Sudan University of Science and Technology
College of Graduate Studies

Clinical Analysis of Image Quality and Technical Protocols for Special Radiologic Procedures

التحليل الاكلينكي لجودة الصور والاساليب التقنية للفحوصات الاشعاعية الخاصة

A thesis submitted for fulfillment of the requirements
of PhD degree in Diagnostic Radiologic Technology

By

Omer Mohamed Ali Loaz

Supervisor

Dr. Abdelmoneim Adam Mohamed Sulieman

Associate Professor

Co- Supervisor

Dr. Mohamed Mohamed Omer Mohamed Yousef

Associate Professor

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الآيـة

بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

(تَبَارَكَ الَّذِي بِيَدِهِ الْمُلْكُ وَهُوَ عَلَىٰ كُلِّ شَيْءٍ قَدِيرٌ * الَّذِي خَلَقَ الْمَوْتَ وَالْحَيَاةَ لِيَبْلُوَكُمْ أَيُّكُمْ أَحْسَنُ عَمَلًا ۚ وَهُوَ الْعَزِيزُ الْغَفُورُ)

سورة الملك (1−2)

Dedication

I dedicate this work to the soul of my parents

To my wonderful and lovely wife for her patience, encouragement

and continues support

To my children Reem and Mohamed for dreaming proudly

About their father holding a PhD degree

To my brothers and sisters

To my best friends for their

Cheers.

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ABSTRACT

In diagnostic radiology, the images pattern employ an interaction of many factors and the ideal balance is to obtain an image, which is adequate for the clinical purpose with the minimum radiation dose. To guarantee adherence to preference standards of quality, image quality criteria recommended by the Commission of European Communities (CEC, 1996) have been used for good radiography practice and the assessment of images globally. The aim of this study was to address the insufficiencies outlined by exploring the level of image quality variation across a number of hospitals in Sudan for a variety of common specific radiologic examinations to experience the level of matching to CEC guidelines in Sudan hospitals, analyze the image quality of special radiologic procedures and to compare the findings with worldwide standards.

This study was carried out in nine major hospitals radiology department in Khartoum between 2012 and 2015. A subjective evaluation of 1183 Images reproduction out of 363 special radiologic procedures including Intravenous Urography (IVU), Hysterosalpingography (HSG), GIT Barium Studies and Voiding cystourethrography (MCUG). For each procedure, ESAK values were recorded.

The researcher set image quality criteria scoring system for each projection, where two assessors reviewed the films in terms of compliance with the CEC recommendations, they were asked to give a graded response of the quality of the imaged structures mentioned in the criteria.

The patients involved in this study distributed 99 (27.2%) patient for IVU, 47 (12.9%) patients for MCUG, 95 (26.1%) patients for Barium Studies and 122 (33.6%) patients for HSG. The frequent of cases between hospitals were 23 (6.3%) cases for Khartoum hospital, 31 (8.5%) cases for Omdurman hospital, 9 (2.5%) cases for Bahry hospital, 35 (9.6%) cases for Souba hospital, 61 (16.8%) cases for Ribat hospital, 70 (19.3%) cases for Military hospital, 53 (14.6%) cases for Fedail hospital, 56 (15.4%) cases for Royal Care hospital and 25 (6.9%) cases for Sudan Diagnostic Centre (SDC) hospital. The films were distributed as 354 (29.9%) films

(IVU), 347 (29.3%) films (HSG), 239 (20.2%) films GIT Barium Studies and 163 (13.8%) films (MCUG), patients images drawn from the Radiology departments of Two University Hospitals (UH), One Military Hospital (MH), Three Teaching Hospitals (TH), Two Specialist hospitals (SH) and only one Private Clinic (PC). The maximum scores ranged as Fully Acceptable; all anatomical structures found to be 65.9 ±14.90, 53.2±21.37, 61.6±13.66, 53.2±28.86, 62.5±15.53, and 64.9±18.92 for (IVU), (MCUG), (B. Swallow) , (B.Meal+ B. Follow Through), (B. Enema) and (HSG) respectively. Also, The ESAK values recorded in this hospital survey were yielded, 1.91±0.90, 1.9±0.49, 1.4±0.48, 2.3± 0.90 and 2.1±0.60 mGy for IVU), (MCUG), (B. Swallow) , (B.Meal+ B. Follow Through), (B.Enema) and (HSG) respectively.

The set of Image Criteria scoring system have been found valuable and endorsement in daily practice in the hospitals suggested, the radiation dose to the patient can be coupled to the required image quality and to the performance of the radiographic procedure or protocols to be update, need to be used and read-through in a comparable way. The need to provide relevant education and training to staff in the radiology departments is of utmost importance.

ملخص البحث

التشخيص بالاشعة الطبية يعتمد على عوامل متعددة ومتداخلة لتكوين عناصر الصور الشعاعية, مما يتطلب دقة عالية في اختيار هذه العوامل وذلك لكي تحوي معلومات اكلينيكة كافية لتحقيق هدف التشخيص الصحيح وباقل كمية تعرض اشعاعي للمريض, ولضمان مطابقتها للمعايير المطلوبة لجودة الصور التى اوصت بها موجهات الوكالة الاوربية لقياس جودة افلام الاشعة عام 1996 والتي تم تطبيقها في العمل اليومي في اقسام الاشعة بالمستشفيات عالميا. ان هدف هذه الدراسة كان لمعرفة وقياس الاختلاف في مستوى جودة الصور لعدد من مستشفيات السودان ولعدد من الفحوصات الشعاعية الخاصة الملونة ,واختبار مدي مطابقتها لتوصيات موجهات الوكالة الاوربية لقياس جودة افلام الاشعة وتحليل الوضع الراهن لنوعية الافلام المنتجة باقسام الاشعة بالسودان للفحوصات الخاصة ومقارنتها بالمستويات العالمية.

هذه الدراسة اجريت في اكبر تسع مستشفيات يالعاصمة السودانية الخرطوم في القترة مابين 2012 و2015 . وقد تم تحليل وتقييم عدد 1183 صورة ناتجة من 363 فحص خاص شملت فحوصات القناة البولية وفحوصات الاحليل والمثانة بالصبغات وفحوصات القناة الهضمية بالباريوم (المرئي والمعدة والامعاء الدقيقة والغليظة) وفحوصات الجهاز التناسلى (الرحم وانابيب فالوب) للنساء بالصبغات, كما تم تسجيل جرعة التعرض السطحي للجلد لكل فحص. قد وضع الباحث نظاما لحساب قيمة كل معيار لكل وضع على حدة لجودة الصور وذلك بواسطة اثنين من تقني الاشعة ذوي الخبرة الكافية لمراجعة وتقييم الافلام استنادا على توصيات الوكالة الاوربية لتقييم جودة افلام الاشعة, وقد طلب من المحكمين اعطاء درجات لكل فلم علي حسب الخصائص المذكورة لكل معيارللفحوصات المختلقة.وقد كان توزيع المرضي99 (27.2 %) فحص الكلي والمسالك البولي و47 (12.9 %) فحص للاحليل والمثانة و95 (26.1) فحص للقناة الهضمية بالباريوم و 122 (33.6 %) فحص للجهاز التناسلي للنساء. وكان عدد الحالات موزعا23 (6.3%) لمستشفى الخرطوم التعليمي و 31 (8.5%) لمستشفى امدرمان التعليمي و 9 (2.5%) لمستشفى بحري

التعليمي و35 (9.6%) لمستشفى سوبا الجامعي و61 (16.8%) لمستشفى الرباط و (19.3%) 70 لمستشفى السلاح الطبي و53 (14.6%) لمستشفي فضيل و56 (15.4%) لمستشفى رويال كير واخيرا 25 (6.9%) لمركز السودان للتشخيص . وكان مجموع الافلام التي خضعت للتحليل توزعت بواقع 354 (29.9%) و163 (13.8%) و239 (20.2%) و347 (29.3%) لفحوصات الكلي والمسالك البولية و فحص الاحليل والمثانة والقناة الهضمية بالباريوم والعقم للنساء علي الترتيب. واعتمادا علي وضوح الاعضاء التشريحية وظهورها في الفلم فقد وجدت النتائج ان الدرجة القصوى لاعلي جودة تتراوح مابين 14.90± 65.9 و21.37±53.2 و13.66±61.6 و28.86±53.2 و 15.53±62.5 و18.92±64.9 لفحوصات الكلي والمسالك البولية و فحص الاحليل والمثانة و القناة الهضمية بالباريوم (المرئي والمعدة والامعاء الدقيقة والغليظة) وفحص الجهاز التناسلي للنساء علي الترتيب. كما سجلت جرعات التعرض السطحي للجلد في هذا المسح 0.90±1.91و 0.49±1.9 و 0.48±1.4 و 0.90 ±2.3 و0.60±2.1 ملي قري لفحوصات الكلي والمسالك البولية و فحص الاحليل والمثانة و القناة الهضمية بالباريوم (المرئي والمعدة والامعاء الدقيقة والغليظة) وفحص الجهاز التناسلي للنساء علي الترتيب.

ان وضع نظاما لحساب قيمة خصائص جودة الافلام قد وجد ذو فائدة عظيمة لتطبيقه في العمل الروتيني اليومي في اقسام الاشعة بالمستشفيات وكذلك ربطه بقياس قيمة التعرض الاشعاعي السطحي للمريض اثناء الفحص لتحقيق الجودة المطلوبة وقياس اداء طرق التصوير وتحديثها وذلك لقرائتها على وجه المقارنة والمفاضلة. كما برزت الاهمية القصوى والحوجة الماسة لتدريب وتطوير مهارات العاملين في اقسام الاشعة بالمستشفيات.

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LIST OF ABBREVIATIONS

CEC	Commission of European Communities
ROC	Receiver Operating Characteristics
VGA	visual grading analysis
IVU	Intravenous Urography
CT	computed tomography
MRI	Magnetic resonance imaging
PACS	Picture Archiving and Communication System
CR	Computerize Radiography
DR	digital radiography
SFR	Screen Film Radiography
IVP	Intravenous Pyelography
EU	Excretory Urography
KUB	kidney, Ureter and bladder
MCUG	Maturating Cystourethrography
VUR	Vesico-Ureteric Reflux
LAO	Left Anterior Oblique
RAO	Right Anterior Oblique
GI	Gastrointestinal
SBFT	Small-bowel follow-through
HSG	Hysterosalpingography
ACR	American College of Radiology

ALARA	As Low As Reasonably Achievable
QC	Quality Control
MSE	Mean-Squared Error
MTF	Modulation Transfer Function
NPS	Noise Power Spectrum
CNR	Contrast to-Noise Ratio
SQRI	Square-Root Integral
DQE	detective Quantum Efficiency
DRLs	Diagnostic Reference Levels
TPF	True-Positive Fraction
FPF	False-Positive Fraction
IC	Image Criteria
ICS	Image Criteria Score
IAEA	International Atomic Energy Agency
GL	Guidance Levels
AEC	Automatic Exposure Control
ESAK	Entrance Surface Air Kerma
SI	International Scheme
J	Joules
G	Gray
DAP	Dose Area Product
NRPB	National Radiological Protection Board

ICRP	International Commission on Radiological Protection
Rad	Radiation Absorbed Dose
Rem	Roentgen Equivalent Man
Q	Quality Factor
Ci	Curie
Gy	Gray
Sv	Sievert
Bq	Becquerel
TLD	Thermo Luminescent Dosimeter
UNSCEAR	United Nations Scientific Committee on the Effect of Atomic Radiation
Cf	Conversion factors

CHAPTER ONE

Introduction

1. Introduction

The image in diagnostic radiology is a representation of structures of organs and tissues under investigation, a general definition of image quality must address the effectiveness with which the image can be used for its intended task. The image criteria allow an immediate evaluation of the image quality of the respective radiograph, which appropriate for the most frequent requirements of special radiologic imaging investigations (Karl A, 2004; European Commission, 1996).

The justification and optimisation principles in recent European legislation1 and adopted in national legislation 2 have led to much radiation dose measurement research. In particular studies by many authors have demonstrated wide inter- and intra-hospital variations in radiation levels, demonstrating the need for realistic and relevant dose reference levels to be employed within any country. The principles of justification and optimisation, however, involve more than dose monitoring. Adherence to justification insists that: ''All individual medical exposures shall be justified in advance, taking into account the specific objectives of the exposure'' (Council Directive 97/43/, 1997). Optimisation requires that all radiation doses from medical exposures shall: ''be kept as low as reasonably achievable consistent with obtaining the required diagnostic information'' (Council Directive 97/43/, 1997; S.I. No. 478, 2002).

To guarantee adherence to preference standards of quality, image quality criteria recommended by the Commission of European Communities (CEC, 1996) have been used for good radiography practice and the assessment of images globally (Brennan, 2002; Offiah and Hall, 2003; Rainford, 2007). The compliance of diagnostic radiography practice to these image criteria has been suitable in general performance and standardization of dealings in radiographic examination of patients. Using of these criteria has been valuable for the optimization of the imaging process in many clinical settings (Brennan and Johnston, 2002; Rainford et al, 2007).

The determination of the optimum circumstances requires a measure of the radiation dose and image quality. The objective measures of image quality are an absolute descriptor of system performance; however, how they relate to the clinical setting has to be assessed using subjective analysis. (Launders et al).

Radiological images for special investigation necessitate high quality to maximize diagnostic efficacy. Patients should be confident that the image produced is of optimal quality. A set of nearly objective guidelines for good radiographic techniques and the matching level of the image quality have been published by the European Union. The guidelines have proved to be a useful tool to unify the practices in Europe. In efforts to deal with the problem on dose reduction without affecting the patient care, the image criteria allow an immediate evaluation of the image quality of the respective radiograph, which appropriate for the most frequent requirements of special radiologic imaging investigations (CEC, 1996; Karl, 2004; Rainford et al, 2007).

An evaluation of radiologic protocols and image quality includes all those factors or variables that relate to the precision or accuracy with which the structures and tissues being radiographed are reproduced on radiographic film or other image receptors. Some of these factors or variables relate more directly to radiographic positioning, which pursue an argument of the applied aspects of these factors (Statkiewicz Sherer et al, 1998).

The Image quality is significantly defined in the course of the utility of the images in achieving these tasks. The consensus for defining diagnostic image quality is maintained on such a task-based approach. This approach is at variance from subjective assessment by measuring the performance achieved and essentially setting a particular task for the image (Barrett and Myers 2004; Tapiovaara Markku, 2006).

The variable degree of subjectivity to evaluate the image quality depends on which approach has been used. A relative measurement obtained by ranking a set of images in quality order to the strength of agreement between different observers will give an indication of quality when applied clinical studies used in routine practice, may be very useful. To achieve this, simpler techniques are required. Quality criteria for radiological images have been agreed for standard radiological examinations and methods have been developed to compare clinical images with the specific requirements that these criteria demand. Such an approach has already proven to be effective in clinical practice for diagnostic radiology. Scientific societies have implemented guidelines to guarantee an adequate level of quality and performance fluoroscopy (G Bernardi et al, 2001).

The using of visual grading analysis (VGA) of the reproduction of important anatomical structures especially those pointed out in the European quality criteria for evaluating image quality in radiography has become an established method because the validity of such studies can be high since the quality criteria are based on the anatomical background and visual grading studies are relatively easy to conduct, especially in comparison with receiver operating characteristics (ROC) studies, the time consumption is moderate, at least for the observers, which means that it is realistic to believe that these methods can be implemented at almost any hospital (Bath and Månsson, 2007).

Using ROC methodology, are generally accepted as the most reliable way of evaluating the diagnostic value the sensitivity and specificity of medical imaging techniques, the practical difficulties associated with such studies make complementary ways of evaluating image quality indispensable. Visual grading studies are an alternative solution, simple to carry out with clinically available images and not requiring any external ground truth. But in order for these studies to gain general acceptance, the data analysis methods must be appropriate (Smedby and Fredrikson, 2010).

The patient identification, the date of examination, positional markers and the name of the facility must be present and legible on the film. These annotations should not obscure the diagnostically relevant regions of the radiograph. An identification of the radiographers on the film would also be desirable.

An evaluation of radiologic protocols and image quality includes all those factors or variables that relate to the precision or accuracy with which the structures and tissues being radiographed are reproduced on radiographic film or other image receptors. Certain of these factors or variables relate more directly to radiographic positioning, which pursue an argument of the applied aspects of these factors (Statkiewicz· Sherer et al, 1998).

The diagnostic radiology images configuration involve a complex interplay of many factors and the supreme stability is to obtain an image, which is sufficient for the clinical purpose with the minimum radiation dose. Some factors are classified as physical parameters and can be measured objectively in physical test phantoms, but the diagnostic images must still be interpreted by human an observer which does not always mean an ideal observer. This subjective nature of image interpretation makes the objective approach to a full assessment difficult. The ideal method for evaluation of imaging quality and techniques is through clinical trials. Scoring of image quality criteria relating to features observed in a normal clinical radiograph gives a simple method through which image quality can be assessed and related to the radiation dose used. But if optimal performance is to be achieved, it is necessary to understand both the influence of the physical factors in the image formation on dose and image quality and to apply the correct methodology in these analyses of optimization of the imaging process (Karl A, 2004).

Recent studies emphasized that using visual grading of the reproduction of important anatomical structures especially those pointed out in the European quality criteria for evaluating image quality in radiography has become an established method because for a number of reasons. First of all, the validity of such studies can be assumed to be high since the quality criteria are based on clinically relevant structures and the anatomical background is therefore included. Second, visual grading studies are relatively easy to conduct, especially in comparison with receiver operating characteristics (ROC) studies, which is important when optimizing equipment at the local level. Third, visual grading methods have in special cases been shown to agree both with methods based on receiver operating characteristics analysis and with calculations of the physical image quality. This is important, and validates in some way the hypothesis that the possibility to identify pathology correlates to the reproduction of anatomy is the basic idea of visual grading. Inconsistencies between the methods have been reported, but have been explained with the different tasks for the methods rather than low validity for visual grading. Finally, the time consumption is moderate, at least for the observers, which means that it is realistic to believe that these methods can be implemented at almost any hospital (Bath and Månsson, 2007).

In diagnostic radiology the images pattern engages an interaction of many factors and the perfect balance is to obtain an image, which is adequate for the clinical purpose with the minimum radiation dose received by the patient, so that the appropriate options can be selected (CJ Martin et al.2007).

The greatest amount of details and optimal density, display a good quality of radiographic image reasonable contrast and least distortion (Pontual ML et al, 2005).

1.1 Statement of the Problem

Diagnostic requirements for a normal, basic radiograph; indicates decisive factors for the Radiation Dose to the Patient, as far as available, and gives an example for good radiographic technique by which the diagnostic requirements and the dose criteria can be achieved.

Few studies reported regarding the evaluation of the radiographic technique and the diagnostic requirements and the dose criteria, in Sudan and worldwide.

Although, radiography started before one century, there is still a massive need in establishment of quality image measures including criteria that can be employed and checked in a comparable way to the radiation dose of the patient, which can be linked to the needed image quality and to the performance of the procedures protocols.

Image quality criteria suggested by the Commission of European Communities (CEC, 1996) have been used for good radiography practice and the assessment of images worldwide to guarantee adherence to preference standards of quality.

Updated lists of the Quality image Criteria for fluoroscopic examinations as in intravenous Urography (IVU), Bariums Studies, Hysterosalpingography, urinary tract for different projections and, where necessary to applicable these criteria in routine daily work in hospitals.

Understood for these principles of justification and optimisation to be applied, diagnostic images produced in X-ray departments must have high quality, so patients and referring clinicians can be assured that each medical exposure is providing the necessary diagnostic information.

In most hospitals, there is a lack of standardization, which reduces diagnostic efficiency.

Application of radiation protection principles : justification and optimisation is recommended, in order to assure the benefit of the patient (accurate diagnosis) from the imaging procedures outweighing the radiation risk.

1.2 The Objectives of this study are:

1. To address the insufficiencies outlined by exploring the level of image quality variation across a number of hospitals in Sudan for a variety of common specific radiologic examinations.

2. Institution of quality image and protocols measures for special radiologic investigations in Sudan Hospitals.

3. To experience the level of adherence to CEC guidelines in Sudan hospitals, analyze the image quality of special radiologic Procedures and to compare the findings with global standards.

4. To test whether these criteria allow a reasonable measurement of the quality of special radiologic Procedures images. The image criteria allow an immediate evaluation of the image quality of the respective radiograph and to address the problem on dose reduction without affecting the patient care.

5. Design basic criteria that lead to the necessary quality of the diagnostic information with reasonable dose values applied to the patient in these hospitals participated in the survey throughout the three province Khartoum state hospitals.

1.3 Thesis Outline

The thesis is outlined into five chapters as follows: Chapter one general introduction of image quality, criteria scores, and methods for evaluating, subjective evaluation and objectives of the study. Chapter two is devoted to the literature review to the previous local and international studies, radiologic special procedures technical protocols, and focused on dose measurement techniques and review radiation dosimetry techniques and differences between clinical and physical evaluation of image quality. Chapter three Materials and Methods of special examinations are presented in this chapter. Features of the machines used in the study and patients sample and characteristics, image criteria scoring, also describe the dose calculation. Chapter four presents the results, and data collected from the investigation. Chapter five discusses the findings of the study, image quality criteria maximum scores and gives some conclusions about the radiation dose. Brief recommendations for future research are also specified.

1.4 Thesis outcome

The following papers were published and prepared during this study:

1. O. Loaz, M. Yousef, A. Sulieman. Quality Analysis of Hysterosalpingography Images produced in Sudan Hospitals. Sch. J. App. Med. Sci., 2015; 3(3B):1110-1116.(Appendix **D**)

2. O. Loaz, M. Yousef, A. Sulieman. Clinical Evaluation of Image Quality for Intravenous Urography basis on the European commission guidelines on quality criteria in Sudan. Sch. J. App. Med. Sci., 2015; 3(3F):1436-1442.(Appendix **E**)

CHAPTER TWO

Literature Review

2. Literature Review

2.1 Diagnostic Medical Imaging

The various imaging modalities developed over the last five decades include radionuclide imaging, Ultrasonography, computed tomography (CT), magnetic resonance imaging (MRI) and digital radiography. Therefore, diagnostic imaging has grown over the years from a state of infancy to a high level of maturity. It is very clear that medical imaging has become established as having an important role in patient management, and especially radiologic diagnosis. From the standpoint of viewing of clinical images, the major achievement in medical imaging might seem to lie in the production of many different types of images. However, modern medical imaging includes not only image production, but also image processing, image display, image recording and storage, and image transmission, most of which are included in a picture archiving and communication system (PACS). Thus, image production is only one of many aspects of modern imaging science and technology (Kunio Doi, 2006).

The essential properties of biological tissues that are accessible through acquirement and interpretation of images vary spatially and temporally in response to structural and functional changes in the body. Analysis of these variations yields information about static and dynamic processes in the human body. These processes may be changed by disease and disability, and identification of the changes through imaging often permits detection and delineation of the disease or disability. Medical images are pictures of tissue characteristics that influence the way energy is emitted, transmitted, reflected, and so on, by the human body. These characteristics are related to, but not the same as, the actual structure (anatomy), composition (biology and chemistry) and function (physiology and metabolism) of the body. Part of the art of interpreting medical images is to bridge among image characteristics, tissue properties, human anatomy, biology and chemistry, and physiology and metabolism, as well as to determine how all of these parameters are affected by disease and disability (William R, and E. Russell, 2002).

