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Original Article

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Clinical Evaluation and Standardization of Image Quality and Technical Protocols for Special Radiological Procedures

Elgeili Yousif[1], Omer Loaz[2], Hussain Almohiy[2], Mohamed Algahtani[2], Magbool Alelyani[2], Mohammed Salih[1], Qurain Turki Alshammari[1*]

[1]*Department of Diagnostic Radiology, College of Applied Medical Sciences, University of Hail, Saudi Arabia.*
[2]*Department of Radiological Sciences, College of Medical Applied Sciences, King Khalid University, Abha, Saudi Arabia.*

***Email:** g.algrain@uoh.edu.sa*

ABSTRACT

This work aimed to standardize and state" the insufficiencies outlined and variation in image quality, among some hospitals in Sudan for a common in specific radiologic examinations. A subjective evaluation of 1,103 image reproductions from "363 special radiologic procedures including Intravenous Urography (IVU), Hysterosalpingography (HSG), GIT barium studies" and Micturating Cystourethrography (MCUG), and the Entrance Air Surface Kerma (ESAK) values recorded for each procedure. The maximum scores ranged as Fully Acceptable; all anatomical structures were found to be i65.9 ±14.9, i53.2 ±21.4, i61.6 ±13.7, 53.2 ±28.86, 62.5 ±15.53 and 64.9 ±18.92 for IVU, voiding Cystourethrography, (barium swallow), (barium meal + barium follow-through), (barium enema) and HSG, respectively. In addition, the ESAK values recorded in this hospital survey were 1.9 ± 0.89, 1.85 ±0.48, 2.3 ± 0.85, and 2.1 ± 0.59 mGy for IVU, Voiding Cystourethrography, "Barium studies and HSG", respectively. The image criteria scoring systems (ICs) were found to be valuable and proposed to endorse in daily practice in the hospitals, and coupled the radiation dose to the patient to the required image quality. This study will help to standardize the image quality of some special examinations typically used in hospitals in Sudan.

Key words: *Image quality, Radiographic special investigations, Barium studies, IVU*

INTRODUCTION

The diagnostic image is a depiction of the structures of the organs and tissues that are investigated [1]. Image quality determines how effective the image is for its intended task [2-4]. Few reported studies have considered the evaluation of radiographic technique and the diagnostic requirements and radiation dose criteria, either in Sudan or worldwide. In most hospitals, a lack of standardization reduces diagnostic efficiency [5]. To guarantee a standard of quality, the Commission of European Communities (CEC) has endorsed image quality criteria, which are applied globally to ensure good radiographic practices and efficient image assessment [6, 7]. This made the imaging process more efficient in many clinical settings [8].

In this study, we attempted to implement standards in multiple Sudanese hospitals to improve diagnostic efficiency and fully comply with CEC guidelines. This study aims to analyze the quality of the images taken during special radiological procedures, comparing the findings with global standards to see whether these measures allow for reasonable image quality assessment.

MATERIALS AND METHODS

This observational, retrospective study was carried out in nine major hospitals in Khartoum, Sudan. Data from ten x-ray units were used in the study. A subjective evaluation was done on 1,103 images of fluoroscopic investigations, including intravenous urography (IVU), Hysterosalpingography (HSG), GIT barium studies, and avoiding Cystourethrography (MCUG).

Study population

A number of 363 special fluoroscopic investigations were examined, retrospectively: 26.2% (95 patients) were barium procedures, 12.9% (47 patients) were MCU procedures, 27.3% (99 patients) were IVU procedures and 33.6% (122 patients) were HSG procedures. For each procedure, the mean values of patient age (years), patient weight (kg), tube potential (KVp), and exposure settings (mAs) were recorded. More details are provided in **Table 1**.

