Clinical Analysis of Image Quality for Barium Special Investigations

****Omer Loaz, *Hussain Almohiy, ***Mohamed Yousef, ****Sulieman A, *****Mehenna Arib**

*Department of Diagnostic Radiology Sciences, King Khalid University, College of Medical Applied Sciences, Abha - P.O. Box 3665, Saudi Arabia, **Sudan University of Sciences and Technology, College of Medical Radiologic Sciences, Al Baladya Street, P.O. Box 1908, Postal Code - 11111, Khartoum, Sudan, *** Battrjee Medical College, Department of Radiological Sciences, Jeddah, Saudi Arabia, ****Prince Sattam Bin Abdulaziz University, College of Applied Medical Sciences, Radiology and Medical Imaging Department, Alkharj 11942, P.O. Box 422, Saudi Arabia, *****Secondary Standard Dosimetry Laboratory, Biomedical Physics Department, King Faisal Specialist Hospital and Research Centre, Riyadh, Saudi Arabia.

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ABSTRACT

This study aimed to report the inadequaciesintheassessment ofthe image qualityrange of some hospitals in Sudan for a selection of standard specific radiologic exams toexperience the level of matching to European Commission guidelines and to compare the findings with worldwide standards.

A subjective evaluation of 319 Images obtained from 95 individual radiologic GIT Barium Studies distributed as 138, 101 and 80 images from 40 (B. Swallow), 14 (B.Meal), 15 (B. Follow Through) and 26 (B. Enema),respectively. For each procedure, theEntrance Surface Air Kerma (ESAK) values were recorded. The image quality criteria scoring system was set for each projection, where two assessors reviewed the compliance of the films with the CEC recommendations. The maximum scores obtained were found to be Fully Acceptable; all anatomical structures were found to be61.6±13.66, 53.2±28.86, 62.5±15.53 for(B. Swallow), (B.Meal+ B. Follow Through) and (B. Enema) respectively. Also, The ESAK values recorded in this hospital survey yielded, 1.4±0.48mGy, 2.3± 0.90mGy and 2.1±0.60 mGyforthe same cases respectively. The set of Image Criteria scoring system practiced in this study has been found to be convenient, and it is advised to be implemented in routine practice in the hospitals and moreover, the image quality needs to be combinedwith the patient dose.

KEY WORDS: barium study**,** european guidelines**,** image quality, image criteria, .

INTRODUCTION:

Barium investigations remain the technique of choice for the diagnosis and evaluation of many gastrointestinal (GIT) disorders (Etaiwi and Shareadeh, 2008). Barium is a thick, white chalky substance. An upper gastrointestinal series investigates the first part of the small intestine, however, the lower gastrointestinal series is evaluating the colon (Costas H, 2012) Nowadays, the radiologists are facing challenges in generatingquality assurance program, tointegrate reproducible assessmentmethods and deliver a significantoutcome relatively to clinical efficiency. In diagnostic imaging, the definition of image quality may depend upon various factors such as physical and technical factors (Jessen K. A., 2002).

Corresponding Author:
Dr Hussain Almohiy,
B.Sc. M.Sc. (MI), GDM, Adip, PhD,
Chairman, Department of Radiological Science, College of Applied Medical Sciences, King Khalid University,
P.O. Box 9060 Abha, 61431, Saudi Arabia
Phone No.: 96672417742
Facsimile: 96672417071
E-mail: hmohiy@kku.edu.sa

MATERIALS AND METHODS:

This descriptive observational study was held in eight hospitals in Sudan state. Ten x-ray machines were considered in this work. A subjective evaluation of 319 Images of special radiologic investigation of GIT Barium Studies has been carried out in this study which focused on different techniques of special GIT barium investigations that affect image quality and radiation dose with relation to imaging protocols implemented inthe following state hospitals; Teaching

