received in chest radiography in children referred to educational hospitals of Birjand University of Medical Sciences. If the optimization in the imaging protocol is done correctly and regularly, the average DAP value will be closer to the other studies. It seems that in this study, the most important factor that has increased DAP values compared to other studies is insufficient collimation of radiation field size. In our study, it was observed that there is a significant relationship between weight, age, height of patients, and radiation field with DAP values and the amount of DAP in the present study has a significant difference with the amounts of other studies. It is recommended that retraining workshops be held regularly for radio technologists in order to always be familiar with new techniques to reduce the absorbed dose of patients.

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