2.2 Radiology Imaging History

In the year of his fiftieth birthday, and the year following his engagement to the leadership of the University of Würzburg, Rector Wilhelm Conrad Roentgen noticed a barium platinocyanide screen fluorescing in his laboratory as he generated cathode rays in a Crookes tube some distance away. Rector Roentgen spent the next six weeks in his laboratory, working alone, and sharing nothing with his colleagues, Three days before Christmas he brought his wife into his laboratory, and they emerged with a radiograph of the bones in her hand and of the ring on her finger. The Würzburg Physico-Medical Society was the first to hear of the new rays that could penetrate the body and photograph its bones. Roentgen delivered the news on the 28th of December 1895 (Alexi Assmus, 1995).

Following the discovered the x-ray. A major development was the application of contrast agents for a better image contrast and organ visualization using special gamma cameras and in 1955 - The first x-ray image intensifier allowed the pick up and display of x-ray movies. During 1960's - The principles of sonar were applied to diagnostic imaging. Ultrasonic waves generated by a quartz crystal were reflected at the interfaces between different tissues, received by the ultrasound machine and turned into pictures using computers and reconstruction software. Challenges include targeted contrast imaging, real time 3D or 4D of ultrasound and molecular imaging, in 1968 - The use of targeted contrast agents began, later in 1970 - The digital imaging techniques were implemented into conventional fluoroscopic image intensifier with the first computed tomography, digital images are electronic snapshots sampled and mapped as a grid of dots and pixels. The multislice spiral CT technology has expanded the clinical applications dramatically and in 1980's- The first MRI device was tested on clinical patients (Medical imaging Education, 2013; Larry R. Brown, 1993).

Many major developments are converging today to raise imaging to a more prominent Medical Imaging Trends role in biological and medical research and in the clinical practice of medicine. These developments are ever-increasing sophistication of the biological questions that can be addressed as knowledge expands and understanding grows about the complexity of the human body and its static and dynamic properties. Accelerating advances in computer technology and information networking that support imaging advances such as three- and four-dimensional representations, superposition of images from different devices, creation of virtual reality environments, and transportation of images to remote sites in real time. Growth of massive amounts of information about patients that can best be compressed and expressed through the use of images and growing importance of images as effective means to convey information in visually-oriented developed cultures. A major challenge confronting medical imaging today is the need to efficiently exploit this convergence of evolutionary developments to accelerate biological and medical imaging toward the realization of its true potential. Images are our principal sensory pathway to knowledge about the natural world. To convey this knowledge to others, rely on verbal communication following accepted rules of human language, of which there are thousands of varieties and dialects. In the distant past, the acts of knowing through images and communicating through languages were separate and distinct processes. Examples of such advances include the printing press, photography, motion pictures, television, video games, computers, and information networking. Each of these technologies has enhanced the shift from using words to communicate information toward a more efficient synthesis of images to provide insights and words to explain and enrich insights. Today this synthesis is evolving at a faster rate than ever before, as evidenced, for example, by the popularity of television news programs and documentaries and the growing use of multimedia approaches to education and training (William R, and E. Russell, 2002).

2.3 Digital Radiography

Medical imaging and patient information are being managed using digital data during acquisition, transmission, storage, display, interpretation, and consultation increasingly. The management of these data during each of these operations may have an impact on the quality of patient care. “CR” and “DR” are the commonly used terms for digital radiography detectors. CR is the short form for computed radiography, and DR is the short form for digital radiography. CR uses a photo stimulable storage phosphor that stores the latent image, which is subsequently read out using a stimulating laser beam. It can be easily adapted to a cassette-based system analogous to that used in screen film (SF) radiography. Historically, the acronym DR has been used to describe a flat-panel digital X-ray imaging system that reads the transmitted X-ray signal immediately after exposure with the detector in place. Generically, the term CR is applied to passive detector systems, while the term DR is applied to active detectors. It is applicable to the practice of digital radiography defines motivations, qualifications of personnel, equipment guidelines, data manipulation and management, and quality control and quality improvement procedures for the use of digital radiography that should result in high-quality radiological patient care(ACR, 2012).

2.4 Radiologic Special Procedures

2.4.1 Intravenous Urography (IVU)

The terms Intravenous Urography (IVU) and intravenous pyelography (IVP) are used as synonyms for excretory Urography (EU). IVU is a radiologic examination of the urinary tract that uses intravenous (IV) iodinated contrast media in combination with plain radiographic and the term intravenous pyelogram (IVP) has often been used in the past for this examination. However, this is not an accurate term for this exam because *pyelo* refers to the renal pelvis of the kidney, and the excretory or intravenous urogram includes a study of the entire urinary tract, which includes the total collecting system (A CR, 2009; Bontrager, 2001).

The indications for an EU examination include, but are not limited to evaluate the presence, or continuing presence, of suspected or known ureteral obstruction, assessment of the integrity of the urinary tract following trauma or therapeutic interventions, or when cross-sectional imaging is inappropriate or unavailable, assessment of the urinary tract for suspected congenital anomaly, when thought to be more appropriate than cross-sectional imaging and assessment of the urinary tract for lesions that may explain hematuria, for infection or abnormalities that may predispose to infection, for possible renal parenchymal mass, or for possible lesions of the urothelium when cross sectional examinations using US, CT or MRI are either unavailable or felt to be inappropriate for the clinical circumstance (A CR, 2009).

2.4.1.1Technique

The standard procedure used for intravenous Urography with optional images outlined as the preliminary kidney, ureter, and bladder (KUB) radiograph is an indispensable part of the sequence. This image should be obtained with appropriate technique (65–75 kVp, high milliamperage, short exposure time) to maximize inherent soft-tissue contrast and optimize visualization of calcium-containing lesions that are potentially of urinary tract origin (Dunnick NR,2001).

The image Coverage of the whole abdomen to include diaphragm to symphysis pubis and lateral properitoneal fat stripe for the acute abdomen and to Visualize of the whole of the urinary tract (kidneys, ureters and bladder -KUB).Visualize sharp reproduction of the bones and the interface between air-filled bowel and surrounding soft tissues with no overlying artifacts, e.g. clothing. In calculus disease, good tissue differentiation is essential to visualize small or low-opacity stones (Whitley et al, 2005).

The patient should null and void immediately prior to undergoing this examination. An assessment of the probable location of calcifications in the abdomen with respect to the urinary tract should be made prior to the injection of contrast material, which can obscure a calcification. Oblique conventional radiographs may be extremely helpful in ascertaining the position and nature of calcifications. This is especially important when a patient has flank pain but no obvious urinary tract calculus is seen on the KUB radiograph .contrast materials currently in use are excreted almost exclusively by glomerular filtration, with subsequent concentration in the postglomerular nephron and progressive opacification of the urinary tract. The urographic imaging sequence is designed to optimize depiction of Emphysematous pyelonephritis in a patient who was referred for Urography for left flank pain. Preliminary radiograph reveals striated gas within the renal parenchyma as well as a large perirenal gas collection that extends into the retroperitoneum surrounding the adrenal gland. Urographic nephrograms are produced primarily by filtered contrast material within the nephron, with optimal visualization of the renal parenchyma 1-3 minutes after bolus injection (Raymond B. Dyer, 2001).

Figure 2.1: IVU 10 minutes (Kenneth L. Bontrager, MA , John P. Lampignano,2014-8th ed)

2.4.1.2 Radiation protection

The ’‘pregnancy rule’‘ should be observed unless it has been decided to ignore it in the case of an emergency and gonad shielding can be used, but not when there is a possibility that important radiological signs may be hidden. By following a well-planned procedure, the necessity to repeat the examination is avoided, thus limiting the radiation dose to the patient (Whitley et al, 2005).

2.5 Macturating cystourethrography (MCUG)

Macturating cystourethrography (MCUG) is considered to be the gold standard method used to identify and grade vesico-ureteric reflux (VUR) and show urethral and bladder abnormalities following administration of contrast media. The studies may be combined**.** These studies include cystography, cystourethrography, voiding cystourethrography, and urethrography (antegrade and retrograde). One or more scout images are obtained before the infusion or injection of contrast for any of these studies. Images are obtained at rest and/or during voiding (A Suleiman, 2007; ACR, 2010).

2.5.1 Patient Preparation

A MCUG requires no special preparation. If the procedure is to be followed by an IVU, then the patient should follow the preparation for an IVU. This procedure should be described to the patient by written simple instructions.

The patient should be brought in to the room and the procedure again explained simply and clearly. If possible, the same sex technologist as patient should perform the catheterization.

Throughout voiding, fluoroscopic images of the urethra taken (in the lateral position for males and supine position for females patients); for neurogenic bladder fluoroscopic images of the renal area and the bladder view taken following voiding (A Suleiman, 2007).

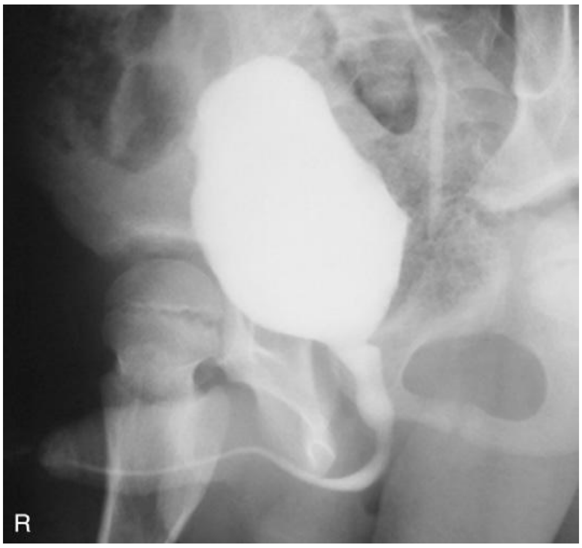

Figure 2.2: MCUG, RPO, Male. (Kenneth L. Bontrager , John P. Lampignano,2014-8th ed)

In infants and children with a neuropathic bladder, micturition may be accomplished by suprapubic pressure. Spot films arc taken during micturition and any reflux recorded. A video recording may be useful. The lower ureter is best seen in the anterior oblique position of that side. Patients should micturate in the LAO position, with right hip and knee flexed, or in the RAO position, with left hip and knee flexed, so that spot films can be taken of the entire urethra. As a final point, a full-length view of the abdomen is taken to demonstrate any reflux of contrast medium that might have occurred unnoticed into the kidneys and to record the post-micturition residue (Stephen et al, 2000).

Indications for cystography include, but are not limited to, evaluation of: Recurrent urinary tract infections, Suspected vesico-ureteric reflux, Bladder morphology, Bladder diverticula, Suspected rupture, Suspected fistulae, Integrity of postoperative anastomoses or suture lines, Bladder outlet obstruction, Incontinence, Hematuria and Neoplasia, Evaluation of post void residual volume (American College of Radiology, 2010).

2.5.2 Materials

Many materials used; Sterile tray with three small bowls, cotton balls, and a clamp, Sterile gauze, Sterile container for collecting a urine specimen for the catheter, 8 French feeding tube, Sterile water, warmed, 2%lidocaine jelly, Antiseptic skin cleanser, warmed, Gloves, Towels and Urine receptacle.

2.5.3 Technique

The patient lies supine on the X-ray table. Using aseptic technique a catheter, lubricated with Hibitane 0.05% in glycerine, is introduced into the bladder. Residual urine is drained. Contrast medium is slowly dripped in and bladder filling is observed by intermittent fluoroscopy, it is important that initial filling is monitored by fluoroscopy in case the catheter is in the distal ureter (thereby mimicking vesico-ureteric reflux) or vagina. The catheter should not be removed until the radiologist is convinced that the patient will micturate or until no more contrast medium will drop into the bladder. The examination is expedited if the catheter remains in situ until micturition commences and then is quickly withdrawn. Small feeding tubes do not obstruct micturition (Morus, 2007).

The bladder is filled slowly by gravity with a dilute contrast material, about 17% weight/volume, to minimize irritation of the bladder wall and possible chemical cystitis. When bladder capacity is approached, gravity filling will slow and then stop automatically. Bladder capacity is determined by the patient's age. When it has been determined that the bladder is full, the patient is asked to voiding before the catheter is removed. This part of the procedure can take time, although running faucets and dripping warm water onto the perineum will usually start the process. Images recorded during fluoroscopy include the following:

Scout radiograph of the kidneys and bladder before contrast is instilled, Right and left oblique views of the bladder when full to show the vesicoureteral regions, Urethra while voiding and Post void radiograph of the bladder and kidneys.

A radiograph is sometimes taken during early filling of the bladder to show or rule out an uretrocele. More radiographs may be taken when an abnormality is discovered. When the procedure is completed, the patient should be told to drink plenty of water or a favorite juice for remainder of the day to minimize post procedural dysuria. The patient should be advised that a burning sensation may occur when urinating and the urine may be pink. This is not unusual, and drinking plenty of fluid will help resolve these problems quickly.

2.6 Radiologic Barium studies

Barium studies, also called contrast studies, include use of a liquid agent that when swallowed provide an image of the inside of the intestine in relation to the wall of the organ and surrounding structures. Barium is a thick, white chalky substance. An upper gastrointestinal series is a barium study evaluating the esophagus, stomach, and first part of the small intestine. The administration of hypertonic water-soluble contrast agents, such as Gastrografin used in upper GI and small-bowel follow-through examinations, causes a shift of fluid into the intestinal lumen, thereby increasing the pressure gradient across the site of obstruction (Costas H, 2012).

2.6.1Barium preparations

Examinations of different parts of the gastrointestinal tract require barium preparations with differing properties. The Barium swallow, e.g. E-Z HD 250% 100 ml (or more, as required),Barium meal, e.g. E-Z HD 250% w/v 135 ml. A high density, low-viscosity barium is required for a double-contrast barium meal to give a good thin coating that is still sufficiently dense to give satisfactory opacification. It is also contains simethicone (an antifoaming and coating agent) and sorbitol (a coating agent), Barium follow-through, e.g. E-Z Paque 60-100% w/v 300 ml (150 ml if performed after a barium meal). This preparation is partially resistant to flocculation and Small bowel enema, e.g. two tubs of E-Z Paque made up to 1500 ml (60%o w/v). N.B As the transit time through the small bowel is relatively short in this investigation; there is a reduced chance of flocculation. This enables the use of barium preparations which are not flocculation resistant. Some advocate the addition of Gastrografin to the mixture as this may help reduce the transit time still further (Chapman and Nakielny, 2001).

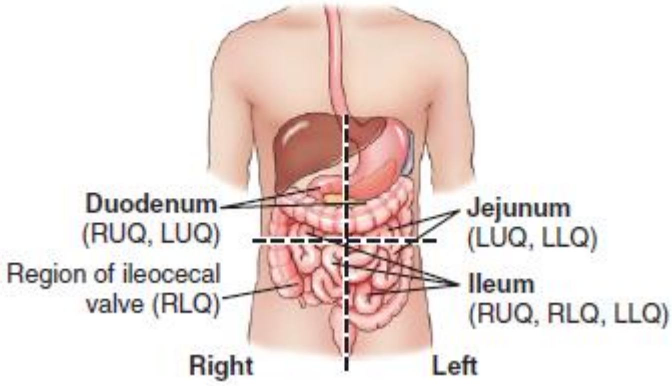

Figure2.3 : Small intestines -four quadrants (Kenneth L. Bontrager , John P. Lampignano,2014-8th ed)

2.6.2 Esophagram (Barium Swallow)

Useful procedures for evaluating the esophagus and the upper gastrointestinal (GI) tract with single-contrast and double-contrast (biphasic) examinations are confirmed. Their goal is to establish the presence or absence, nature, and extent of disease with a diagnostic quality study, using the minimum radiation dose necessary (ACR a. 2008).

Indications of Esophagram can assess symptoms of bloodstained vomit, Dyspepsia, Mechanical pain on swallowing, coughing, choking, a sensation of something stuck in the throat, Chest pain of suspected no cardiac origin Symptomatic or suspected gastro esophageal reflux, Assessment of fistulae and perforation, Pre operative anatomical demonstration and Speech and Language therapy studies and the contraindications Patients who have undergone recent esophageal or gastric surgery or recent trauma are not candidates for double contrast examination (Oldnall, 2013).

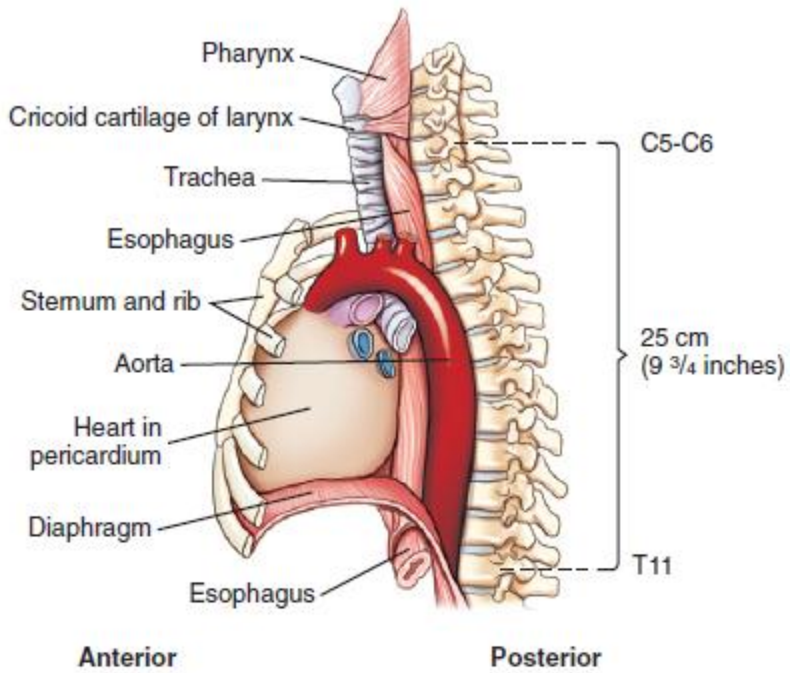

Figure2.4: Demonstrate Esophagus in mediastinum-lateral view. (Kenneth L. Bontrager , John P. Lampignano,2014-8th ed)

2.6.2.1 Technique

For a routine Esophagram the patient should be instructed to refrain from taking anything by mouth for a minimum of 2 hours before the procedure. The radiologic examination should include an evaluation of oral and pharyngeal morphology as well as function. Both types of examinations require postero-antenior as well as lateral views. On the postero-antenior view, the inner margin of the aryepiglottic folds often becomes well coated with barium. On the lateral view the arytenoids may remain vertical and split the barium column, with some barium going into the larynx and the remainder filling the hypopharynx or crossing the UES In such cases, there is severe impairment of vocal cord closure. The esophagus should also be elevated. The optimal filming method for oral and pharyngeal morphology is the spot film, whereas imaging for function requires rapid filming, (Dodds WJ a. et al, 1990; Dodds WJ b. et al, 1990).

The techniques for the timed barium swallow. While standing the patient was asked to ingest a low-density barium sulfate suspension (45% weight in volume) over 30-45 sec. Patients told to drink the amount of barium they could tolerate without regurgitation or aspiration (between 100 and 2(8) ml). With the patient in a slightly left posterior oblique position three-on-one spot films (35 x 35 cm) of the esophagus were taken at I.2 and 5 min after the start of the barium ingestion. If possible spot films were taken when the esophagus was in a relaxed, rather than spastic. State: otherwise. The film exposed when the barium column was continuous and could be captured on the entire film lengthwise. Care should be taken to keep constant the distance of the fluoroscope carriage from the patient on the three spot films. The barium completely cleared the esophagus by the 2-minfilm, the 5-min film not taken. The purpose of the 2-min film is to assess interim emptying. At all times the patient kept in the upright standing position (de Oliveira et al, 1997).

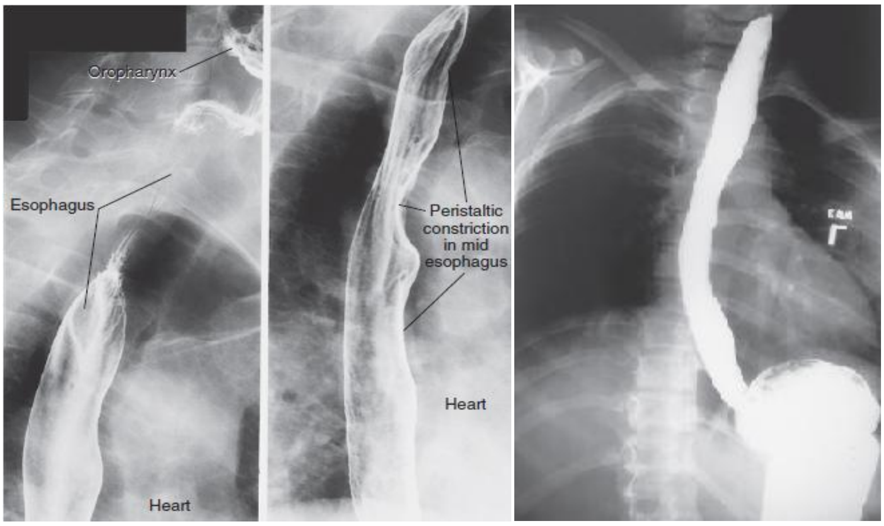

Figure 2.5: RAO esophagogram—upper esophagus. Midesophagus and lower esophagus are just above diaphragm. (Kenneth L. Bontrager , John P. Lampignano,2014-8th ed)

2.6.3 Barium Meal

Barium radiology remains the method of choice for the diagnosis and evaluation of many gastric disorders. Double-contrast radiography is widely used for examination of the upper gastrointestinal tract (stomach). However, it is not practiced routinely in many developing areas, partly because of high cost of the effective agents. In the majority of elderly patients, the technical quality of double contrast barium meal examinations is sufficiently high to offer considerable diagnostic utility (Etaiwi and Shareadeh, 2008).

Indications for barium gastro esophageal include minor abnormalities; reflux hiatus hemia, Gastric erosions, and duodenitis and major abnormalities including malignancy or suspected malignancy and gastric or duodenal ulceration (Etaiwi and Shareadeh, 2008).