Hospitals (TH), Military Hospitals(MH), University Hospital (UH), Private Hospitals (PH) and Specialist Hospitals (SH) radiology departments. The following diagnostic technics were included: Direct Digitized Radiography (DR), Computerized Radiography (CR) and Screen Film Radiography (SFR). An overall number of 319 special radiologic barium exams over 95 subjects, were considered and distributed as follows (see table 1);40 subjects (42.1%) had undergone B. Swallow procedures, 29 patients (30.5%) had (B.Meal + B. follow through) exams, and 26subjects (27.4 %) received B.Enema exams. The data were gathered and presented in tables and figures when appropriate. The mean and range were used to evaluate statistically the obtained results. In the radiological procedure, the radiation dose is multifactorial; The means were calculated using the Excel software & SPSS program. For dose calculation, the individual patient exposure parameters, tube voltage (kV), tube current (mAs) and Focus onskin distance (FSD)were verified. Patient information (Age, Weight,Height,and BMI) were estimated andthe patients (ESAK) were measured in all Radiology Department.

Table 1: Examinations frequency and percentage.

Examinations	Number of patients	Percentage
B. Swallow	40	42.1%
B. Meal	14	14.7%
B.F. Through	15	15.8%
B. Enema	26	27.4%
Total	95	100%

Image quality analysis - Clinical criteria:

As can be seen in table 2, the level of visualization of important anatomical featureswas delineated and specified using the following anatomical structures criteria: Visualization; distinguishing features are detectable (features just able to be seen). Reproduction; information of anatomical structures can be seen (details emerging).

Procedural and Technical Image Criteria:

The images involved in this study were considered to be accepted by a radiologist. The radiographs extensively containing pathology or showing surgical tools that are hiding criteria of image evaluationnot involved. The anatomical criteria

Table 2: Basic criteria used for the valuation of the quality of radiographic images.

Image criteria	Degree of visibility	Score
Visualization of characteristic features	- Details identified and totally reproduced	1
	- Details just observable.	2
	- Details not observable.	3
Reproduction of anatomical structures.	- Detail visible and defined.	1
	- Details just observable.	2
	- Detail not observable.	3
Visually sharp reproduction	- Details defined.	1
	- Details just distinct.	2
	- Details not distinct.	3

1 = Fully Acceptable, 2 = Probably Acceptable and 3 = Poor

assessment were taken from the CEC endorsements (CEC, 1996). The researchers have splitthe study into technical quality criteria (QTC) to focus only on the anatomy that is affected by technical means like KVp, m Asetc, and procedural quality criteria (PQC) that are essentially Technologists' action technique such as positioning of the patient. The standards, given in Tables 3 were approved by skilled clinicians.

All radiographs were selected from the daily practice of individually radiology department. Images were valuedvia a subjective assessment which enclosed all the stated TQC which delivered a worthy exhibition of the PQC.

Assessors Panel:

At least two expert technologists have assessed films in this survey. Each member of the assessment group has scored separately Image criteria from 0 (Poor), 1 (probably acceptable), 2 (Fully acceptable). The assessors have re-assessed the same selected images randomly and using the same assessing situations to minimize the intra- assessor variation.

Image criteria scores (ICS):

The image quality assessment was performed as follows: Using the image quality criteria of Table 3,the assessors reviewed the films regarding compliance with the CEC recommendations, and they were requested to provide a classified respect to the quality of the imaged constructions stated in the criteria. Image criteria for series of radiographs were done at

Table 3: Barium Studies Images criteria and code.

Criteria	Code
Bowel outline reproduction must be demonstrated with marginal unsharpness.	C1c
The entire abdomen to include the esophagus and diaphragm up to the symphysis pubis.	C2c
Visually sharp reproduction of the bones and the boundary amid the air-filled bowel and nearby soft tissues with no covering artifacts.	C3c
In good tissue, differentiation is essential to visualize esophagus, small bowel, large bowel, and stomach or GIT accessories organs.	C4c

intervals after contrast administration, modified to patients individually. Therefore, every criterion was counted up one by one and coded one if the films were fulfilling the criterion set before and zero if not. Observers scored the films from C1c to C4c, with each criterion scoring 0 or 1. So, a radiograph fulfilling all the criteria scores 4, and with three, two and one criteria present, the scores are 3, 2 and 1, respectively. The statistics from the evaluators have been pooled and analyzed to minimize the effects of the results subjectivity.