Table 1. Number of exams, number of radiographs, and mean values for patient demographic information (height, age, BMI, and weight)

Exam	No.	Patient age (yrs.)	Height (cm)	Weight (kg)	BMI (kg im^{-2})
VU	99	24–45	151.5 (145–158)	59.5 (51–68)	24.9 (22.7–27.2)
MCUG	47	18–67	148.5 (135–162)	57.5 (40–75)	26.3. (21.9–28.6)
Barium studies	95	16–80	145 (125–165)	57.5 (37–78)	27.3 (23.7–28.7)
HSG	122	27–41	165.0 (156–174)	66.5 (51–82)	24.4 (21.0–27.1)

Intravenous urography (IVU), barium studies, voiding Cystourethrography (MCUG), Hysterosalpingography (HSG)

The number of Images (percentage%) of UV, MCUG, barium studies, HSG were 354 (29.9%), 163 (13.8%), 239 (27%), 347 (29.3%), respectively. The total Number of images was 1103.

Image quality analysis

The analysis of Image quality depends on two criteria namely, clinical and procedural and technical criteria. A list of criteria used for image analysis, which comply with CEC guidelines, is illustrated in the following **(Table 2)**.

The term percentage differences (PDs) is used in this discussion to express the differences between the means of the technical quality criteria (TQC) and procedural quality criteria (PQC) as minimum hospital percentage and maximum hospital percentage value.

Table 2. IVU, MCUG, barium studies, and HSG image criteria and respective codes

	No.	Criteria	Code
IVU	**1**	1. Visualization of the whole urinary tract, from the upper pole of the kidney to the base of the bladder.	**C1a**
	2	2. Visualization of the kidney outlines.	**C2a**
	3	3. Visualization of the renal pelvis, the calyces (Pyelographic effect), and the pelvic-ureteric junction.	**C3a**
	4	4. Visualization of the area normally traversed by the ureters and the entire bladder.	**C4a**
MCUG	**1**	1. Visualization of the whole urinary bladder area to the base of the urethra.	**C1b**
	2	2. Visualization of the urethra.	**C2b**
	3	3. Visualization of the vesicoureteral junction.	**C3b**
	4	4. Visualization of the area normally traversed by the ureters and the whole bladder area.	**C4b**
BARIUM STUDIES	**1**	1. The bowel pattern is visible with minimal blurriness.	**C1c**
	2	**1.** Coverage of the whole abdomen, including the esophagus and diaphragm, down to the symphysis pubis.	**C2c**
	3	2. Sharp image of the bones and the interface between the air-filled bowel and the surrounding soft tissues with no overlying artifacts (e.g., clothing).	**C3c**

	4	3. Good tissue differentiation in the visualization of the esophagus, small intestine, large intestine, stomach, or the GIT accessory organs.	**C4c**
HSG	**1**	**2.** Visualization of the uterus opacification or uterine outline.	**C1d**
	2	Visualization of the fallopian tubes.	**C2d**
	3	**3.** Visualization of the Fimbrial rugae.	**C3d**
	4	**4.** Visualization of intraperitoneal spillage.	**C4d**
IQS	**C1**	Weakly visualized and not diagnostic.	Yes/No
	C2	Weakly visualized but diagnostic.	Yes/No
	C3	Good visualization and diagnostic.	Yes/No
	C4	Outstanding visualization.	Yes/No

Intravenous urography (IVU), barium studies, voiding cystourethrography (MCUG), Hysterosalpingography (HSG), and image quality scores (IQS).

Quantitative evaluation method

First, the skin dose (ESD) is calculated based on the x-ray tube output parameters. For patients who underwent fluoroscopic imaging, the following parameters were recorded to estimate the ESD: peak tube voltage (KVp), a current-time product of exposure (mAs), and focus-to-film distance (FFD). The ESD of the fluoroscopic investigation was quantified directly by calculating the entrance air surface kerma (ESAK) for the patients who underwent IVU, MCUG, a barium study, or HSG, as shown in the following formula [9]:

$$ESAK = op \times \left\{ i\,\frac{kv}{80i} \right\}^{2} \times mAs \times \left\{ \frac{i100}{FSD} \right\}^{i2} BSF \tag{1}$$

Where *op* is the output in mGy/mAs at a distance of 100 cm from the x-ray source laterally, *Kv* is the peak tube voltage recorded for any particular exam; *mAs* is the current time product, and *FSD* is the focus-to-skin distance (in cm).

