Sudan University for Sciences and Technology

College of Graduate Studies and Scientific Research

Evaluation of Conventional X-ray Machines in the Primary Health Care Centers in Khartoum State

تقييم أجهزة الأشعة التقليدية في مراكز الرعاية الصحية الأولية بولاية الخرطوم

Thesis Submitted for Partial Fulfillment for The Academic Requirements of Master Degree in Medical Physics

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Dedication

To my father sprit

Acknowledgement

Great thanks to everybody who helps me to finish this work

الخلاصة

تقوم هذه الدراسة 27 جهاز أشعة سينية تعمل في المراكز الصحية التابعة لإدارة الرعاية الصحية الأولية بوزارة الصحة ولاية الخرطوم , وقد تم تقسيم هذه الأجهزة لثلاث مجموعات حسب الشركة المصنعة حيث وجد أن المجموعة الأولي وتمثل نسبة 66.7% من مجموع الأجهزة قيد الدراسة بها مشاكل ميكانيكية تعيق حركة الجهاز مما يؤدي الي صعوبة التعامل معه كذلك توجد مشلكة في الكيلوفولت والزمن في غالبية أجهزة هذه المجموعة كما أثبتت الدراسة , والمجموعة الثانية والتي تمثل نسبة 22.2% توجد بها مشكلة برمجة , المجموعة الثالثة والأخيرة والتي تمثل نسبة 11.1% لا توجد بها مشاكل تذكر مقارنة بالمجموعتين السابقتين. وبمتابعة العملية الشرائية للأجهزة لا يوجد نظام واضح ينظم هذه العملية وفي مجال ضبط الجودة لا يوجد برنامج جودة متبع وكذلك لا يوجد فريق أو شخص يقوم بعمل إختبارات ضبط الجودة.

Abstract

This study evaluate 27 X-ray units worked in the Primary Health Care Centers in Khartoum State, these units divided in three groups according to the manufacturing company, the first group acts as 66.7% of units under study it has mechanical problems which make the move of unit too difficult also there is a problem in kilovolt and time accuracy .The second group acts as 22.2% of all units which has programming and software problem. The third one acts as 11.1% of all units which has no problems compared with the previous groups. For the purchasing operation there is no obvious system organized it, also there is no quality control program and team or person who is responsible or concerned with quality control tests.

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List of Abbreviations

IAEA: International Atomic Energy Agency

WHO: World Health Organization

ICRP: International Commission on Radiological Protection

ILO: International Labor Organization

OECD: Organization for Economic Co-operation and development

NEA: Nuclear Energy Agency

FAO: food and Agriculture Organization

PAHO: Pan American Health Organization

IBSS: International Basic Safety Standards

Rad: Radiation absorbed dose

QC: Quality Control

Sv: Sivert

REM: Roentgen Equivalent Man

Ma: milliampare

mAs: milliampare second

Kvp: Kilovoltage peak

CV: Coefficient of Variation

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Chapter one

Introduction

Chapter one

1.1 Introduction

X-ray discovered in 1895 by Conrad Rontgen, German Physicist by using gas discharge tubes, which can penetrate opaque objects. It used in medical field for diagnostic and therapeutic purposes.

For diagnostic purposes devise of special construction is used to produce radiographic images which is named X-ray machine. The use of X-ray as a diagnostic tool is based on fact that various component of the body have different densities for the rays when it passed from point source penetrate the body, the internal structure of the body absorbs varying amount of radiation, the radiation that leaves the body form an image on special type of receptor.

X-ray machines consist of x-ray tube which is made of special type of glass containing cathode and anode produces x-ray under certain circumstances, control panel which contains electric circuits control the production of x-ray, table for patient setting and the high tension tank contains transformers to produce high voltage and oil for cooling purposes.

1.2 Problem of the study:

Patients are exposed frequently to high radiation and no control of exposure factor in most radiology departments in Sudan there is a limitation in knowledge of the harm effects of ionizing radiation and the lack of knowledge of the persons working with radiation about the basic principles

of radiation protection and physical variables that control the dose and distribution within the patient to give a high quality image in order to minimize the patient dose and increase the image quality. Most of these radiology departments only take in account the image quality without taking care about patient dose .Here we have many factors which affect patient dose and image quality such as x-ray tube, diaphragm and putter bucky.

1.3 Objective of the Study:

1.3.1 General Objective

To assess the performance of the x-ray machines which are used in the Primary Health Care Centers in Khartoum State.

1.3.2 Specific Objectives of the Study:

To assess Kvp and time reproducibility.

To assess Kvp and time accuracy.

To assess HVL and linearity.

To assess QC program.

To assess the mechanical parts.

1.4 Importance of Study:

It is important when purchasing x-ray machine to participate persons who deal with this type of equipment such as committee of biomedical engineer, medical physicist, x-ray technician and radiologist for technical opinions.

1.5 Overview:

This thesis is concerned with the evaluation output of conventional x-ray machine in Primary Health Care Centers in Khartoum State.

It divided into five chapters. Chapter one include an introduction, while chapter two include literature review (theoretical background and previous studies)and chapter three deals with materials and method , chapter four contains results and chapter five discussion, conclusion and recommendations for this thesis and suggestions for future work.

Chapter tow

Theoretical Background

Chapter two

2.1 Theoretical Backgrounds

2.1.1 Organization of Radiation Protection:-

Over the last decades, there has been a growing awareness throughout the world of the need to give greater emphasis to the protection of patients undergoing radiation exposure for medical purposes and to control the radiation exposure of workers, medical patients and the public. Therefore, many countries have developed laws, which are supported by administrative measures and enforced by inspectors. Equally important is to have internationally agreed standards, and the International Atomic Energy Agency (IAEA) has played a key role in developing and refining these. The IAEA together with the World Health Organization (WHO), the International Commission on Radiological Protection (ICRP), International Labor Organization (ILO), Organization for Economic Co-Operation and Development (OECD), Nuclear Energy Agency (NEA), Food and Agriculture Organization (FAO) and Pan American Health Organization, have recently revised and updated there International Basic Safety Standards (IBSS) for protection against ionizing radiation and the safety of radiation sources, the use of radiation is governed by this international authorities, Which concerned with minimizing the exposure of staff and members of the public that may also include the protection of the fetus on the rare occasions that a patient may require x-ray image while pregnancy .(2)

2.1.2 Radiation Quantity and Units:

During the early days of radiological experience there was no precise unit of radiation does that was suitable either for radiation protection or for radiation therapy. For these purposes the radiation protection, a common "dosimeter" was a piece of dental film with a paper clip attached. A daily exposure great enough to just produce a detectable shadow was considered a maximum permissible dose. For greater does and for therapy purposes the dose unit was frequently the "skin erythema unit". Because of the great energy dependence of the dose units could be biologically meaningful or useful either in quantitative study of the biological effects of radiation or for radiation protection purposes. Furthermore, since the fraction of the energy in a radiation field that is absorbed by the body is dependent, it is necessary to distinguish between radiation exposure and radiation absorbed dose. (6

2.1.2.1 Absorbed Dose:

Absorbed dose is a non-stochastic quantity, defined as the expectation value of the energy imparted to matter, ε, per unit mass of tissue at the point of interest dm.

$$D=d\varepsilon/dm \quad 2.1$$

Radiation damage depends on the absorption of energy from the radiation and is approximately proportional to the concentration of absorbed energy in tissue. (ICRP 60: 1990 recommendation)

2.1.2.1.1 Gray:

The basic unit of radiation dose called the gray (Gy) and is defined as:

One gray is an absorbed radiation dose of one joule per kilogram. The gray is universal applicable to all types of ionizing radiation dosimeters. (6)

2.1.2.1.2 Rad:

Before the universal absorption of the SI units, radiation dose was measured by a unit called the rad (Radiation Absorbed Dose). One rad is an absorbed radiation dose of 100 ergs per gram.

$$1 \text{ rad} = 100 \text{ ergs/g} \quad 2.2$$

Since 1 J=10^7 ergs, and since 1kg=1000g, 1Gy=100 rads.

Although the gray is the newer unit, and will eventually replace the rad. (6)

2.1.2.2 Kerma:

Kerma is a non-stochastic quantity, defined as the expectation value of the energy transferred (εtr) by uncharged particles (e.g. photons or neutrons) to charge particles per unit mass at the point of interest dm.

$$K = d\varepsilon \text{ tr}/dm \quad 2.3$$

Kerma has been defined as, an acronym for, the sum of the kinetic energies of all those primary charged particles released by uncharged particles (here photons) per unit mass (Kinetic Energy Released per unit mass) the unit of kerma is grey (Gy), where 1 Gy=1j kg-1.

