Evaluation of Entrance Surface Air Kerma in Patients During PA Chest Radiography Using CALDose Program in Al Najaf Governorate Hospitals

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\textbf{Abstract.} Due to its value in providing diagnostic information, large Figure of chest X-rays conducted everywhere. This therefore necessitate assessing patients’ dose to avoid any potential harm. This work is aimed at evaluating the Entrance Surface Air Kerma (ESAK) for adult patients undergoing chest radiographic examination (posterior - anterior (PA)) in Al Najaf (Iraq). The ESAK were evaluated for 186 patients utilizing CALDose program. The tube output measurements were carried out using Rad-Check dosimeter. Patient demographic data was also recorded (height and weight). Nine X-ray units were considered in this research (i.e. Al-Furat hospital (AFH), Al Sajad General Hospital (ASGH), Al-Hakeem hospital (AHH), Al-Zahra hospital (AZH), Al-Sadder hospital (ASH), Al Hydria General Hospital (AHGH), Middle Euphrates cancer center (MECC), Al Manzrah General Hospitals (AMGH) and Al Mishkhab Hospital (AMH)). The resulted data revealed that the ESAK for the considered hospitals AFH, ASH, ASGH, AHH, AZH, AHGH, MECC, AMGH and AMH are 0.67, 0.069, 0.59, 0.05, 0.79, 0.76, 0.48, 0.21 and 0.18, respectively with an overall average of 0.425 ± (0.299) mGy. In AZH, the ESAK was generally higher than those of other X-ray units of this study. Finally, performing a regular quality control (QC) checking with dose audit is largely advised.

1.Introduction

It is well known that using ionizing radiation in diagnostic radiography brings a huge medical benefit to the patients. However, the associated health risks that this radiation might cause is unavoidable. Consequently, continuous radiation dose monitoring should be carried out in order to reduce the potential harm (1). The amount of dose received by the patient undergoing conventional radiographic examination can be considered low when compared with other radiologic practices using radiation of ionizing nature. Nevertheless, it has been reported that the contribution of using this type of radiation, in medical diagnosis, to the collective is the largest among all other artificial sources (2). So, increasing the knowledge concerning the hazards of ionizing radiation necessitates the regular patients’ radiation dose assessment during diagnostic X-ray examinations (3). In this context, given that the X-rays are ionizing and highly energetic radiation, therefore producing a potential harmful effect on people health that can be resulted from its use is an important issue that needs to be considered (4).
Medical imaging using X-radiation represents the major source of medical exposure elsewhere in this world taking into account the valuable role that these examinations have for diagnostic purposes (5). In the third world countries, the conventional radiographic procedures remain an essential tool for diagnosis when compared with other imaging modalities (e.g. magnetic resonance imaging (MRI), computed tomography (CT) and digital radiography (DR) (6). The reason behind the latter argument is that the low cost of using conventional X-ray during the last century made it a common tool for medical diagnosis (5).

The purpose of the present study was to estimate the patient (adults) entrance surface air kerma (ESAK) that undertaking (PA) chest X-ray examinations in certain number of Al Najaf governorate hospitals (Iraq).

2. Materials and Methods

The main hospitals and most of the health centers that located in the governorate of Al Najaf were considered in this research. This include nine X-ray units that were spread in the center and those at the suburbs of the governorate to include AFH, ASH, ASGH, AHH, AZH, AHGH, MECC, AMGH and AMH. Before the starting the research, an ethical approval was requested from Al Najaf General Health Institution. Data on all the X-ray units were recorded. Table 1 presents the manufacturer of the X-ray tube, the model of the unit, the year of installation and the type of imaging device (i.e. DR or CR).