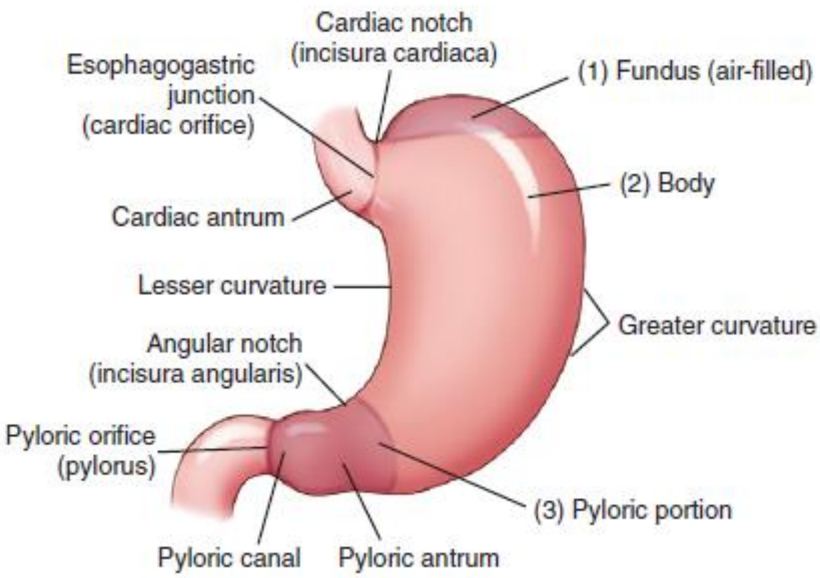

Figure 2.6: Demonstrate Stomach-openings, greater and lesser curvatures, and subdivisions. (Kenneth L. Bontrager , John P. Lampignano,2014-8th ed)

2.6.3.1 Technique

Double contrast is the method of choice to demonstrate mucosal pattern and Single contrast uses for children, since it usually is not necessary to demonstrate mucosal pattern and very ill adults to demonstrate gross pathology only. The double contrast method use to swallow a gas-producing agent. The patient then drinks the barium while lying on the left side, supported by the elbow. This position prevents the barium from reaching the duodenum too quickly and so obscuring the greater curve of the stomach. The patient then lies supine and slightly on the right side, to bring the barium up against the gastro-esophageal junction. This manoeuvre is screened to check for reflux, which may be revealed by asking the patient to cough or to swallow water while in this position. The significance of reflux produced by tipping the patient's head down is arguable, as this is an unphysiological position. If reflux is observed, spot films are taken to record the level to which it ascends. An i.v. injection of a smooth muscle relaxant (Buscopan 20 mg or glucagon 0.3 mg) is given. The administration of Buscopan has been shown not to effect the detection of gastro-esophageal reflux or hiatus hernia. The patient is asked to roll onto the right side and then quickly over in a complete circle, to finish in an RAO position. This roll is performed to coat the gastric mucosa with barium. Good coating has been achieved if the area egastricae in the antrum are plainly visible (Chapman and Nakielny, 2001).

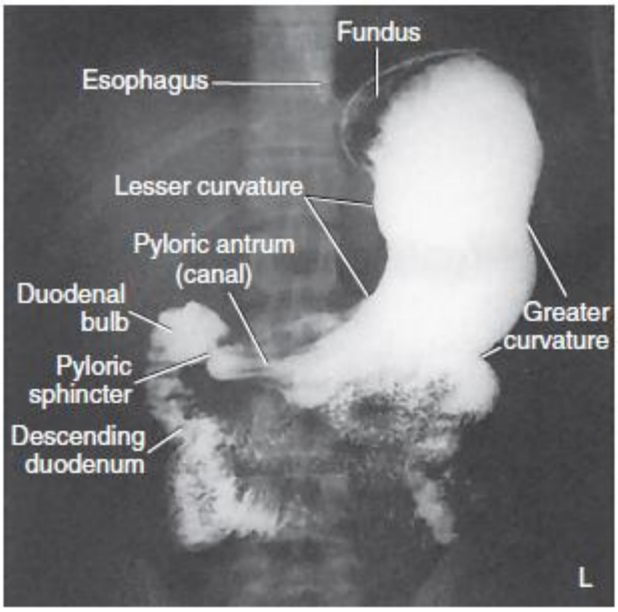

Figure 2.7: Shows Barium-filled stomach and duodenum(Kenneth L. Bontrager , John P. Lampignano,2014-8th ed)

2.6.4 Small-bowel follow-through

Small-bowel follow-through (SBFT) has been the standard radiologic approach used to asses' patients with gut diseases and provided information about intra luminal disease extension and small bowel motility disorders (Markova et al, 2010).

Indications for barium small bowel examination include, but are not limited to: Suspected or known small bowel obstruction, Evaluation for presence of primary or secondary neoplasm, Inflammatory bowel disease, Unexplained gastrointestinal

(GI) bleeding, Malabsorption, The procedure may also be indicated in the follow-up of patients under treatment for known small bowel disease or to evaluate postsurgical anatomy (American College of Radiology, 2008).

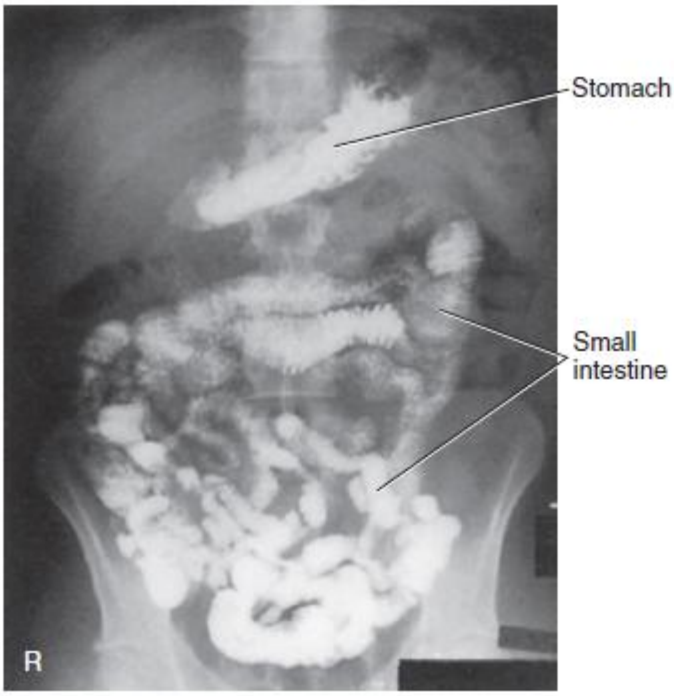

Figure 2.8: Shows Small bowel series-PA. (Kenneth L. Bontrager , John P. Lampignano,2014-8th ed)

2.6.4.1Technique

The aim is to deliver a single column of barium into the small bowel. This is achieved by laying the patient on the right side after the barium has been ingested. Metoclopramide enhances the rate of gastric emptying. If the passage time through the small bowel is found to be slow, a dry meal may help to speed it up. If a follow-through examination is combined with a barium meal, glucagon is used for the duodenal cap views rather than Buscopan because it has a short length of action and does not interfere with the small-bowel transit time.

Prone PA films of the abdomen are taken every 20 min during the first hour, and subsequently every 30 min until the colon is reached. The prone position is used because the pressure on the abdomen helps to separate the loops of small bowel. Spot films of the terminal ileum are taken supine. A compression pad is used to displace any overlying loops of small bowel that are obscuring the terminal ileum.

Additional films may be needed to separate loops of small bowel oblique with X-ray tube angled into the pelvis and with the patient tilted head down. Also, to demonstrate diverticula let patient in erect to demonstrate any fluid levels caused by contrast medium retained within the diverticula (Chapman and Nakielny, 2001).

2.6.5 Barium Enema

The radiographic examination of the colon by single contrast or double-contrast technique is a proven and useful procedure. The purpose of this examination is to establish the presence or absence of disease and its nature by opacifying the lumen and/or the wall of the colon. The goal is to obtain a diagnostic quality study by visualizing the colon in multiple projections (American College of Radiology, 2008).

Figure2.9: Shows Cross-table lateral overhead radiograph obtained with the patient in a right-sidedown decubitus position)(Rubesin et al, Double-Contrast Barium Enema Examination Technique1) Radiology x June 2000 , Volume 215 x Number 3.

2.6.5.1 Technique

The barium suspension must be radiopaque enough so that a thin layer of barium will be visible yet not so opaque that it obscures large elevated lesions in the barium pool. Scout radiographs are obtained in all inpatients. Routine radiography of the abdomen is not necessary before all barium enema examinations. Traditionally, barium instilled into the rectum while the patient lies in the prone position. In patients suspected of having disease involving the anterior wall of the rectum or recto sigmoid junction, the patient should be examined first in the lateral position. Thus, in patients suspected of having rectovaginal fistula, endometriosis, or Intraperitoneal metastases, we start barium instillation with the patient in the left-side-down lateral position.

The enema tube is opened only partly, as rapid distention of the rectum with barium increases the urge to defecate. The patient can be turned in various positions to facilitate passage of the barium through the colon. In general, turning the patient to the left anterior oblique or left side-down position moves barium into the proximal sigmoid colon, descending colon, and splenic flexure. Placing the patient in a slight Trendelenburg position aids passage of barium into the splenic flexure. Once a full column of barium reaches the apex of the splenic flexure, turning the patient to the prone position will move barium into the middle of the transverse colon. During this time, the radiologist uses fluoroscopy only briefly but carefully analyzes colonic contour and looks for filling defects in the barium pool.

If an abnormality is seen while barium is filling the colon, a spot radiograph is obtained. A large enough volume of barium is required to scrub and coat the colon. If about one-third of the luminal diameter of distended colon is filled with barium, as demonstrated on radiographs obtained with the patient in the decubitus position, then enough barium has been instilled to coat the colon. Too little barium results in poor mucosal coating or incomplete filling of the right side of the colon. Too much barium results in large barium pools that may obscure lesions enface. In general, we instill a column of barium into the middle of the transverse colon where it crosses the spine. Once the barium reaches the middle of the transverse colon, the enema bag is gently lowered to the floor and the rectum is drained by gravity. The goal is to empty the rectal ampulla barium, so that when air is insufflated, bubbles will not be created in the barium pool. The goal is not to clear the entire recto sigmoid colon of barium. In patients with a redundant sigmoid colon, the patient may be turned to various oblique positions, including an erect or semi erect position, in greater effort to clear barium from the sigmoid colon. Room air is gently and intermittently insufflated into the colon. Rapid successive squeezes on the insufflations bulb results in discomfort and may incite recto sigmoid spasm. Many radiologists distend the colon with carbon dioxide rather than room air, as carbon dioxide is rapidly reabsorbed from the colon, which results in less discomfort during and after the examination. When we tried various carbon dioxide insufflations systems, however, we did not always achieve adequate colonic distention, especially late in the examination when overhead radiographs were being obtained, as carbon dioxide was absorbed and colonic distention was diminished (Stephen et al, 2000).

2.7 Hysterosalpingography

Hysterosalpingography (HSG) or Uterosalpingography consists of radiographic imaging of the cervical canal, endometrial cavity, fallopian tubes, and peritoneal cavity during injection of contrast media with fluoroscopic visualization since it emergence in 1910, HSG should be done with the minimum radiation exposure necessary to provide sufficient anatomic detail for diagnosis of normal or abnormal findings. An experience-based understanding of the relative merits of other imaging examinations such as sonography, hysterosonography, computed tomography (CT), nuclear medicine, and magnetic resonance imaging (MRI) will result in the selection of the most appropriate test (ACR, 2011; Suleiman et al, 2012).

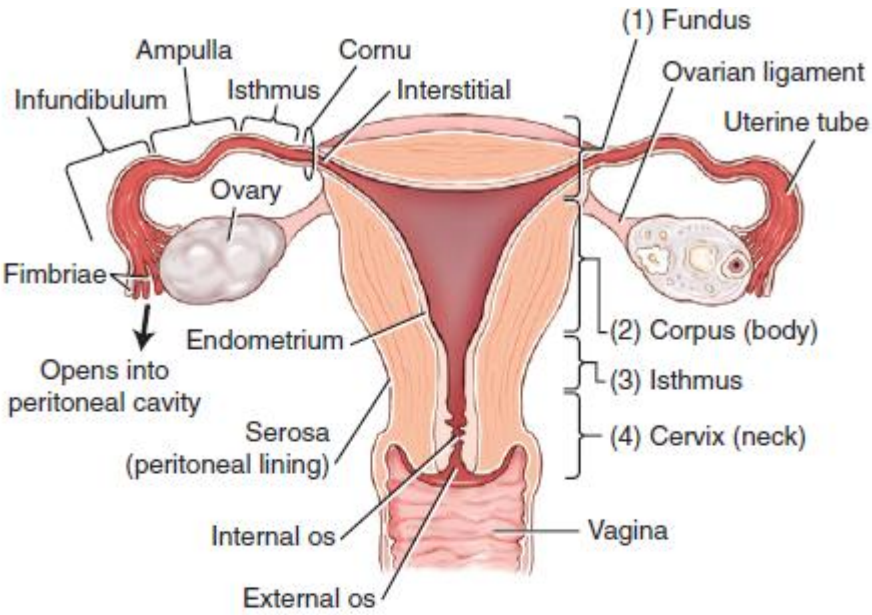

Figure 2.10: Demonstrate Female reproductive organs- frontal view (Kenneth L. Bontrager , John P. Lampignano,2014-8th ed)

Eglė T and his friend found The sensitivity of 81.4% and specificity of 47.8% the likelihood ratio of a positive test result of 1.6 and a negative test result of0.4 for Hysterosalpingography, while evaluating general tubal pathology was determined (Eglė T. et al, 2008), while Soares and his colleges showed that HSG had a sensitivity of 50% and a positive-predictive value of 28.6% for polyploidy lesions, and a sensitivity of 0% for endometrial hyperplasia. The same study showed HSG to have a sensitivity of 44.4% for uterine malformations, and a sensitivity of 75% for the detection of intrauterine adhesions (Soares et al, 2000).

Despite the entrance of newer imaging modalities, HSG is used mainly in the assessment of infertility.HSG still remains the best procedure to image the fallopian tubes. Although evaluating feminine infertility, with or without the presence of repeated miscarriages, is the main indication for this method, it can also be used in other cases, such as pain in the pelvis tract, congenital or anatomic abnormalities, anomalies of the menstrual cycle, and abnormal menses. Also, it is sometimes used as a preoperative control for women who are about to have uterine or tubal surgery (Athanasios C, et al, 2009).

The main contraindication of the examination is possible pregnancy. This is usually avoided by scheduling the examination in the follicular phase of the menstrual cycle, after menstrual flow has ceased but before the patient has ovulated, usually between the 7th to the 10th day of the menstrual cycle. If necessary, a pregnancy test may be performed prior to the procedure. Because of the scattering risk, the examination should be avoided when there is active intrapelvic inflammation (ACR, 2011).Another contraindication is vaginal or uterine bleeding because of the risk of unrestrained bleeding, which could lead to transfusion or surgical recovery procedures

2.7.1.Technique

Hysterosalpingography is carried out within the first ten days after the last menstrual period and when menstrual flow has ceased. The patient is advised to desist from sexual intercourse in the days after her menses and prior to the procedure, to ensure that she is not pregnant during the procedure. Using an aseptic technique and appropriate volume (typically in the range of 10 to 30 ml) of contrast agent administered under intermittent fluoroscopic observation to demonstrate the anatomic structures to be studied. If hydrosalpinx is demonstrated, over distention of the fallopian tube(s) should be avoided, and a 10 minute delayed image after ambulation could be obtained. The contrast should be injected slowly to prevent spasm and discomfort. Oil-based and various water-soluble contrast agents can be used for HSG, a speculum is used to distend the vagina and an 8F Foley catheter is inserted into the uterine cavity. Diluted, water soluble, Hyperosmolar iodinated contrast agent is then hand injected into the uterine cavity via the Foley catheter. A normal Hysterosalpingograms depicts a smooth triangular uterine outline with opacification of both fallopian tubes and free spillage of contrast into the peritoneum. Occasionally, in difficult cases, the Leech-Wilkinson or other uterine catheters may be used (ACR, 2011; Eng.et al.2007).

One plain radiograph of the pelvis is necessary before the contrast medium is administrated into the uterine cavity, so that possible intrapelvic masses or calcifications will not complicate interpretation of the images. A metallic marker is placed over one side of the pelvis to indicate the right or left side of the patient. Next, the examination is performed under fluoroscopic control so that radiographs can be taken during the filling of the uterine cavity (usually 2-3 cm3 of contrast medium is sufficient) and again during the filling of the fallopian tubes. Finally, after the removal of the salpingographer, we radiographically check the presence of contrast medium in the peritoneal cavity.. Additional spot radiographs are obtained to document any abnormality that is seen. Before the first radiograph, we also fluoroscopically check the reflux of the contrast medium (Athanasios C, et al, 2009).

Team work has a responsibility to minimize radiation dose to individual patients, to staff, and to society as a whole, while maintaining the necessary diagnostic image quality. Need to put into practice the conception of (ALARA) "as low as reasonably achievable" (ACR, 2011).

2.8 Quality of image in radiology

In medical imaging, a good image quality is of major importance to assure an accurate diagnosis. Radiographic images should allow the interpreter to evaluate the anatomic details and function relevant for clinical decision-making. The quality imaging depends on the technical performance of the imaging system, as well as patient cooperation and radiologic protocol technique. However, correct radiologic technique (protocol) remains of uppermost importance and its impact on quality can be judged only by evaluating the final images (G Bernardi, 2001).

Assessments of image quality must be made to balance against patient dose. The subjective nature of image interpretation makes an objective approach to such measurement difficult. Methods widely applied involve the use of test objects, which although providing a measure of imaging performance may be difficult to link to clinical image formation. The ideal method for evaluation of imaging techniques is through clinical trials and this should be used to address major questions. Scoring of quality criteria, relating to features observed in a normal clinical radiograph, provides a simple method through which image quality can be assessed in every hospital radiology department (Martin CJ, 1999).

Recent studies in image quality can be divided into two essentially different approaches. The first approach focuses on experimental evaluation. A typical setup would include a small group of human subjects judging quality, and possibly some related attributes such as sharpness, contrast, or colorfulness, of a set of displayed images which are manipulated to reproduce the sound effects of several different design choices (T.J.W.M. Janssen, 1999).

Image quality is usually defined for specific tasks and could be studied physically or subjectively. The aim of quality control (QC) is to define levels of acceptability of radiographs in order to satisfy set clinical targets. This underscores its importance in defining safe radiation dose levels for radiologic procedures. Radiographic practice in most developing countries has received a boost in recent years with conscious attention to the development of quality assurance and control programmes (NO Egbe et al, 2007).

Visual comparison by human observers is one common approach to the assessment of image quality. That is, an observer views a few images and then states whether she or he thinks the images better or worse than those produced. This method is both subjective and irreproducible. Researchers also may focus on quantitative measures such as mean-squared error (MSE), resolution, sensitivity, or signal-to noise ratio. However, there are many different definitions for each of these figures of good point, which hinder comparisons between different imaging systems, modalities and researchers. Another problem associated with these figures of merit is that they are not always related to the performance of observers using the imaging systems on the tasks for which they are intended (Matthew A et al, 2005).

The image criteria in most cases specify important anatomical structures that should be visible on a radiograph to aid accurate diagnosis. Some of these criteria depend fundamentally on correct positioning and cooperation of the patient, whereas others reflect technical performance of the imaging system (Final report of Africa, Asia and Eastern Europe, 2004).

The quality of image is determined by at least five factors: contrast, resolution, noise, artifacts, and distortion. Out of these factors, resolution and noise are the most commonly used physical characteristics. As well known, they are described by the modulation transfer function (MTF) and noise power spectrum (NPS), respectively. The MTF describes the ability of an imaging system to reproduce the frequency information contained in the incident X-ray signal. The NPS describes the frequency content of the noise of an imaging system. However, one of the dilemmas in medical radiography imaging is the extent to which these metrics affect image quality (Du-Yih Tsai et al, 2008).

Klaus Bacher and his colleague in their study titled as evaluation of image quality and patient radiation dose in digital radiology conducted 2006, clarified that contrast is generated by the differential attenuation of x-rays in tissues and the latter radiation (or subject) contrast is transformed by the detector into differences in optical density in the radiograph or differences in brightness on the monitor (image contrast). The capability to convert subtle differences in the patient's tissue into image information is called contrast resolution and is an important characteristic of the imaging system. The final image contrast is affected by the applied x-ray energy spectrum and the contrast resolution capabilities of both detector and display system. In digital imaging technology, contrast is mostly described as the contrast to-noise ratio (CNR). The CNR is defined as the signal intensity differences between two image regions A and B with different attenuation divided by the image noise Ơ

$$CNR = (A\text{-}B)/\,Ơ$$

Spatial resolution refers to the ability of an imaging system to accurately depict small objects in an image. This is frequently described in visually discernible line pairs per mm (lp / mm). In all imaging modalities, a level of noise is present as a random or stochastic component into the image. When an average number of x-rays in a pixel is N, the noise 0- in this pixel will be:

$$\sigma = \sqrt{N} .$$

In addition, the total noise is affected and increased by the system noise. In digital systems, system noise includes electrical noise and quantization noise. Moreover, normal tissue anatomy can act to mask subtle lesions and therefore can reduce the contrast resolution. The latter effect is called anatomic noise. Some authors described the square-root integral (SQRI) as metrics of perceived image quality but Peter G. J. Barten considered in this metric a fixed mathematical expression for the contrast sensitivity of the eye is used. With the SQRI method the effect of various display parameters, such as resolution, contrast, luminance, display size, and viewing distance on subjective image quality can be taken into account. Experimental data of subjective image quality, measured by various authors, are compared with calculated SQRI values. From the comparison it appears that the calculated SQRI values show a good linear correlation with perceived subjective image quality not only at variation of resolution but also at simultaneous variation of other display parameters (Klaus Bacher et al, 2006; Peter G. J. Barten, 2004).

Necessary component to perform a task-based assessment of image quality is the specification of the observer performing the task. Observers can be human, model human, mathematically ideal, or computer observers. The observer is responsible for using the image to produce a decision in a classification task or a set of numbers in an estimation task. The human observers in medical imaging are usually trained professionals such as radiologists, Technologists or Medical physists. The background statistics and proper system modeling in addition to a practical and useful observer model are the cost significance (M. A. Kupinski and E. Clarkson, 2005).

2.9 Clinical and Physical image quality analysis

2.9.1 Objective and subjective

The challenges in producing a Quality Assurance program, which incorporates reproducible measurement techniques and provides a meaningful result in terms of clinical utility, are considerable, Branch of the difficulty in determining or validating image quality from test measurements is that the definition of image quality is not straightforward. Image quality is task dependent: it cannot be defined in isolation, but only in reference to function. An image-processing algorithm which provides sufficient quality for one type of diagnosis may prove inadequate for another. In medical imaging, image quality definition may depend on the observer, or on a range of clinical, physical and technological factors. The optimal use of ionizing radiation in diagnostic radiology involves the interplay of three important basic aspects of the imaging process: diagnostic quality of the image, radiation dose to the patient and choice of examination technique (Jessen K. A., 2002).

The goal of an objective image quality assessment is to develop quantitative metrics that can automatically predict perceived image quality [Wang 02b]. Image quality assessment and comparison metrics play an important role in a broad range of applications. They can be utilized to monitor image quality, they can be employed to benchmark image processing algorithms, and they can be embedded into the rendering algorithms to optimize their performances and parameter settings. It is well known, that classical comparison metrics like Root Mean Square Error (RMSE) are not sufficient when applied to the comparison of images, because they poorly predict the differences between the images as perceived by the human observer. This fact has led to the development of more advanced perceptual quality assessment techniques.

Objective image quality metrics serve primarily to assessment of the difference between two images, an original image and a distorted image. They can be classified according to the availability of an original image, with which the distorted image should be compared. Most existing approaches are known as full-reference, meaning that a complete reference image is assumed to be known. We deal with full-reference metrics. In some applications, however, the reference image is not available, and a no- reference or “blind” quality assessment approach is desirable. In a third type of methods, the reference image is only partially available, in the form of a set of extracted features made available as side information to help evaluate the quality of the distorted image. This is referred to as reduced-reference quality assessment.

A number of methods for investigating the relationship between dose and image quality have been developed. Objective measurements of physical characteristics, such as modulation-transfer function, detective quantum efficiency or contrast-to-noise-ratio, and contrast-detail studies are often used. Alternatively, anthropomorphic phantom studies and clinical studies can be used for subjective (quality rating) and objective (lesion detection) observer performance studies.

