

A Derived Exposure Chart for Computed Radiography in a Negroid Population

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Received 13 May 2016; accepted 12 July 2016; published 15 July 2016

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Abstract

Background: Computed radiography has a wider exposure latitude when compared with film-screen imaging system. Consequently, the risk of dose creep is high. A conscientious effort is therefore, needed by the radiographer to keep exposure as low as reasonably achievable. **Objective:** To derive a computed radiography exposure chart for a negroid population using AGFA photostimulable phosphor plates and a GE static X-ray machine. **Materials and Method:** A static X-ray machine, a digitizer, and photostimulable phosphor plates were used for the X-ray examination. Chest examinations were done at a Focus-Film-Distance (FFD) of 150 - 180 cm while all other examinations were conducted at 90 - 100 cm FFD. The range of exposure factors (kVp, mA and mAs) used by radiographers in the centre was noted and the 90th percentile calculated. Over a three-month period, the patients were examined with the 90th percentile of tube potential (kVp) while keeping other factors constant. The kVp was gradually decreased and halted if radiologists and radiographers unconnected with the work expressed misgivings about the quality of the image. A similar procedure was adopted for the tube current (mA). The threshold adopted as low as reasonably achievable was the factor preceding the point of observation by other personnel. Metrics for central tendency from the statistical packages for social sciences, version 17.0 was used to analyze the data. **Results:** 335 subjects of both gender aged 0 - 92 years were examined by the researchers. Adult exposure factors used by the radiographers (and those derived by the researchers) had a range of 45 - 130 kVp (62 - 94 kVp), 63 - 320 mA (100 - 250 mA) and 4.0 - 25.0 mAs (5.0 - 20.0 mAs) respectively. Pediatric chest (and researchers-derived) factors were 50 - 75 kVp (52 - 65 kVp), 50 - 250 mA (100 - 220 mA) and 3.20 - 10.0 mAs (3.2 - 6.5 mAs) respectively. **Conclusion:** Upper threshold of adult (and paediatric) exposure factors in computed radiography with comparable equipment and accessories should not exceed 94 kVp (65 kVp), 250 mA (220 mA) and 20.0 mAs (6.5 mAs) respectively. The derived exposure chart is also adequate to address motion unsharpness in chest examinations.

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Keywords

Computed Radiography, Exposure, Radiographer, kVp, Tube Current, X-Ray

1. Introduction

Computed Radiography (CR), scientifically known as Photostimulable Phosphor (PSP) radiography, is a digital technology for the acquisition of radiographic images [1] [2]. It is the most common digital radiography modality in radiology departments today, with an estimated 7000 systems in use worldwide. As of September 2000, there were five manufacturers of CR imaging devices: Agfa, Fuji, Kodak, Konica and Lumisys. However, their photostimulable phosphor storage plates have dissimilar dose response characteristics.

This lack of calibration uniformity makes the definition of the acceptable exposure ranges for CR cumbersome [1]. Even though manufacturers have responded to this challenge by offering an Exposure Index (EI), its reliability as a feedback mechanism for CR is also questionable [3].

The opinion of radiologists appears to be the stop-gap measure. They react negatively to digital images with excessive noise but rarely complain about images with reduced noise [4] [5]. While increased noise is an indication of reduced dose, this is however, not desirable as it potentially reduces the visibility of subtle pathology [6]-[8], whereas reduced noise may be an indication of overexposure and concomitantly, increased patient dose [9] [10].

The wider exposure latitude and post-processing algorithms of digital technology mask the evidence of underexposure and overexposure [8], a characteristic recognized and exploited by radiographers who eventually fall into the error of dose creep [11]. Dose creep is recognized as a gradual increase in X-ray exposures over time that results in increased radiation dose to the patient. This occurs where judgment to determine the correct radiographic exposure factors is needed when taking into account a large range of patient sizes [9].

Since reduction in patient dose is one of the important considerations for the implementation of CR in a traditional film-based radiology department [5], eliminating dose creep is very important. One effective way to do this is to develop validated radiographic technique charts for all performed examinations. These exposure charts are an essential quality assurance component of any diagnostic X-ray department. Internationally, most countries require regular use of these charts [11].

The review of the literature reveals some exposure adaptation system. However, some are several decades old [8] [12]-[15], and they were derived with Caucasian and Asian populations.

A simple CR-specific chart derived using negroid populations from and in Africa, and which covers the most common examinations, is what this work was designed to address. This chart is specific to AGFA photostimulable phosphor plates and GE static X-ray machines manufactured not earlier than 2003. Centers with comparable machine age and ratings as well as similar photostimulable phosphor plates will find the results useful in dose optimization and quality control.