| Hospital | Manufacturer | Model            | Year of installation | System types (DR/CR) |
|----------|--------------|------------------|----------------------|----------------------|
| AFH      | Shimadzu     | 1/2P13GK-85      | 2012                 | CR                   |
| ASGH     | Raymax       | E7239X           | 2009                 | CR                   |
| AHH      | Toshiba      | E7254FX          | 2017                 | DR                   |
| AZH      | Shimadzu     | 0.6/1.2P18DE-85  | 2015                 | DR                   |
| ASH      | Toshiba      | E7254FX          | 2017                 | DR                   |
| AHGH     | Shimadzu/ Japan | 0.6/1.2P18DE-85 | 2013                 | CR                   |
| MECC     | Shimadzu     | 0.6/1.2P18DE-85  | 2016                 | CR                   |
| AMGH     | Shimadzu/ Japan | 1/2P13DK-85    | 2018                 | CR                   |
| AMH      | Toshiba      | E7254FX          | 2017                 | DR                   |

Age, weight and height were recorded for each patient enrolled in this work. The latter data were used to calculate the body mass index. The minimum number of patients that were set is 20 (≥18 y) for each X-ray unit (7). For the ESAK to be estimated, the physical parameters such as mAs, kVp and SID were recorded for all patients undergoing PA chest radiography.

In this study, the entrance surface air kerma (ESAK) was calculated using computer software known by CALDose (version X.5.0). The CALDose is a tool utilized for calculating of ESAK, body organ absorbed doses (BOD) and effective dose (ED) in diagnostic radiology. The latter process conduction based on the exposures parameters set by the users (8).

It provides many combinations of 40 kVp (50 to 120 kVp) and a range filtration (from 2 to 5 mm Al), together with variable focus to detector distance (FDD) (8). Based on the exposure
parameters that set by the operator, CALDOSE-X5 displays 6 images of the phantom as well as the position of the X-ray radiation (Figure 2). (9).

![Figure 2](image1.png)

**Figure 2.** A representation of the modeling of PA chest radiography in the CALDose program

In order to run this program, it is necessary to supply it with the X-ray output (μGy/mAs) that corresponds to the kVp's ranged from 50 to 120 with an interval of 10 kVp. The latter was repeated for every X-rays unit considered in this work (8).

The output of every X-ray tube was measured using an ionizing chamber called Rad-Check Plus model 06-526 X-ray (Nuclear Associates, Victoreen Division, NY, USA). The measurement process was conducted at 10 mAs and a distance of 100 cm from X-ray source (Figure 3).

Every measurement was repeated three times for each kVp used in order to calculate average value of the output, thus reducing the amount of random error that might occur. A value of 8.7 mGy conversion factor for each Rontgen (R) was utilized to obtain the output in the unit of mGy (10).

![Figure 3](image2.png)

**Figure 3.** The tube output measurement process
3. Results and discussion

A total number of 186 patients were involved in this work. The demographic data of the patients can be seen Table 2. According to this table, the mean weight of the patients ranges from 70.71 ± (14.09) kg to 85.23 ± (15.54) kg. Regarding patients' height, it is clear that it was almost comparable at an average of about 167.34 cm, and therefore the body mass index for all patients in this research ranged from 26.81 ± (6.31) to 30.72 ± (6.47) (kg.m\(^{-2}\)).

Table 2. The weight, height and body mass index of enrolled patients.

| Hospital | Weight (kg) | Height (cm) | BMI (kg/m\(^2\)) |
|----------|-------------|-------------|------------------|
|          | Average (SD)| Average (SD)| Average (SD)     |
| AFH      | 80.13 (16.71)| 169.86 (8.3)| 27.815 (5.83)    |
| ASGH     | 76.42 (15.24)| 166.76 (8.34)| 27.35 (3.07)     |
| AHH      | 74.35 (15.33)| 168.05 (7.04)| 26.81 (6.416)    |
| AZH      | 78.55 (14.46)| 168.75 (6.8)| 27.48 (4.18)     |
| ASH      | 85.23 (15.54)| 167.23 (8.24)| 30.72 (6.47)     |
| AHGH     | 70.71 (14.09)| 162.76 (6.89)| 26.85 (6.31)     |
| MECC     | 81 (20.95) | 171.3 (8.89) | 27.5 (7.02)      |
| AMGH     | 76.65 (17.13)| 166.45 (8.26)| 27.69 (6.24)     |
| AMH      | 75.45 (21.35)| 164.91 (5.89)| 27.79 (7.957)    |

The X-ray output values (mGy) as normalized to 10 mAs for the nine X-ray units can be demonstrated the Table 3.