The detective Quantum Efficiency (DQE) is a measure of the combined effect of the noise and contrast performance of an imaging system; it is expressed as a function of object detail. Noise can be expressed by the signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR) or by the noise power spectrum (NPS). An imaging system’s ability to render the contrast of an object as a function of object detail is traditionally expressed as its modulation-transfer function (MTF). The combination of the functions NPS and MTF determines the above mentioned DQE. These objectives physical measurements describe the systems technical imaging performance but it is still difficult to translate the outcome to the clinical situation that is far more complex than these measurements can describe (W.J.H. Veldkamp et al, 2009).

Cook et al, 2003 developed their own scoring system for the assessment and optimization of clinical image quality. A C Offiah and C M Hall, 2003 also suggests that modification of the criteria is required when clinical quality is being assessed. However it should be noted that the CEC intend the criteria to be used for the optimization of radiographic technique and reduction of patient dose.

The tendency towards higher inter observer reliability for the image criteria compared with the visual grading analysis technique. Subjectively however the second was felt by both observers to be the easier to apply. Although interpretation between two observers was ambiguous, the CEC criteria were able to detect differences in quality of film–screen and digital images. It is therefore uncertain if visual grading analysis results between departments can be directly compared. For this reason, and for improved inter observer reliability, it is suggested that the image criteria technique is that of choice (A C Offiah and C M Hall, 2003).

The fluoroscopic-captured image technique go along with by the reduced number of images has influence on lowering radiation dose without compromising the capability of findings (Sulieman et al, 2007).

Image quality in radiology is most meaningfully defined through the usefulness of the images in accomplishing these tasks. The consensus for defining diagnostic image quality is maintained on such a task-based approach (Barrett and Myers 2004). This approach differs from subjective assessment by setting a specified task for the image and actually measuring the performance achieved. This controlling of the consequence is not done in a subjective assessment, and often even the task is left unspecified (Tapiovaara Markku, 2006).

The determination of the optimum conditions requires a measure of the risk (radiation dose) and benefit (image quality). When selecting the optimum conditions the dose (mAs), beam quality (kVp) and image processing have all to be assessed. The objective measures of image quality are an absolute descriptor of system performance; however, how they relate to the clinical setting has to be assessed using subjective analysis. The suggestion that the Commission of the

European Communities guidelines is not the "optimum" and more research is required into the whole problem of optimization. In particular, studies of much greater scientific integrity are required before optimum techniques can be recommended to the radiology community (J H Launders et al).

DRLs are used in diagnostic radiology: dose levels in medical radiodiagnostic practices for typical examinations for groups of standard-sized patients or standard phantoms for broadly defined types of equipment, DRL is not a dose limit, but should not be go beyond in ordinary practice and is a good indication of what is so called ‘‘best practice (Sulieman et al, 2007; Marcelo B. Freitas and Elisabeth M.Yoshimura, (2009).

2.10Assessment techniques

2.10.1 Receiver Operating Characteristic (ROC) analysis

The perceptive measure of the quality of the observer might be the number of correct responses. However, such a measure has a serious drawback in that it is strongly dependent on the prevalence of signal (or disease). Conventional ROC analysis fully describes all of the tradeoffs that a particular human or automated decision maker can achieve among the frequencies of true-positive, true negative, false-positive, and false-negative decisions in any particular 2-group classification task, that is, in any situation in which only 2 states of truth are relevant, in which the decision maker must decide to which of the 2 states each test case belongs. Sensitivity is the probability that an observer detects an existing signal and specificity is the probability that a healthy patient is determined as being healthy by the observer are two common measures that fulfill the requirement of independence of the prevalence of signal (Bath M, Månsson LG, 2007; Charles E. Metz, 2006).

The ROC curve is the graphic representation of this mutual relationship between sensitivity and specificity, calculated for all possible threshold values. The vertical axis of the graph shows the sensitivity or TPF. The horizontal axis represents the false-positive fraction (FPF-1-specificity). Each operating point on the ROC curve represents the combination of sensitivity and specificity at a given threshold value. At unrealistically high threshold values, all patients are classified as normal, resulting in a TPF of 0 and a FPF of 0 (specificity_1). This corresponds to the operating point in the lower left-hand corner of the ROC graph. Lowering the threshold will increase both the TPF and FPF (lower specificity). For the lowest possible threshold, the TPF and FPF are both 1 (specificity_0), corresponding to the upper right-hand corner of the ROC graph (Arian R, 1998).

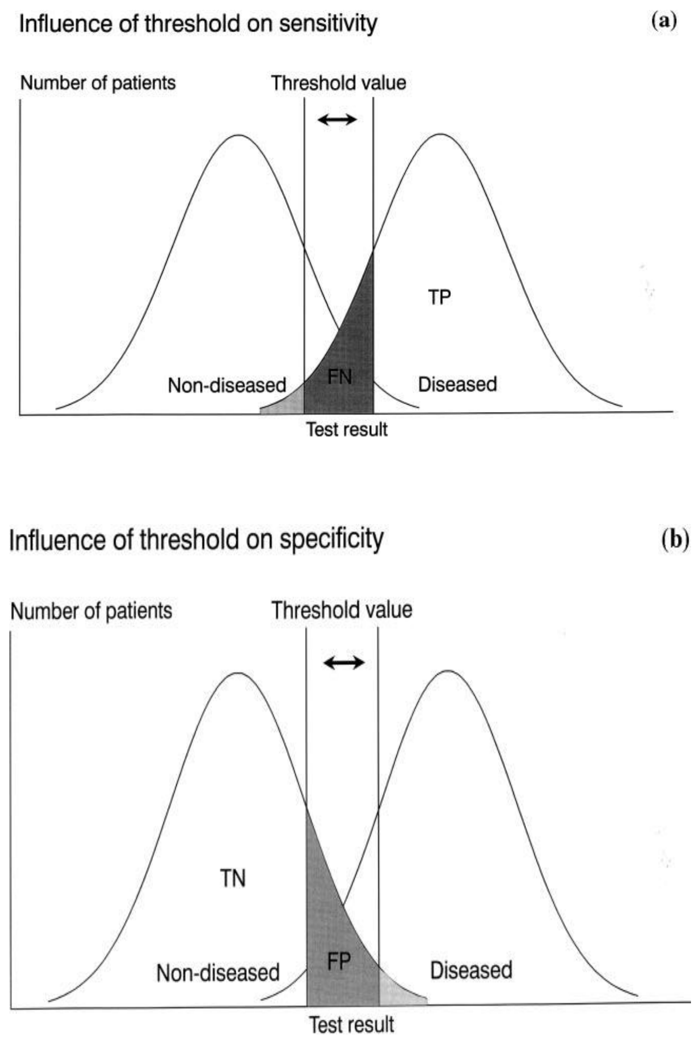

Figure 2.11: (a) Demonstrates the influence of the threshold value on the sensitivity. (b) Shows the influence of the threshold value on the specificity. (Van Erkel and Pattynama, 1998).

2.10.2Visual grading methods

Visual grading methods have been found to agree both with methods based on receiver operating characteristics (ROC) analysis and with calculations of the physical image quality. The possibility to detect pathology correlates to the reproduction of anatomy is the basic idea of visual grading. The time consumption is moderate, at least for the observers, which it is realistic to believe that these methods can be implemented at almost any hospital, which means that a study is easy to justify from an economical perspective for the hospital. Two methods of great relevance are image criteria (IC) and Visual grading analysis (VGA). These criteria are statements of the needed level of reproduction of important anatomical structures. Fulfillment of image criteria (IC) is a simple visual grading method, in which the task of the observer is to state whether a certain criterion is fulfilled or not in the image. An image criteria score (ICS) is then simply calculated as the proportion of fulfilled criteria (Bath M, Månsson LG, 2007).

An alternative of the method, intended to increase the sensitivity to small differences in image quality, involves simultaneous viewing of two images, where the score is meant to express a comparison of the two images, such as 20 for certainly better in image A than in image B, 19 for ‘‘probably better in image A than in image B’’, 0 for ‘‘equivalent’’, +1 for ‘‘probably better in image B than in image A’’ and +2 for ‘‘certainly better in image B than in image A’’. Again, this judgment may refer to a general concept of image quality or to a single well-defined criterion. Visual grading studies are an alternative solution, simple to carry out with clinically available images and not requiring any external ground truth. But in order for these studies to gain general acceptance, the data analysis methods must be appropriate (Smedby and M Fredrikson, 2010).

Visual grading analysis (VGA) is a second approach to let the observer grade the visibility of important structures, for example the structures from the European Commission as established ‘‘quality criteria’’ for different radiological examinations (CEC, 1996). In this way, the observer is given more freedom to state his opinion about the image quality. VGA is either performed in an absolute manner, where the observer states his opinion about the visibility of a certain structure on an absolute scale (typically consisting of four to five scale steps ranging from ‘‘very bad’’ to ‘‘very good’’), or in a relative manner, where the observer compares an image with a reference image and gives a statement of the relative visibility of the structure (typically consisting of five scale steps ranging from ‘‘much worse’’ to ‘‘much better’’) (Månsson LG, 2000).

2.11 Optimization in Medical diagnostic radiology

A diagnostic radiological procedure is justified, if the benefits to the individual patient from the medical diagnostic obtained with the radiological image balance the individual detriment the exposure may cause. Once a medical exposure has been justified, the principle of optimization is applied. For diagnostic medical exposures, this value is interpreted as being the lowest dose possible, which is consistent with the required image quality that is necessary for obtaining the desired diagnostic information (Marcelo B et al, 2009).

Due to image potential benefit to the patient there are no prescribed dose limits, if medical exposure has been justified, but practitioners should apply the principle of optimization to ensure that patient dose is as low as reasonably achievable while obtaining the necessary diagnostic information. Optimization could be achieved by selection of present equipment, technique, well-trained personnel and well-defined diagnostic reference levels (DRLs) consistent with the intended diagnostic purpose (A Sulieman et al, 2007).The formation of images in diagnostic radiology involves a complex interplay of many factors and the ideal balance is to obtain an image, which is adequate for the clinical purpose with the minimum radiation dose. Scoring of image quality criteria relating to features observed in a normal clinical radiograph gives a simple method through which image quality can be assessed and related to the radiation dose used. But if optimal performance is to be achieved, it is necessary to understand both the influence of the physical factors in the image formation on dose and image quality and to apply the correct methodology in these analyses of optimization of the imaging process (K. A. Jessen, 2004).

As the International Atomic Energy Agency (IAEA) mentioned in the International Basic Safety Series (BSS) Number 115 that the optimization of medical exposure should be considered in terms of the image quality and the radiation dose that patient received. The guidance levels (GL) for medical exposure should be established as the intention to be an indication of doses for averaged size patients. In agreement with the recommendations of the ICRP, it is often helpful in the management of operations to establish values of measured quantities above which some specified action or decision should be taken. These values are generally called reference or guidance levels. It should be applied with flexibility to allow higher exposures with clinical judgments and should be revised as technology and technique improve. Poor image quality and using relatively high dose techniques result in unnecessary radiation exposure to patients to initiate an immediate investigation into the reasons and to trigger appropriate corrective action. The retake analysis is the good indicator for the image quality which should be considered closely to the patient dose (S Petcharleeya et al, 2007; Final report of Africa, Asia and Eastern Europe, 2004).

It is accepted that diagnostic exposure is justifiable only when there is a valid clinical indication, no matter how good the imaging performance may be. Every examination must result in a net benefit to the patient. Once a diagnostic examination has been clinically justified, the subsequent imaging process must be optimized to obtain the required diagnostic information for a patient dose. Optimization of fluoroscopic examinations such as the barium meal would be achieved by ensuring in the first instance that the imaging and dose performance of the fluoroscopic system met acceptable standards and then, second, that the examination protocol achieved the diagnostic aims for the minimum use of radiation (Final report of Africa, Asia and Eastern Europe, 2004).

The mainly important factor in the optimization of conventional radiography is the choice of screen / film combination. A definite relationship exists between film optical density and radiation exposure for every screen / film combination, and this can be described by a characteristic curve. While the dynamic range of film is very limited, digital imaging systems have wide dynamic ranges, enabling images with acceptable contrast to be obtained for a broad range of exposure levels. The exposure factors used will be optimized through the experience of the radiographers, and exposure charts employed for each X-ray unit. An automatic exposure control (AEC) device is usually employed in fixed radiographic imaging facilities. This comprises a set of X-ray detectors behind the patient that measure the radiation incident on the cassette (CJ Martin et al, 2007).

2.11.1 Assessment of Image Quality and Radiation Dose

Schaefer-Prokop et al in their recent extensive review of 27 studies that investigated dose requirements and image quality of various digital chest radiography systems indicated that the majority of studies applied only one methodology. They pointed out that there is increasing interest in how well objective measures reflect the subjective grading of image quality and how much small differences in visual grading affect diagnostic performance under clinical conditions. In most of the studies, the ranking of system performance was identical for both methodologies. The relationship between dose and image quality can be assessed quantitatively and qualitatively. Quantitative assessment involves objective physical measurements, such as modulation-transfer function, detective quantum efficiency or contrast-to-noise ratio, and contrast-detail studies. Qualitative assessment mainly refers to the observer performance studies (lesion detection or quality rating). However, studies differ in how much a radiologist's or radio technologist perception and abilities are involved and how well they represent the clinical situation (Zhonghua Sun et al, 2012).

The radiographic technique, including examination parameters such as tube voltage, tube current and filtration has frequently been adopted from screen-film technology. Digital systems, however, are characterized by their flexibility as the dose can be reduced at the expense of image quality and vice versa. Digital techniques increasingly offer options for dose reduction. At the same time there is a risk to accidentally substantially increase patient dose due to the lack of visual control. Therefore, the implementation of dose indicators and dose monitoring is mandatory for digital radiography. The use of image quality classes according to the dose requirements of given clinical indications are a further step towards modern radiation protection. The inverse correlation between radiation dose and image contrast is eliminated with digital systems. Image contrast and brightness can be optimized independently. Therefore, "film blackening" due to higher doses does not exist with digital systems .the imaging parameters need to be individually optimized according to the best performance of a system and The traditional means of dose adjustment, such as positioning and collimation, are as valid for digital techniques as they were for conventional techniques (Uffmann M and Schaefer-Prokop C, 2009).A number of studies has been reported to investigate the possible clinical effects of dose reduction in digital radiography and how low dose reduction can be achieved. A 50% dose reduction was found to be feasible in a variety of simulated chest pathologies without significant loss in diagnostic performance (Kroft LJM et al, 2007).

As in conventional radiography, a straight linear exists between the mAs and the dose. The setting for mAs should be adapted to the characteristics of the scanner unit, the patient's size, and the dose requirements for each type of examination. Appropriate use of mAs also depends on the patient's size, which is an important parameter to consider in dose optimization. In order to avoid unnecessary over exposure, mAs should be internationally adapted by the operator unless automatic exposure control (AEC) devices, or similar, are available (ICRU 1976). General rule; mAs setting may be halved when the patient's trunk diameter – typically 30 cm decreases by 4 cm without loss of image quality.

2.12Radiation Quantities

There are many different physical quantities that can be used to express the amount of radiation delivered to a human body. Generally, there are advantages and applications as well as disadvantages and limitations for each of the quantities. There are two types of radiation quantities: those that express the concentration of radiation at some point, or to a specific tissue or organ, and there are also quantities that express the total radiation delivered to a body. We will be considering each of these quantities in much more detail. The general relationship between the concentration and total radiation quantities are illustrated below.

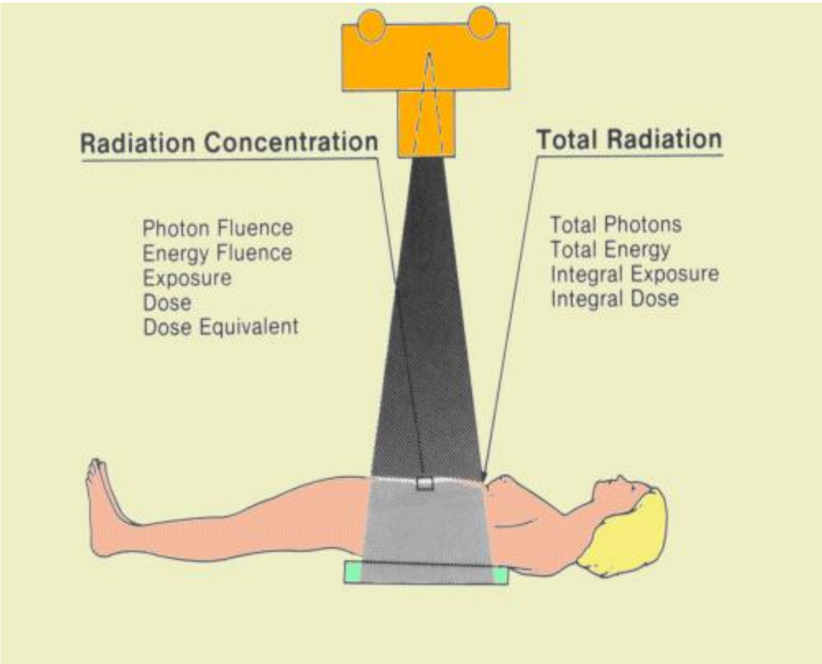

Figure 2.12: Demonstrate Radiation quantities

(http://www.sprawls.org/resources/RADQU/)

2.12.1 Exposure

Exposure is a radiation quantity that expresses the concentration of radiation delivered to a specific point, such as the surface of the human body. There are two units for expressing Exposure. The conventional unit is the roentgen (R) and the SI unit is the coulomb/kg of air (C/kg of air). The unit, the roentgen, is officially defined in terms of the amount of ionization produced in a specific quantity of air.

The ionization process produces an electrical charge that is expressed in the unit of coulombs. So, by measuring the amount of ionization (in coulombs) in a known quantity of air the exposure in roentgens can be determined.

2.12.2 Air Kerma

Air kerma is a radiation quantity that is used to express the radiation concentration delivered to a point, such as the entrance surface of a patient's body. It is a quantity that fits into the SI scheme. The quantity, kerma, originated from the acronym, KERMA, for Kinetic Energy Released per unit mass (of air). It is a measure of the amount of radiation energy, in the unit of joules (J), actually deposited in or absorbed in a unit mass (kg) of air. Therefore, the quantity, kerma, is expressed in the units of J/kg which is also the radiation unit, the gray (G).

2.12.3 Absorbed Dose:

Absorbed Dose is the radiation quantity used to express the concentration of radiation energy actually absorbed in a specific tissue. This is the quantity that is most directly related to biological effects. Dose values can be in the traditional unit of the rad or the SI unit of the gray (Gy). The rad is equivalent to 100 ergs of energy absorbed in a gram of tissue and the gray is one joule of energy absorbed per kilogram of tissue.

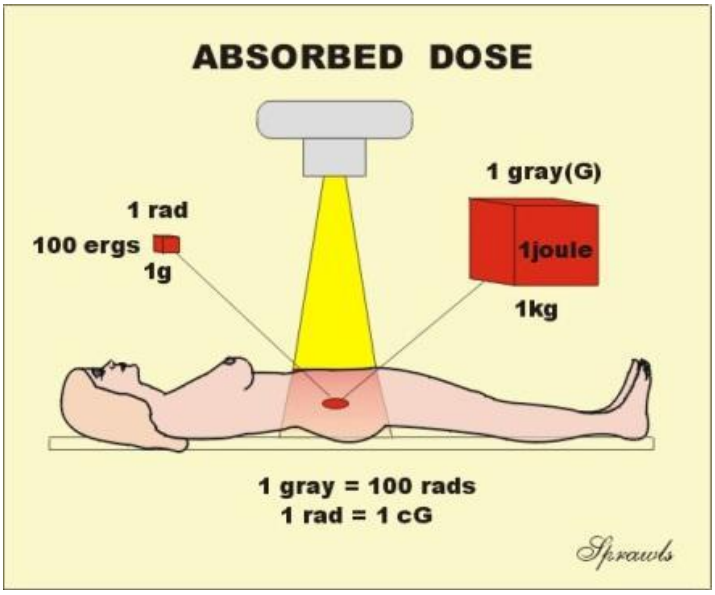

Figure2.13: Demonstrate Absorbed Dose (http://www.sprawls.org/resources/RADQU/)

2.12.4 Entrance Surface Dose (ESD)

Entrance skin exposure is defined as the exposure in roentgens at the skin surface of the patient without the backscatter contribution from the patient. This measurement is popular because entrance skin exposure is easy to measure, but unfortunately the entrance skin exposure is poorly suited for specifying the radiation received by patients undergoing radiographic examination. The entrance skin exposure does not take into account the radio sensitivity of individual organs or tissues, the area of an x-ray beam, or the beam's penetrating power, therefore, entrance skin exposure is poor indicator of the total energy imparted to the patient.

2.12.5 Entrance Surface Air Kerma (ESAK)

The entrance surface air kerma (ESAK) is defined as the kerma in air at the point where the central radiation beam axis enters the hypothetical object, i.e. patient or phantom, in the absence of the specified object (Zoetelief et al, 1996). The entrance surface dose, or alternatively the entrance skin dose (ESD) is defined as the absorbed dose to air on the x-ray beam axis at the point where x-ray beam enters the patient or a phantom, including the contribution of the backscatter (NRPB, 1992). The ESD is to be expressed in mGy. Some confusion exists in the literature with regard to the definition of the ESD. That is, whether the definition should refer to the absorbed dose to the air as defined above or absorbed dose to tissue (NRPB, 1999).

2.12.6 Dose Area Product (DAP)

Dose area product (DAP) is defined as the absorbed dose to air (or the air kerma) averaged over the area of the x-ray beam in a plane perpendicular to the beam axis, multiplied by the area of the beam in the same plane. The Gy cm2 is the preferred unit for DAP (NRPB, 1992). The quantity is also referred as kerma area product.

2.12.7 Equivalent Dose

In radiological protection, it is the absorbed dose averaged over a tissue or organ (rather than at a point) and weighted for the radiation quality that is of interest (ICRP, 1991). The weighting factor for these purposes is called the radiation weighting factor, W_R, and is selected for the type and energy of the radiation incident on the body, emitted by the source.

2.12.8 Effective Dose

The International Commission on Radiological Protection (ICRP), along with other entities concerned with radiation protection, has introduced the concept of dose equivalent in order to discriminate between different types of radiations. The dose equivalent H is defined as the absorbed dose multiplied by a dimensionless factor Q. Q, known as the quality factor, is based on the biological effectiveness of different kinds of radiation, which in turn depends on the linear energy transfer (LET) of that particular radiation. LET is defined by the ICRP as the unrestricted. To account for the differing g radio sensitivities of different tissues the ICRP further introduced the concept of effective dose. A Along with the quality factor Q, the absorbed dose is multiplied by a tissue weighting factor (wT)) specific to the organ of interest. Since the sum of t the ICRPs tissue weighting factors is unity, each individually weighted organ dose can be summed to obtain an effective dose that represent the risk for all stochastic effects to an irradiated individual.

