# Proposed Guidelines for Image Quality Optimization in Chest PA X-Ray Examinations In Bangladesh

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# Proposed Guidelines for Image Quality Optimization in Chest PA X-Ray Examinations In Bangladesh

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ABSTRACT: The common practice for chest PA examinations in Bangladesh employ low kV imaging. This practice involves low-contrast images and requires much larger radiation doses than those associated with higher beam energy. Thus, we propose a model relating the change of Entrance Surface Dose (ESD) in response to changes in beam energy, in accordance with European standards for diagnostic radiographic chest imaging to find the optimal ESD corresponding to values of kVp used in Bangladeshi hospitals.
Results show that in order to maintain the standards of *Quality for Diagnostic Radiographic Image* every 10kVp increase in beam energy must be followed by a decrease of 8/6 in ESD that corresponds to a reduction of 15% in the equivalent dose. Hence, the range of optimal ESD accounting for the kVps practiced for chest PA examinations is 5.6-10 mGy, which represents a factor of 35 above the recommended ESD. Finally we investigate the effect of Body Mass Index (BMI) on optimal ESD for overweighed Bangladeshi patients. We find that, for each additional 1kg, the ESD must increase 18% in order to maintain standards for chest PA x-ray image.

*Keywords*— Diagnostic Imaging, Radiation Protection and Dosimetry, Quality Control

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## I.INTRODUCTION

Beam energy (kVp) is a controlling factor for contrast on an image. When kVp is increased, the corresponding increased amount of scatter radiation reaching the image receptor adds density to the image. Scatter radiation will change the contrast in the image, which will increase the grey scale. This change on grey scale may obscure the fine detail of the anatomy, therefore compromising the final interpretation of the image. Conversely, low kVp examinations penetrate fewer thicknesses and produce images with fewer shades of grey.

However, chest anatomy is comprised of soft tissue and vital organs with slight density disparities and therefore few differences in contrast. Hence, chest PA examinations require a large grey scale range, i.e., a large contrast range for an optimum image. Higher kVps will produce more shades of grey, allowing for better visualization of chest anatomy.

Nevertheless, studies for Bangladesh [1,2] suggest that hospital practice of referrals for chest PA x-ray examinations involves x-ray examinations with lower kVps than those indicated internationally [3]. Hence, using beam energy of 50-90 kVp does not satisfy the standards of Quality for chest PA x-ray images.

Since the lower the kVp the larger the ESD to achieve a quality image [3], this practice implies the use of higher ESDs and demands for several repeats of examinations.

Both situations will contribute to the increase in risk of radiation-induced cancer, especially in case of adults, those of 20-29 years old [4,5].

Hence, evidence suggests that Bangladeshi hospitals fall short to carry out chest PA examinations according to theoretical guidelines. This raise the following questions:

a) What is the optimal relationship between the ESD and kVp to achieve a quality image while not compromising patient safety; b) given a) what is the respective optimal ESD to the kVps practiced in hospitals? c) Since in patients with BMI>30 the dose increase can reach factors of 70–80 for extremely obese patients [6], how does a overweight patient's BMI affect the optimal ESD in Bangladesh? And finally d) what measures can be implemented in Bangladeshi hospitals to preserve both image quality and patient's safety?

## II. EXPERIMENTAL PROCEDURE

Our purpose is twofold. First, we aim to find the model relating beam energy to ESD that represents the standards of *Quality for Diagnostic Radiographic Image* for chest PA [3].

In order to attain it, we run an OLS regression of ESD (0.3-10 mGy) in a range of kVp (50-125), where the lower limit corresponds to the minimum beam energy used for chest PA examinations in Bangladesh and the upper limit corresponds to the European recommended value for this type of examinations [3].

Then, we construct an integrated database of 16,000 patients with data from studies for Bangladesh [1,2,6] referring to age, weight, height, kVps and ESDs for over 100 hospitals. We simulate a uniform distribution of data in *stata 9.0* respecting the parameters given by those studies.

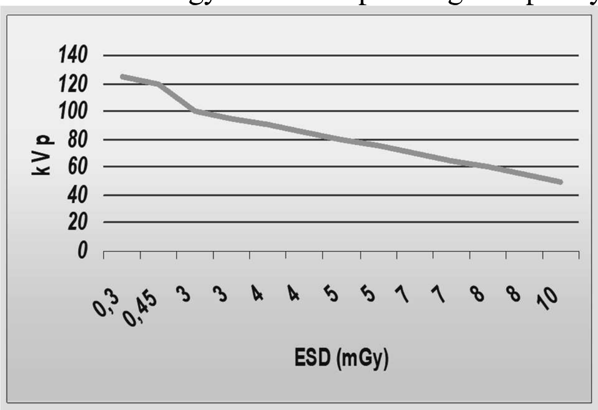
Subsequently, we apply the theoretical model to the kVps practiced in hospitals to obtain the optimal ESD for the kVps observed. Next, we compare the magnitude of

optimal ESDs obtained from model with the reference level that minimizes the patients' risk of radiation induced cancer (0.3 mGy).
Second, since previous studies [7] predict that larger BMIs require larger amounts of ESD, we aim to calculate the effect of BMI in overweight patients on optimal ESD.
Thus, we regress the optimal values of ESD on patients with a BMI of 30 or more.