In a photon field, the kerma at the point of interest is expressed as

$$K = \int_{E=0}^{E=\max} \Psi(E)\, \mu tr/p \quad 2.4$$

Where Ψ (E) is the distribution of photon energy fluence, and $\mu tr/p$ is the mass energy – transfer Photon energy fluence is defined as the product photon fluence and energy E. Kerma is greater than absorbed dose by a factor of 1/ (1-g). This relation is valid only for irradiation in the condition of charged particle equilibrium i.e. when the number and energies of charged

particles leaving is equal to the number and energies of particles entering this volume.(1)

$$D= (1-g) K 2.5$$

The factor g represents the average fraction of the kinetic energy of secondary charged particles (produced in all types of interactions) that is subsequently lost in radiative (photon emitting) energy-loss processes as the particles slow to rest in the medium. (6)

2.1.2.3 Exposure:

Exposure is a radiation quantity referring to the intensity of radiation for external radiation of any give energy flux, the absorbed to any point with in an organism depends on the types and the energy of radiation, the depth within the organism of the point at which the absorbed dose is required, and elementary constitution of the absorbing medium at this point. The exposure unit is a measure of photon flux, and is related to the amount of energy transferred from the X-ray field to a unit mass of air. One exposure unit is defined as that quantity of x-or gamma radiation that produces in air, ions carrying 1 coulomb of charge (of either sign) per Kg air.

1x unit= 1c/Kg air.

The exposure unit is based on ionization of air because of the relative ease with which radiation induced ionization can be measured. The exposure unit may be converted into more fundamental unit of energy absorption per unit mass of air by using the charge on a single ion is $1.6x10^{-19}$Coulombs and that the average energy dissipated in the production of a single ion pair in air is34ev.(3)

2.1.2.4 Equivalent Dose:

Equal doses of all types of ionizing radiation are not equally harmful. Alpha particles produce greater harm than do beta particles, gamma rays and x

rays for a given absorbed does. To account for this difference, radiation does is expressed as equivalent does. The equivalent does (HT) is a measure of the radiation does to tissue where an attempt has been made to allow for the different relative Biological effects of different types of ionizing radiation. Equivalent does is therefore a less fundamental quantity than radiation absorbed does, but is more biologically significant.

Equivalent does has units of Sieverts (Sv). Another unit, roentgen equivalent man (REM or rem), is still in common use in the US, although regulatory and advisory bodies are encouraging transition to Sieverts (100 Rontgen equivalent man=100 REM= 1 sievert.).

Equivalent does (HT) is calculated by multiplying the absorbed does to the organ or tissue (DT) with the radiation weighting factor, WR. This factor is selected for the type and energy of the radiation incident on the body, or in the case of sources within the body, emitted by the source. The value of WR is 1 for x-rays, gamma rays and beta particles, but higher for protons, neutrons, alpha particles etc.

$$H_{T,R} = W_R * D_{T,R} \quad 2.6$$

Where $H_{T,R}$ = equivalent dose to tissue T from radiation R

$D_{T,R}$ = absorbed dose D (in grays) to tissue T from radiation R

The dose in Sv is equal to "absorbed dose" multiplied by a "radiation weighting factor" Prior to 1990; this weight factor was referred to as Quality Factor (QF). (12)

2.1.2.5 Effective Dose:

Effective dose equivalent (Now replaced by Effective Dose) is used to compare radiation doses on different body parts on an equivalent basis because radiation does not affect different parts in the same way. The effective dose is the sum of weighted equivalent doses in all the organs and tissues of the body.

Effective dose = sum of [organ doses * tissue weighting factor].

The effective dose (E) to an individual is found by calculating a weighted average of the equivalent dose (H) to different body tissues, with the weighting factors (W) designed to reflect the different radio-sensitivities of the tissues:

$$E = \Sigma i \, Hi \, Wi \quad 2.7$$

The unit for effective dose is the sievert (Sv) .One sievert is a large dose. The effects of being exposed to large doses of radiation at one time (a cute exposure) vary with the dose. Here are some.(ICRP 60, 1990 recommendation.)

Examples:

10 Sv - Risk of death within days or weeks.

1 mSv- Risk of cancer later in life (5 in 1000).

100 mSv-TLV for annual dose for radiation workers in any one year.

20 mSv-TLV for annual average dose, averaged over five years.

2.1.3 Limits or Guidelines:

20 mSv-limit value for average annual dose for radiation workers, average over five years.1 mSv Recommended annual dose limits for general public. (ICRP (International Commission on Radiation Protection) **)**

2.1.4 Image Quality

Quality of the image is its ability to reproduce in visible pattern the varying transmission of the x-ray through the object radiograph.

Image quality determine by three factors

1. Image contrast.

2. Image sharpness.

3. Image resolution. (4)

2.1.4.1 Image Contrast: Image contrast is the difference between various parts of the visible image.

Factors which affecting image contrast:

1. **The patient:** The atomic number, density and thickness of the structure

creating the contrast. All the factors must be chosen appropriate to each circumstance, so as to render the structure of interest visible on the radiograph as contrast.

2-**The Radiation**: The quality of the primary radiation (depends on KVp and applied waveform) is the variable which the technologist has attempt to achieve the contrast required. The presence of scatter radiation has marked effect on contrast, it determined by the KVp, the volume of tissue radiated (beam size and patient thickness) and the nature of any grid present.

3-**The Recording Medium:** The type of films, screen and processing used determined the film contrast. Also the quantity of radiation which controlled by Kvp, mAs and s. (10)

2.1.4.2 Image Sharpness: Is the breadth of the boundary between two areas of different density.

2.1.4.3 Image Resolution: Is its ability to reproduce as separate images structural details which separated by very small distance.

2.1.4.4 Effects of Poor Quality Image:

A poor quality image has three negative effects:

1- If the image is not adequate quality, practitioners may not have all the possible diagnostic information that could have been made available to them and this may lead to incorrect diagnosis.

2-If is so poor that it cannot be used then the patient shall be exposed again causing an increase in the cost of diagnosis.

3-Unnecessary radiation exposure to staff also occurs. (10)

2.1.5 Quality Assurance:

Quality assurance is the plane that involves continues monitoring to insure consistency, regular testing to detect equipment malfunction, regularity scheduled for equipment maintenance, and ongoing assessment of the variables that could affect image quality and diagnosis. Main purpose of quality assurance is to produce optimum quality image with minimum radiation exposure and cost to the patient. Quality assurance involves two areas: quality control and quality administration. (7)

2.1.5.1 Quality Control:

Is the integral part of quality assurance, it is a series of distinct technical procedure and tests that ensure the production of high quality diagnostic image.

These tests will enable the facilities to recognize whether parameters are out of limits, parameters result in poor quality image and increase radiation to the patient.

2.1.5.2 Quality Administration:

Is the management procedure that provide for the organization of quality assurance program.

2.1.6 Quality Assurance Program:

Distinct organized structure designed to furnish quality assurance for diagnostic radiology facility.

2.1. 7 Benefits of Quality Assurance Program:

A well-administrated radiographic quality assurance program has numerous benefits use of such program is one of the methods that can minimize unnecessary radiation to patients in diagnostic radiology facilities. Although the reduction in unnecessary patient's exposure is significant these programs can also improve the all over efficiency of radiographic service delivery, increasing patient's satisfaction.

The radiology facility is also the beneficiary of quality assurance. Improvement of the radiographic image quality is achievable, as is increased consistency of image production. Quality control procedure can increase reliability, efficiency, and cost-effectiveness of the equipment used by the facility. These are important gains, considering in health care delivery. Although increase overall department efficiency in itself is a major advantage, the betterment of personnel morale resulting from such improvement may be the most important benefit in the end.

2.1.8 Quality Assurance Program Recommendation:

The recommendation for establishing quality assurance programs in diagnostic radiology facilities was based on research, empiric data, and feedback from the professional community. Although the recommendation is not mandatory, the CDRH (Center for Devices and Radiological Health) strongly believe the goals of reduction un-productive patient radiation, minimizing unnecessary cost, and improving the constancy of quality images.