2.13 Radiation Units

2.13.1 Roentgen

The roentgen is a unit used to measure a quantity called exposure. This can only be used to describe an amount of gamma and X-rays, and only in air. One roentgen is equal to depositing in dry air enough energy to cause 2.58 x 10-4 coulombs per Kg. It is a measure of the ionizations of the molecules in a mass of air. The main advantage of this unit is that it is easy to measure directly, but it is limited because it is only for deposition in air, and only for gamma and x rays.

2.13.2 Rad (Radiation Absorbed Dose)

The rad is a unit used to measure a quantity called absorbed dose. This relates to the amount of energy actually absorbed in some material, and is used for any type of radiation and any material. One rad is defined as the absorption of 100 ergs per gram of material. The unit rad can be used for any type of radiation, but it does not describe the biological effects of the different radiations.

2.13.3 Rem (Roentgen Equivalent Man)

The rem is a unit used to derive a quantity called equivalent dose. This relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Equivalent dose is often expressed in terms of thousandths of a rem, or m rem. To determine equivalent dose (rem), you multiply absorbed dose (rad) by a quality factor (Q) that is unique to the type of incident radiation.

2.13.4 Curie (Ci)

The curie is a unit used to measure a radioactivity. One curie is that quantity of a radioactive material that will have 37,000,000,000 transformations in one second. Often radioactivity is expressed in smaller units like: thousandths (mCi), one millionths (uCi) or even billionths (nCi) of a curie. The relationship between Becquerel and curies is: 3.7 x 1010 Bq in one curie.

2.13.5 Gray (Gy)

The gray is a unit used to measure a quantity called absorbed dose. This relates to the amount of energy actually absorbed in some material, and is used for any type of radiation and any material. One gray is equal to one joule of energy deposited in one kg of a material. The unit gray can be used for any type of radiation, but it does not describe the biological effects of the different radiations. Absorbed dose is often expressed in terms of hundredths of a gray, or centi-grays. One gray is equivalent to 100 rads.

2.13.6 Sievert (Sv)

The sievert is a unit used to derive a quantity called equivalent dose. This relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Equivalent dose is often expressed in terms of millionths of a sievert, or micro-sievert. To determine equivalent dose (Sv), you multiply absorbed dose (Gy) by a quality factor (Q) that is unique to the type of incident radiation. One sievert is equivalent to100 rem.

2.13.7 Becquerel (Bq)

The Becquerel is a unit used to measure a radioactivity. One Becquerel is that quantity of a radioactive material that will have 1 transformation in one second. Often radioactivity is expressed in larger units like: thousands (kBq), one millions (MBq) or even billions (GBq) of a Becquerels. As a result of having one Becquerel being equal to one transformation per second, there are 3.7 x 1010 Bq in one curie.

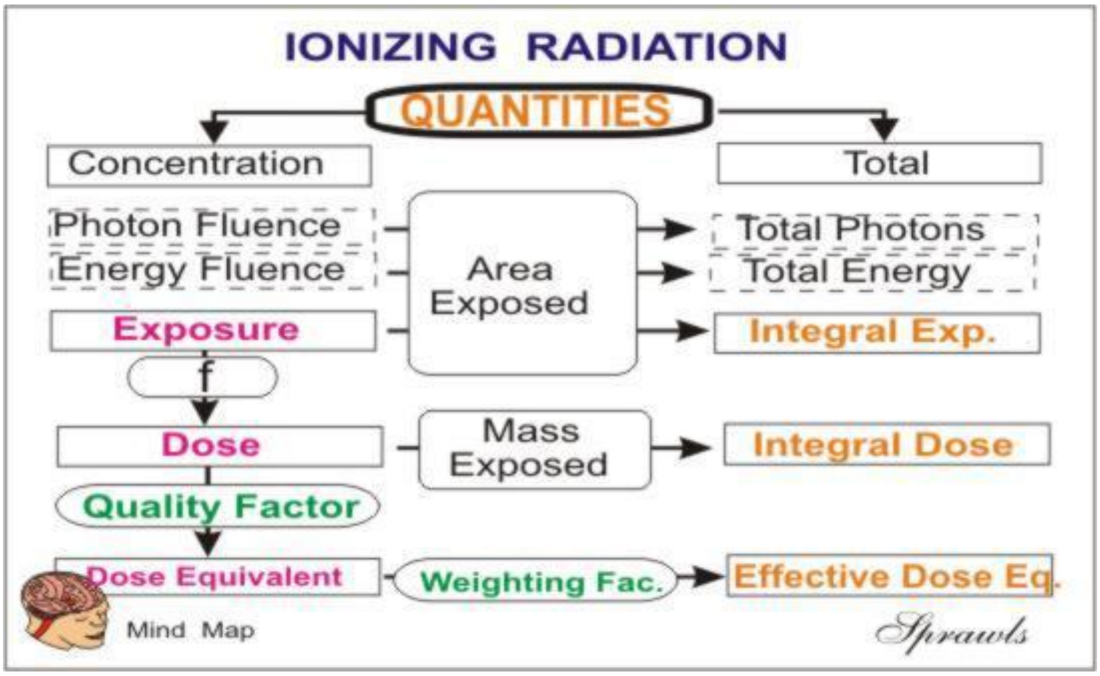

Figure 2.14: Demonstrate Ionizing radiation quantities and Units (www.physics.isu.2011)

2.14Measure for radiation dose to the patient

The dose quantities that can be measured for radiographic exposures are the entrance surface dose (ESD) and the dose-area product (DAP).The ESD is the dose to the skin at the point where an X-ray beam enters the body and includes both the incident air kerma and radiation backscattered from the tissue. It can be measured with small dosimeters placed on the skin, or calculated from radiographic exposure factors coupled with measurements of X-ray tube output. The DAP is the product of the dose in air (air kerma) within the X-ray beam and the beam area, and is therefore a measure of all the radiation that enters a patient. It can be measured using an ionization chamber fitted to the X-ray tube (CJ Martin et al, 2007).

The radiation risks from a range of medical x-ray examinations (radiography, fluoroscopy, and computed tomography) were assessed as a function of the age and sex of the patient using risk models described in Publication 103 (ICRP, 2007) and UNSCEAR (2006, Annex A). Such estimates of risk based on typical organ doses were compared with those derived from effective doses using the International Commission on Radiological Protection's nominal risk coefficients.

A reference dose value for each type of radiograph which is based on the third quartile (75th percentile) value has seen in earlier European patient dose surveys. To initiate an investigations into the reasons for using relatively high dose techniques and trigger appropriate corrective action. The reference dose value can be taken as a maximum from which progress should be pursued to lower dose levels in line with the principle of optimization of protection. Reference values are provided for the entrance surface dose to a standard-sized patient for each type of radiograph considered. The entrance surface dose for standard-sized patient is expressed as the absorbed dose to air (mGy) at the point of intersection of the X ray beam axis with the surface of a standard-sized adult patient (70 kg body-weight or 5 cm compressed breast thickness in case of mammography), backscatter radiation included (Final report of Africa, Asia and Eastern Europe, 2004).

2.14.1Measurement of ESD in Fluoroscopy

ESD is a reliable dose quantity or a descriptor of the deterministic effects of exposures in Fluoroscopy commonly used to give an indication of the typical dose to the patient. In addition, the measurement of ESD permits easy comparison with published diagnostic guidance or reference levels. The use of thermoluminescent dosimeter (TLD) chips placed on the skin of the patient is a simple means of measuring ESD. Estimating patient doses in fluoroscopy is made difficult by the nature of the examination. Any combination of factors such as kVp, mA, beam area, projection, body part irradiated can change at any time throughout the examination. Keeping track of such changes is unrealistic and a more holistic approach is needed. Dose area product is a measure of the energy imparted to the patient, and in turn is related to effective dose. Measurement of dose area product is easily achievable with a transmission ionization chamber attached to the x-ray tube assembly (Final report of Africa, Asia and Eastern Europe, 2004; Vano, E et al, 1998).

Mc Parland has developed a method utilizing DAP for the estimation of ESD (entrance skin dose. It has been shown that this approach to the calculation of ESD from DAP measurements can contribute an uncertainty of up to ±40% to the measurement of ESD16. Therefore the dose at the centre of the beam may be estimated by dividing the DAP by the beam area at the entrance surface to the patient15. This correspondence has been shown to be quite accurate in practice31. Thus the following equation can be used to calculate the ESD from DAP measurements16:

$$ESD = \frac{DAP}{A} \times C.F. \times BSF$$

Where:

BSF is the back-scatter factor appropriate for any given beam kVp, field size, and HVL which is used in practice. DAP is the Dose Area Product recorded in any given instance. A is the beam area recorded in any given instance. C.F. is the calibration factor for the DAP meter estimated using standard procedures.

In radiography, the assessment of air kerma or dose at the entrance surface of the patient is a common approach to patient dosimetry. Entrance surface air kerma (ESAK) is the air kerma on the central X-ray beam axis at the point where the X-ray beam enters the patient or phantom, which includes the effects of backscatter.

ESAK is recommended by the ICRU for dosimetry in medical imaging. The entrance surface dose (ESD) is defined as the absorbed dose to air at the point of intersection of the X-ray beam axis with the entrance surface of the patient, including backscattered radiation. The United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR) 2008 report uses entrance surface dose for patient dosimetry. ESAK and ESD may be measured using thermoluminescent dosimetry (TLD) but measuring ESD with TLDs is not suitable for routine patient dose assessment. Normally, patient dose is assessed by applying suitable Monte Carlo calculated conversion coefficients to a routinely measured quantity such as ESD (N Jabbari et al, 2012).

2.15 Previous studies

Karl Arne Jessen(2004) in his study; Balancing image quality and dose in diagnostic radiology mention that some factors are classified as physical parameters and can be measured objectively in physical test phantoms, but the diagnostic images must still be interpreted by human observers which do not always mean an ideal observer. This subjective nature of image interpretation makes the objective approach to a full assessment difficult. The ideal method for evaluation of imaging techniques is through clinical trials. Scoring of image quality criteria relating to features observed in a normal clinical radiograph gives a simple method through which image quality can be assessed and related to the radiation dose used. But if optimal performance is to be achieved, it is necessary to understand both the influence of the physical factors in the image formation on dose and image quality and to apply the correct methodology in these analyses of optimization of the imaging process.

L.A. Rainford et al (2007) entitled their study CEC analysis of radiological images produced in Europe and Asia; Diagnostic efficacy relies on optimised image quality and in the interest of patients this should not vary across sites for the same investigation. Previous work performed in Sweden reported variations for chest and dental images. The aim of this investigation was to establish if this problem was more widespread and involved several imaging departments (n=20) in four countries and a range of examinations. They recommend the method used to differentiate between technical- and procedural-based criteria, so causal means responsible for image quality variations and corrective action can be more easily identified.

Gustav Ullman, et al (2004), in their published report; Comparison of clinical and physical measures of image quality in chest PA and pelvis AP views at varying tube voltages, they concluded that the significance of a clinical image quality descriptor based on VGA analysis applied to the CEC image criteria (based on structures in the normal anatomy) may be questioned in the light of recent research on the detectability of pathological lesions in clinical chest and lumbar spine images. While VGA analysis and the CEC image criteria will give an overall evaluation of the characteristics of a good image, the detection of pathological lesions depend also on other features in the image such as anatomical noise and anatomical background structures.

Tingberg A, et al (2005), in their study the evaluation of image quality of lumbar spine images: a comparison between FFE and VGA. Mentioned that the free-response forced error experiment FFE is a precise method for evaluation of image quality, but the results are only valid for the type of lesion used in the study, whereas VGA is a more general method for clinical image quality assessment. The results of the FFE study indicate that there might be a potential to lower the dose levels in lumbar spine radiography without losing important diagnostic information.

W. E. Muhogora et al (2001) in their study ; Experiences With The European Guidelines On Quality Criteria for Radiographic Images In Tanzania, concluded that the performance of European guidelines on quality criteria for radiographic images and the usefulness of the criteria in optimization studies of x-ray examinations has been demonstrated. The compliance of majority radiographs ~obtained after implementation of dose reduction measures! To the guidelines is evidence that the radiation protection of patients was sufficiently optimized. The minimization of patient doses implies that the radiation risk associated with the x-ray examinations was also minimized following the reduction in the number of waste film and hence retakes films. Provided that the radiology staffs are familiar with the criteria and local clinical requirements are met, the European guidelines on quality criteria for radiographic images can practically be adopted.

Martin CJ et al (1999), in their research; the Techniques for Measurement of Image Quality in diagnostic radiology concluded that, in order to obtain images which are adequate for the clinical purpose with the minimum radiation dose to the patient, methods are required to evaluate the performance of imaging systems. Measurements using test objects alone describe the behavior of equipment under specific conditions and usually provide a measure of performance of the image receptor under ideal conditions. A full evaluation of image performance can only be obtained from lengthy trials to determine clinical outcomes, but these methods are not suitable for routine use in hospitals. Diagnostic performance criteria referring to visualization of anatomical features in normal individuals are being established for simple assessments of clinical images. Scoring of such quality criteria for radiographic and CT images provides a simple method through which image quality can be assessed in every hospital department to ensure their adequacy for diagnosis. The techniques which are simplest to use rely on subjective assessments and do not provide a true objective measure of performance, but are they sufficient for general hospital use? The way and how much should be doing to assess image quality in hospital departments and the choice of techniques used.

Also, P. Mayo et al (2010) they conducted study entitled Analysis of Image Quality Parameter of Conventional and Dental Radiographic Digital Images. They developed constancy phantoms RACON and RADEN are designed to evaluate different digital technologies of the radiographic equipments, as conventional radiographic for the RACON phantom and dental radiographic equipment for

RADEN phantom. These two phantoms are enough sensible to detect variations in the operating conditions of the equipment because of the designed test objects inside of them. The detection of these tests varies depending on equipment operating conditions of voltage (KVp), current (MA) and time (S). In addition the developed software to detect the test objects automatically for both phantoms let perform an objective analysis of the digital image. In this way, objective parameters as image quality index are useful to determine the quality of the system image chain. In this sense, the software reproduces the human observer detection trends, so it is comparable to validate it. It has been implemented in a graphical menu to be friendly for the user manages to analyze these images. As future works, they want to install this software in PACS System in hospitals to guarantee the constancy of image quality of radiographic equipments in a quickly and professional way.

M. A. Kupinski and E. Clarkson(2005) in their study the Objective Assessment of Image Quality, they argued that, the computational time required to objectively assess image quality is still far greater than the time required by subjective approaches or approaches that use measures not related to a task and an observer. Thus, the acceptance of these approaches in many areas of medical imaging has been slow. However, as these techniques become more advanced and more efficient, their use in medical imaging will increase. Clearly, task-based approaches to assessing image quality will play a vital role in future system developments and in properly understanding the strengths and limitations of various systems and algorithms.

Tapiovaara Markku (2006) in his review reports the Relationships between Physical Measurements and User Evaluation of Image Quality in Medical Radiology. A generally accepted principle is that image quality is most meaningfully defined and measured in relationship with the intended task of the image. Therefore, the best way of evaluating the quality of medical imaging should be to measure clinical performance by quantitative methods, such as the

ROC analysis. This is not usually a practical option, however: if clinical images are used, one must generally be content with subjective, opinion-based evaluations instead of a truly quantitative measurement. Subjective evaluation suffers from inter-observer, intra-observer and case-sample variability, which restrict its use to reliably finding only large image quality differences. The precision can be improved significantly if the evaluation is done in a relative way, by comparing images side-by-side. Anyway, the significance to actual clinical performance remains often unclear.

Sulieman et al, 2011 quantified the patients‟ radiation doses during Barium studies investigations (barium swallow, barium meal and barium enema) are the basic routine radiological examination. A total of 33 investigations of barium studies were measured by using Thermo luminescence dosimeters. The result showed that the patient entrance surface doses were 12.6±10, 44.5±49 and 35.7±50 µGy for barium swallow, barium meal, follow through and enema, respectively.

Brodhead DA et al (1995), was study Barium exams performed on 10 digital and four non-digital fluoroscopic systems were monitored with dose-area product meters. The mean size corrected dose-area product for a barium meal examination was found to be 7.62 Gycm2 for a digital set compared with 15.45 Gycm2 for a non-digital set with 2462 and 1308 patients included in each measurement series, respectively. Dose-area products were also a factor of approximately two lower for barium enema, barium swallow and barium follow-through examinations performed on digital systems. The findings emphasize the importance of regular patient dose measurement to ensure that patient doses are kept as low as reasonable achievable.

(Sulieman et al, 2008) estimated the radiation dose to patients and staff during Hysterosalpingography. Thirty-seven patients with infertility were examined using two digital X-ray machines. Thermo luminescence dosimeters (TLD) were used to measure entrance surface dose (ESD) for patients during the procedure. The mean ESD of the patient were 3.60. HSG with fluoroscopic technique demonstrate improved dose characteristics, compared to the conventional radiographic-based technique, reducing the surface dose by a factor of 3, without compromising the diagnostic findings.

Fotakis et al (2003) examined the pediatric patients up to 5 years of age undergoing Micturating Cystourethrography. Entrance surface doses (ESD) were measured with thermoluminescent dosimeters for 30 children. The average ESD values per view varied from 0.34 mGy up to 0.57 mGy. In order to calculate the organ and effective doses, Monte Carlo MCNP-4A radiation transport simulation code was used. It was applied to three mathematical phantoms representing newborn, 1 and 5 year old children and all the patients were classified in those three groups. The effective dose conversion factors (C(f)) were calculated as the ratio of effective dose over the entrance dose. The mean effective dose per view for male and female patients was found to be E=0.16 mSv. The effective dose per examination for male patients was E=0.86+/-0.31 mSv and E=0.76+/-0.28 mSv for female patients.

Sulieman A et al 2007 Evaluated by means of thermo luminescence dosimetry (TLD) the entrance surface dose (ESD) to the newborn and pediatric populations undergoing MCUG using fluoroscopic imaging. MCUG with digital equipment and fluoroscopy-captured image technique can reduce the radiation dose by approximately 50%, while still obtaining the necessary diagnostic information.

Badreldin M.A Elhag et al (2012) in their recent study estimated the pediatric radiation doses in intravenous Urography. They measured the entrance surface dose (ESD) and Effective Dose (ED) and estimated the radiation risks for pediatric patients undergoing IVU procedures. A survey of radiation doses to 21 pediatric patients during intravenous procedures was carried out in this study. Entrance surface doses (ESDs) Effective doses (E) were calculated using published conversion factors and methods recommended by the national Radiological Protection Board (NRPB).The mean and the range of age of the patients were 6.0±4.40 (6 to 13.8) years. The mean patient dose in this study was 4.9 mGy±2.1

in a range of 2.4 to 10.4 mGy. The mean number of films was 12.8±3.8. They concluded that the measured ESD in their study was higher than the previous reported studies in the literature. This can be attributed to the use of low kV, short SSD, small filtration and low speed films. An optimization technique is required in the light of the current practice in order to reduce the unnecessary exposure.

CHAPTER THREE

Materials and Methods

3. Materials and Methods

3.1 Study Area and Duration

This observational descriptive study was carried out in nine major hospitals in Sudan capital Khartoum. Ten x-ray units were included in the work. Radiographic Images were taken between 2012and 2015 in the respective hospitals.

3.2Sample size

A subjective evaluation of 1183 Images of special radiologic investigation including Intravenous Urography (IVU), Hysterosalpingography (HSG), GIT Barium Studies and Voiding cystourethrography (MCUG). The cases distributed as (63 case for TH, 96 for UN, 109 for SH, 70 for MH and 25 for PC) and the radiographs were spread as (170 for TH, 345 for UN, 333 for SH, 240 for MH and 95 for PC).

The current study focused on different techniques that affect image quality and radiation dose with relation to imaging protocols implemented in Khartoum state hospitals; Teaching Hospitals (TH) (Khartoum, Bahri and Omdurman), Military Hospitals(MH), University Hospital (UH) (Soba, Alribat), Private Hospitals (PH) (Sudan Diagnostic Centre) and Specialist Hospitals (SH) (Fedail Hospital and Royal Care) radiology departments. It was included: Direct Digital Radiography (DR), Computed Radiography (CR) and Screen Film Radiography (SFR). Emphasis placed on special radiologic procedures as well as other characteristics such as patient clinical information, age, and weight and body mass index.

3.3 Study population

A total of 363 special radiologic procedures were investigated. 26.2% (95 patients) of the sample were barium procedures, 12.9% (47 patients) had undergone MCU procedures, while 27.3% (99 patients) of the sample were IVU procedures and 33.6% (122 patients) of the sample were HSG procedures. For each procedure, mean values of patient's age (year) and weight (kg), tube potential (kVp) and exposure setting (mAs).

The data gathered were presented in tables and figure when appropriate. The mean and range was used to evaluate statistically the results. In the radiological procedure, the radiation dose is multifactorial; the range was used to represent the data distribution. The means were calculated using the excel software & SPSS program. For dose calculation, patient individual exposure parameters were recorded (tube voltage (kV), tube current and exposure time product (mAs) and Focus to skin distance (FSD). Patient demographic data (age, height, weight, BMI) were estimated per department and presented in table (3.2). Patients "ESAK" were measured in all radiology department.

Table 3.1: Shows Exam frequency and percentage.

Exam	Account	Percent
IVU	99	27.3
MCUG	47	12.9
B.swallow	40	11
B.meal	14	3.9
B.F. Through	15	4.1
B.enema	26	7.2
HSG	122	33.6
Total	363	100

Table 3.2: Shows Number of exams, number of radiographic and the Mean values for patient demographics (age, height, BMI and weight).

Exam	N	Patient age (ys)	Height (cm)	Weight (kg)	BMI (kg m^{-2})
IVU	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	34(27–41)	165.0 (156-174)	66.5 (51-82)	24.4 (21.0-27.1)

Table 3.3: Shows Images frequency and percentage

Exam	IVU	MCUG	Barium Studies	HSG	Total
No. Image	354	163	319	347	1183
Percent	29.9%	13.8%	27.0%	29.3%	100%

3.4Radiographic equipment and imaging protocol

All the procedures were performed at nine radiology departments equipped with different X-ray machines as illustrated in Table3.4.

Figure 3.1: Demonstrate imaging system in starting position (https://rpop.iaea.Org/health professionals/ 1-fluoroscopy.htm)

Table 3.4: Shows an X- ray machines technical data

Hospital	Machine Type	Filtration (mm Al)	Maximum (kVp)	Processing Type	Type
Omdurman	Shimadzu1/2P13DK installed 2006	1	150	AP	SFR
Khartoum	Toshiba installed 2004	2	150	LC	CR
Bahry	Shimadzu1/2P13DK installed 2008	1.5	150	AP	SFR
Ribat	Siemens installed 2005	3.5	125	LC	CR
Souba	Toshiba KXO-15E installed 2002	2	130	AP	SFR
Milltry	Toshiba KOX-30 installed 2010	2	125	LC	CR
Fedail	Shimadzu installed 2010	2	125	LC	CR
Royal Care	Toshiba installed 2010	2	125	LC	CR
SDC	Siemens installed 2001	2	150	AP	SFR

AP= Automatic Processor, LC= Laser Camera, SFR= Screen Film Radiography and CR= Computerize Radiography.