BSF is the backscatter factor, calculated automatically by the Dose Cal software after all input data is entered manually.

RESULTS AND DISCUSSION

The fluoroscopic examination images were subjectively categorized as Fully Acceptable (minimal or no defects), Partially Acceptable (major defects but sufficient clinical information), or Poor (major defects and inadequate clinical information). There were 478 images collected from male patients and 625 images collected from female patients. The Number of IVU, MCUG, Barium studies, HSG in male patients were 212, 131, 135, 0, respectively. The Number of IVU, MCUG, Barium studies, HSG in female patients were 142, 32, 104, 347, respectively. The mean, standard deviation, minimum, and maximum of films per exam for all investigations are shown in **Table 3**.

Table 3. The mean, standard deviation, minimum, and maximum of films per exam for all investigations

No.	Exams	Mean	Std. Deviation	Minimum	Maximum
1	**IVU**	6.7	2.95	4.00	19.00
2	**MCUG**	9.5	7.63	3.00	34.00
3	**B. swallow**	14.6	12.59	2.00	55.00
4	**B. meal**	19.9	10.43	6.00	41.00
5	**B. follow-through**	12.9	7.91	3.00	28.00
6	**B. enema**	12.4	5.87	4.00	25.00
7	**HSG**	5.8	4.18	2.00	22.00

Intravenous urography (IVU), barium swallow (B. swallow), barium meal (B. meal), barium follow-through (B. follow-through), barium enema (B. enema), voiding Cystourethrography (MCUG), Hysterosalpingography (HSG).

The mean number of images per exam, the minimum values, and the maximum values were recorded in **(Table 4)**. Comparable values of the maximum image quality score have been recorded for the examined radiological procedures **(Table 4)**.

Table 4. Measurements recorded for the maximum image quality scores

Exams	IVU	MCUG	B. swallow	B. meal + if-through	B. enema	HSG
No. of measurements	275	104	105	70	66	277
Maximum image quality scores	65.9 ±14.90	53.2 ±21.37	61.6 ±13.66	53.2 ±28.86	62.5 ±15.53	64.9 ±18.92

Intravenous urography (IVU), barium swallow (B. swallow), barium meal (B. meal), barium follow-through (B. if-through), barium enema (B. enema), and Hysterosalpingography (HSG).