Absorbed Dose calculations:

The exposure to the skin of the patient throughout radiographic examination or fluoroscopy can be estimated by calculating the Entrance Air Surface Kerma ESAK, for the patients who underwent the Barium Studies, using the following formula (ICRP., 2005).

Where:

(OP) is the output in mGy/(mAs) at 100 cm from the x-ray source at 80 kVp, (kV) the tube peak potential, (mAs) the tube time current, (FSD) the focus-to-skin distance, in cm and the backscatter factor(BSF).

RESULTS:

Image Quality Criteria (IQC) for special radiologic investigation were recently settled by CEC. These data are useful for daily quality assessment but are not entirely recognized for some radiographic examinations. The maximum quality scores were expected as are producibility method's indicator.

Results attained from this study present a simple and easy method for clinically evaluating radiographic images via fewer parameters. The image quality criteria (IQC) involves Technical Quality Criteria (TQC) and Procedural Quality Criteria (PQC).

A subjective judgment on image quality was obtained in this Hospitals survey, which was defined as fully acceptable (least or no imperfections), probably acceptable (mainim perfections with adequate clinical data) or Poor (mainim perfections, insufficient clinical data), for the Radiographic exams under assessment; B. Swallow, B.Meal., B. Follow Through and B. Enema.

The ESAKs were measured in all radiology departments for the special radiologic examinations. The dosage values in imaging are in order in milli-Gray. The results are presented per department, per procedures and gender for all type of imaging technique and modality according to the examination type. The results were arranged in the Tables (mean ± standard deviation (SD)) and the variation of the analyses in parenthesis. The mean and the standard deviation were calculated using the Excel software & SPSS program.

As a be seen in table 4, the patient images included in this analysis were 319 films among which 190 (59.6%) and 129 (40.4%) for males and females respectively (distributed respectively as 68 (48.2%) and 73 (51.8%) for B. Swallow, 61 (61.6%) and 38 (38.4%) for B. Meal. + B. Follow Through and 61 (77.2%) and 18 (22.8%) for B. Enema).

The table 5 and the figure 1 show the distribution of the films per exam for all the concerned examinations. The distribution of the images for each radiologic investigation among the hospitals is summarized in table 6 and illustrated by the figure 2.

The mean range of films per exam for all investigations included B. Swallow, B.Meal. B. Follow Through, and B. Enema was recorded 14.6±12.59, 19.9±10.43, 12.9±7.91 and 12.4±5.87 with minimum and maximum account 2, 6, 3, 4 and 55, 41, 28 and 25 respectively.

The radiologic investigation among the hospitals distributed as follow; Barium Studies were 2 (2.1%), 2 (2.1%), 13(13.6%), 19 (20%), 10 (10.5%), 20 (21%), 26 (27.3%) and 3(3.1%) for H1, H2, H3, H4, H5, H6, H7 and H8 respectively.

Table 4: The gender v. Images distribution for each radiologic investigation.

Gender	B. Swallow	B.Meal + B. Follow Through	B.Enema	Total
Male	68	61	61	190
	48.2%	61.6%	77.2%	59.6%
Female	73	38	18	129
	51.8%	38.4%	22.8%	40.4%