The CDRH recommendations include 10 elements that are considered essential for available program:

2.1.8.1 Responsibility:

Although quality assurance is the responsibility of the entire staff of the diagnostic radiographic facility, an efficient and effective quality assurance program requires accountability; therefore, distinct and documented assignments of responsibility for the program and its components are essential for success. The size of the facility, scope of the program and available resources are some of the factors that dictate the levels to which these responsibilities are assigned. A physicist, in house service engineer, a chef radiographer, supervisory personnel, staff radiographer and a consultant are examples of the individual who have quality assurance responsibility.

2.1.8.2 Evaluation:

The performance of the facility should be evaluated. This information can be used to determine the scope and deign of quality assurance program for the facility and to provide data that can be used for comparison with data generated at future points in time. These comparison evaluations demonstrate the effectiveness of the quality assurance program, the most often applied procedure used to evaluate facility performance is the analysis of rejected radiographs, commonly known as reject analysis. On another level, equipment-monitoring results should be evaluated to assess the need of corrective action or to determine trends that may indicate that preventive maintenance is required.

2.1.8.3 Purchase Specifications:

When new equ1ipment is purchase, the facility should determine the desired performance criteria for the equipment. These performance criteria are then reflected in the purchase specifications. Before final acceptance,

the equipment should be tested to ensure the actual performance specifications. The future monitoring and testing of the equipment can be compared with the equipment performance meets the criteria requested in the purchase specifications. The future monitoring and testing of the equipment can be compared with the equipment performance criteria to determine whether the equipment is continuing to perform at the acceptable level. (7)

2.1.8.4 Standards for Image Quality:

Standards for image quality should be established for the performance parameters of the x-ray system that are of interest to the facility. The creation of these standards should, when possible objectively indicate the amount of performance variation can be accepted before the quality of the image is affected. A subjective determination of the standards is often used when objective standards cannot be defined. If the equipment monitoring results show that the equipment does not meet the acceptance limits of the standard, then corrective action should be taken.

2.1.8.5 Monitoring and Maintenance:

Is sometimes referred to as quality control portion of the program, it the center of a quality assurance program. The CDRH suggests that every facility consider monitoring the following system components:

1. Wet chemical film/image processing.
2. Performance of radiographic/fluoroscopic units.
3. Cassettes and grids.
4. Illuminators.
5. Darkroom.

The CDRH includes a listing of parameters for all system components in its recommendation; a maintenance program that includes the preventive and

corrective aspects of equipment maintenance is an important aspect of any quality assurance program.

2.1.8.6 Education:

A plan for education personnel in quality assurance responsibilities is recommended. A mechanism for the continuing education of these individuals should also be included. A subtle but important aspect of this element is instructing the facility's staff about the importance, design and goals of the quality assurance program. The real strength of a quality assurance program is based on the support and commitment of the entire staff.

2.1.8.7 Committee:

The committee might be better described as communication. Large facilities may require a quality assurance committee structure for planning, review and evaluation purposes. Smaller facilities may not require a formal committee but instead may rely on input directly from the staff. The intent of this element is to emphasize the importance of maintain open communication among all participants in the quality assurance program.

2.1.8.8 Records:

The documentation of equipment monitoring result, maintenance action and other such activities should be included in a quality assurance program**.** Regular and systematic methods of collecting data are the foundation on which the review and evaluation elements of the program are based.

2.1.8.9 Quality Assurance Manual:

A quality assurance program should develop and maintain a complete, comprehensive and up-to date manual which should serve as a source document or guide for all elements of the program. The manual should include items such as quality assurance personnel, monitoring procedures

monitoring schedules, monitoring evaluations, corrective actions and service records.

2.1.8.10 Review:

Periodic review is necessary to determine the status of the quality assurance program. A look at the entire program can determine whether it is opening at its maximum effectiveness or whether change must be made. Inspection of the important program elements reveals their correctness, appropriateness, consistency, regularity and effectiveness in achieving the goals of program.

2.1.9 Visual Checklists:

Control Panel	Test
Meters	Kvp, mAs, or other meter must function
Displays	All numbers/ letters must function
Indicator light	Kvp, mAs, time must light
Exposure switch	Depression of exposure switch must cause x-ray production. Release of switch must cause x-ray to cease immediately, check x-ray production indicator(light or sound)

Table 2-1 Control Panel Visual Checklist

Illuminator	Light must work if light level decrease or not work service must be called.
Field size control	Moving of size control must increase or decrease size of light field.

Table 2-2 Collimation Visual checklist

Table movement	Movement must be smooth and the table must remain in the position placed in.
Bucky Movement	Movement must be smooth and bucky must remain in the position placed in.

Table 2-3 X-ray Table Visual Test

Cables	Cable must be not kinked, frayed, twisted or cracked.
Mechanical	Arms, table, bucky tray, etc must be checked for integrity and stability. They must not be warped, cracked, unstable, have loss screws or bolts. Arms holding x-ray tube must drift from position when placed for x-ray.

Table 2-4 General Visual Checklist

2.1.10 Quality Control Test

2.1.10.1 Quality Control Test Tools: In order to perform Q.C test a number of tools are required to be available depending on many factors as consider the cost of the test tools, consider the reliability, the test tools must be easy to operate and come supplied with clear concise instructions for use and do not purchase expensive and high accuracy test tools if the equipment to be tested is incapable of giving a high degree of accuracy in itself.(8)

2.1.10.2 Test Types:

2.1.10.2.1 Acceptance Test:

Performed upon newly installed equipment to verify purchase specifications and to establish performance base line. The frequency of this test is only when new machine is installed.(9)

2.1.10.2.2 Monitoring Test:

Performed for vital parameters on routine basis. The frequency of this test is every 2-3 months.

2.1.10.2.3 Annual Test:

Performed for vital parameters once per year.

2.1.10.3 Tests Procedures:

Generator and x-ray tube checklist

Record on the report form the following:

X-ray generator manufacturer, serial number, generator type, generator rating (maximum kvp, mA and mAs), exposure warning devices and x-ray tube selection and identification (if one or more).

X-ray tube manufacturer, model, inherent filtration, filtration non-removable (without tools), marking or focal spot position and maximum rated kvp.

2.1.10.4 Assessment and Evaluation:

Most of this information should be displayed by either permanent markings or labels on either the x-ray control or the x-ray tube housing if the data are not easily accessible, they may be available in the equipment manuals or from the manufacturer or manufacture's agent. If more than one radiographic x-ray tube can be operated from a single control panel, indication must be provided at or near the housing and on the control panel showing which x-ray tube has been selected. The exposure switch must be protected against accidental operation and of the dead-man type unless specifically exempted the exposure switch must arranged so that it cannot be operated outside the shielded area. (5)

2.1.10.5 Tube Voltage Accuracy Test:

Purpose of test: To determine the accuracy of the tube voltage.

Equipments required: Kv meter.

Method:

1. Read the operating instructions supplied with the Kvp meter and carry out the test. Following these instructions. It is important that kvp limits and requirements to mA, time and distance set out in the _+. Remember to elect the battery in the meter to ensure it does not need changing.

2. Ensure that the meter is placed on a flat surface, perpendicular to the reference axis of the x-ray beam, and center to the detector, collimate as necessary.

3. Repeat the test three times for each kvp tested to check for constancy.

Record the average of the three reading on the result sheet.

Assessment and Evaluation:

If any result varies by ± 10% contact the service engineer.

2.1.10.6 Accuracy of Exposure Timer Test:

Purpose of test: Used to check the accuracy of exposure timer.

Equipment required: kv meter (multifunction meter).

Method:

1. Place the digital meter on the table top with the detector facing tube.

2. Position the x-ray tube at the standard distance from the cassette such as 100 cm.

3. Center the tube to the sensor area and collimate the beam to its edges.

4. Switch on the timer meter ensuring that it is in the correct phase setting the equipment to be tested.

5. Select different exposure time at many times.

6. Make an exposure.

7. Recording reading on display at three times or more.

8. Record the average of the three readings on the result sheet.

Assessment and Evaluation:

If any result vary ±10% contact your service engineer.

2.1.10.7 Relative mA and mAs Linearity:

Purpose of test: This test will determine that mA or mAs stations are linear, relative to the first exposure throughout the range of mA and mAs stations. This will ensure that an exposure of 20 mAs is twice the value of an exposure at 10 mAs.

Equipment required: kv meter.