Table 3. The output of the X-ray tube measured at the nine hospital

| Hospital | Output of X-ray tube (mGy/mAs) |
|----------|-------------------------------|
| AFH      | 0.057                         |
| ASGH     | 0.055                         |
| AHH      | 0.042                         |
| AZH      | 0.039                         |
| ASH      | 0.042                         |
| AHGH     | 0.056                         |
| MECC     | 0.04                          |
| AMGH     | 0.052                         |
| AMH      | 0.039                         |
It can be seen from this Table that the highest tube output was seen at 0.057 mGy.mAs\(^{-1}\) at AFH while the lowest value was found to be (0.039 mGy.mAs\(^{-1}\)) at AZH.

Table 4 presents the exposure parameters set for the chosen patients that undertaking chest X-ray examinations. The average kVp that was used ranges from 68.85±(4.93) kV at AHGH to 95.45±(4.13) kV at AMH. The average mAs set was at a range of 1.55±(0.87) mAs to 26.72± (2.8) mAs. All the chest examinations were carried out using the SID scale that extends from 132.14±(7.95) to 193.91± (3.02) cm.

**Table 4.** The exposure’s factors (kVp, mAs and SID) distributions for PA chest radiographic examinations in all hospitals.

| Hospital code | kVp Mean ± SD (Range) | mAs Mean ± SD (Range) | SID (cm) Mean ± SD (Range) |
|---------------|------------------------|------------------------|---------------------------|
| AFH           | 74.31 ± 2.57 (70 - 80) | 14.4 ± 1.68 (9 - 16)   | 144.45 ± 3.51 (135 - 152) |
| ASGH          | 78.66 ± 4.7 (70 - 90)  | 12 ± 0 (12 - 12)       | 144.9 ± 4.07 (135 - 151)  |
| AHH           | 81.95 ± 9.42 (70 - 95) | 1.65 ± 0.96 (1 - 4)    | 164.4 ± 11.1 (156 - 181) |
| AZH           | 72.35 ± 9.83 (60 - 95) | 26.72 ± 2.8 (22.4 - 32)| 146.8 ± 5 (135 - 155)    |
| ASH           | 79.42 ± 9.14 (70 - 100)| 1.55 ± 0.87 (1 - 4)    | 143.14 ± 3.29 (135 - 149)|
| AHGH          | 68.85 ± 4.93 (60 - 82) | 16.28 ± 1.92 (14 - 20)| 132.14 ± 7.95 (110 - 144)|
| MECC          | 71.45 ± 4.93 (60 - 80) | 12.46 ± 1.74 (9 - 14.2)| 132.5 ± 7.41 (120 - 143)|
| AMGKH         | 75.65 ± 6.47 (65 - 90) | 8.2 ± 0.89 (8 - 12)    | 181.75 ± 5.03 (173 - 190)|
| AMH           | 95.45 ± 4.13 (90 - 101)| 6.33 ± 0.29 (5 - 6.4)  | 193.91 ± 3.02 (189 - 200)|

Patients’ ESAK which was calculated for the patient’s undergoing PA chest X-ray radiography can be seen in Table 5. From this Table, it can clearly be seen that the minimum ESAK value was recorded at AHH with a value of 0.013 mGy while the maximum ESAK value was reported in AHGH at 1.86 mGy. It clear that there is a significant difference in the mean value of the ESAK across all hospitals. It can also be demonstrated that the highest average ESAK value was reported at AZH with a value of 0.795 mGy while the lowest average ESAK was seen at AHH with a value of 0.053 mGy.

**Table 5.** Statistical description of the ESAK (mGy) for PA chest radiographic examinations in all hospitals.
From the results presented by (Table 5), there is a wide variation in patients’ doses seen in AHH, in which the ratio (max / min) was very large at 12.72; this indicates for that the highest value was 12 times greater than its corresponding lowest value. The values of the ESAK for AHH and ASH hospitals were much lower than those of other hospitals. The reason for this could be attributed to the mAs set in these hospitals which is much low (see Table 4), while the ESAK value for AZH is much high when compared to other hospitals. In this regards, the mAs setting is an important physical parameter that proportionally affecting X-ray intensity when it is increase or decrease and therefore directly impacting the the ESAK level (11).