2. Materials and Methods

The work is a mixed design incorporating both prospective and retrospective components. It was carried out between June to September, 2015 at a teaching hospital in Nigeria. Confidentiality was maintained by omitting names, ward, address and clinical indications of the subjects during data collection.

The X-ray machine used was a GE silhouette VR, high frequency, 3-phase, static digital unit with a maximum tube potential and current of 140 kVp and 600 mA respectively, and a total filtration of 2.7 mmAl. It was manufactured in 2003 and installed in 2011 by VAMED. A potter-bucky couch and erect chest stand were used. Other equipment and accessories were a CR-12-x digitizer and new 17 × 14 inch photostimulable phosphor imaging plates (model CRMD1.0) manufactured by Agfa Healthcare, Belgium, and installed at the teaching hospital in October, 2014.

Any patient who came for X-ray examination within the study period and could stand erect formed part of the population. Their age and gender were obtained from their request cards. Chest examinations were done at a focus-film-distance (FFD) of 150 - 180 cm while all other examinations were conducted at 90 - 100 cm FFD.

Although the researchers are staff of the centre in focus, the work was blinded to all other staff to minimize

bias. Because of the wide exposure latitude and post-processing features of the computed radiography modality, it was observed that the radiographers in the centre did not have specific exposure parameters for different body habitus. The subjects were therefore, not categorized in accordance with body size but considered as a homogeneous group.

The range of exposure factors (kVp, mA and mAs) used by other radiographers in the centre were noted by the researchers. Subsequently, the 90th percentile of the factors was calculated. Over a three-month period, the patients were examined with the 90th percentile of tube potential (kVp) while keeping other factors constant. The kVp was gradually decreased and halted if radiologists and radiographers unconnected with the work expressed misgivings about the quality of the image. A similar procedure was adopted for the tube current (mA).

Descriptive statistics from the statistical packages for social sciences, version 17.0 (SPSS Incorporated, Chicago, Illinois, USA) was used to analyze the data.

3. Results

335 subjects of both gender aged 0 - 92 years were examined by the researchers (**Table 1**). Adult exposure factors used by the radiographers (and those derived by the researchers) had a range of 45 - 130 kVp (62 - 94 kVp), 63 - 320 mA (100 - 250 mA) and 4.0 - 25.0 mAs (5.0 - 20.0 mAs) respectively. Pediatric chest (and researchers-derived) factors were 50 - 75 kVp (52 - 65 kVp), 50 - 250 mA (100 - 220 mA) and 3.20 - 10.0 mAs (3.2 - 6.5 mAs) respectively (**Table 2**). A comparison of this work with another one gave comparable results except in chest where their kVp (106) and mAs (3.33) was significantly higher than ours (73 kVp, 10 mAs) as shown in **Table 3**. Statistical analyses using one-sample t-test for both mAs (3.33; 10) and kVp (106; 73) with $p < 0.05$ as level of significance gave a statistically significant difference between the mAs ($p = 0.002$) and kVp ($p = 0.000$) respectively. Further correlation to determine the level of clinical significance yielded $r = 0.675$ (mAs) and $r = 0.236$ (kVp) respectively. These indicate that the difference in mAs is clinically significant while that in kVp is not clinically significant (**Table 4**).

4. Discussion

Digital technology has wider exposure latitude and post-processing algorithms which can mask the evidence of underexposure and overexposure. These characteristics have serious impact on diagnosis and patient radiation dose respectively [8]. Understanding what constitutes under-exposure and over-exposure is however, cumbersome [1], because computed radiography modality has the capability to normalize various degrees of exposure adjustment and produce a standard optical density irrespective of errors [8]. This work was an attempt to define over-exposure by revealing the minimum exposure parameters that can yield images of acceptable diagnostic quality.

Our findings show that no matter the temptation to err on the side of dose creep, a much lower kVp, mA and mAs can give acceptable results (Figures i-viii). The densest anatomy can be conveniently examined with a maximum of 250 mA and <94 kVp (**Table 2**). This disagrees however, with the finding of a similar work where the researchers compared film/screen technology, CR and direct digital radiography, and found that CR needs a higher exposure to the patient to provide equivalent image quality to film/screen [16]. This is likely if optical

Table 1. Throughput of adult subjects examined during the study period.

Parameter	Male	Female	Total	%
Chest	80	103	183	55
Lumbo-sacral spine	18	22	40	12
Skull	14	18	32	9.6
Knee	11	13	24	7.2
Femur	9	12	19	5.7
Cervical spine	6	13	19	5.7
Pelvis/hip	7	9	16	4.8
Total (%)	145 (43.3%)	190 (56.7%)	335	100

Table 2. Derived exposure chart.

