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Evaluation of Exposure Indices on PA Chest X-Ray in Direct Digital Radiography

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Abstract

Introduction: Direct Digital Radiography (DDR) is an advanced form of digital radiography which produces a digital radiographic image instantly on a computer. The wide dynamic range of digital detectors does not need precise exposure factors and the acquired images can be manipulated to make it diagnostically reportable. Underexposed images can be identified easily because of their high background noise; however, overexposed images, because of the compensation of the digital detector, correcting 5-10 times overexposures, present difficulties in recognizing the dose delivered to the patients. Radiological technologists therefore may take radiographs with higher dose exposures to avoid re-examination. Exposure creep or dose creep has been frequently observed with digital radiography system. Exposure Index (EI) can be used to measure the detector response to radiation in the relevant image region of an image acquired with a digital x-ray imaging system. So, this study was performed to evaluate the exposure indices on PA view of CXR in routine clinical environment.

Methodology: Quantitative cross-sectional research design was used. The study was conducted in radiology department of Tribhuvan University Teaching Hospital (TUTH) during three months period. Convenience sampling technique (non-probability sampling) was used to collect the data. Examinations were performed on the Hitachi ZU-L3TY model x-ray machine, EI readout from Agfa NX version 3.0 DDR system was obtained and compared with department`s Target Exposure Index (TEI). Deviation Index (DI) was calculated from the target EI and the Exposure Index (EI) observed. Patient related information, EI, TEI and DI were recorded in separate sheet.

Results: Total of 850 CXRs were examined. Out of them only 19.41% (138) cases had Deviation Index (DI) range of ± 0.5 indicating EI value close to Target Exposure Index (TEI). About 14.77% (105) cases had DI range of +1 to +3.0 and 42.05% (299) cases had DI range of - 1 to -3.0. Similarly 3.09% (22) cases had DI >+3.0 and 20.68% (147) cases had DI <-3.0.

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Conclusion: Compared to the TEI, the observed EI values were much different which indicates that proper exposure technique were not applied. Only 19.41% examinations were optimally exposed and remaining 80.59% were not optimally exposed. The study's findings highlight the necessity for radiographers to get additional knowledge and training regarding the use of EI in order to improve their performance in digital radiography.

Introduction

Digital Radiography (DR) was initially introduced about 30 years ago and has now become standard technology in most radiology departments. The switch to digital technology has resulted in a substantially greater dynamic range of radiographic exposure settings than a traditional film screen. This means that a diagnostic image can be produced with a significantly wider range of entrance dosages without compromising image quality. However, it is necessary to guarantee that enhanced dynamic range does not result in excessive patient radiation doses; thus, an indicator of exposure is required. With today's digital radiography technology, this takes the shape of an exposure indicator, which provides specific feedback on the amount of radiation reaching the image detector. It's worth noting, nevertheless, that the Exposure Index (EI) isn't a true measure of patient dose [1].

There were a number of manufacturer-dependent EIs, which led to misunderstanding among users. To combat this, the Electrotechnical Commission (IEC) and the American Association of Physicists in Medicine (AAPM) collaborated with DR system manufacturers to produce an international standardized EI. The standard EI was created to produce a linear relationship between detector exposure and index value [1].

This approach assigns a target Exposure Index (EIT) value to each examination type, which is thought to represent the best balance of dose and image quality. Either the manufacturer or the clinical site can define the EIT. The Deviation Index (DI) is a simple numerical representation of how far an exposure's EI value deviates from the anticipated EIT for that investigation. A DI value of zero is produced by EI values equal to the EIT. Positive DI values result from EI values more than the EIT, whereas negative DI values result from EI values less than the EIT. DI values can only be meaningful if proper EI targets are chosen [2].

Materials and Methods

Study design

Quantitative cross-sectional study.

Research setting and population

This study was conducted in the Department of Radiology and Imaging, Tribhuvan University Teaching Hospital, Kathmandu, Nepal from December 2021 to April 2022. All the patient's undergoing x-ray of chest who were more than 15 years were the participants of the study.

Exclusion criteria

Examination of anatomical region with presence of prosthesis, gonadal or breast shield, improper shielding and gross-pathology.

Sampling method

Convenience sampling technique (non-probability sampling).

Data collection method

Patient related information, direct EI readout DI were recorded on separate worksheet.

Instruments

High output x-ray machine (hitachi ZU-L3TY model medical corporation), Agfa NX version 3.0 DDR system.

Measurement of exposure index

The displayed EI for each study was noted. The EIs was automatically generated by the DR system.