Method:

1. At each kvp set point take an initial exposure and with 100 mA or 10 mAs keep kvp and distance settings fixed and change only mA or mAs settings. All values are calculated relative to the first exposure at each kvp set point.

2. Press and hold the real mA or mAs button on the meter until you here a second beep.

3. Set the kvp, time and distance on x-ray unit. FFD of 100cm is recommended (40 in).

4. For ease of comparison, set the mA to 100(or the mAs to 10) and take the initialization of exposure.

5. Make exposures at various mA or mAs but do not change the other exposure factors.

6. Clear the meter and make the next exposure.

Assessment and Evaluation:

All data values are given relative to the initial exposure, with initial exposure of 100mA or 10 mAs , an exposure at 250 mA should give relative linearity reading of 250 and a relative mAs linearity reading of 25 relative mA/mAs linearity should be maintain to within ± 10 %.

2.1.10.8 Reproducibility Test:

Purpose of test:

To determine the reproducibility tube voltage and exposure times.

Equipment Required: kv meter

Method:

1. Ensure that any required x-ray tube warm-up has been followed.
2. Ensure that the x-ray beam covers the area of the detector recommended by the manufacturer.
3. Over a period not exceeding 10 minutes obtain a measure of 5 consecutive measurements at a single commonly used exposure setting.

NOTE: Before each exposure, the exposure setting should be altered and returned to the initial setting.

Assessment and The evaluation:

Reproducibility is assessed in terms of the coefficient of variation (CV), which is define as the ratio of the standard deviation to the mean values of a series of measurements calculated by the following equation:

CV=(standard deviation / mean)

CV =√ { ∑(kvp-kvp(av))2 /(n-1)}/ kvp(av)

The coefficient of variation (CV) less than (5%).

2.1.10.9 Half Value Layer Test:

Purpose of test: To assess the x-ray beam quality.

Equipment Required: Aluminum filters, kv meter, tape measure and masking tape.

Method:

1. Ensure that any required x-ray tube warm-up has been followed.

2. Any user added or adjustable filtration in the x-ray beam should be removed or set to the minimum value before proceeding with this test.

3. Position the detector and ensure that the x-ray beam cover the area that recommended by the manufacturer.

4.Select a tube voltage of 80 kvp and make an initial exposure using a mid-range tube current of about 100 mA and exposure time > o.1 and < 0.2.

NOTE:

If necessary other kvp values may used.

Record the dose.

Obtain a series of dose measurements adding increasing thickness of aluminum to the beam before each exposure until the dose has been reduce to 50% or less of that obtained without any added filtration.

NOTE:

The filters can be taped to the face of the light beam collimator.

Assessment and Evaluation:

The half value layer (HVL) is that thickness of a nominated material required reducing the x-ray beam output to one-half of its attenuated value.

It is a convenient measure of the quality of x-ray beam.

The minimum HVL requirements are shown in table 2.5 below:

Measured kvp	mm Al
70	2.1
80	2.3
90	2.5
100	2.7
110	3.o
120	3.2
130	3.5
140	3.8
150	4.1

The HVL measurement will increase with an increase in filtration, x-ray tube voltage and generator frequency.

When the x-ray tube assembly has user-variable filtration, the HVL should be made with the lowest filter selection. The HVL should also be re-measured with the most commonly used filtration in place.

While the HVL could be measured at any nominated kvp, 80 kvp is recommended for consistency. (Health Department of Western Australia, Radiological council 2000, Diagnostic X-ray Equipment Compliance Testing)

2.1.10.10 Focal Spot Size Test:

Purpose of the test: To determine the approximate size of the focal spot of the x-ray tube.

Equipment required: Focal spot test tool and loaded cassette.

Method:

1. Placed the loaded cassette on the x-ray table.

2. With FFD of 61 cm center the x-ray tube to the center of the cassette.

3. Collimate the beam around the test tool ensuring that the central ray passes through its center to give an image having reasonable contrast.

4. Be sure the cathode and anode of the tool parallel to those of the tube.

Assessment and Evaluation:

Test tool on the film image measure the diameter of the test object. Use this figure and the exact diameter of the test tool obtain and accurate value for M (magnification factor).

On the film image, measure the distance between the two regions of blurring at the widest point. This gives a value for D (blurring diameter).

For test tool with spokes set at 8 intervals.

i.e. $Fs = M*1$

$M - 1 = Lp/\ mm$

Where Fs = effective focal spot size

Lp /mm = line pair per millimeter resolved by x-ray tube.

M = the geometric magnification.

Compare your result with the nominal dimensions of the focus shown on the x-ray tube.

2.1.10.11 Light Beam Collimator Test:

Purpose of the test:

To check for misalignment of the light field and the radiation field of a standard light beam diaphragm and to evaluate the alignment of the reference axis.

Equipment Required:

Sprit level, collimator test tool, beam alignment test tool, cassette with intensifying screen (standard speed) and meter ruler.

Method:

1. Ensure that the x-ray tube and x-ray table are level and the anode-cathode tube axis is parallel to the tabletop.

The spirit level may used for this purpose.

2. Center the x-ray, table and buckeye if used together at a source to tabletop distance of 100 cm.

3. Placed the collimator test tool on the table with the beam alignment tool directly in the center.

4. Placed loaded cassette on the couch top or in the buckeye tray, ensure that this is also centered.

5. Cone down on the rectangular area on the collimator test tool.

6. Make an x-ray exposure which will produce a density of approximately 1.0 on the resulting radiograph, use the same focal spot on each occasion the test is carried out.

7. Process the radiograph.

8. In the case of an x-ray tube with dual target angles, it is necessary to carry out this test using both broad and fine foci using a separate cassette for each.

Assessment and Evaluation:

View the radiograph to see if the irradiated field shows just inside the rectangular frame or within 5 mm of it. Check that the two ball bearings are superimposed. If they overlap the central ray is perpendicular to within 0.5 degree if the test results appear unacceptable, ask advice from a competent person.

2.2 Previous Study:

In a study by (Mohammed Yosif Mohammed, 2005), titled in “Quality Assurance for Radiographic Imaging (Military Corps Hospitals in Sudan)”

It conclude that obviously there is missing of quality assurance and it's associated program, quality committee, quality control team, no availability of Q.C tools. Complete absence of preventive maintenance and Q.C program are the main reasons for the degradation of image quality and life span shorting of the x-ray machine.

Another study by (Fatima Abdulla Abuzaid, 2004), titled in “Quality assurance of diagnostic x-ray Machines in Algazera State Hospitals”

The study showed that there is complete absence of Q.C measurement and evaluation beside the complete absence of Q.C training in all x-ray departments in the state in addition to that there is a clear negligence in the area of the maintenance of the x-ray machines.

Chapter three

Materials and methods

Chapter three

Materials and Methods

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3.1 Materials

3.1.1 Test Tools and Procedure:

To carry out the quality control tests on the x-ray machine in Primary Health Care Centers in Khartoum State a number of test tools were used such as multifunction meter, star pattern for focal spot size, collimator test tool and Al sheets for HVL.

Before starting Q.C tests a checking for calibration and power supply (batteries) of the meter must be done to confirm that they give correct readings.

Figure 3.1 Multi-function meter

Figure 3.2 Example of HVL Tool

3.1.2. Direct interview:

To evaluate the QC and status of the x-ray machines in Primary Health Care Centers in Khartoum State a direct interviews were made with the technicians in order to focus on the difficulties they face during their work and to know their suggestions to improve the performance of the machines also focusing on availability of QC tests tools in the departments and QC program, also ask about QC training for technicians.

3-2 Method of Data Analysis:

Data will be analyzed by EXCEL a program used for calculating the collected data from the machine to evaluate its performance.

The total number of the machines under study is 27 of different types; 24 machines are major and 3 machines are mobile also they are different in companies; 18 machines are Yangzhou, 6 machines are Dergem and 3 machines are Shemadzu which are the mobile units, the percentage as the following; 66.7% Yangzhou (group one), 22.2% Dergem (group two) and 11.1 Shimadzu (group three).