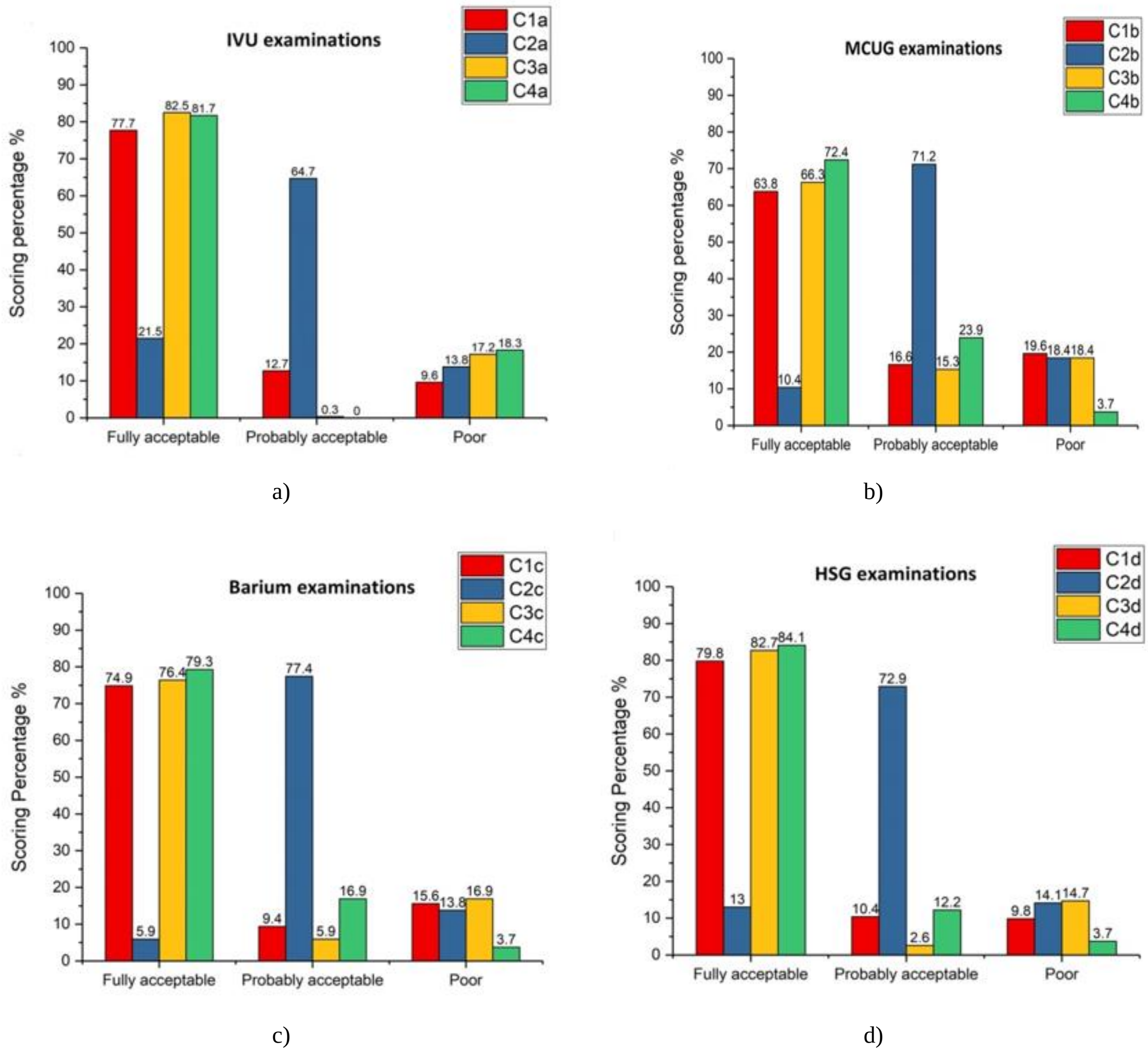

Figure 1. Image criteria and codes across all included exams.

The maximum image quality criteria scoring percentage values of technical quality criteria (TQC) and procedural quality criteria (PQC) for all procedures is summarized in **Figure 2**.