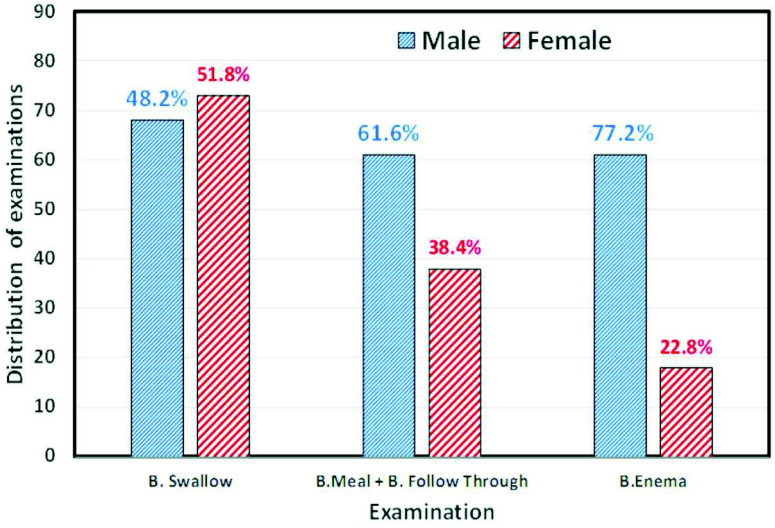

Figure 1: Images distribution for each radiologic investigation.

Table 5: Mean, Standard Deviation, Minimum, and Maximum of the films per-examination.

No.	Examinations	Mean	Std. Deviation	Minimum	Maximum
1	B. Swallow	14.6	12.59	2.00	55.00
2	B. Meal	19.9	10.43	6.00	41.00
3	B. F. T.	12.9	7.91	3.00	28.00
4	B. Enema	12.4	5.87	4.00	25.00

The results of image quality valuation set on the CEC guides scores ranged Fully Acceptable; all anatomical structures were seen. Consequently, images quality yields an utmost score of 61.6±13.66, 53.2±28.86 and 62.5±15.53 for (B. Swallow), (B.Meal+ B. Follow Through) and (B. Enema) respectively.

The results of image quality marks ranged probably Acceptable; 26.6 %, 29.2% and 26.9% for B. Swallow, (B.Meal and B. Follow through) examinations and B. Enema, respectively.

The total score results of image quality measurement ranged poor or rejected; 11.8%, 17.6% and 10.6% for B. Swallow, B.Meal,and B. Follow through and B. Enema examinations respectively.

The highest entrance air kerma dose (ESAK) value for Barium Studies was recorded atH3 hospital (3.3 mGy) while the lowest ESAK value was registered at H8 hospital (1.1 mGy) with mean average 2.2 ± 0.85.

DISCUSSION:

Images in radiology necessitate great quality to take full advantage of diagnostic usefulness. When the patients are being irradiated, the image reproduced should be of the optimum quality regardless of the site of the investigation. It is also recognized that the

Table 6: Distribution of Images for each radiologic investigation vs. hospitals.

Hospitals	B. Swallow	B. Meal+ F.T	B. Enema	Total	
				Number	Percentage
H1	16	0	0	16	5.0%
H2	2	0	0	2	0.6%
H3	18	27	4	49	15.4%
H4	34	12	18	64	20.1%
H5	21	3	12	36	11.3%
H6	21	12	30	63	19.7%
H7	12	47	16	75	23.5%
H8	14	0	0	14	4.4%
Total	138	101	80	319	100%

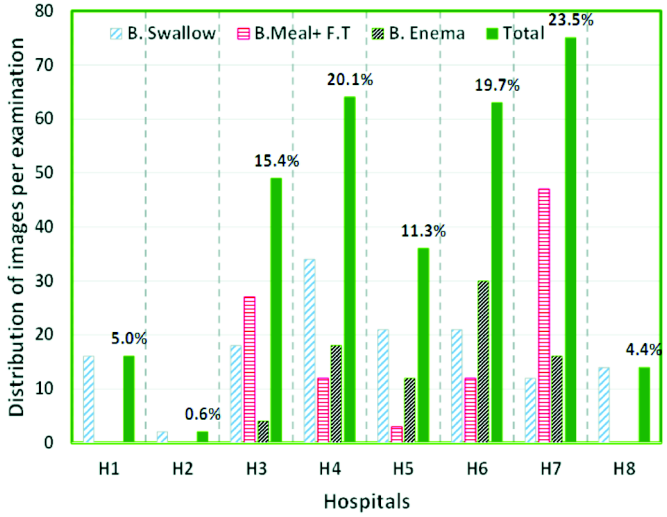

Figure 2: Distribution of images for each radiologic investigation among the hospitals.