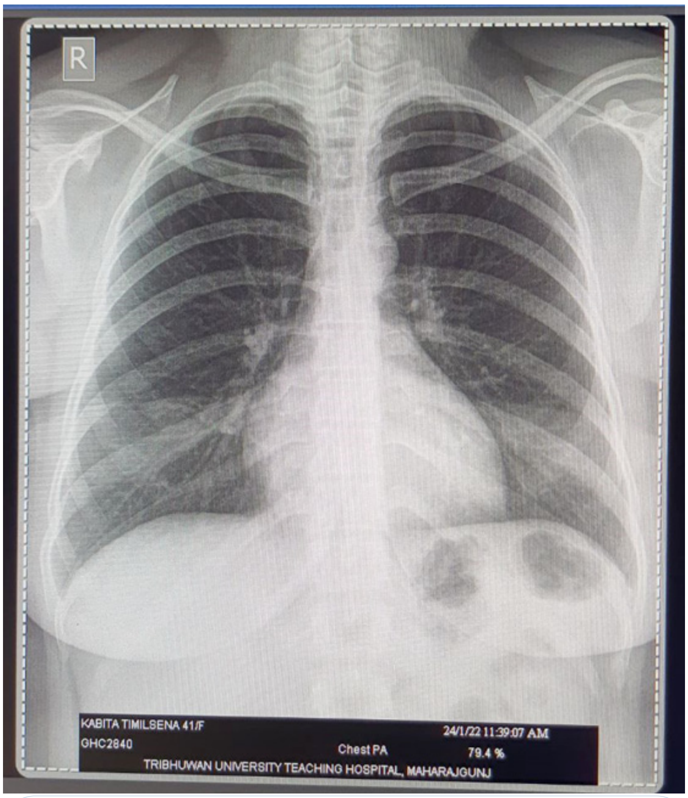


Figure 1: Method for recording the exposure index.

Data analysis

The data obtained were tabulated in excel 2016 worksheet and analyzed statistically by using an IBM SPSS 26. Data obtained were analyzed using the descriptive statistics to summarize the measurement of EI, and inferential statistics (Mann- whitney test for two independent sample) to verify if there were significant differences of EI between male and female patients. $P<0.05$ was considered to be statistically significant.

Results

During the study period, 850 cases were observed. CXR was the most frequently performed examination in the radiology department of TUTH.

Demographic distribution of population

A total of 850 patients were enrolled in the study. Among them 399 were male and 451 were female. The mean age of study population was 41.87±16.06 years. The minimum age of population was 15 years and maximum was 83 years.

Table 1: Descriptive statistics of population.

Gender	No. of patient	Mean age	SD	minimum	Maximum
Male	399	40.54	16.07	16	83
Female	451	43.05	15.98	15	80
Total	850	41.87	15.99	15	83

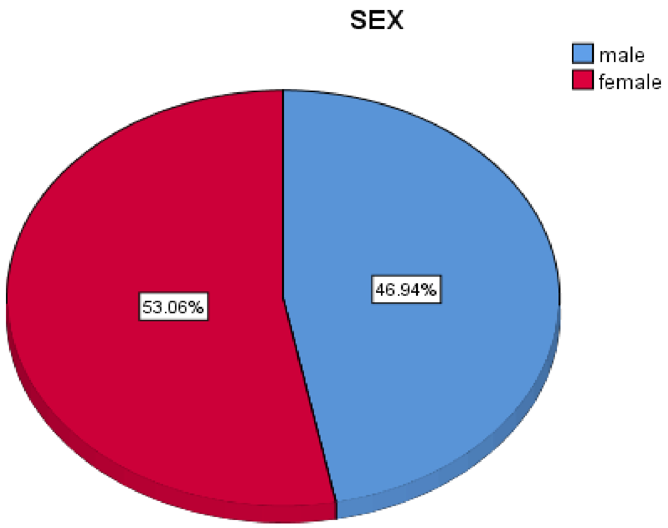


Figure 2: Pie Diagram Showing the gender wise distribution of population.

The patients were divided into five groups on the basis of age having class width of 14 from 15 years to 83 years as follows:

Table 2: Frequency distribution of population.

Age group	Frequency
15-29	245
30-44	249
45-59	203
60-74	136
>75	17
Total	850

There were 245 patients in age group 15-29, 249 in age group 30-44, 203 in age group 45-59,136 in age group 60-74 and 17 in age group >75.