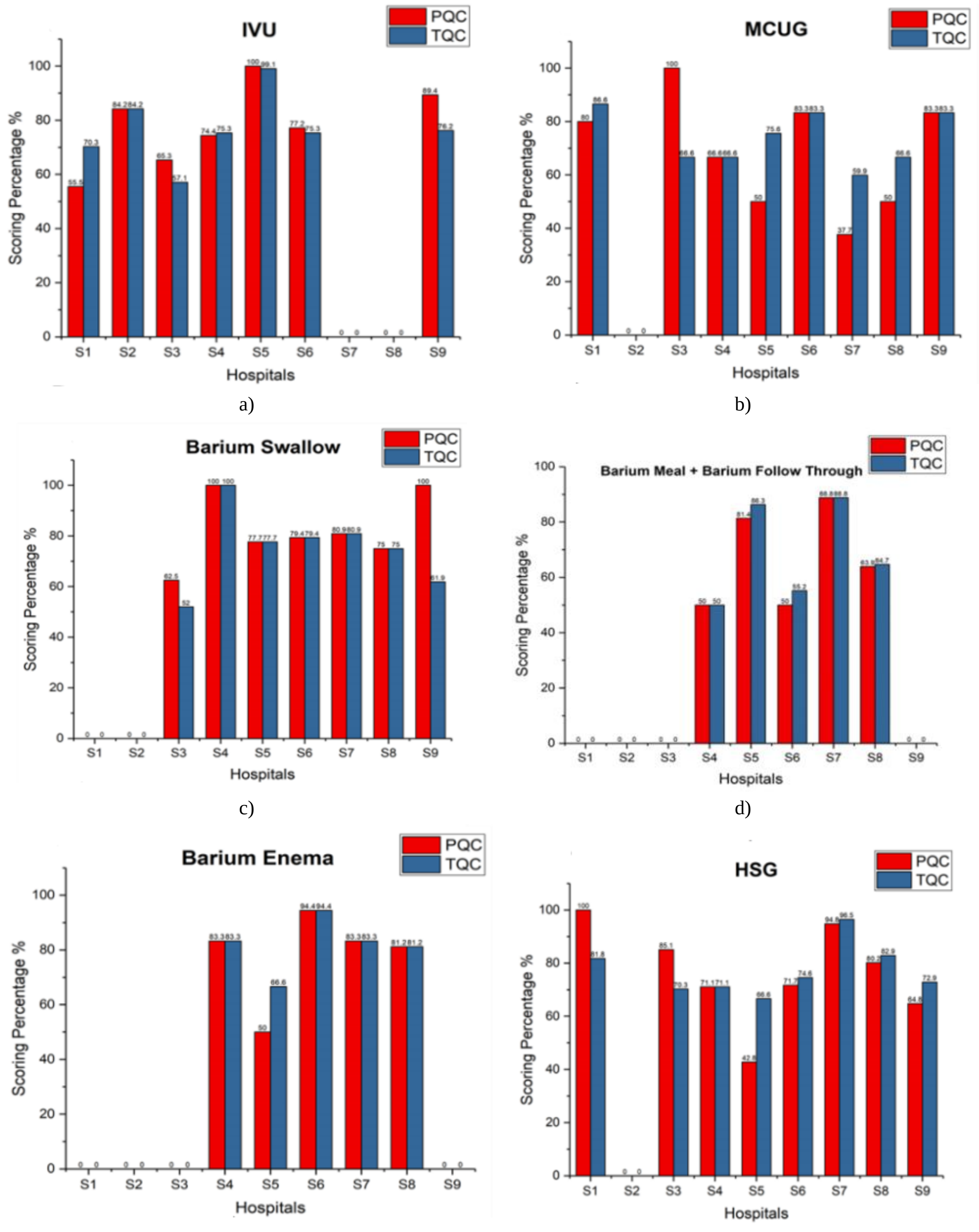

Figure 2. The maximum image quality criteria scoring percentage values of technical quality criteria (TQC) and procedural quality criteria (PQC) for all procedures for each hospital.

The range values for ESAK consisted of x-ray tube potential, focus to film distance (FFD), patient size, filtration applied, and automatic exposure control (AEC), as seen in **Table 5**.

Table 5. Special investigations with mean *KVp*, *mAs*, and ESAK doses to patients at different hospitals

Examination	*KVp*~ Range	*MAs*~ Range	FFD	Mean ESAK mGy
IVU	60–86	10–50	100/109	1.9 ±0.89
MCUG	55–90	8–46	100/109	1.85 ±0.48