Chapter four

Result,

Chapter Four

Results

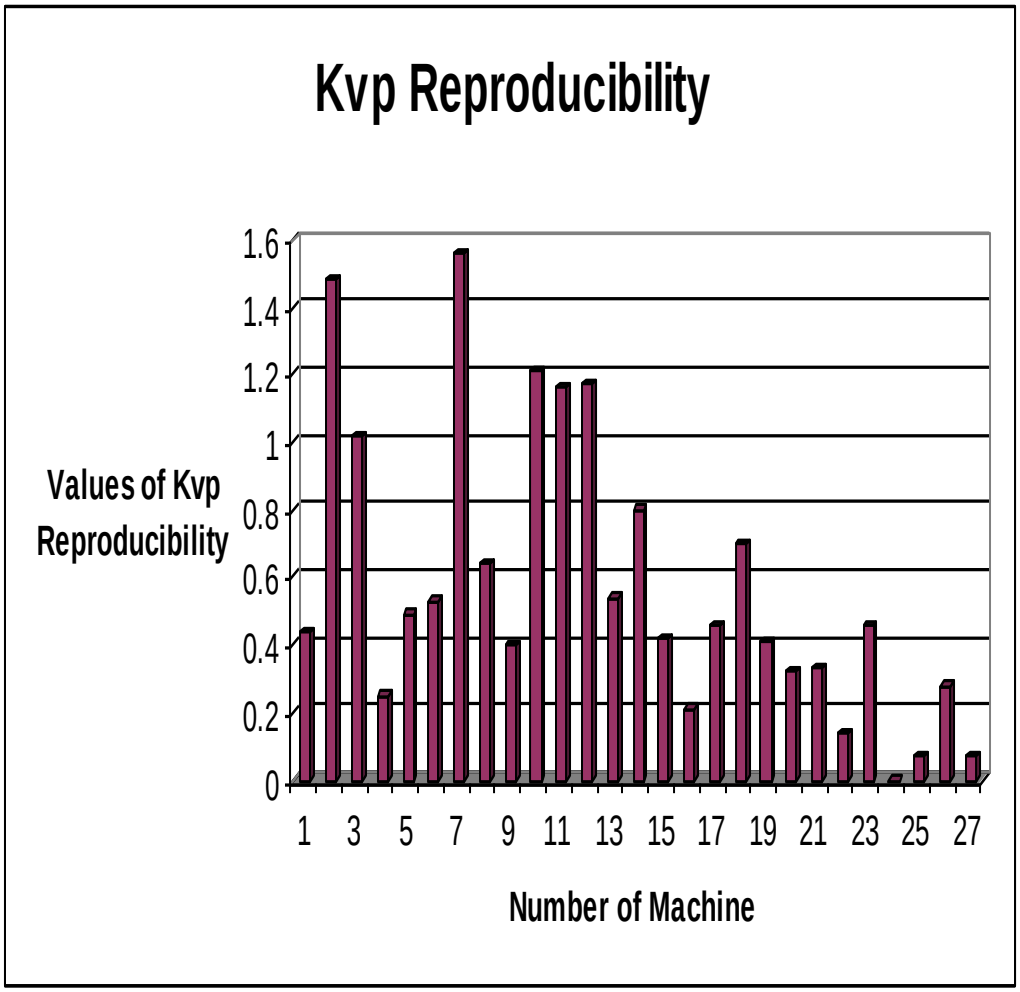


Figure4.1 Kvp Reproducibility

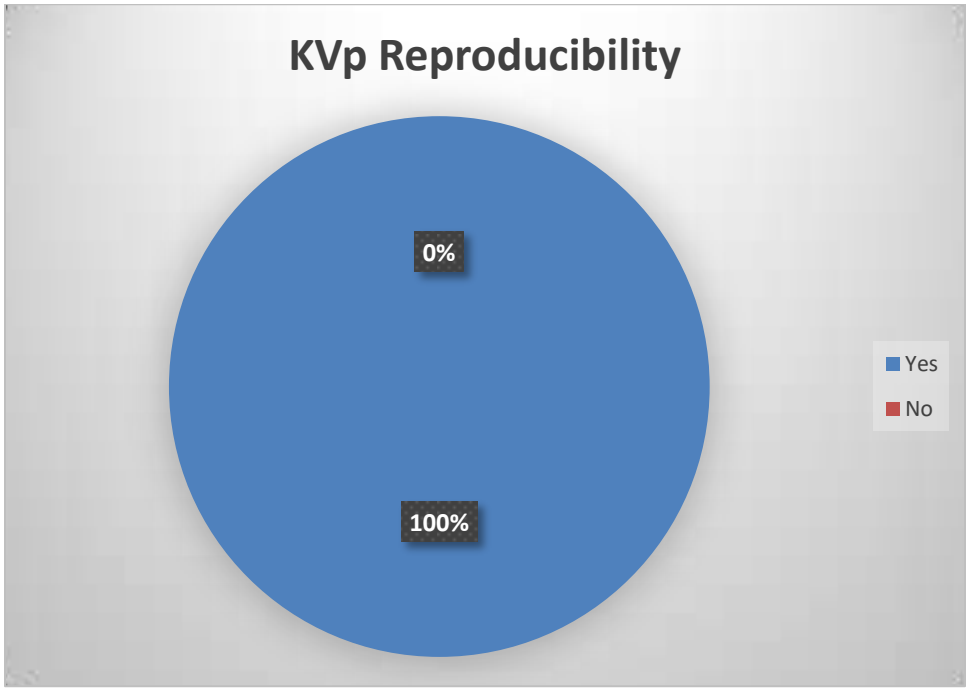
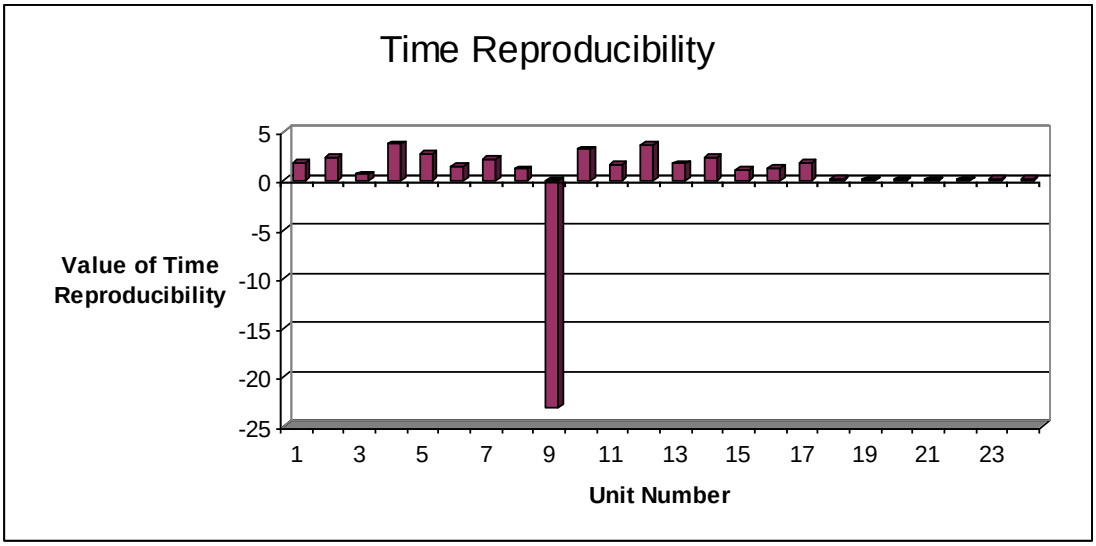