This variation in ESAK values imposes that there is a necessity to establish a reference level (Diagnostic reference level – DRL) for these procedures in order to harmonies the imaging protocol between different hospitals (12). The high ESAK values in certain Hospitals can be attributed to the nature of the imaging system used (e.g. CR) and patient habitus (e.g. weight). The wide dynamic range of a CR systems permits a high tolerance for variations in patient radiation exposure/ dose (13).

For the purpose of comparing the results obtained by this study with various published literature in term of patient ESAK/ reference level, Figure 3 compares this work findings with those reported by UNSCER(14), IAEA(15), USA(16), UK(17), South Korea(18), EC 180(19), Iran(20), Nigeria(21), Sudan(22), Oman(23), Japan(24) and Brazil(3). From Table 5,

| Hospital | Patients No. | Minimum | Maximum | Average (SD) | Median | Max/Min |
|----------|--------------|---------|---------|--------------|--------|---------|
| AFH      | 22           | 0.432   | 0.855   | 0.670 (0.099)| 0.662 | 1.98    |
| ASGH     | 21           | 0.434   | 0.83    | 0.593 (0.097)| 0.558 | 1.91    |
| AHH      | 20           | 0.013   | 0.173   | 0.053 (0.037)| 0.041 | 12.72   |
| AZH      | 20           | 0.33    | 1.673   | 0.795 (0.325)| 0.696 | 3.82    |
| ASH      | 21           | 0.027   | 0.198   | 0.069 (0.054)| 0.041 | 7.33    |
| AHGH     | 21           | 0.533   | 1.86    | 0.769 (0.314)| 0.656 | 3.49    |
| MECC     | 20           | 0.211   | 0.662   | 0.485 (0.106)| 0.496 | 3.13    |
| AMGH     | 20           | 0.148   | 0.459   | 0.213 (0.068)| 0.193 | 3.10    |
| AMH      | 22           | 0.14    | 0.217   | 0.180 (0.020)| 0.177 | 1.55    |
it can be noticed there was a clear variation in the ESAK value obtained by this study at some facilities with aforementioned studies/reports.

Figure 4. An illustration for patient dose obtained by this study with internationally reported values.

To illustrate, the ESAK in Oman was the lowest among other publications, while the ESAK calculated at this study was lower than those of UNSCER and Sudan and comparable to the level recently reported by IAEA(15), Iran (20), EC 180 (19), Nigeria(21) and Japan(24). Also, the ESAK calculated in this study seems to be higher than those of the UK(17), USA(16), South Korea(18) and Brazil(3).

In order to benefit of the results obtained by this work, the radiographic operators of different institutions were informed about importance of the findings emphasizing the conduction of the protocols concerning the optimization of dose to avoid and/or reduce unnecessary radiation exposure that the patients might receive. Further to this, evaluating the image quality along the dose assessment is an essential step in the way of optimizing the radiographic practice (25). It is recommended that this work to be extended in future and therefore to check the effectiveness of the optimization process in saving the dose while maintain the image quality. Thus, the authors would recommend not only establishing the dose reference levels (DRL) for the aforementioned institution, but to also emphasize the regular dose and image quality monitoring (26).

Finally, the resulted data of the current study may provide an essential guidance for estimating patient doses in digital radiography (DR) as prerequisite to optimization of dose. This study can be considered as starting point for dose optimization that can be conducted by health institutions. Further works are certainly required to fully employ DR features for the optimization of radiation dose and image quality (e.g. Exposure index ) (27).
4. Conclusion

The determination of patient doses (ESAK) and their comparison are essential steps in the way of reducing the unnecessary radiation in diagnostic radiography. The results revealed that the highest ESAK was seen in the AZH, while the lowest ESAK was seen in AHH. It highly recommended that each hospital is establishing its own ESAK level that are appropriate to their equipment, to optimize patient safety, physical parameters and patient size must be considered. The findings of this study indicate that most entrance surface air kerma values in the investigated hospitals can be enhanced by evaluating their radiological techniques of x-ray inspection and the staff in charge on a regular basis.

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