Table 7: The maximum image quality scores for each exam.

Examinations	B. Swallow	B. Meal+ Follow Through	B.Enema
No. Measurements	138	101	80
Maximum Image quality scores	61.6 ±13.66	53.2 ±28.86	62.5 ±15.53

image quality can vary for different investigations (Leitz WK, et al. 1993; Akesson L et al. 1993). The present study intends to find the level of difference in image quality for selected barium in vestigations. The scoring methods of anatomical image criteria implemented have been used efficiently in recent studies which have the best discernment concerning films of variable quality (Doherty P et al, 2003; Grondin Y et al, 2004; Peters SE et al, 2002).

This pilot evaluation of Barium studiesimages in hospitals surveyedallowed us to study the image quality of 319 Barium Films in combination with standard protocols implemented and theESAK values obtained.The Maximum Image criteria scores ranged between 53.2% and 62.5%.Images quality yielded utmost scores of 61.6±13.66, 53.2±28.86 and 62.5±15.53 for B. Swallow, B.Meal+ B. Follow Through and B. Enema respectively, which is

Table 8: Series of procedural information through hospitals for each exam.

Technical Parameters	B. Swallow	B.Meal	B. F. T	B.Enema
Tube output (KVp)	55-125	64-94	64-94	94-94
Tube output (mAs)	10-32	3-43	3-43	3-43
Receptor-focus distance(cm)	100/109	100/109	100/109	100/109
Accurate Collimation	82.5%	100%	100%	100%
Correct Marker	yes	yes	yes	yes
Correct Gonad Shield	None	None	None	None

Note: Barium Studies = B. Meal+ B. F. Through+ B. Enema.

compliant with CEC image quality criteria. The ESAK values recorded in the surveyed hospital yielded,1.4±0.48mGy, 2.3± 0.90mGy and 2.1±0.60 mGy for B. Swallow, B.Meal+ B. Follow Through and B. Enema respectively.

The results obtained in the present study indicate that the image criteria system selected is the best and it can be stated that the scoring method used defers reproducible statistics in all rates, in agreement with A. C.Offiah and C. M. Hall, 2003. The Image Criteria system (ICS) set by the CEC were able to distinguished discrepancies in the quality of both film–screen and digital images. Furthermore, the validity of using VGAS and the ICS of CEC as analysis tools of clinical image quality were raised recently by Tingberg et al. 2005; Bath M and Mansson LG., 2007). The values achieved in this work are incoherence with data reported in the literature. In addition, the image differences found among hospitals for all projections examined.

The variation factor (VF) is used as a term and is counted for each projection by dividing the maximum hospital percentage value by the minimum hospital percentage so that the improvement effort is easily identified when image discrepancies are acknowledged as linked to the performance of equipment or radiographic Technique. Furthermore, to categorize anatomical criteria, detailed differencesmay berelated to technical or procedural factors. Rainfordet al (2007),stated for the first time the variation factor as an indicator for separating causal agents.

Through all investigations, the meantechnical and procedural VFs were 1.8 and 1.7, respectively, so it may suggest that visualization of procedural criteria, which relies mainly on the radiographerperforming of the investigations approach, different by a marginally lesser amount than technical criteria. The amount of VF for both procedural and technical quality was equal in value to 1.8 for B.Meal + B. Follow Through and was 1.6 and 1.9 for the B. Swallow exam, 1.9 and 1.4 for B. Enema. The effectiveness of breaking up the causative factors into technical or procedural groups is shown for the B. Swallow investigation, where the technical VF is at a reasonably low level of 1.6, but the procedural VF value is 1.9. This may prove that the difference in general images score is mostly owing to the radiographic protocol applied and proper procedural employed rather than equipment.