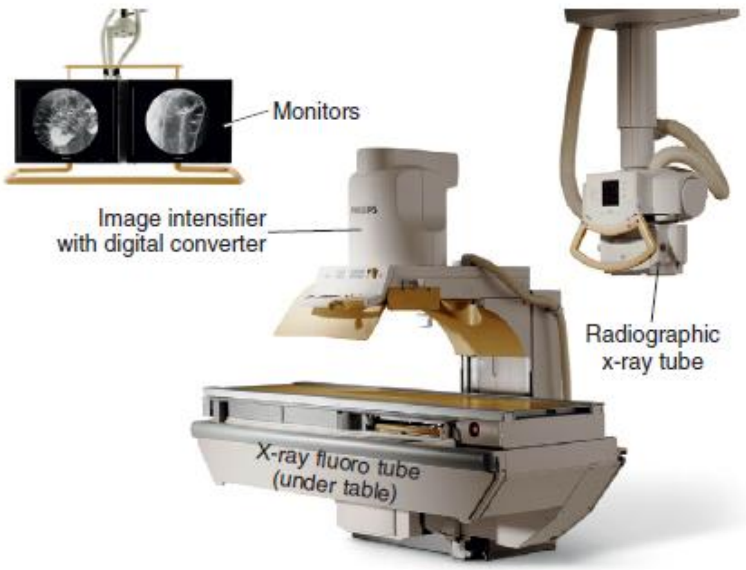

Figure 3.2: Demonstrate the Combination digital system. (Courtesy Philips Medical Systems.)

Radiographic and fluoroscopic images were taken at specific time intervals according to the examination protocol to capture the contrast as it travels through the different system of the organ of interest. This gives a comprehensive view of patient's anatomy and some information on the functioning of the system. Usually, ascout image is taken before the contrast medium is administered.

3.5 Image quality analysis

3.5.1Clinical criteria

It had been defined as level of visualisation of important anatomical features; the levels of visualisation were expressed using the following description of terms for Anatomical structures criteria:

- **Visualization**; distinguishing features are detectable (features just able to be seen).
- **Reproduction**; information of anatomical structures is able to be seen (details emerging).
- **Visually sharp reproduction**; anatomical details are clearly defined (details clear).

Table3.5: Shows the basis criteria employed during the assessment of the quality of radiographic images.

Image criteria	*Degree of visibility*	*Score*
Visualization of characteristic features	-Feature detected and fully reproduced	**1**
	-Feature just observable	**2**
	-Feature not observable	**3**
Reproduction of anatomical structures.	-Detail detectable and clearly defined	**1**
	-Feature just detectable	**2**
	-Detail not observable	**3**
Visually sharp reproduction	- Details clearly defined	**1**
	-Details just clear	**2**
	-Details not clear	**3**

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

3.5.2Procedural and Technical Image Criteria

All images in the study were considered acceptable by a radiologist. Any radiographic images containing extensive pathology or demonstrating surgical fixators that obscured criteria used for image assessment were not included. The anatomical criteria employed in the evaluation of image quality were derived from the CEC recommendations and the authors were divided into technical quality criteria (TQC) which mainly focused on anatomy that was affected by technical agents such as exposure factors, filtration etc, and procedural quality criteria (PQC) that were mainly affected by the radiographers' technique such as patient positioning. All criteria (Tables 3.6, 3.7, 3.8 and 3.9) were ratified by a panel of experienced clinicians.

According to the European guidelines, the image criteria refer to characteristic features of imagined anatomic structures of each radiograph with a specific degree of visibility. The observers evaluated the image quality of all radiographs of each x-ray projection according to the basis indicated against all anatomical structures.

The study was divided into parts, the first relating the revise and evaluation of some radiographic parameters or protocols defined as Patient Identification: Correct positioning and printing of identification was assessed, Collimation of the X-ray beam to the area of interest, The anatomical marker position, correct positioning without interference with diagnostic information, Optical density of the film, contrast and sharpness. This was studied with assessment by experienced radiographers. The same film viewing boxes, which had been previously tested for uniform light output, as well as controlled conditions of glare and ambient light levels, were used for assessment of all films and use correct positioning of gonad shield.

Radiographs were scored 'sufficient in quality' or 3 if they satisfied all the six criteria listed, as well as being free of the characteristics listed under 'poor quality'. A score of 'not adequate' or 2 was given to films with three or more, but less than the six listed criteria, while 'Poor/None' or a score of 1, was given for films with less than three listed criteria, as well as evidence of any, or all of artifacts, wrong use of grids, motion blur, poor film screen contact, fog, and geometric faults. These affect the overall image quality and therefore the decision making process. It was the opinion of the assessors that films in this latter category would normally have been rejected if there was a QA Programme in place. The films were studied by experienced radiographers working independently.

For the assessment of image quality, the observers evaluated the image quality of all radiographs of each x-ray film. Images were judged depending on the routine practice of each radiology department. According to the European guidelines, the image criteria refer to characteristic features of x-rayed anatomic structures of each radiograph with a specific degree of visibility. Images were evaluated using a subjective analysis which enclosed all the specified technical quality criteria and provided a good exhibition of the procedural quality criteria. The hard-copy image was displayed on a light box meeting the CEC guidelines for maximum luminance (2000-4000 cd/m2) and uniformity (<30%).

3.5.3Assessors Panel

In this study all images were evaluated independently by a minimum of two expert Radiographers, The evaluators had an average of 10 years working experience. For images displayed using soft-copy images, the evaluators were allowed to apply manipulation tools if required to at all extent needed to display the suitable criteria.

For all images, each member of the evaluation group was asked to score each criterion applicable to that image from 0 (Poor), 1 (probably acceptable), 2 (Fully acceptable).To minimize the intra-observer variation, observers were asked to re-evaluate the same randomly selected image, using the same evaluating conditions.

3.5.4Image criteria scores

Image quality assessment was as follows. Using the image quality criteria in Table 3.6, 3.7, 3.8 and3.9, assessors reviewed the films in terms of compliance with the CEC recommendations, they were asked to give agraded response of the quality of the imaged structures mentioned in the criteria. Image criteria are to be referred to sequences of films, AP projection taken before or at intervals after contrast administration, modified to patients individually, therefore every criterion counted up one by one coded 1 as yes if films fulfilling the criterion set before and zero if not.

3.5.5 Image quality Criteria for each investigation

For the assessment of image quality, criteria adhering to the guidelines recommended by the European Commission (EC) 1996), were adopted for this study. These were:

3.5.5.1Intravenous Urography (IVU)

Image criteria are to be referred to sequences of radiographs, taken at intervals after contrast administration, modified to patients individually.

Table 3.6: Shows an IVU Images criteria and code

No.	Criteria	Code
1	Production of the area of the whole urinary tract from the upper pole of the kidney to the base of the bladder.	**C1a**
2	Reproduction of the kidney outlines.	**C2a**
3	Visualisation of the renal pelvis and calyces (pyelographic effect) and the pelvi-ureteric junction.	**C3a**
4	Visualization of the area normally traversed by the ureters and whole bladder area.	**C4a**
	• Weakly visualised and not diagnostic.	Yes/No
	• Weakly visualised but diagnostic.	Yes/ No
	• Good demonstration and diagnostic.	Yes/No
	• Outstanding visualisation.	Yes/ No

3.5.5.2 Voiding cystourethrography (MCUG)

Image criteria are to be referred to sequences of radiographs, taken at intervals after contrast administration, modified to patients individually.

Table 3.7: Shows the MCUG Image criteria and code

No.	Criteria	Code
1	Production of the area of the whole urinary bladder area to the base of the urethra.	**C1b**
2	Reproduction of the urethra.	**C2b**
3	Visualisation of the vesico-ureteric junction.	**C3b**
4	Visualization of the area normally traversed by the ureters and whole bladder area.	**C4b**
	• Weakly visualised and not diagnostic.	Yes/No
	• Weakly visualised but diagnostic.	Yes /No
	• Good demonstration and diagnostic.	Yes/No
	• Outstanding visualisation.	Yes/No

3.5.5.3GIT Barium Studies

Image criteria are to be referred to series of radiographs, taken at intervals after contrast administration, modified to patients individually.

Table 3.8: Shows the Barium Studies Images criteria and code

No.	Criteria	Code
1	Reproduction of the bowel pattern should be demonstrated with minimal unsharpness.	C1c
2	Coverage of the whole abdomen to include the esophagus and diaphragm up to symphysis pubis.	C2c
3	Visually sharp reproduction of the bones and the interface between air-filled bowel and surrounding soft tissues with no overlying artifacts, e.g. clothing..	C3c
4	In good tissue differentiation is essential to visualize esophagus, small bowel, large bowel and stomach or GIT accessories organs.	C4c
	• Weakly visualised and not diagnostic.	Yes/No
	• Weakly visualised but diagnostic.	Yes/No
	• Good demonstration and diagnostic.	Yes/No
	• Outstanding visualisation.	Yes/No

3.5.5.4Hysterosalpingography (HSG)

Image criteria are to be referred to sequences of radiographs, taken at intervals after contrast administration, modified to patients individually.

Table 3.9: Shows the HSG Image criteria and code

No.	Criteria	Code
1	Production of the Uterus opacification or uterine outline.	**C1d**
2	Reproduction of the Fallopian Tube.	**C2d**
3	Visualisation of Fimbrial rugae.	**C3d**
4	Visualisation of Intraperitoneal spillage.	**C4d**
	• Weakly visualised and not diagnostic.	Yes / No
	• Weakly visualised but diagnostic.	Yes / No
	• Good demonstration and diagnostic.	Yes/ No
	• Outstanding visualisation.	Yes/ No

Observers scored the films from 1 to 4, with each criterion scoring 0 or 1. Thus, a film with all four criteria scored 4, and those with three, two and one criteria present scored 3, 2 and 1, respectively. The data from the assessors were pooled and treated with the method of analysis of means, to reduce the effects of subjectivity in the results.

3.5.6 Techniques

3.5.6.1 Intravenous Urography IVU

The standard procedure used for intravenous Urography with optional images outlined as the preliminary kidney, ureter, and bladder (KUB) radiograph is an essential part of the series. This image should be obtained with appropriate technique (Optimal kVp, high milliamperage, short exposure time) to maximize inherent soft-tissue contrast and optimize visualization of lesions that are potentially of urinary tract origin (Dunnick, 2001).

An injection of x-ray contrast medium is given to a patient via a needle or cannula into the vein, typically in the arm. The contrast is excreted or removed from the bloodstream via the kidneys, and the contrast media becomes visible on x-rays almost immediately after injection. X-rays are taken at specific time intervals to capture the contrast as it travels through the different parts of the urinary system.
The image coverage of the whole abdomen to include diaphragm to symphysis pubis to visualize the whole of the urinary tract (kidneys, ureters and bladder - KUB).Visualize sharp reproduction of the bones and the interface between air-filled bowel and surrounding soft tissues with no overlying artifacts (Whitley et al., 2005). On the day of the IVU, give no solid foods until after the test is finished.

3.5.6.1 .1 Films of (IVU)

Plain film (control film) was taken firstly to evaluate the patient preparation, centering, exposure factors and radio opaque calculi before injection of contrast media. A water soluble contrast media was injected through a cannula based on patient weight, after five minutes take a film and then two films should taken after fifteen and twenty five minutes following contrast media injection. Prone and delayed films may require according to the patients conditions. A contrast media used in all patients was non ionic water soluble iodine based (Omnipaque).

3.5.6.2 Micturating Cystourethrography (MCUG)

A standard protocol for MCUG was established in order to ensure consistency of performance efficiency and applicable of radiation protection principles. Ultrasound was usually performed to the urinary system before the investigation. 200 ml of contrast medium (50 ml of ionized contrast medium diluted in 150 ml of normal saline solution (0.9%)) was administered via a urethral catheter using gravity drip. Catheterization was performed under strict aseptic conditions: the skin was carefully cleaned with antiseptic solution (Bethadine) and then a propitiated size Fello Catheter inserted in the urethra with the help of a sterile anesthetic gel (Xylocine gel 2%). After urine egression the catheter was advanced a few centimeters more and secured to the skin surface with tape. The catheter taped in the left inner thigh of the patient in order to avoid its projection over the male urethra in the lateral views. Intermittent fluoroscopy performed with automatically or manual selected kV and mAs exposure parameters to detect VUR or other abnormality. Radiographic images were taken in cases of presence of reflux or of difficulty in evaluating a finding such as air-filled intestinal loops obscuring the area of interest. One fluoroscopic image obtained before the administration of contrast to ensure the correct position of the catheter (scout view). After contrast administration, the examination has two phases: filling of the bladder and voiding. Fluoroscopic images were taken during early filling of the bladder (valuable in case of ureteroceles and Grade 1 reflux that can be obscured by a fully filled bladder) and with full bladder. During voiding, fluoroscopic images of the urethra taken (in the lateral position for males and supine position for females patients); fluoroscopic images of the renal area and the bladder view taken following voiding (for neurogenic bladder). Occasionally right or left oblique views performed. Since VUR is an intermittent phenomenon, filling and voiding of the bladder is repeated at least three times.

3.5.6.3Barium Studies

Barium studies are investigations of gastro-intestinal tracts by using barium sulphate to diagnose the pathology using a fluoroscopic machine. The use of these procedures also have been accompanied by public health of concerns resulting from the increasing radiation exposure to both patient and health care personnel ,however there is no diagnostic reference level worked with it.

3.5.6.3.1Patient Preparation

Patients were prepared according to the age and type of examination; nothing by mouth except water on the morning of the examination, Water Enema in the morning of the examination.

3.5.6.3.2Examination Technique

3.5.6.3.2.1Barium Swallow

Useful procedures for evaluating the esophagus and the upper gastrointestinal (GI) tract with single-contrast and double-contrast examinations are confirmed. Their goal is to establish the presence or absence, nature, and extent of disease with a diagnostic quality study, using the minimum radiation dose necessary (ACR a. 2008). The barium sulphate is taken into the mouth it is initially held in the front of the mouth and patient asked to swallow gradually and films are taken (Sutton, 2001).

3.5.6.3.2.2 Barium Meal and Follow-Through

The patient should be starved, preferably overnight, so that the small bowel and caecum are empty. Some investigators give a mild oral contact laxative the day before to aid this. A lower density barium suspension used for the stomach is needed taken orally and a prone over couch film taken at 10 and 30 min. However, modern digital fluoroscopic units allow over couch films to be dispensed with altogether, so that the examination is completely radiologist based. Once contrast has reached the caecum, and allowing this to perfuse the small bowel (Sutton, 2001).

3.5.6.3.2.3Barium Enema:

Remains the routine radiological technique for colonic examination, It represent the gold-standard technique for imaging fine mucosal detail and is also pre-eminent for best demonstration of general colonic configuration and caliber in general, the equipment available will determine the radiographic technique used. Traditionally the barium suspension was introduced to mid-transverse colon level using gravity a series of over couch films were then taken to image the entire colon in double contrast. A typical sequence would include prone straight and angled films, right and left 35° supine oblique, right and left lateral decubitus films, a left lateral rectal film and an erect 35 x 35 film to image the flexures. However, now that digital fluoroscopic equipment is widely available, many investigators prefer to image the colon using spot digital radiograph, progressively filming as the colon is filled (Sutton, 2001)

3.5.6.4Hysterosalpingography (HSG)

At the beginning of the procedure the patient placed in the lithotomy position at the end of the X-ray couch in sterile towels. A vaginal speculum inserted into the vagina, the vaginal walls and cervix are cleaned with antiseptic solution. A canula inserted into cervical canal, which attached with syringe fill with contrast medium (CM). A scout image was obtained prior to the administration of the contrast solution to ensure the correct position of the cannula and patient preparation. Subsequently, images acquired after each phase of contrast medium injection until the diagnosis was obtained or Intraperitoneal spill was documented, after the injection of the CM, a minimum four films were obtained during conventional radiography by using 10x12 inch films with vertical center rays 5cm superior to symphysis pubis which include the flowing : AP plain radiograph, 2. AP film with CM to show the uterus, AP film with CM to show the uterine tubes, AP film with CM to show spill of CM in the peritoneal cavity. Oblique images were acquired only if indicated. Radiographic images were taken in cases of difficulty in evaluating a finding. The technologists were performing the investigations as their daily practice. Demographic data: (age, height and weight and body mass index (BMI (kg/m2) and exposure factors: (kVp and tube current-time product (mAs) obtained for all patients.

3.6 Absorbed Dose calculations

Firstly, ESD dose was calculated from x-ray tube output parameters. To calculate the ESD the following x-ray tube exposure parameters were recorded for patients who underwent the specified diagnostic procedure: peak tube voltage (kVp), exposure current-time product (mAs), the focus-to-film distance (FFD), patient sex and patient gender. The exposure to the skin of the patient during standard radiographic examination or fluoroscopy can be measured directly or estimated by a Calculation of the Entrance Air Surface Kerma ESAK completed for the patients who underwent the IVU, MCUG Bariums Studies and HSG depending on the following formula (ICRU. 2005; Gyekye POKE, 2012).

$$ESAK = op_{\times} \{\frac{Kv}{80}\}^{2}{}_{\times}mAs_{\times} \{\frac{100}{FSD}\}^{2} BSF.$$

Where:

(OP) is the output in mGy/ (mAs) measured at a distance of 100 cm from the tube focus along the beam axis at 80 kVp, (kV) the peak tube potential recorded for any given examination, (mAs) the product of the tube current (in mA) and the exposure time(ins), **(FSD)** the focus-to-skin distance (in cm). **(BSF)** the backscatter factor, the normalization at 80 kV and 10 mAs was used as the potentials across the X-ray tube and the tube current are highly stabilized at this point. BSF is calculated automatically by the Dose Cal software after all input data are entered manually in the software. The tube output, the patient anthropometrical data and the radiographic parameters (kVp, mA s, FSD and filtration) are initially inserted in the software.

3.6.1RAD-CHECK ™ puls X-ray exposure meter

Proven Rad-Check technology specifically designed to provide with the ultimate in adaptability and cost-effective operation. Fast and easy to use! Battery operation and built-in detector eliminate setup time. Measures dose up to 2 R; dose rate up to 20 R/min. Energy response is ± 5% from 30 to 150 kVp for the RAD-CHECK PLUS internal chamber. Extremely compact...6" x 6 1 /4" x 2 3 /4" high; weighs only 18 oz. RAD-CHECK PLUS can perform: Entrance skin exposure measurements (ESE), Fluoroscopy exposure measurements, Exposure checks, radiographic (mR/mAs). Beam quality; Half Value Layer (HVL), mAs reciprocity; mA Station Checks... Plus and many others, depending on the remote external chambers used.

3.6.2 Specifications of Rad-Check

Ranges: 0.001 to 2 R, 0.01 to 20R/min Internal Chamber: 30 cc volume, energy response ±5% from 15-65 keV (30-150 kVp filtered). 20.5 cm^2 (5.1 cm diameter) effective measurement area. Center of Chamber 1.03 cm below top of chamber

Standard Calibration: At 75 kVp with 4 mm Al filtration at 22° C and one atmosphere Reproducibility: Within 2% short-term over 100 mR to 2 R range (1 mGy to 20 mGy) Electrometer Drift: 0.5 to 1 mR/minute typical; 6 mR/minute max (5 μGy to 10 μGy; 60 μGy/minute max).

CHAPTER FOUR

Results

4.Results

Image quality criteria (IQC) were resultant from where scoring was required regarding the degree of visibility of anatomic structures have been irradiated. 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 aim of this study was to test whether these criteria allow a measurement of the quality of special radiologic investigation images and to evaluate the dose related to Intravenous Urography (IVU), Micturating cystourethrography (MCUG), barium studies and Hysterosalpingography (HSG). The maximum quality scores were was assumed to be an indicator of the method's reproducibility.

The results attained from this study presents an uncomplicated and easy method for clinical evaluating radiographic images via less parameters in terms of image quality criteria (IQC) involves Technical Quality Criteria (TQC) and Procedural Quality Criteria (PQC).

a subjective opinion on image quality were obtained in this Hospitals survey, which was defined as fully acceptable (minimal or no defects), probably acceptable (major defects with sufficient clinical information), Poor (major defects, insufficient clinical information) for the Radiographic exams under evolution; IVU, MCUG, Barium Studies (B. Swallow , B.Meal. , B. Follow Through and B. Enema) and HSG.

The results were tabulated in the Tables (mean ± standard deviation (SD)) and the range of the readings in parenthesis. The dose values in diagnostic radiology are small, therefore the dose were presented in milli-Gray. The mean and the standard deviation were calculated using the excel software & SPSS program. For dose calculation, patient individual exposure parameters were recorded (tube voltage (kV), tube current and exposure time product (mAs) and Focus to skin distance (FSD). Patient demographic data (age, height, weight, BMI) were presented per department. Patients" ESAKs were measured in all radiology departments for the special radiologic exams. The results are presented per department, per procedures and per gender for all type of imaging technique and modality according to the examination type. The results were presented in tables and figure when appropriate. In the radiological procedure, the Image quality and radiation dose are multifactorial; the percentage was used to represent the data distribution.

The patient images included in this analysis were 499 (44.1%) for males distributed 192 (59.3%), 124 (81.0%), 65 (48.1%) , 25 (65.8%), 34(59.6%) , 59(76.6%) for IVU, MCUG, B. Swallow , B.Meal. B. Follow Through, B. Enema and HSG, also females accounted 632 (55.9%) were distributed 132 (40.7%), 29 (19.0%), 70 (51.9%), 13 (34.2%), 23 (40.4%), 18 (23.4%), 347 (100.0%) respectively.

Table4.1: shows distribution of sex between investigations

Sex	IVU	MCUG	B. Swallow	B.Meal	B. Follow Through	B.enema	HSG	Total
Male	192	124	65	25	34	59	0	499
	59.3%	81.0%	48.1%	65.8%	59.6%	76.6%	.0%	44.1 %
Female	132	29	70	13	23	18	347	632
	40.7%	19.0%	51.9%	34.2%	40.4%	23.4%	100.0 %	55.9 %

The radiographic investigation involved in this study counted 99 (27.2) patient for IVU, 47 (12.9) patients for MCUG, 95 (26.1) patients for Barium Studies and 122 (33.6) patients for HSG (Figure 4.1).

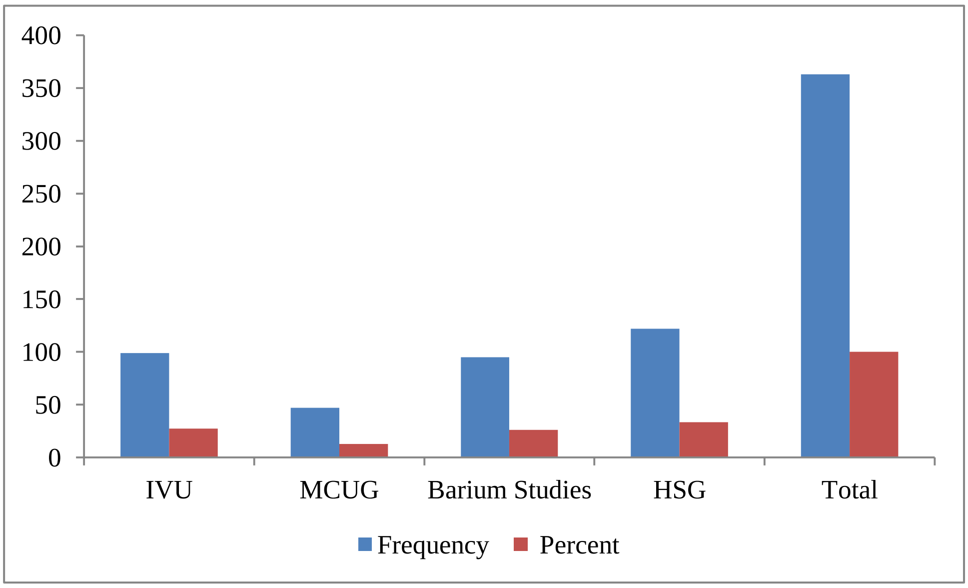

Figure 4.1: Demonstrate exams distribution among Hospitals.