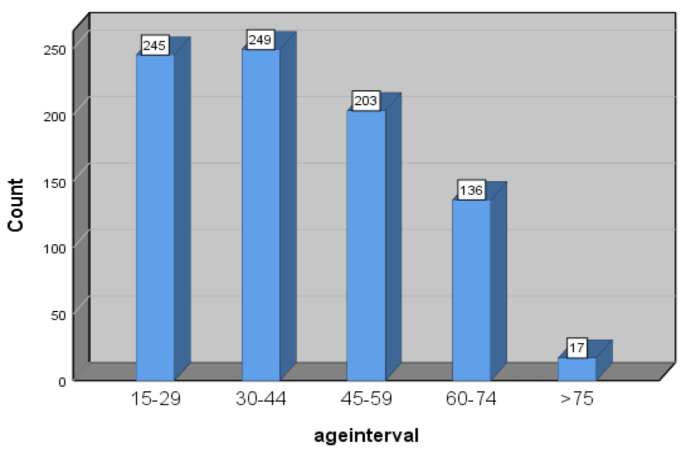


Figure 3: Bar Diagram of the distribution of Sample Size According to Age Group.

Exposure Index

Exposure Index (EI) and Gender

Table 3: Mean and SD of EI on chest PA (n=850).

Variables	TEI	Chest PA				
		Mean	SD	Maximum	Minimum	median
Female	200	172.86	92.50	605	16	150.0
Male	200	173.48	82.25	673	30	159.0
Total	200	173.15	87.79	673	16	155

The mean value of EI was found to be 172.86±92.50 in female and 173.48±82.25 in male and the minimum value was 16 in both male and female and the maximum value was found to be 605 in female and 673 in male. The mean value of EI was found to be 173.15±87.79 and the minimum value was 16 and the maximum value was found to be 673 [Table-3]. On performing Mann-Whitney test for two means, EI values were not found be the statistically significant between male and female, p= 0.237.

Exposure Index and Age Group

Table 4: Mean distribution of EI according to age group.

Age group	EI	
	Mean	SD
15-29	193.62	95.18
30-44	161.04	83.89
45-59	156.32	67.65
60-74	183.50	100.74
>75	173.30	71.30
Total	173.15	87.79

The mean EI was 193.62±95.18, 161.04±83.89, 156.32±67.65, 183.50±100.74 and 173.30±71.30 for age group of 15-29, 30-44, 45-59, 60-74 and >75 respectively [Table 4].

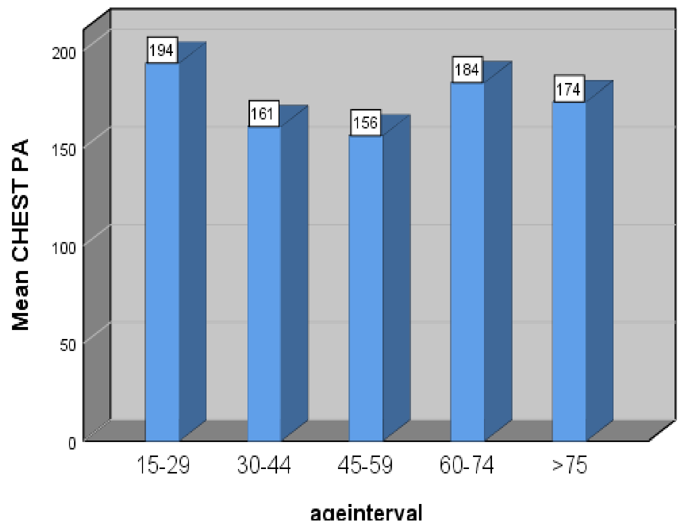


Figure 4: Mean distribution of EI on chest PA with age group.

Correlation of EI with age

The Spearman's Rho Correlation was used to determine the relationship between the EI and age.

Table 5: Correlation for EI with age.

Correlation coefficient (r)	-0.084
P value	0.015

There was a weak negative correlation between the age and EI (r= -0.084) which is statistically significant at a p-value of 0.015. The scatter plot diagram below (Fig- 5) summarizes the result:

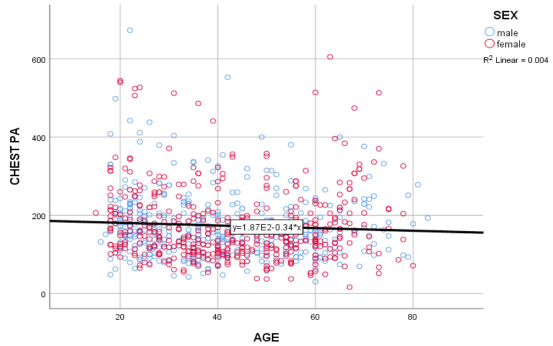


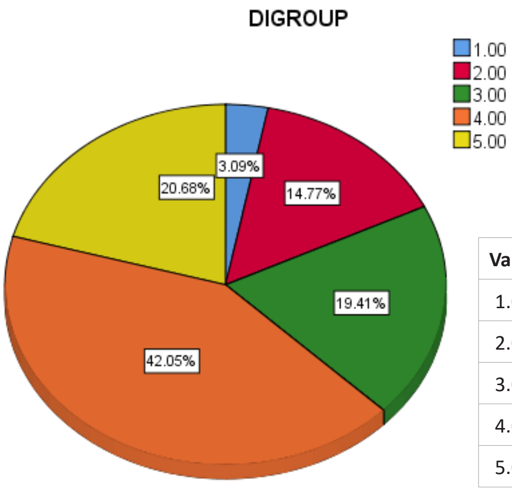
Figure 5: Scatter plot between age and EI in chest PA.

Deviation Index

Table 6: Mean DI with and its frequency according to range.

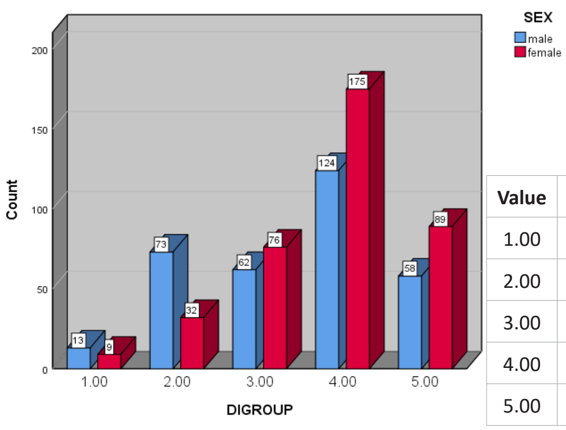
Examination	Mean DI	SD	DI				
			>+3.0	+1.0 to +3.0	-0.5 to +0.5	-1.0 to -3.0	<-3.0
CXR PA	-1.11	2.07	22	105	138	299	147

About 19.41% (138) of cases had DI -0.5 to +0.5, 14% (105) had DI +1 to +3, 42.05% (299) had DI -1 to -3, 3% (22) had DI >+3 and 20% (147) had DI <-3.



Value	DI range
1.00	>+3.0
2.00	+1.0 to +3.0
3.00	-0.5 to +0.5
4.00	-1.0 to -3.0
5.00	<-3.0

Figure 6: Pie Diagram showing the distribution of DI.



Value	DI range
1.00	>+3.0
2.00	+1.0 to +3.0
3.00	-0.5 to +0.5
4.00	-1.0 to -3.0
5.00	<-3.0

Figure 7: Frequency distribution of DI in male and female.

There were 13 males and 9 females, 73 males and 32 females, 62 males and 76 females, 124 males and 175 females and 58 males and 69 females for DI ranges of >+3, +1 to +3, -0.5 to +0.5, -1 to -3 and <-3 respectively.

Discussion

Manufacturers along with AAPM (American Association of Physicist in Medicine) in collaboration with IEC (International Electrotechnical Commission) devised a system to indicate the level of incident remnant rays reaching to the digital detectors. A target EI may be given by the manufacturers or set by the institute itself. The DI indicates how much the exposure index has deviated from the targeted EI for a specific examination and has a great importance. This gives the direct feedback to the technologist about selection of the exposure parameters. The EI should be within the range as provided by the vendors for maximum radiation protection to the patient and the DI should fall within ± 0.5.

The purpose of this study was to determine the range of EI in our institute for routine chest examination and to examine if patient gender and age had any impact on the EI values. This study was done using Agfa NX version 3.0 DDR system to define optimum exposure on PA view of chest x-ray in the Nepalese population and to study the variation in EI according to age and gender. The examinations were performed using grid and the automatic exposure control was ON during every exposure.

Our study can be a source of critical information for radiographers and radiotechnologists, and recognition of deviation of EI from its normal value can help guide correct patient exposure. The convenience sampling technique was used to collect the data from the department of radiology TUTH. In our department the TEI was not provided by the manufacturers. So the target was established by observing 50 chest x-ray examinations with best image quality at lowest possible exposure factors.

Shapiro-wilk test indicated that data associated with EIs were non-normally distributed. So we used the non-parametric test for the further analysis of our data i.e. Mann-Whitney test.

In our study the results showed that the EI were correlated with patient age and gender [Table 5]. The difference in EI between male and female was statistically insignificant with a p value of 0.237. The EI had a very weak negative correlation with age, r = -0.084 at a p value of 0.015.