Barium studies*	60–125	3–43	100/109	2.3 ±0.85
HSG	63–85	10–40	100/109	2.1 ±0.59

*Barium studies = B. meal, B. follow-through, and B. enema

The clinical evaluations used in this survey were subjective. Error reduced by using suitably skilled groups of radiologic technologists and gathering a huge set of data. This evaluation of the image quality of IVU, MCUG, barium studies, and HSG films in Sudanese hospitals was done using standard techniques and low ESAK values. As illustrated in **Figure 1**, the maximum image criteria scores range from 53.2 % to i65.9 %, and specific maximum image quality scores were 65.9 ± 14.90 for IVU, 53.2 ± 21.37 for MCUG, 61.6 ± 13.66 for barium swallow, 53.2 ± 28.86 for barium meal and follow-through, 62.5 ±15.53 for barium enema, and 64.9 ± 18.92 for HSG, in compliance with CEC recommendations. The ESAK values documented in this hospital survey were 1.9 ± 0.89, 1.85 ± 0.48, 2.3 ± 0.85, and 2.1 ± 0.59 mGy for IVU, MCUG, barium studies, and HSG, respectively. The obtained values are consistent with each other and with the data presented in the scientific and medical literature [10-14].

The Percentage difference (PDs) of IVU, MCUG, barium swallow, barium meal, barium follow-through, barium enema, and HSG were found to be 15.29%, 4.79%, 24.73%, 10.74%, and 9.89%, respectively. This suggests that the PQC depends on the radiographer's technique to indicate more diverse values than the TQC. The causes of poor image quality are normally technical; for example, exposure factors (KVp, mAs, and type of filter) and other procedural/equipment considerations.

The maximum image quality scores yielded 62.9, 84.2, 61.2, 74.8, 99.5, 73.6, and 82.8. The mean ESAK per IVU procedure was 1.1 mGy, 2.1 mGy, 3.6 mGy, 1.0 mGy, 1.6 mGy, 1.6 mGy, and 2.4 mGy in S1, S2, S3, S4, S5, S6, and S9, respectively. The average means were 77 ±13.27 and 1.9 ±0.89 mGy for IQC and ESAK, respectively. The CEC guidelines recommend 10 mGy as a reference dose for an IVU; this means that the patient dosimetry values observed in this work are well within the recommended dosage recognized worldwide. These variations may be explained by the comparatively small numbers of IVU images in the current survey range (approximately 6.4), or perhaps equipment performance improved due to developments in imaging technology. The ESAK values observed here were similar to those found by Halato *et al*. (2010), in a study conducted on adult patients [14]. The dose value in our work was less than what was stated to be as dose for adult patients in the study by Suliman *et al*. (2014) [15]. The quality criteria applied, generally, include a system for assessing other general aspects of the image, such as blackening, contrast, sharpness, and diagnostic acceptability. The maximum image scores were 61.6 ±13.66 for barium swallow, 53.2 ±28.86 for barium meal and follow-through, and 62.5 ±15.53 for barium enema. The highest ESAK value for barium studies (3 mGy) was recorded at Hospital 3 (S3), while the lowest ESAK value (1.4 mGy) was recorded at Hospital 6 (S6), with a mean average of 2.3 ± i0.85. Sulieman *et al*. (2010) quantified the patients' radiation doses during barium examinations [16].

The mean ESAK value was found to be 2.1 mGy per image for HSG, which is close to the range reported in the literature [17, 18], while the number of images for this study was five per fluoroscopic investigation. However, we also found that in two private hospitals, up to 22 images were recorded in some radiographic exams where HSG investigations were. The image quality criteria scoring system is eligible to facilitate the practice in any diagnostic department with no need for a special instrument or dose assessment. However, the IQS will only benefit a radiology department if the staff is willing to identify and correct the shortcomings in their radiographic technique.

CONCLUSION

The results obtained in this work, demonstrate that the analysis of medical image quality is important for assessing the medical imaging process in a clinical setting. The image quality depends on multiple factors, including personnel training, protocols, and equipment type and output. These factors, together with a lack of worldwide standards, mean that both image quality and dose parameters vary from hospital to hospital. This may increase the risk of irradiation in patients undergoing specific fluoroscopic imaging.

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ETHICS STATEMENT : This study was approved from Hail University and Health sector in Khartoum and written informed consents were gotten from all patients

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