Table 10 shows the mean calculated scores for each investigation for analog and digital acquisition technology. These results are also illustrated by the figures 3 and 4 which illustrate the mean calculated scores and the mean ESAK (mGy) for each examination.

Since the initiation of digital acquisition technology through hospitals, will meaningful to compare the image quality of films acquired digitally with images reproduced by analog in this hospitals survey. The mean percentage scores for both means of acquisition are reviewedin the above Table. For technical and procedural quality criteria, barium meal and Follow Through were greater with the analogacquisition system, while Barium swallow and barium Enema images scores were greater with the Digital acquisition system, which stressesthat visualization of anatomical features in this investigations was equal in both technologies. Even the scores variances among the acquisition methods are minor, which would suggest that it is due to well trained and skilled operator. Even L.A. Rainford et al. (2007)reported higher percentage scores for the analog films related to the digital films, the analog acquisition was greater for all scores, and they argued

Table 9: Percentage values of technical quality criteria (TQC) and procedural quality criteria (PQC) for each the projections.

B. Enema		B. Meal + B. F. T.		B. Swallow		Hospital
PQC	TQC	PQC	TQC	PQC	TQC	
*	*	*	*	52	62.5	H1
*	*	*	*	*	*	H2
66.6	50	86.3	81.4	77.7	77.7	H3
94.4	94.4	55.2	50	79.4	79.4	H4
83.3	83.3	50	50	100	100	H5
83.3	83.3	88.8	88.8	80.9	80.9	H6
81.2	81.2	64.7	63.9	75	75	H7
*	*	*	*	61.9	100	H8
1.4	1.9	1.8	1.8	1.9	1.6	VF

Key; * = Lack of data analysis. VF = Variation factor: Computed for every assembly of criteria and exam by dividing the maximum percentage value by the minimum value.

Table 10: Shows the mean calculation scores for each investigation for analog and digital acquisition technology.

ESAK (mGy)	Total	Procedural Quality Criteria	Technical Quality Criteria	Examination	
1.5 ± 0.54	71.9	63.8	80	Analogue	B. Swallow
1.2 ± 0.45	83.8	83.8	83.8	Digital	
3.1 ±0.21	83.8	86.3	81.4	Analogue	B. Meal+Follow Through
1.9±0.73	63.8	64.6	63.1	Digital	
3.1 ±0.21	58.3	66.6	50	Analogue	B. Enema
1.9±0.73	85.3	85.3	85.3	Digital	

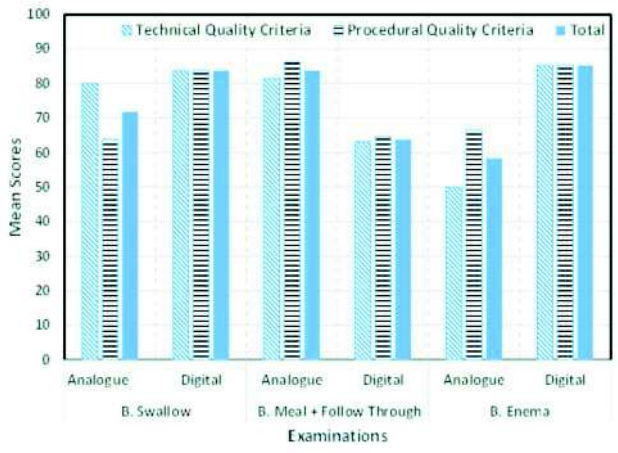

Figure 3: Mean scores for each examination.