Variable	Age (years)	FFD (cm)	kVp		mAs		mA	
			Range	Derived	Range	Derived	Range	Derived
Chest (PA)	0 - 3	90 - 100	50 - 60	52	3.20 - 6.25	3.20	50 - 125	100
	4 - 9	150	50 - 65	55	3.20 - 6.25	4.5	50 - 160	140
	10 - 17	150	50 - 75	65	4.0 - 10.0	6.5	80 - 250	220
	21 - 89	150 - 180	68 - 82	73	5.25 - 12.60	10	160 - 250	230
Lumbo-sacral	33 - 92	90 - 100	78 - 130	94	8.0 - 25.0	20	100 - 320	250
Pelvis	18 - 88	90 - 100	70 - 85	75	8.0 - 16.0	12.8	80 - 250	220
Knee	21 - 86	90 - 100	45 - 70	62	4.0 - 6.30	5.0	63 - 125	100
Femur	24 - 90	90 - 100	60 - 85	75	6.3 - 20.0	10.0	100 - 250	200
Cervical/S (AP)	32 - 87	90 - 100	63 - 88	75	4.0 - 12.5	6.4	50 - 150	100
Skull (OF/Lat)	18 - 91	90 - 100	74 - 80	70	8.0 - 10.0	8.5	160 - 200	180

Table 3. Comparison of different works.

Parameter	Williams <i>et al.</i> , 2007 (mobile unit)			Williams <i>et al.</i> , 2007 (static unit)			Present study, 2015 (static unit)		
	kVp	mAs	mA	kVp	mAs	-	kVp	mAs	mA
Chest (PA)	85	10	-	106	3.33	-	73	10.0	230
Femur (AP/Lat)	55	10	-	76	16	-	75	10.0	200
Pelvis (AP)	55	24	-	80	20	-	75	12.8	220
Cervical/S (AP)	60	7.5	-	76	20	-	75	6.4	100
Cervical/S (Lat)	65	15	-	76	20	-	75	6.4	100
Knee (AP)	55	25	-	70	6.67	-	62	5	100
Knee (Lat)	55	16	-	70	6.67	-	60	5	63
Lumbosacral/S (AP)	75	48	-	80	20	-	94	20.0	250
Lumbosacral/S (Lat)	85	150	-	80	80	-	94	20.0	250
Skull (AP)	60	16	-	80	13.33	-	70	8.5	180
Skull (Lat)	55	10	-	76	6.67	-	70	8.5	180

Table 4. Statistical comparison of the present study with a similar work for chest parameters.

	Williams <i>et al.</i> , 2007	Present study, 2015	One-sample t-test	Remark	Pearson's correlation	Remark
kVp	106	73	p = 0.000	Statistically significant	r = 0.236	Not clinically significant
mAs	3.33	10	p = 0.002	Statistically significant	r = 0.675	Clinically significant

p < 0.05 (level of significance).

density is the primary interest but our work shows that a comparably higher exposure may not be necessary to produce diagnostically useful images.

It has however, been shown that increasing the tube potential in chest radiography from 60 kVp to 90 kVp will result in a decrease in entrance surface dose (ESD) by 60% and effective dose by 20%. Therefore, the use of low tube potentials for dense anatomy is discouraged [17]. Even though an image that is diagnostically useful can still be produced at a lower kVp, the researchers were mindful of the consideration for entrance surface dose

to start their decrease in exposure factors from the 90th percentile and eventually arrived at a tube potential of 70 kVp (skull), 73 kVp (chest), 75 kVp (femur), 75 kVp (pelvis) and 94 kVp (lumbosacral) respectively (**Table 3**). Previous researchers however, pegged the optimum tube potential for adult chest radiography at 60 kVp [18], and 106 kVp [11]. The wide variation between the three works is possibly an indication of differences in subjects, training and inter-radiographer idiosyncracies.

5. Conclusion

Dose creep can be minimized by a computed radiography-specific exposure chart. Such a chart has been derived for a negroid population in Nigeria using AGFA photostimulable phosphor plates and a GE static X-ray machine manufactured not earlier than 2003. In addition, the upper threshold of adult exposure factors using comparable equipment and accessories is 94 kVp, 250 mA and 20.0 mAs respectively. The radiographer, rather than technology, is the major determinant of patient dose in view of their ability to manipulate exposure parameters.

Limitation

A comparison of our exposure chart with that of other hospitals in the locality would have given an idea into the extent of variations using comparable as well as different equipment and accessories. Unfortunately, there are no documented charts in the literature from our locality.

Recommendations

Similar works that will replicate ours should be carried out using different PSP plates than the AGFA used by us to determine the extent of variation between different receptors. In addition, the entrance skin dose level of the recommended exposure factors should be investigated to ascertain if they are within acceptable limits.

Declarations

Conflict of interest and funding: nil.

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