Figure 4.2 Kvp Reproducibility Percentages



.Figure 4.3 Time Reproducibility

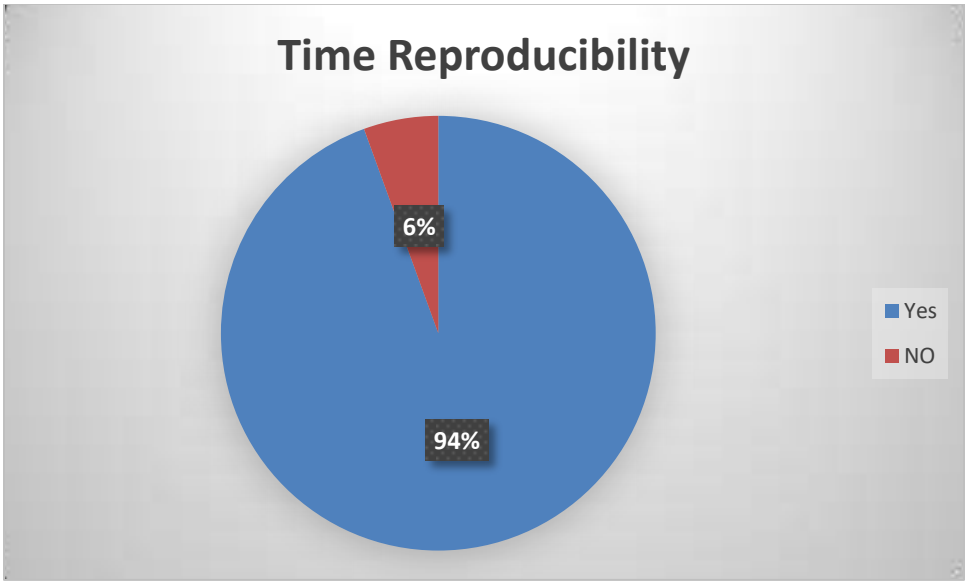


Figure 4.4 Time Reproducibility Percentages

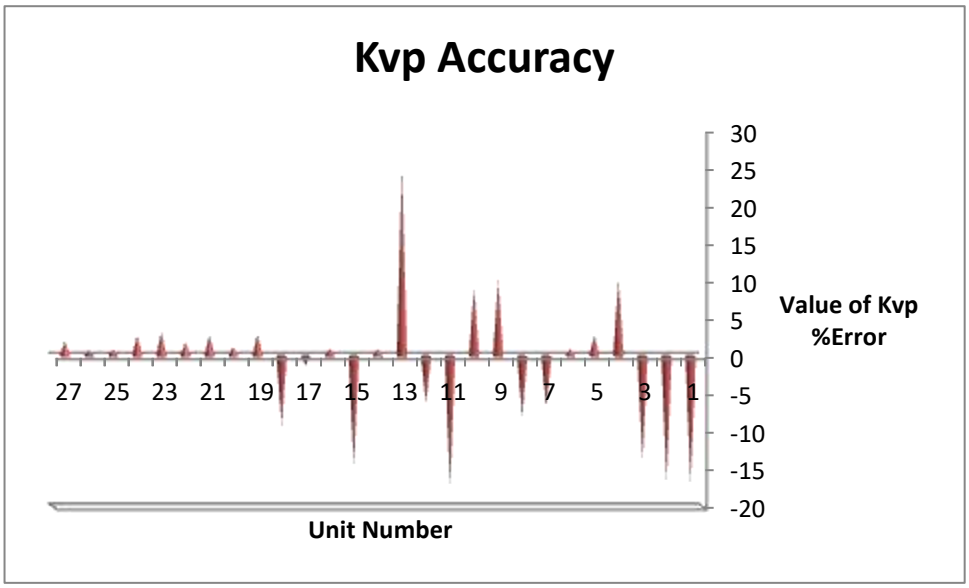


Figure 4.5 Kvp Accuracy

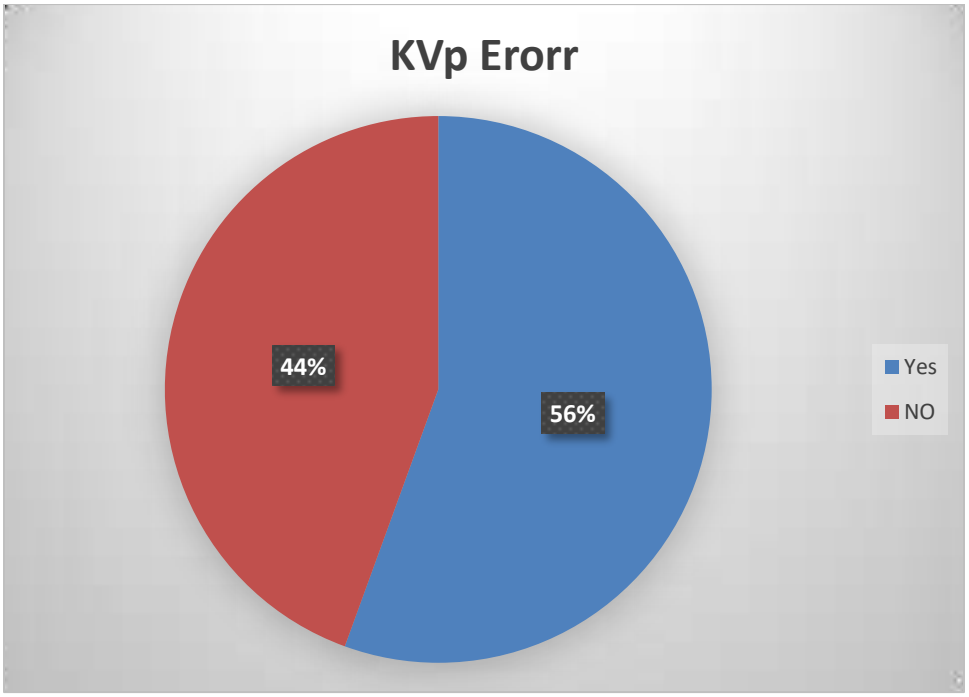


Figure 4.6 Kvp Accuracy Percentages

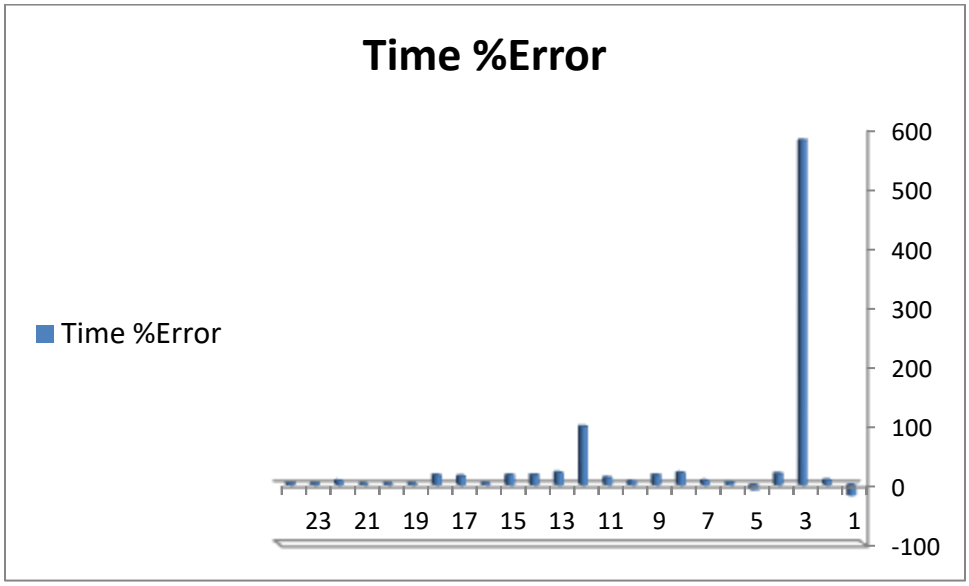


Figure 4.7 Time Accuracy

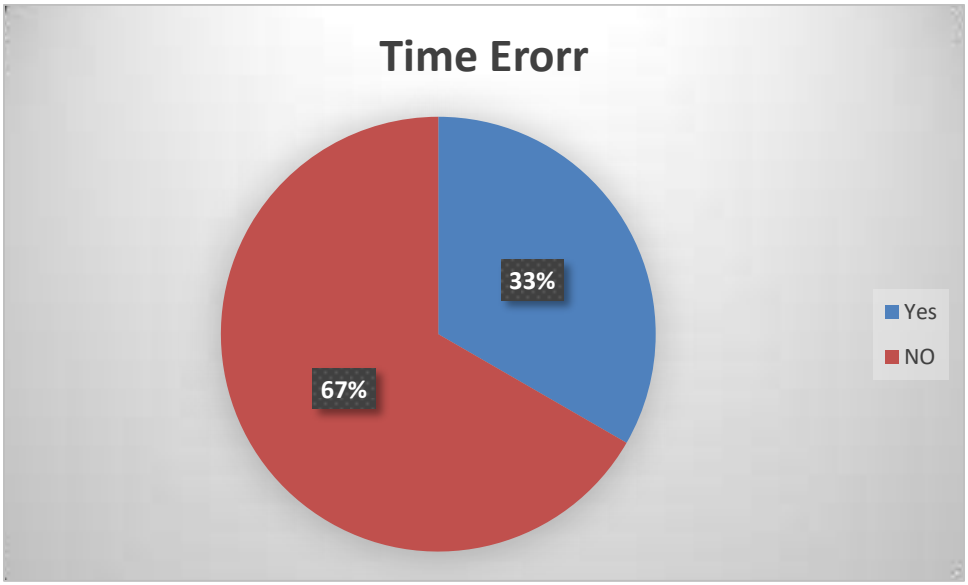


Figure 4.8 Time Error Percentages

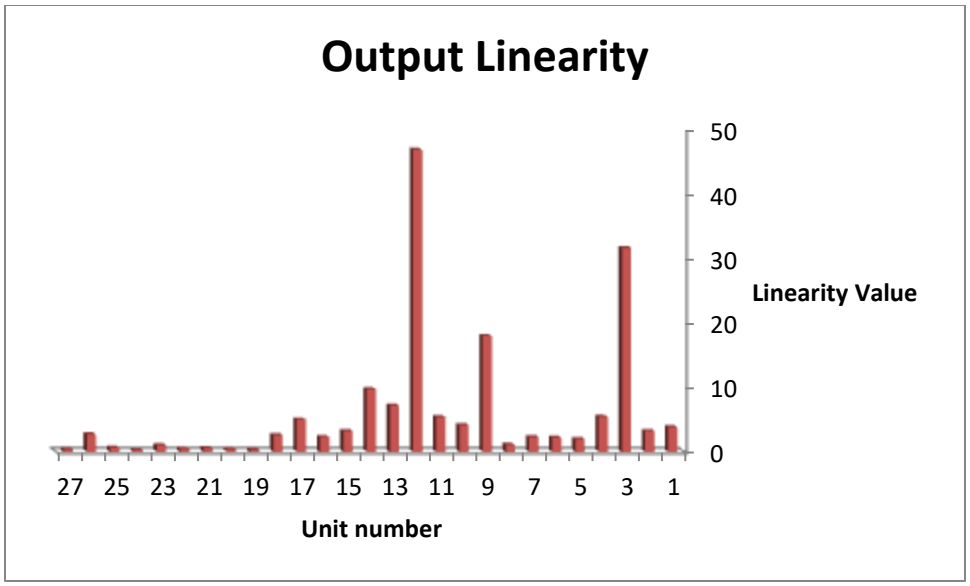


Figure 4.9 Linearity

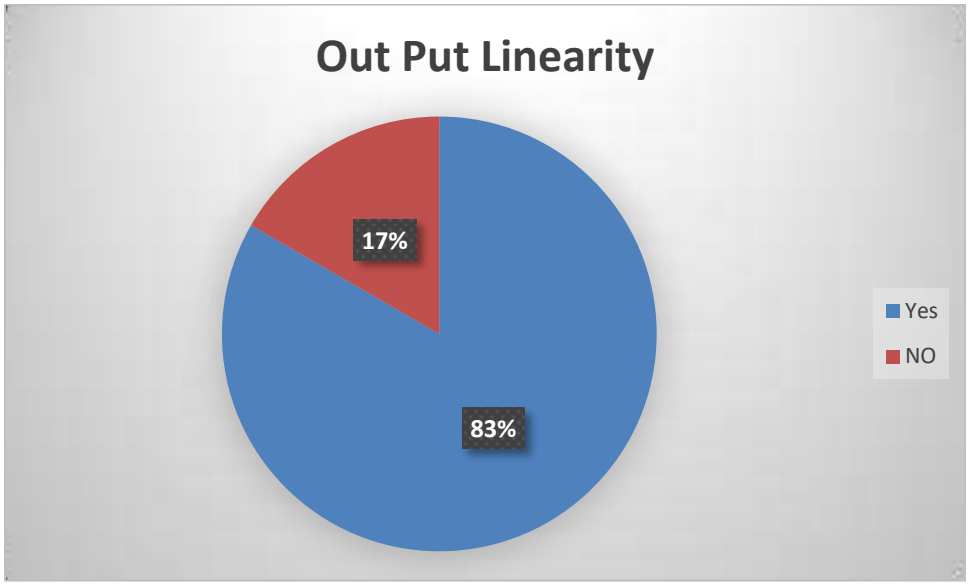


Figure 4.10 Linearity Percentages

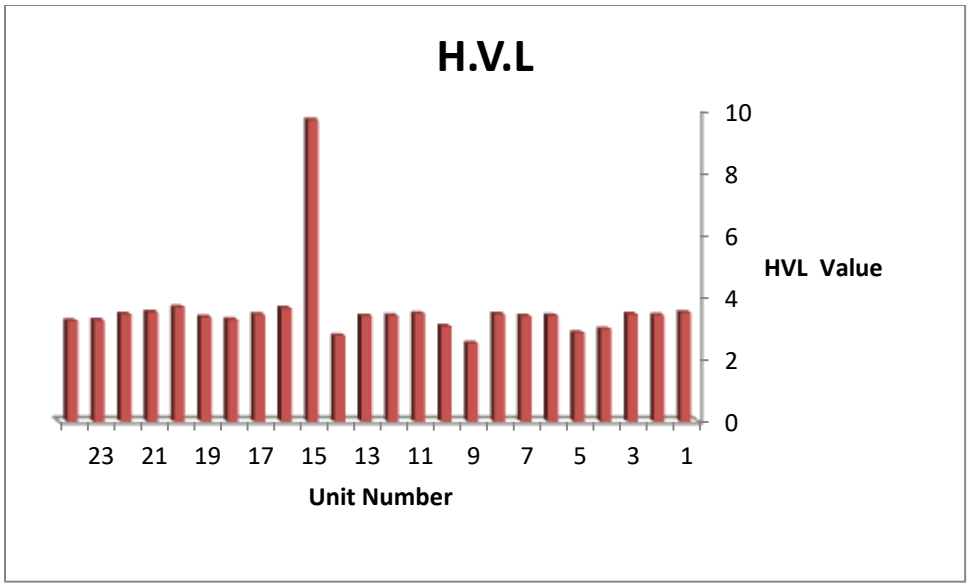


Figure 4.11 HVL

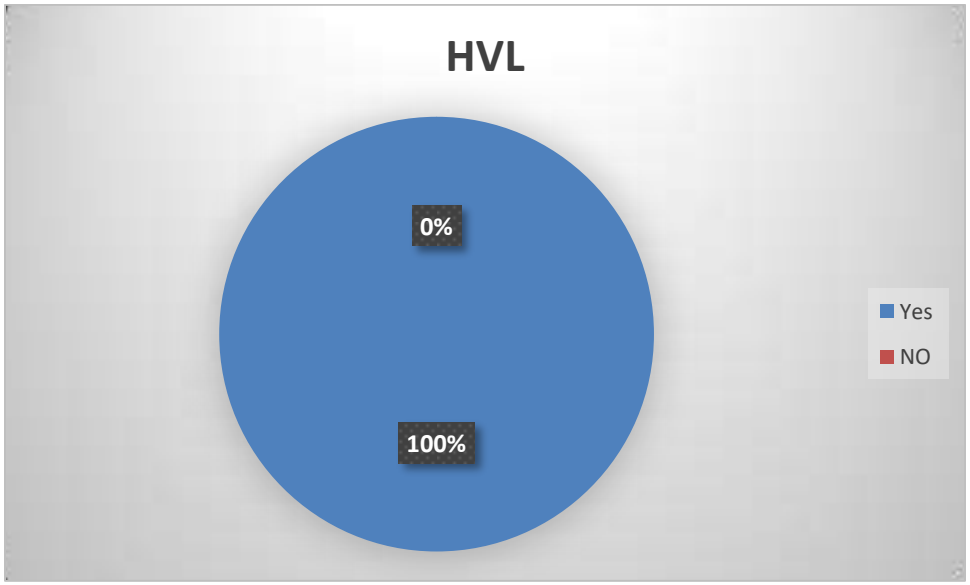


Figure4.12 HVL Percentages

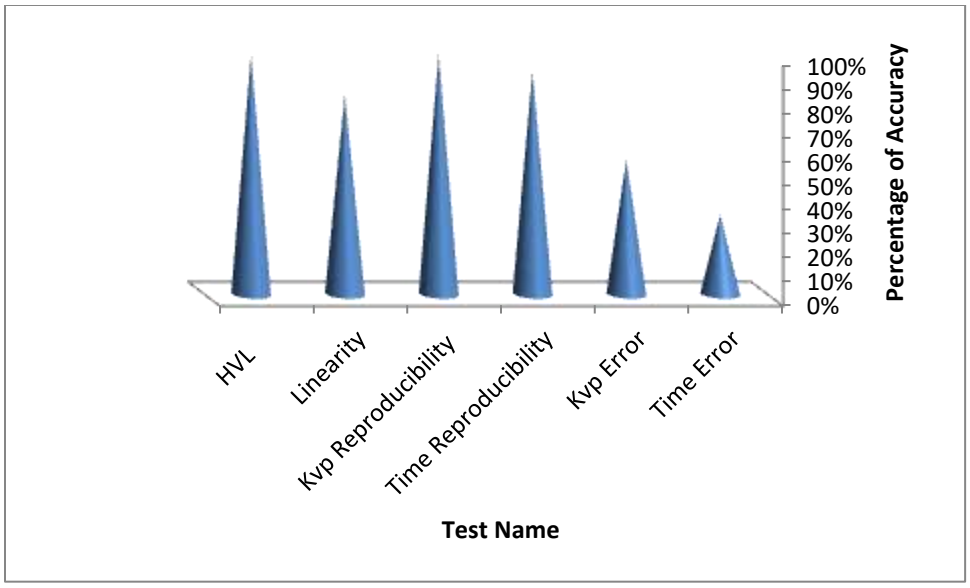


Figure 4.13 Percentage of Tests Accuracy

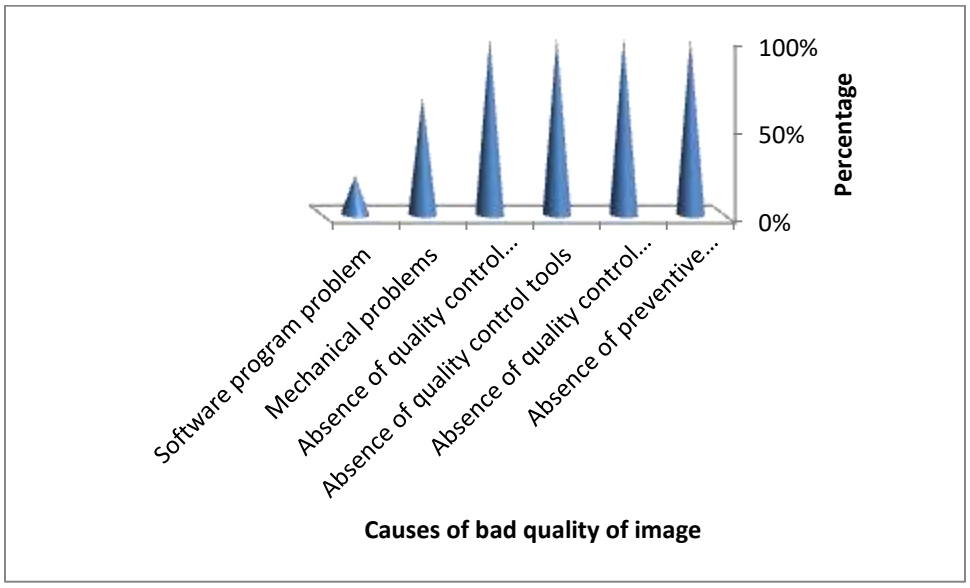


Figure 4.14 Interview Result

Chapter five

Discussion, conclusion and recommendation

Chapter Five

Disscussion, Conclusion and Recommendation

5.1 Discussion

The total number of x-ray units of study is 27 units. Table 4.1 shows kvp and time reproducibility which are directly affect the patient dose and image quality.

Reproducibility is assessed in term of the coefficient of variation (CV) which is define as the ratio of standard deviation to the mean values of a series of measurements calculated by the following equation:

CV= standard deviation/ mean

CV must less 5%.

Table 4.1 shows the reproducibility of Kvp and time. The reproducibility test show how selected kvp and time are the same when repeated them.

The minimum kvp reproducibility is zero for unit 24 and the maximum one is 1.56 for unit 7 the tow values are within the accepted range.

The minimum time reproducibility is -23.05 for unit 9 which is not accepted and the maximum is 3.70 for unit 4 which is accepted. Time reproducibility is not applicable for unit 25, 26 and 27 because they have no separate time switch.

Table 4.2 show the accuracy of kvp and time, for every unit set a series of kvp and time values consecutively each one give the exact measured value of kvp, from the selected and measured values the percentage of error is calculated which is not exceed ±10%, the final result for each unit is the mean of all readings. The maximum percentage error for kv is 25.18 for unit 13 which is not accepted and the minimum one is-17.44 for unit 11 also not accepted.