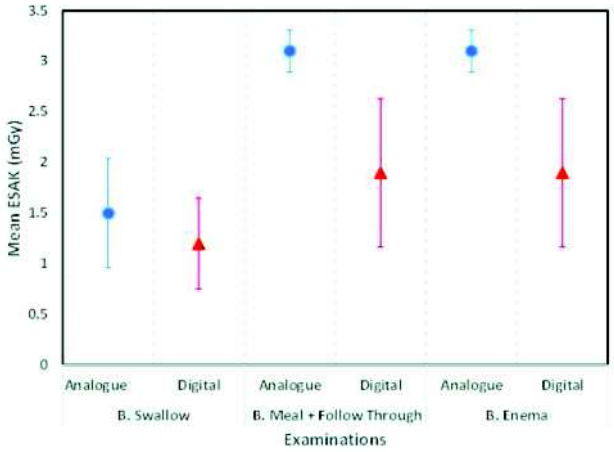

Figure 4: Mean ESAK (mGy) per examination.

that the causes may be related to the poorer spatial resolution of digital in compare to the analog systems. Also, recent research revealed that applying lower tube voltage improves the prominence of anatomical features and abnormalities in digital chest images and growths the disturbance appearance of thoracic bones

Table 11: Dose characteristics of barium examinations compared to published results.

ESAK in μGy	Mean No of Radiographs	Number	Author
1.4	14.6±12.59	50 (S)	Present study
2.3	19.9±10.43	41 (M)	
2.3	12.9 ±7.91	42 (F)	
2.4	12.4±5.87	50 (E)	
24	NR	42 (E)	Delichas et al.(2003)
NR	4.3	38 (S)	Ruiz-Cruces, et al.(2000)
NR	1.6 0-25	1587(M)	Brodhead et al.(1995)
6.4	0.6 0-30	1308 (E)	

(S) Barium swallow, (M) Barium meal, (F) Barium Follow Through and (E) Barium enema.

(W.J.H. Veldkamp et al.,2009).

The link of the screen-film system speed, kV,FID, automatic exposure control (AEC)and total filtration showed that hospitals in Sudan under evaluation in this study perform in compliance with the recommendation by the European Commission in respects to Barium Studies investigations.

The ESAK values obtained in this survey emphasized by González L et al. (1999) as they reported that the radiographic technique (protocols) and other determining factors demonstrate variations of one order of magnitude, and even more in the individual doses depending on the equipment used and the expertise of the operators. The relatively small exposure dose levels obtained in this work may be due to a variety of elements in dose calculations and patient dosimetry in diagnostic radiology and influenced by equipment unit sacting and screen film systems speed and a statistical number of patients.

ESAK values during Barium Studies linked with image quality scores. The Quality Criteria implemented in this workinvolved a method for counting more features of the image, such as sharpness, density, contrast and diagnostic adequacy. The maximum image quality scores yielded 61.6±13.66, 53.2±28.86 and 62.5±15.53 for B. Swallow, B.Meal+ B. Follow Through and B. Enema), respectively.

The highest entrance air kerma dose (ESAK) value for Barium Studies recorded at H3 hospital (3.3 mGy) while the lowest ESAK value registered at H8 hospital (1.1 mGy) with mean average 2.2 ± 0.85.this is higher than what was determined by Sulieman et al., (2011) who studied the patient's exposure doses throughout Barium studies examinations (barium swallow, barium meal, and barium enema) using Thermoluminescence dosimeters (TLD) and found that the patient ESDs were 12.6±10μGy, 44.5±49μGy and 35.7±50 μGy for barium swallow barium meal and enema, respectively. Table 11 shows the comparison of our results to published values.

For the hospitals, involved in this survey, in certain circumstances, it may be difficult to adhere to all the CEC recommendations due to equipment restrictions and the radiographic staff members who themselves are not in aware of the image quality conception, which seems to be another limitation. Therefore, there is an indication ofthe necessity for advanced and continuous training programmes for the personnel in radiology centers.

CONCLUSION:

According to the recent results obtained in the present study, it could be concluded that the set of the image Criteria scoring system utilized has been found to be valuable, and their implementation in routine practice in the hospitals is strongly advised. The patient irradiation dose can be linked to the required image quality and the need to provide appropriate training to employees in the radiology centers is essential.

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