The mean EI of 850 chest radiographs was found to be 173.15±87.79 ranging from minimum 16 to maximum 673 indicating that optimum exposure techniques were not used [Table 3]. The mean DI of those examinations was -1.11± 2.07 with range 14.40 from minimum -10.97 to maximum 5.27 [Table 6]. Only 19.41% (138) cases had DI in between ± 0.5 and 14.7% (105) cases, 42.05% (299) cases, 20.68% (147) cases, 3.09% (22) cases had DI value in between +1 to +3, -1 to -3, less than -3.0 and greater than +3 respectively [Table 6]. However, all the cases observed during the study period were reported. None of the case had been requested for repeat examination due to improper exposure technique. Due to the wide dynamic range of DR detector, overexposure and underexposure can be masked by postprocessing but in penalty of compromising image quality.

Our study concluded that only 3.09% of examinations were exposed with more than double the optimum exposure while in the study of Mervyn D. et al. He found that 5% of exposures had more than +3 deviation units or greater than 100% above the target exposure, which is somehow similar to our conclusion. He also reported that 46% of exposures were between 20% below and 26% above the target, 78% of exposures were between 40% below and 60% above the target and 93% of exposures were between 50% below and 100% above the target [3].

In our study most of the chest x-rays about 62.73% images were under exposed as these images had deviation index of less than -1 compared to expected result. Among them 42.05% were underexposed and 20.68 were severely underexposed. About 3.09% were severely overexposed, 14.77% were overexposed and only 19.41% were optimally exposed. Most of the underexposed images resulted due to use of secondary grid. These results were similar a study by Haney Alsleem et.al. Who found that about 54 % of pediatric radiographs were underexposed, with deviation indexes of less than -1. The majority (66%) of the underexposed images used a grid as with ours, while 59 % of the overexposed images did not(4). Similarly about 38% of PA CXR examinations in a study done by H warren-forward et.al. were under-exposed because the MRR was too high. However there are a number of factors that can affect EI variation on a patient level. These include: whether or not Automatic Exposure Control (AEC) is used and, if so, was the patient centered correctly over it; differences in patient body habitus, which would affect the exposure factors required; and for the chest exam, whether or not filters are used to reduce breast shadowing [5].

In our study we found that about 80.58% of exposures were outside the optimum range. While A. Creeden et.al. found that 36.0% exposures had DI values outside the manufacturer's recommended Optimal range. This extreme reported EI values outside the optimum range in our study may be due to lack of optimization of exposure index chart, malpractice and as well as lack of proper knowledge about the EI. So we also need to optimize the exposure index chart periodically [2].

In our study we noticed significantly higher median EI values for the male patients than that of the female patients for AGFA DDR x-rays. But Ursula Mothiram et.al. found significantly higher median EI values recorded for female patient radiographs than those for male patients for all manufacturers, except for Philips digital radiography (DR), where increased EI values indicate lower exposure (P=0.01). Significantly higher median EI values were demonstrated for Philips DR chest X-rays without as compared to those with the employment of a grid (P=0.03), while significantly lower median EI values were recorded for Carestream Health Computed Radiography (CR) chest X-rays when an implant or prosthesis was present (P = 0.02) [1].

In our study we found that the EI values in female is lower than the male while the similar study of L. Lanca and A. Silva et.al., found higher IgM values in female patients than in male patients. This difference was observed because the average body habitus of the Nepalese female population is smaller than that of the male population which may not be the case in Australia. Similarly in our study we found that only 3% of examinations received double the exposure but in their study they found that 42% examinations received at least double the exposure necessary to produce an adequate image. They came to the conclusion that the exposure procedure chart should be adjusted in order to achieve a significant reduction in detector dose [6].

Conclusion

Compared to the TEI, the observed EI values were much different which indicates that proper exposure technique were not applied. Only 19.41% examinations were optimally exposed and remaining 80.59% were not optimally exposed. The study's findings highlight the necessity for radiographers to get additional knowledge and training regarding the use of EI in order to improve their performance in digital radiography.

Abbreviations

AAPM: American Association of Physicists in Medicine; **CXR:** Chest; **DI**: Deviation Index; **DR:** Digital Radiography; **EI:** Exposure Index; **IEC:** International Electrotechnical Commission; **IOM:** Institute of medicine; **PA:** Posterio Anterior; **SD:** Standard Deviation; **TEI or EIT:** Target Exposure Index; **TUTH**: Tribhuvan University Teaching Hospital.

Declaration by authors

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