The maximum percentage time error is 581 for unit 3which is out of the accepted range and the minimum percentage is -8.7 for unit 5which is accepted. The test is not applicable for unit 25, 26 and 27 because they have no separate time switch

Table 4.3 shows the result of linearity and half value layer (HVL). The linearity determine that mA and mAs are linear, linearity should be maintain within ±10%, the maximum linearity is 46.76 for unit 12 which is out of limit and the minimum is 0,27 for unit 24 which is within the limit.

The maximum HVL is 9.7 mm of Al for unit 15 and the minimum is 2.52 for unit 9 the tow values are accepted, the test is not applicable for unit 25 , 26 and 27 because there diaphragm design not helps to carry out the test.

Direct interviews with the technicians show that absence of the preventive maintenance is 100%, absence of QC program is

100%, absence QC tools is 100% , absence of QC training is 100% , beside that there are many mechanical problems which are 66% such as diaphragm shutter movement, bucky tray clips and movement, oil comes out from the tube housing, difficulty in movement of the tube, the kv selector do not work below 60 kv, so in case of need to spare parts it is too difficult to be available even from the agency, no operation manual to help the technicians in operating the units in addition to unavailability of service manual for maintenance in 77.8% of all the units, software and programming problem is 22.2%.

The result of QC tests showed that the time and Kvp accuracy give lower reading 33% and 56% consecutively which they are the most parameters affect the image quality, time reproducibility 94% which determine irradiation time and control movement sharpness, linearity 83%,HVL 100% and kvp reproducibility 100% which determine quality of radiation, all these factors together affect image quality and consider a clear sign of increasing doses to the patients and staff.

The continuous weakness of these parameters is the main reason for producing bad image quality which reflected in great difficulty in diagnosis of the x-ray image and frequent repetition will result, this increase consumption of x-ray films and chemicals which delivered unnecessary radiation doses to the patients and workers.

Also the results showed that there is no person or team deal with QC in all centers therefore there is complete absence of QC measurements, no

training courses in QC for technicians and no QC program and tools. In addition results showed there is complete absence of preventive maintenance for x-ray machines which lead to progressive deterioration of their performance.