Figure 4.2 demonstrated the total of 363 cases included in this survey distributed among hospitals were 23 (6.3%) cases for Khartoum hospital, 31 (8.5%) cases for Omdurman hospital, 9 (2.5%) cases for Bahry hospital, 35 (9.6%) cases for Souba hospital, 61 (16.8%) cases for Ribat hospital, 70 (19.3%) cases for Military hospital, 53 (14.6%) cases for Fedail hospital, 56 (15.4%) cases for Royal Care hospital and 25 (6.9%) cases for Sudan Diagnostic Centre (SDC) hospital.

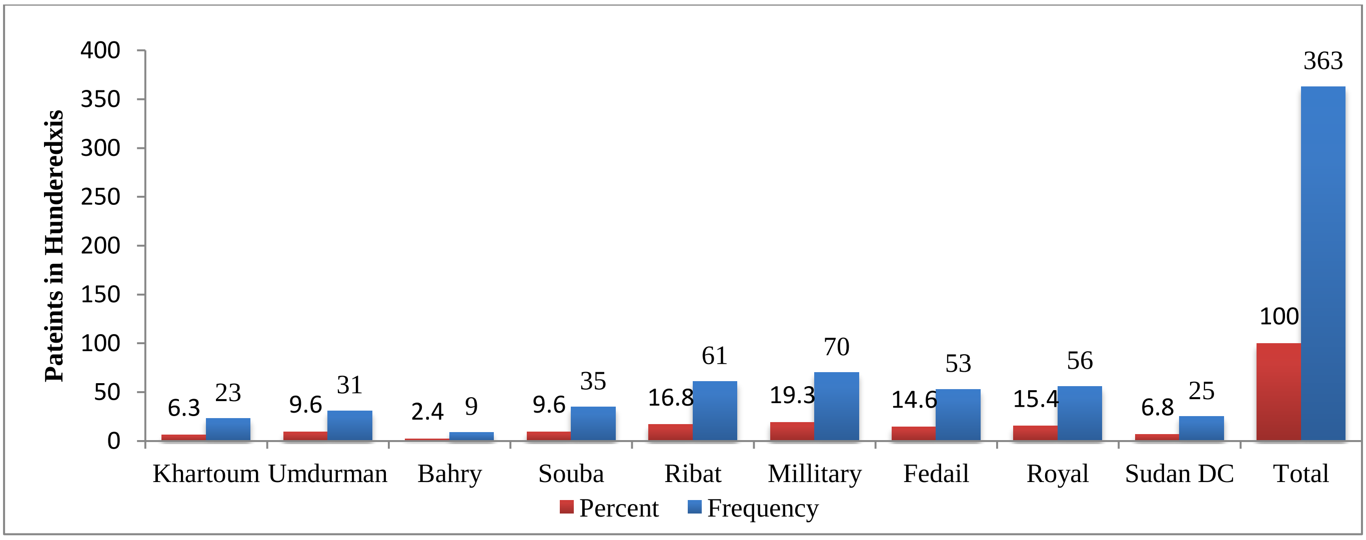

Figure 4.2: Shows Patients distribution among Hospitals.

Figure 4.3 shows the study inclusion 1183 Images of special radiologic investigations distributed as 354 (29.9%) images (IVU), 347 (29.3%) cases (HSG), 239 (20.2%) cases GIT Barium Studies and 163 (13.8%) cases (MCUG), patients images drawn from the Radiology departments of Two University Hospitals (UH), One Military Hospital (MH), Three Teaching Hospital (TH), Two Specialist hospital (SH) and only one Private Clinic (PC).

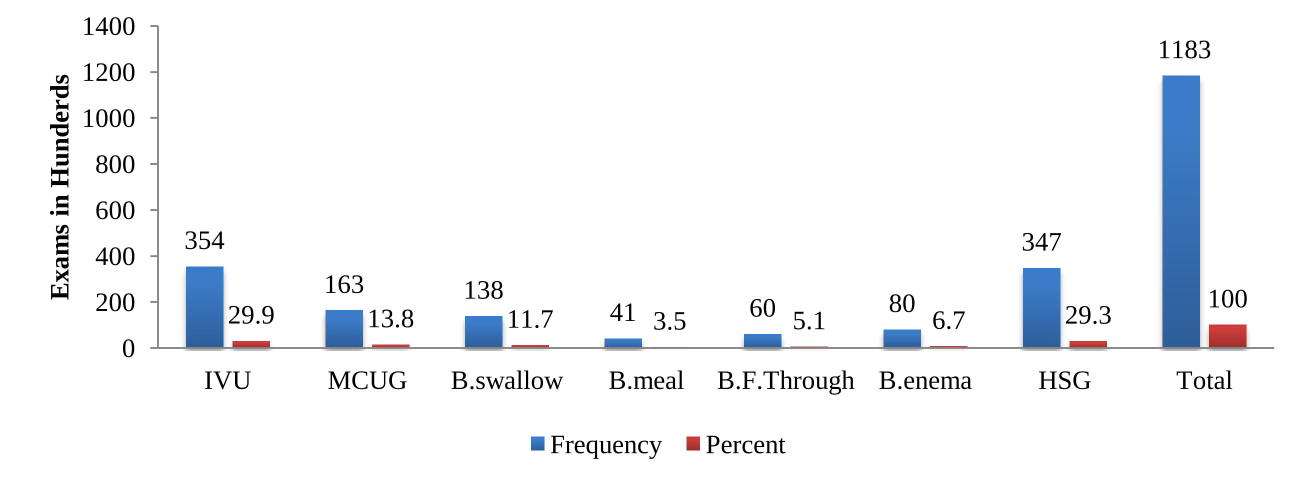

Figure 4.3: Shows Images distribution for each radiologic investigation.

Table4.2: Shows The mean range Std. Deviation, Minimum and Maximum of films per exam for all investigation.

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

The mean range of films per exam for all investigations included IVU, MCUG, B. Swallow, B.Meal. B. Follow Through, B. Enema and HSG were recorded 6.7±2.95, 9.5±7.63, 14.6±12.59, 19.9±10.43, 12.9±7.91, 12.4±5.87 and 5.8±4.18

with minimum and maximum account 4, 3, 2, 6, 3, 4, 2 and 19, 34, 55, 41, 28, 25 and 22 respectively.

Table4.3: shows No. of measurement for each exam in each hospital

Hospitals	IVU	MCUG	B.swallow	B.meal+ Follow Through	B.enema	HSG	Total
Khartoum	27	10	0	0	0	33	70
Omdurman	26	9	16	0	0	27	78
Bahry	19	0	2	0	0	1	22
Souba	41	48	18	27	4	7	145
Ribat	66	24	34	12	18	46	200
Military	137	15	21	3	12	52	240
Fedail	0	45	21	12	30	58	166
Royal	0	6	12	47	16	86	167
SDC	38	6	14	0	0	37	95
Total	354	163	138	101	80	347	1183

Table 4.4: Shows exams account among hospitals vs. special radiologic investigations.

Exams	Khartoum	Omdurman	Bahry	Souba	Ribat	Military	Fedail	Royal	SDC	Total
IVU	**7** (7%)	**11** (11.1%)	**6** (6%)	**9** (9%)	**20** (20.2%)	**39** (39.3)	**0** (0%)	**0** (0%)	**7** (7%)	**99** 100%
MCUG	**2** (4.2%)	**5** (10.6%)	**0** (0.0%)	**11** (23.4%)	**6** (12.7%)	**5** (10.6%)	**14** (29.7%)	**2** (4.2%)	**2** (4.2%)	**47** 100%
Barium Studies	**0** **(0.0%)**	**2** (2.1%)	**2** (2.1%)	**13** (13.6%)	**19** (20%)	**10** (10.5%)	**20** (21%)	**26** (27.3%)	**3** (3.1%)	**95** 100%
HSG	**14** (11.5%)	**13** (10.7%)	**1** (0.8%)	**2** (1.6%)	**16** (13.1%)	**16** (13.1%)	**19** (15.5%)	**28** (22.9%)	**13** (10.7%)	**122** 100%
Total	**23**	**31**	**9**	**35**	**61**	**70**	**53**	**56**	**25**	**363**

The distribution of exams between hospitals for IVU illustrated 7 (7%), 11 (11.1%), 6(6%), 9(9%), 20(20.2%), 39(39.3) and 7(7%) for Khartoum, Omdurman, Bahry, Souba, Milltry, Ribat, Fedail, Royal hospital and SDC respectively. Also, for MCUG showed 2 (4.2%), 5 (10.6%), 11 (23.4%), 6 (12.7%), 5 (10.6%), 14 (29.7%), 2 (4.2%) and 2 (4.2%) for Khartoum , Omdurman, Souba, Milltry, Ribat, Fedail, Royal hospital and SDC respectively, and for 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 Omdurman, Bahry, Souba, Milltry, Ribat, Fedail, Royal hospital and SDC respectively, lastly HSG exam distributed 14 (11.5%), 13 (10.7%), 1 (0.8%), 2 (1.6%), 16 (13.1%), 16 (13.1%), 19 (15.5%), 28 (22.9%) and 13 (10.7%) for Khartoum Omdurman, Bahry, Souba, Milltry, Ribat, Fedail, Royal hospital and SDC respectively.

Table 4.5: No. Measurements achieved the maximum Image quality scores .

Exams	IVU	MCUG	B.swallow	B. Meal+ Follow Through	B.enema	HSG
No. 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

Two quality scores were defined (total score and minimum score) and percentage mean average was assumed to be an indicator of the method’s reproducibility.

The results of image quality assessment set on the European guidelines seen in Tables 4.6 to 4.10, illustrate the scores ranged Fully Acceptable; all anatomical structures were seen, consequently images quality yields a utmost scores of 65.9 ±14.90, 53.2±21.37, 61.6±13.66, 53.2±28.86, 62.5±15.53, and 64.9±18.92 for (IVU), (MCUG), (B. Swallow) , (B.Meal+ B. Follow Through), (B. Enema) and (HSG) respectively.

The results of image quality estimation found in Tables from 4.5 to 4.10, it can be noticed that the scores ranged probably Acceptable; 19.4%, 31.8%, and 26.6 %, 29.2%, 26.9% and 24.5% for IVU, MCUG, B.Swallow, B.Meal and B.follow through examinations, B.Enema and HSG, respectively.

The total scores results of image quality measurement seen in Tables below, From Tables 4.5 to 4.10, ranged poor; 14.7%, 15%, 11.8%, 17.6%, 10.6% and 10.6% for IVU, MCUG, B.Swallow, B.Meal and B.follow through examinations, B.Enema and HSG, respectively

Table4.6: Shows Fulfillment with European guidelines (CEC) for 354 images of IVU examinations.

		Number of scores per score category		
No.	***Clinical Image criteria***	***1***	***2***	***3***
1	**C1a**	275 (77.7%)	45 (12.7%)	34 (9.6%)
2	**C2a**	76 (21.5%)	229 (64.7%)	49 (13.8%)
3	**C3a**	292 (82.5%)	1 (0.3%)	61 (17.2%)
4	**C4a**	289 (81.7%)	0 (0%)	65 (18.3%)

Fully Acceptable=1, Probably Acceptable=2 and Poor =3. And C1=Criteria No 1, C2=Criteria No2, C3=Criteria No3 and C4=Criteria No4.

Table4.7: Shows Fulfillment with European guidelines (CEC) for 163 images of MCUG examinations.

		Number of scores per score category		
No.	***Clinical Image criteria***	***1***	***2***	***3***
1	**C1b**	104(63.8%)	27 (16.6%)	32 (19.6%)
2	**C2b**	17 (10.4%)	116 (71.2%)	30 (18.4%)
3	**C3b**	108 (66.3%)	25 (15.3%)	30 (18.4%)
4	**C4b**	118 (72.4%)	39 (23.9%)	6 (3.7%)

Fully Acceptable=1, Probably Acceptable=2 and Poor =3, and C1b=Criteria No 1, C2b=Criteria No2, C3b=Criteria No3 and C4b=Criteria No 4.

Table4.8: Shows Fulfillment with European guidelines (CEC) for 319 images of Bariums examinations.

		Number of scores per score category		
No.	***Clinical Image criteria***	***1***	***2***	***3***
1	**C1c**	239 (74.9%)	30 (9.4%)	50 (15.6%)
2	**C2c**	19(5.9%)	247 (77.4%)	53 (13.8%)
3	**C3c**	244 (76.4%)	19 (5.9%)	56(16.9%)
4	**C4c**	253 (79.3%)	54(16.9%)	12 (3.7%)

****Fully Acceptable=1, Probably Acceptable=2 and Poor =3, C1c=Criteria No 1, C2c=Criteria No2, C3c=Criteria No3 and C4c=Criteria No 4.***

Table 4.9: Shows Fulfillment with European guidelines (CEC) for 347 images of HSG examinations.

		Number of scores per score category		
No.	***Clinical Image criteria***	***1***	***2***	***3***
1	**C1d**	277 (79.8%)	36 (10.4%)	34 (9.8%)
2	**C2d**	45(13.0%)	253 (72.9%)	49 (14.1%)
3	**C3d**	287(82.7%)	9 (2.6%)	51 (14.7%)
4	**C4d**	292(84.1%)	42 (12.2%)	13 (3.7%)

Fully Acceptable=1, Probably Acceptable=2 and Poor =3, C1d=Criteria No 1, C2 d =Criteria No2, C3 d =Criteria No3 and C4 d =Criteria No 4.

Table 4.10: The Maximum Image Quality criteria scoring values of technical quality criteria (TQC), procedural quality criteria (PQC) all projections for each hospital.

Hospitals	IVU		MCUG		B. Swallow		B.Meal + B. Follow Through		B. Enema		HSG	
	PQC	TQC	PQC	TQC	PQC	TQC	PQC	TQC	PQC	TQC	PQC	TQC
Khartoum	55.5	70.3	80	86.6	*	*	*	*	*	*	100	81.8
Omdurman	65.3	57.1	100	66.6	62.5	52	*	*	*	*	85.1	70.3
Bahry	84.2	84.2	*	*	*	*	*	*	*	*	*	*
Souba	100	99.1	50	75.6	77.7	77.7	81.4	86.3	50	66.6	42.8	66.6
Ribat	77.2	70.1	83.3	83.3	79.4	79.4	50	55.2	94.4	94.4	71.7	74.6
Military	74.4	75.3	66.6	66.6	100	100	50	50	83.3	83.3	71.1	71.7
Fedail	*	*	37.7	59.9	80.9	80.9	88.8	88.8	83.3	83.3	94.8	96.5
Royal	*	*	50	66.6	75	75	63.9	64.7	81.2	81.2	80.2	82.9
SDC	89.4	76.2	83.3	83.3	100	61.9	*	*	*	*	64.8	72.9

The lowest entrance air kerma dose (ESAK) values recorded at Milltry hospital was (1 mGy) and the highest value recorded at Omdurman teaching hospital was (3.6 mGy) for IVU exams with mean 1.9 ± 0.89 seen in table 4.12. MCUG exams also, recorded (1.1 mGy) as lowest ESAK value at Royal Care hospital and (2.4 mGy) as highest value with mean average 2.5 and SD ±0.48. The highest ESAK value for Barium Studies recorded at Omdurman teaching hospital (3 mGy) while the lowest ESAK value registered at Ribat university hospital (1.4 mGy) with mean average 2.3 ±0.85, also Omdurman teaching hospital again was record (3 mGy) as highest ESAK value and Khartoum teaching hospital was reported (1.1 mGy) as lowest ESAK value for HSG investigations with mean average 2.1 ± 0.59.

Table4.11: Shows the mean entrance air kerma dose to patients at hospitals.

Exam	Omdurman	Khartoum	Souba	Ribat	Milltry	Bahry	Royal	Fedail	S D C
IVU	3.6	1.1	1.6	1.6	1	2.1	N/A	N/A	2.4
MCUG	2.2	1.5	1.5	2.4	1.7	N/A	1.1	1.9	2.5
Barium Studies	3	N/A	3.3	1.4	3	N/A	1.8	1.5	N/A
HSG	3	1.1	1.8	1.6	2.5	1.9	2.1	2.1	2.8

Note: Barium Studies = B.Meal+ B.F.Through+ B.Enema and NA= Not Available.

Range values of ESAK wide-ranging with X-ray tube potential, focal to image receptor distance, patient size, filtration applied and automatic exposure control (AEC). Table 4 gives the radiation dose to the patients with independent of the X-ray tube potential, age, and patient size.

Table 4.12: Special investigation with Mean *kVp, mAs* and Entrance Air Kerma (ESAK) dose to patients at hospitals

Examination	*Mean Range ~kVp*	*Mean Range ~mAs*	*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

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

Table 4.13: Shows range of procedural data across hospitals for the specific projections

Technical parameter	IVU	MCUG	B.swallow	B.meal	B. Follow Through	B.enema	HSG
Tube output (kVp)	60-86	55-90	55-125	64-94	64-94	94-94	63-85
Tube output (mAs)	10-50	8.-46	10-32	3-43	3-43	3-43	10-40
Receptor-focus distance(cm)	100/109	100/109	100/109	100/109	100/109	100/109	100/109
Accurate Collimation	75.7%	85.1%	82.5%	100%	100%	100%	78.6%
Correct Marker	yes	yes	yes	yes	yes	yes	yes
Correct Gonad Shield	None	None	None	None	None	None	None

CHAPTER FIVE

Discussion, Conclusion and Recommendations

5.1Discussion

Radiological images require high quality to maximize diagnostic usefulness. Patients being irradiated should be in no doubt that the image produced is of optimal quality regardless of the location of the examination. There is some evidence that image quality can vary for different examinations (Leitz WK, et al. 1993; Akesson L et al. 1993), but it is currently unclear if the problem is more widespread. The current work aims to establish the level of image quality variation for four common special examinations in hospitals in Sudan. Anatomical criteria and the scoring method applied have been used effectively in previous studies and has been shown to provide a good discrimination between images of varying quality and has been the basis of altered technique in a number of clinical departments (Doherty P et al, 2003; Grondin Y et al, 2004; Peters SE et al, 2002).

The clinical measures employed in this study were subjective; the subjective error inherent in assessment by questionnaire was reduced by use of appropriate and expert groups of radiologic technologist and collection of a large set of data. The clinical assessment methods were chosen to reflect current practice in image quality assessment and to provide a reasonable index of each radiographic practice set awareness of image quality performance.

This trial evaluation of the image quality of IVU radiographs, MCUG, Barium Studies and HSG Films in Sudan hospitals shows that the image quality of the 354 IVU films, 138 MCUG films, 319 Barium Studies Films and 347 HSG Films in combine with standard protocols implemented and low ESAK values obtained, Tables4.6 to 4.10 illustrated the Maximum Image criteria scores ranged between 53.2and 65.9 %,5 (SD ; 13.60 and 21.37,), consequently images quality yields a utmost scores of 65.9 ±14.90, 53.2±21.37, 61.6±13.66, 53.2±28.86, 62.5±15.53, and 64.9±18.92 for (IVU), (MCUG), (B. Swallow) , (B.Meal+ B. Follow

Through), (B. Enema) and (HSG) respectively, compliance with CEC image quality criteria. The ESAK values recorded in this hospital survey were yielded, 1.91±0.90, 1.9±0.49, 1.4±0.48, 2.3± 0.90 and 2.1±0.60 mGy for IVU), (MCUG), (B. Swallow) , (B.Meal+ B. Follow Through), (B.Enema) and (HSG) respectively.

The subjective obtained results from this study suggested that the image criteria system is that of choice, also these results indicates that quality criteria can be expressed into a scoring method defers reproducible data in nearly all rates, in agreement with A C Offiah and C M Hall, 2003. The CEC criteria were able to detect differences in quality of film–screen and digital images. Also, the opinion about the strength of using VGAS and the CEC image criteria as a measure of clinical image quality were raised recently by Tingberg et al (2004) and Håkansson et al (2004) about the validity of using VGAS and the CEC image criteria as a measure of clinical image quality.

Visual grading methods have been found to agree both with methods based on receiver operating characteristics (ROC) analysis and with calculations of the physical image quality. It is reasonable to believe that these methods can be implemented at almost any hospital. Two methods of great relevance are image criteria (IC) and Visual grading analysis (VGA). These criteria are statements of the needed level of reproduction of important anatomical structures. Fulfillment of image criteria (IC) is a simple visual grading method, in which the task of the observer is to state whether a certain criterion is fulfilled or not in the image (Bath M and Månsson LG, 2007).

The values attained in this work are in good agreement between each other and with data reported in the literature. The anatomical criteria employed in the evaluation of image quality were derived from the CEC recommendations and were divided into technical quality criteria (TQC) which mainly focused on anatomy that was affected by technical agents such as exposure factors, filtration etc, and procedural quality criteria (PQC) that were mainly affected by the radiographers' technique such as patient positioning.

Poor image quality causal means mostly descend into two items technical factors such as exposure factors, (KVp, MAs, filter type and acquisition device and procedural parameters such as positioning of the patient/equipment.

In the current study, image differences were found between hospitals for all projections investigated. Variation factor (VF) is a term that will be used throughout this discussion, and is calculated for each projection by dividing the maximum hospital percentage value by the minimum hospital percentage. Across all examinations the mean technical and procedural VFs were 1.7±0.09 and 1.9±0.21, respectively, which suggest that visualization of procedural criteria, which relies largely on the way the examination is performed by the radiographer, varied by a slightly greater amount than technical criteria. This pattern was seen for individual examinations, specifically IVU AP, MCUG AP and oblique, Barium Studies AP and oblique and HSG AP projections.

In this work were implemented quality variations, so identification of corrective action can be facilitated when features responsible for image variations are identified as being related to equipment performance or radiographic protocol. Also to categorize anatomical criteria thus, recorded variations can be linked to technical or procedural factors.

Table 5.1: Shows the IVU and MCUG projections: the percentage values of technical quality criteria (TQC), procedural quality criteria (PQC) and [PQC + TQC] summative criteria (SC).

Hospital	IVU			MCUG		
	TQC	PQC	SC	TQC	PQC	SC
Khartoum	55.5	70.3	62.9	80	86.6	83.3
Omdurman	65.3	57.1	61.2	100	66.6	83.3
Bahry	84.2	84.2	84.2	*	*	*
Soba	100	99.1	99.5	50	75.6	62.8
Ribat	77.2	70.1	73.6	83.3	83.3	83.3
Military	74.4	75.3	74.8	66.6	66.6	66.6
Fedail	*	*	*	37.7	59.9	48.8
Royal Care	*	*	*	50	66.6	58.3
SDC	89.4	76.2	82.8	83.3	83.3	83.3
VF	**1.8**	**1.7**	**1.6**	**2.6**	**1.4**	**1.7**

The percentage value represents the score awarded as a proportion of the maximum possible score. Key; * = Indicates that there was inadequate data analysis. VF = Variation factor. This was calculated for each set of criteria for each examination by dividing the maximum percentage value by the minimum value.