## III. RESULTS AND DISCUSSION

Figure 1 shows the inverse relationship between entrance surface doses and beam energy to maintain the standards of Quality for Diagnostic Radiographic Image [3]

Fig.1 ESD-Beam energy relationship for a good quality image




The resulting model of optimal ESD on kVp is

$$esd=16{,}45-0{,}1290533\ kVp \qquad (1)$$

Hence, our Axiomatic approach for quantification of ESD given the beam energy and the parameters of *Quality for Diagnostic Radiographic Image is*

**Axiom 1:** $\forall k \in N_+ \text{ in } [50,125],\ \exists e \in R_+ \text{ in } [0.3,10]:\ dk/de=-s\ ,\ \forall\ s \in R_+$

Where *e* stands for the entrance surface dose (mGy), *k* stands for the beam energy (kVp) and *d* denotes the derivative. The value of s is 0.1291.

The negative slope of dose-beam energy curve implies that an increase of 10kVp in beam energy will reduce the ESD by approximately 8/6 which corresponds to a reduction of the equivalent dose by 15%, while maintaining the standards of quality for diagnostic radiographic image [3].
Our results are in line with previous studies for West Midlands that find an increase from 54 kVp to 80 kVp will reduce the skin dose by 45% [8].

Table I shows the basic statistics for our database with 16,000 observations with values for studies in Bangladesh.

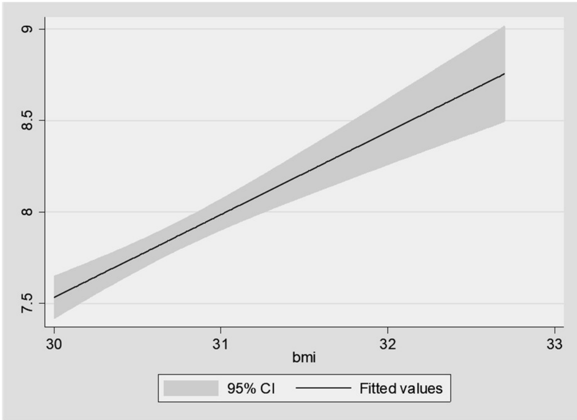
Table I Basic statistics of our database

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| age | 48 | 17.3 | 18 | 78 |
| h | 159 | 7.2 | 141 | 180 |
| w | 63 | 6.4 | 50 | 75 |
| bmi | 25 | 3 | 17 | 33 |
| kvp | 70 | 9.8 | 50 | 90 |
| esd | .77 | .76 | .13 | 4.67 |
| oesd | 7.75 | 1.2 | 5.6 | 10.0 |

Where *esd* are values of ESD in Bangladeshi hospitals [1,2] and *oesd* are the optimal ESD taking into account the values of kVp. The mean beam energy is 70 kVp.
Variables *h* and *w* denote patient's height and weight according to data for Bangladesh [1,2,6] and the maximum BMI is 33.
The range of optimal ESD is 5.6-10 mGy that correspond to 0.67-1.2 mSv. Since the maximum ESD in the database is 4.6 mGy, it means that the radiologist will not be able to obtain a good image with the combination of beam energy and ESD and hence may have to repeat the exposure at least twice, increasing the risk of cancer.
The maximum value of optimal ESD represents a factor of 35 when compared to the reference level of 0.3 mGy.
Furthermore, the characteristics of the exposed individuals matter for the assessment of the risk associated with exposure to ionising radiation. Indeed, the size and anatomy of the individuals have an impact on the absorbed dose distribution in the organs.
Traditional methods to calculate the patient organ doses based on phantoms deliver average doses for an exposed population [9]. Hence, these methods disregard individual patient characteristics [10].
Calculating doses to individual patients involve patient specific calculation methods, accounting for specific BMI. We are particularly interested in calculating the effect of BMI from overweight patients on the optimal ESD.

Regressing the *oesd* on patients with a BMI□30 delivered a coefficient of 0.45. Fig.2 shows the corresponding model

Fig.2 ESD-BMI relationship for BMI□30




Each increase of one unit of BMI will increase the ESD in 0.45 units. That is to say, for example, a patient of 85kg and height 170cm, each additional 1kg implies an increase of 18% in ESD, which correspond to an increase in equivalent dose of approximately 2%.

## IV. CONCLUSION

Radiological practice in chest PA examinations in Bangladesh does not follow the European guidelines for patient's safety and image quality. The quality of x-ray images delivered with low beam energy demands for repetition of examinations, thus increasing the already high doses of ionizing radiation and the risk of radiation induced cancer. We would recommend that the practice for chest PA be changed to 125kVp and hence reduce ESD to patients to the recommended level of maximum
0.3 mGy. This will reduce risks of radiation-induced cancer while meeting the European and internationally accepted standards of image quality for chest PA x-ray
examinations.

Our work provides guidelines on the kVps and corresponding ESD for ensuring optimum image quality and hence a method of reducing the number of exposures.

Finally, we would recommend the implementation, monitoring and auditing of a quality assurance system in Bangladeshi hospitals to minimize not only the risk to patients and staff but also to minimize time and costs of potentially unnecessary exposures.