By referring to the result there are many x-ray machines need to be repair otherwise replaced by new ones.

All units have no operation and service manuals there for the actual size of the focal spot is not known which make the focal spot test is not applicable.

For group three of the units time tests are not applicable for they have no separate time switch and HVL test not applicable for the design of the diaphragm which not help to use the aluminum sheets.

5.2 Conclusion

The QC testing and evaluation combined with absence of organized QC team in Primary Health Care Centers in Khartoum State and complete absence of preventive maintenance are the main causes of continuous deterioration of image quality. There is no clear planning for purchasing x-ray machines with known specifications , also absence of machine calibration play an important role in frequent repetition of x-ray images which increase the running cost of x-ray departments, consumption of x-ray films, chemicals, time and increase radiation dose to the patients and staff , the main reason for all these problems is that the Sudan Atomic Energy Committee (SAEC) is not effective, it should make the performance of quality control tests obligatory for every working x-ray machines not in Khartoum only but around all the country.

5.3 Recommendation

1. Medical physicist and medical engineer are the key of quality control system; their presence is actually top of importance at least in every locality to carry out the routine QC measurements and calibration for x-ray machines to provide effectively the service of preventive corrective maintenance.

2. Establishment of QC team includes x-ray technician, medical engineer, medical physicist, radiation protection officer for quality and training purposes.

3. Operation and service manuals should always be found in x-ray department for maintenance and operating the x-ray machine.

4. Sudan Atomic Energy Commission must regulate the work of all radiation departments in the country and make quality control tests obligatory for any x-ray unit.

5. Increasing the awareness of the importance of QC program by continuous education, seminars and discussions for radiologist, technologist and other medical staff.

6. A plan should be set by the ministry of health to provide QC tools.

7. Establishment of committee its responsibility is to organize the purchasing operation for x-ray equipment of known specifications.

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