Table 5.2: Shows the B. Swallow and B.Meal + B. Follow Through projections: the percentage values of technical quality criteria (TQC), procedural quality criteria (PQC) and [PQC + TQC] summative criteria (SC).

Hospital	B. Swallow			B.Meal + B. Follow Through		
	TQC	**PQC**	**SC**	**TQC**	**PQC**	**SC**
Khartoum	*	*	*	*	*	*
Omdurman	62.5	52	57.2	*	*	*
Bahry	*	*	*	*	*	*
Soba	77.7	77.7	77.7	81.4	86.3	83.8
Ribat	79.4	79.4	79.4	50	55.2	52,6
Military	100	100	100	50	50	50
Fedail	80.9	80.9	80.9	88.8	88.8	88.8
Royal	75	75	75	63.9	64.7	64.3
SDC	100	61.9	80.9	*	*	*
VF	**1.6**	**1.9**	**1.4**	**1.7**	**1.7**	**1.7**

The percentage value represents the score awarded as a proportion of the maximum possible score. Key; * = Indicates that there was inadequate data analysis. VF = Variation factor. This was calculated for each set of criteria for each examination by dividing the maximum percentage value by the minimum value.

Table 5.3: Shows the B. Enema and HSG projections: the percentage values of technical quality criteria (TQC), procedural quality criteria (PQC) and [PQC + TQC] summative criteria (SC).

Hospitals	B. Enema			HSG		
	TQC	PQC	SC	TQC	PQC	SC
Khartoum	*	*	*	100	81.8	90.9
Omdurman	*	*	*	85.1	70.3	77.7
Bahry	*	*	*	*	*	*
Souba	50	66.6	58.3	42.8	66.6	54.7
Ribat	94.4	94.4	94.4	71.7	74.6	73.1
Military	83.3	83.3	83.3	71.1	71.7	71.7
Fedail	83.3	83.3	83.3	94.8	96.5	95.6
Royal	81.2	81.2	81.2	80.2	82.9	81.5
SDC	*	*	*	64.8	72.9	68.8
VF	**1.8**	**1.4**	**1.6**	**2.3**	**1.4**	**1.7**

The percentage value represents the score awarded as a proportion of the maximum possible score. Key; * = Indicates that there was inadequate data analysis. VF = Variation factor. This was calculated for each set of criteria for each examination by dividing the maximum percentage value by the minimum value.

The amount of the VF for both procedural and technical quality was varied from 1.4 and 2.3 for the HSG examination to 1.4 and 2.6, respectively, for the MCUG examination. The usefulness of separating causal agents into technical or procedural categories is shown for the HSG examination, where the technical VF is at a relatively low level of 1.4, but the procedural VF is 2.3. This demonstrates that the variation in overall images score is mainly due to the radiographic protocol employed and proper procedural followed rather than equipment used.

Table 5.4: Shows a summary of the mean percentage scores for each examination for analogue and digital acquisition technology

Examination	Technical Quality Criteria	Procedural Quality Criteria	Total	ESAK mGy
IVU				
Analogue	79.6	79.1	80.2	2.4±085
Digital	69	71.9	70.4	1.2±0.32
MCUG				
Analogue	77.7	77.2	76.4	2.0±0.51
Digital	63.5	72.6	68	1.5±0.32
B. Swallow				
Analogue	80	63.8	71.9	1.5±0.54
Digital	83.8	83.8	83.8	1.2±0.45
B.Meal +Follow Through				
Analogue	81.4	86.3	83.8	3.1±0.21
Digital	63.1	64.6	63.8	1.9±0.73
B. Enema				
Analogue	50	66.6	58.3	3.1±0.21
Digital	85.3	85.3	85.3	1.9±0.73
HSG				
Analogue	64.2	69.9	67	2.3±0.61
Digital	83.5	81.5	82.5	1.8±0.54

Since the emergence of digital acquisition technology throughout diagnostic imaging departments, it is meaningful comparing the image quality of digitally acquired images with analogue images produced in this hospitals survey. The mean percentage scores for the two manners of acquisition are reviewed in Table 5.4. For technical and procedural quality criteria, IVU, MCUG and barium meal and Follow Through were higher with the analogue method of acquisition , while HSG , Barium swallow and barium Enema images scores were higher with the

Digital method of acquisition, which give the impression that visualization of anatomical features in this investigations were equal in both technology. Even the differences in scores between the acquisition systems are generally small, which would propose that it is due to well trained and skill operator depending. Even L.A. Rainford et al (2007) reported greater percentage scores for the analogue images compared with the digital images for all scores were higher with the analogue method of acquisition, and they argued that the reasons for this could be linked to the lower spatial resolution of digitals systems compared with film-based acquisition. Also, studies showed that using a lower tube voltage improves visibility of anatomical structures and lesions in digital chest radiographs but also increases the disturbing appearance of ribs (W.J.H. Veldkamp et al, 2009).

The idea behind the validity of using variation factor as indicator for separating causal agents, as settled recently by Rainford et al (2007), the study author for the first time who discriminates between technical- and procedural-based criteria that may help identify the source of image quality variations and low image quality scores.

The comparison of the FFD, kV, film-screen combination speed, total filtration and automatic exposure control (AEC) revealed that Sudanese hospital under evaluation in this study perform in conformity with the European recommendation in regards to IVU , MCUG, Barium Studies and HSG examinations.

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 expert of the operators.

The relative low dose levels were found in this study could be attributed to number of factors in patient dosimetry in diagnostic radiology and dose measurements affected by: statistical number of patients, equipments performance, and film screen combination (400 speed). Moreover, almost departments are using filtration above the minimum requirements of 2.5 mm AL equivalent an average filtrations per X-ray unit of 3.3 mm AL equivalent.

5.1.1 ESAK values coupled with image quality scores

5.1.1.1 ESAK Measurements during IVU linked with image quality scores

The maximum image quality scores yielded 62.9 ,61.2, 84.2 ,99.5, 73.6 ,74.8 and 82.8 , The mean ESAK per IVU procedure was 1.1 mGy, 3.6 mGy, 2.1 mGy, 1.6 mGy, 1.6 mGy, 1.0 mGy and 2.4 mGy in Khartoum, Omdurman, Bahry, Souba, Ribat, Milltry Hospitals and SDC, respectively. The means average was 77±13.27 and1.9 ± 0.89 mGy for IQC and ESAK respectively. Even the CEC guidelines recommends 10 mGy as reference dose for IVU procedure, radiation doses measured in this work are well within the established international reference doses. These variation could be explained by the rather few number of IVU image in the present study mean about 6.4. or could be because reference doses were recognized 18 years ago and that advances in imaging technology contributed to the improvement of the equipment performance (M.A.Halato et al 2010), This might specify the need for established new reference dose levels acting as compliance in each hospital or in whole country for the current practice, in agree with M.A.Halato et al 2010 as stated in their study.

The ESAK was within the same range of recent study which was performed on adult patients conducted by (M.A.Halato et al, 2010). The dose value in this study was less than the dose value for adult patients reported by Sulieman, A. 2013 and Suliman, I.I., et al 2014 (Table 5.5).

Table5.5: Shows the previous studies results during IVU procedure

Author	No Exam	Country	ESAK mGy
Present Study	99	Sudan	1.9 ± 0.89
Halato et al 2010	42	Sudan	1.6-3.2
Sulieman et al 2013	141	Sudan	12.4 ± 8.7
Suliman I. et al 2014	72	Sudan	6.6 - 15.3

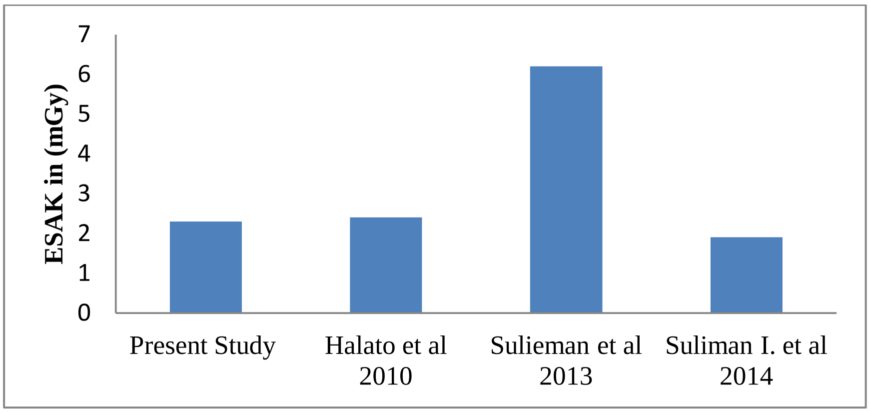

Figure 5.1: Illustrate ESAK values for IVU with previous studies authors

5.1.1.2 ESAK Measurements during MCUG linked with image quality scores

The maximum image quality scores yielded 83.3, 83.3,62.8,83.3, 66.6, 48.8, 58.3 and 83.3 , The mean ESAK per for MCUG procedure was 2.2, 1.5,1.5,2.4,1.7,1.1, 1.9 and 2.5 mGy in Khartoum, Omdurman, Souba, Ribat, Milltry Hospitals and SDC, respectively. The mean 61.6±13.66 and 1.85±0.48 mGy for IQC and ESAK respectively.

In literature, many attempts were made in order to reduce the radiation dose during MCUG. Consequently, Sulieman et al, 2008, reported that, MCUG with digital equipment and fluoroscopy-captured image technique could reduce the dose to a patient up to 50%. Ward et al (2008) reported that, grid-controlled variable-rate pulsed fluoroscopy (GCPFL) reduce the radiation dose to a patient at least eight times lower than continuous fluoroscopy (CFL) during Micturating cystourethrography (MCUG).

Table 5.6: Shows the mean patient parameters, screening time, number of radiographic images, ESAK values in various studies (range is in parenthesis).

Author	N	No. Image	Screening time Minutes)	ESAK (mGy)
Present study	47	9.5±7.63	3-10	1.85±0.48
Suleiman et al (2008)	52	1.18	0.75	1.13
Perisinaks et al (2006)	118	6.3	0.73	NR
Fotakis et al (2003)	30	NR	3	4.58

5.1.1.3 ESAK values during Bariums Studies linked with image quality scores

The Quality Criteria implemented in this survey include a system for scoring more general aspects of the image, such as blackening, contrast, sharpness and diagnostic acceptability, The maximum image quality scores yielded 61.6±13.66, 53.2±28.86, 62.5±15.53 for (B. Swallow) , (B.Meal+ B. Follow Through) and (B. Enema) , respectively, in Khartoum, Omdurman, Bahry, Souba, Ribat, Milltry Hospitals and SDC.

The highest ESAK value for Barium Studies was recorded at Omdurman teaching hospital (3 mGy) while the lowest ESAK value registered at Ribat university hospital (1.4 mGy) with mean average 2.3 ±0.85 and Sulieman et al, 2011 quantified the patients‟ radiation doses during Barium studies investigations (barium swallow, barium meal and barium enema) are the basic routine radiological examination. A total of 33 investigations of barium studies were measured by using Thermo luminescence dosimeters. The result showed that the patient entrance surface doses were 12.6±10, 44.5±49 and 35.7±50 µGy for barium swallow barium meal and enema, respectively.

Table 5.7: Shows the comparison of obtained dose characteristics of barium examinations with published result

Author	N	Mean No of Radiographs	ESAK in µGy
Present study	50 (S)	14.6±12.59	1.4
	41 (M)	19.9±10.43	2.3
	42(F)	12.9 ±7.91	2.3
	50 (E)	12.4±5.87	2.4
Delichas et al(2004)	42(E)	NR	24
Cruces et al(2000)	38(S)	4.3	NR
Brodhead et al(1995)	1587(M)	5.6 0-25	NR
	1308(E)	0.6 0-30	6.4

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

5.1.1.4 ESAK Measurements during HSG linked with image quality scores

The Quality Criteria provided in this survey, offer a system for scoring compliance with the Image Criteria (CEC 1996), which the maximum obtainable image criteria score for this work was 71.6, higher than what have been reported by Abdullah et al (2001) who made a comparison between conventional and high voltage technique during HSG using conventional X-ray machine and their results showed that overall image quality scores 33 and 31 depending on the type of water soluble contrast was used. Mohd Nor et al, 2009 emphasized the finding of this study when they reported that Radiographic imaging quality was considered good to excellent between three contrast agent used with regard to sharp reproduction of uterine outline, fallopian tube outline and free peritoneal spillage outline. However, the Superior Quality scores ranged between 62.8 and 100 for all HSG images criteria they approved for their study.

In this work, test of the methods employed, exact SID, tube voltages (kVp), AEC usage and selection of film screen speed combination in the departments under consideration showed varying levels of fulfillment with the CEC guidelines showed in Table 4.10.

The mean ESAK yielded 2.1 mGy per image in present study. These mean ESAKs calculated for HSG is close to and within range of the reviewed literature recommended reference values. They are however similarity results with Kushner et al. (1986) who obtained a mean ESD (2.2) mGy per image as they studied the radiation dose reduction using low-mode scanning beam digital imaging system also they found ranged between 4 and 10 images, whilst the number of images for this study was 5 (2-13) per procedure. It was observed that the number of films per procedure were within the reviewed studies level except in Two Private hospital where a higher number of films raised up to 22 images in some procedures was recorded in this survey, which indicated that these specific HSG examinations were carried out by trainee radiologists under supervision or gynecologists who are not fully trained in radiation protection.

Comparing this result with the previous data (Table 6 and figure 3), it is clear that, this study reports the observable reduction of the radiation ESAK dose values consequently, decreased risk of hereditary radiation effects. In same means Sulieman et al, 2008 refer to when they study radiation dose optimisation and risk estimation to patients and staff during Hysterosalpingography; radiation protection dosimetry, they obtained an ESAK of 3.6 mGy and Kushner et al, 1986 assessed the ESD during HSG. Though, it seems to be comparable with the previous studies. The ESD during HSG was also estimated at 12.6 mGy by Khoury et al. 2001 and at 14.6 mGy by Gregan et al, 1998 which were observed to be elevated in the dose values than the current study.

Table5.8: **Shows the mean patient parameters, number of radiographic images, ESAK mGy dose in various studies for HSG**.

First Author	No pts	Age Yrs	No. of Film mean	ESAK mG
Present study	122	31.5 (18-45)	5.8 (2-22)	2.1 (1.7-2.8)
Yousef et al.	50	NA	NA	9.5-42.5
Alzimami, K., et al	79	NA	4.5 (1–12)	23.16(9.3–48.4)
A. Sulieman., et al	37	34.0 (20–43)	0.2 (0–1)	3.60 (0.7–8.17)
Gregan et al.	21	31.6 (24–39)	2 (2–4)	14.6 (1.4–45.7)

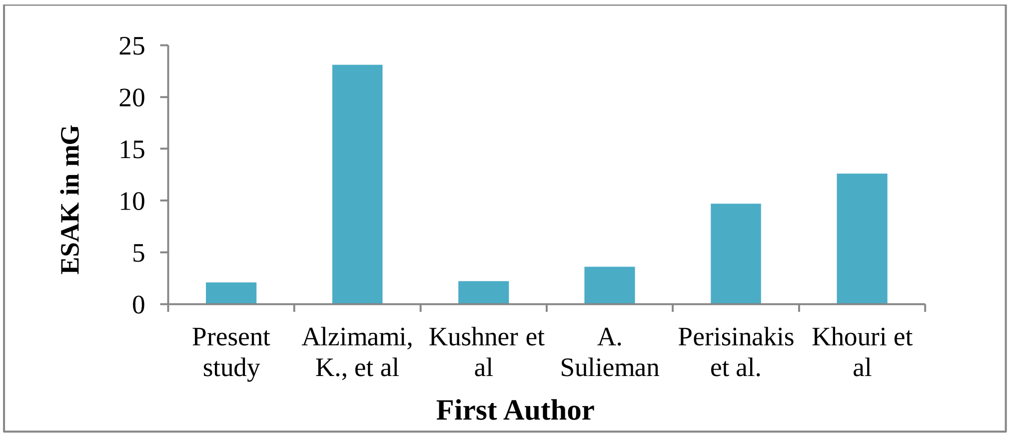

Figure 5.2: Illustrate the comparison of ESAK values for HSG for previously published studies

The present work did have some limitations. The radiographic examinations were not done by the same investigator, which appears to be that the radiologic technologists at some hospitals were unenthusiastic or not appreciated the experience. In addition, the mathematical technique, even if well liable to errors, but could be engaged until dose monitoring tools become more accessible.

Sudanese hospitals involved in this survey, in a certain circumstances it may be difficult to adhere to all the CEC recommendations due to equipment restrictions and the radiographic staff themselves not in awareness to the image quality conception, which seem to be other limitation, Thus there are an indication of the necessitate for the development of continuous education programmes for employees in diagnostic centers.

Finally, the Quality Criteria are intended to be easily applied in practice in any X-ray department without the need for special equipment apart from a means of measuring or estimating the dose to the patient. However, the Quality Criteria will only be of real benefit to an X-ray department if they allow inadequate levels of performance to be readily identified and corrected.

5.2 Conclusion

Depending on the above recent results have been obtained in this study, could concluded that, the analysis of image quality is critical for explanation of the radiographic process in any clinical setting , thus good image quality is dependent on a wide variety of interactions including training of personnel, protocols, equipment age and type. Because of these factors, and a lack of a global standard, make possible relation of both image quality and dose parameters from hospital to hospital, to pass up the increasing danger of hereditary radiation effects in patients undergo the specific radiographic exams.

Features such as inaccurate kVps, light beam diaphragm misalignment, incorrect selections of kVp/automatic exposure devices and inappropriate use of aspect markers are unacceptable, which impact negatively on image quality and radiation dose, have the potential to be responsible for at least some of the variations in quality reported in this study, thus greater adherence to standards should result in smaller quality variations than those described here.

Image quality variations were demonstrated across hospitals for IVU, MCUG, Barium Studies and HSG examinations.

Variations in image quality in some cases were significant, add to this the procedural and technical connecting elements for image quality variations are identified which should simplify corrective action. The country from which the data originated was not a predictor of image quality scores, Therefore, the level of variation was dependent on examination and criteria type and the hospital from where data originated was not a determinant of quality.

finally, The set of Image Criteria approved for evaluation of the quality of diagnostic films for the IVU, MCUG, Barium Studies and HSG examinations in general could be applied without fail by both a team of expert radiologists and those working in the field, so the image criteria scores have been found valuable and endorsement in daily practice in the hospitals suggested, the radiation dose to the patient can be coupled to the required image quality and to the performance of the radiographic procedure or protocols, need to be used and read-through in a comparable way. The need to provide relevant education and training to staff in the radiology departments is of utmost importance.

5.3 Recommendations

With references to the result and conclusion concerning this study, the researcher recommended that:

- A similar study to experience the image quality criteria scoring should be carried out depending on the current study findings considered as first round trail. So, that more accurate result could be achieved.
- Further studies should be conducted to evaluate the clinical image quality for many other radiographic investigations in other different Sudanese hospitals where, they show a significant difference in the present study.
- Special care must be taken during x-ray examinations by using the lowest possible radiation dose without compromising the findings.
- It is recommended that the patient dose from all simple radiographic studies and the routine retake rate analysis should be determined at the department level, then at the national level later in order to recruit the national guidance level of diagnostic imaging
- Continuous review and update of the protocols standard used by radiology professionals, and fewer possible numbers of films without affecting the patient's health care.
- The special procedure must be carried out by professional and trained radiologist and technologist and the residents especially obstetrician must be trained under supervision of experienced radiologists in radiation protection aspects.
- Digital radiography is encouraged to maximize the image quality level and minimize exposure dose the patients.

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Appendix A (Questionnaire)

Clinical Analysis of image quality and Technical protocols of radiological special procedures

Hospital Name; or code…………………………………..…………………………………

Pt. Name; or code:……………………………………………………………………………...

Equipment information:

Manufacturer………………ManufacturingDate……………..…Type………Fixed/Mobile……..

Focalspot……………Totalfiltration.…………..……Maximumk…………………….……..……

X ray tube generator (phase)……………...Maximum MA………………………Tube output (µGy/mAs)at1 m………Maximum time………………..…………Year of Installation…………………………………Tube (Over couch/undercouch)…..………………

Examination: IVU ☐ MCUG ☐ BARIAMS ☐ HSG ☐

Age (Years)	☐		Pt. ID	☐	
Sex	M ☐	F ☐	Anat. Marker	☐	
Height (cm)	☐		Gonad shield	☐	
Weight kg	☐		Pt. positioning	☐	
Collimation	☐		No. of films	☐	
Film density	☐		Duration of exam	☐	Mints

Patient preparation

Before one day……………...…………………………………………….…………………

Before two days …………………………………….…………………………...…...

Contrast Administration…………………………………………………………....

Duration post Contrast……………………...……………..………......................

Indications ……………………………………...……..………….........................

Diagnosis………………………………………………...………………...........................

PROJECTION AP ☐ PA ☐ Lat ☐

ROB ☐ LOB ☐ other ☐

If other please specify: …...

- Patient thickness in the Centre of the beam ☐ cm
- Additional filtration ☐ mm AL equivalent
- Applied nominal focal spot value ☐
- FFD ☐ cm
- Film size ☐ cm x cm
- Automatic exposure control Yes ☐ No ☐
- Chamber selection left ☐ central ☐ right ☐
- Radiographic kVp ☐
- Exposure time ms ☐
- Tube current mA ☐ mAs ☐

•ESD ☐

•Nominal speed class of screen film system………………..……………………

- Type and age of screen……………………………………………..……………..

Film density: ideal ☐ good ☐ poor ☐

Contrast: optimum ☐ too high ☐ too low ☐

Sharpness optimum ☐ poor ☐ unacceptable ☐

Film acceptability: Fully acceptable ☐

Probably acceptable ☐

Acceptable under limited clinical condition ☐

Rejected (give reasons) ☐

……………………………………………………………………………………………

…………………………………………………………………………………...…………

Comment……..……………………………………………………………………...…

……………………………………………………………………………………...…

……………………………………………………………………………………..

Appendix B (Image Quality Assessment Forms I)

Hospital code:

Patient No:

Image criteria *

Image criteria *	1	2	3	4	5	6	7	8	9	10	11	2	13	14	15	16	17	18	19
C1																			
C2																			
C3																			
C4																			
C5																			
C6																			
total																			

Important image details **

Scoring: * 1: yes; 0: no; where any area is obscured by a pathological condition, then 'P' should be placed in the appropriate box.

Maximum total score:

Appendix C (Image Quality Assessment Forms II)

Name:

Hospital code:

	1	2	3	4	5	6	7	8	9	10	11	2	13	14	15	16	17
Appropriate film density (blackening): *																	
Appropriate film density (blackening): *																	
Contrast **																	
Sharpness ***																	
Appropriate beam limitation ****																	
Film acceptability *****																	
Total																	

* Film density: optimum; too much; too little

** Contrast: optimum; too high; too low

*** Sharpness: optimum; sub-optimum; unacceptable

**** Beam limitation: optimum; field size too large; field size too small

***** Film acceptability: 1 = fully acceptable; 2 = probably acceptable; 3 = only acceptable under limited clinical conditions; 4 = unacceptable (give reasons)

Film No.	**Not accepted because of**:

Appendix D: Paper 1

Appendix E: Paper 2