بسم الله الرحمن الرحيم

Sudan University of Science & Technology

College of Graduate Studies

Evaluation of Contrast Media Injection Protocols in Abdominal Examination using Computed Tomography

تقييم بروتكول حقن وسيط التباين في فحوصات البطن باستخدام الاشعة المقطعية

A thesis submitted for partial fulfillment of the requirements of the degree of M.Sc in Diagnostic Radiologic Technology.

Prepared By

Ahd Abdelmuniem Mergani Abdelrahmn

Supervisor

Dr. Mona Ahmed Mohammed

August 2020

الآية

صدق الله العظيم

Dedication

To the flower of my life that supported me and helped me, to the candle of my life that light my way.

To my family

To my supervisor

I dedicate this work for them

Acknowledgments

Thanks my God who enable me to realize the genuine meaning of success, ambitious living my dream come through and giving me.

My gratitude to my supervisor **Dr.Mona**, she did not hesitate to devote her knowledge and time for me. I am also grateful for assistance of the computed tomography department staff for their role in data collection.

Special thanks to everyone participated in this work by any way encourages either advising or appreciating our research.

Abstract

This was descriptive study to evaluate of contrast media injection protocols in computed tomography on period from January to July 2020,in this study it was evaluate the difference between CT devices using in hospitals also correlated between manual and automatic injector, and it was studied influence of HU, flow rate , amount of CM by type of device configuration, and type of injector. Data was collected from six variables (age, gender, HU density, flow rate, amount of CM and configuration device), the samples collected from different five hospitals.

The results of this study show that Comparing of mean for HU density, flow rate and amount of CM among all devices configuration where HU was higher at 128 (315.4) slice and lower at 64 (200.5), the flow rate was higher at machines with 128 (4) and lower at 64 (3.21), while the Amount of CM was higher at 128 (100) and lower in 16 (69.6),correlate between mean of HU density, flow rate and amount of CM, the manual injector give HU, Flow rate, Amount of CM was 242.5, 3.22 and 74.8 respectively while the automatic injector give 201.2, 2.84 and 73.26 respectively.

While compare between number of configuration device with type of injector, for automatic and manual injector, where the automatic injector 44 patients from 16 slice and 30 from 128 slice, while the manual 16 patients from 16 slice and 10 from 64 slice. And proved to study the best device is the 128 configuration and also proved to outweigh the injector automated on manual and also influenced by the value of HU by amount contrast and the size of the patient's . From the result the automatic injector reduce the radiation dose to the patient and this is ethical principle of radiation protection .

ملخص الدراسة

هذه الدراسة وصفية تهدف إلي تقييم برتكولات حقن وسائط التباين في التصوير المقطعي في الفترة من يناير الي يوليو 2020 ، في هذه الدراسة تم تقييم الإختلاف بين اجهزة التصوير المقطعي المستخدمة في المستشفيات ،وايضا المقارنة بين الحاقن اليدوي والحاقن الاوتوماتيكي ، وتمت دراسة تاثر قيمة ال HU ومعدل التدفق ومقدار CM بنوع الجهاز المستخدم ونوع الحاقن،وتم جمع البيانات من ستة متغيرات (العمر ،الجنس ،كثافة HU ،مقدارالتدفق ،مقدار CM والجهاز المستخدم) ، كذلك العينات تم جمعها من خمسة مستشفيات مختلفة .

اجريت هذه الدراسة علي ثلاثة اجهزة مختلفة (16،64،128 شريحة) ،حيث أظهرت نتائج هذه الدراسة أن مقارنة متوسط كثافة HU ومعدل التدفق ومقدار CM من بين جميع الأجهزة حيث كان ال HU أعلي عند 128 (315.4) ، واقل عند 64 (200.5) ، كان معدل التدفق أعلي في الاجهزة مع 128 (4) واقل عند 64 (3.21) ، بينما كان مقدار CM أعلي عند 128 (100) وأقل في 16 (69.6).

في الربط بين متوسط كثافة HU ومعدل التدفق ومقدار CM كان يعطي الحاقن اليدوي HU معدل التدفق مقدار 242.5 ، 3.22 و 74.8 علي التوالي بينما يعطي الحاقن التلقائي 201.2، 2.84و 73.26 علي التوالي.

عند المقارنة بين عدد اجهزة التكوين ونوع الحاقن الاوتوماتيكي واليدوي حيث الحاقن الاوتوماتيكي 44 مريضا من 16 شريحة و 30 من 128 شريحة بينما اليدوي 16 مريضا من 16 شريحة و 10 من 64 شريحة.

واثبتت الدراسة ان افضل جهاز هو 128 وايضا اثبتت ان تفوق الحقن الآلي علي اليدوي وايضا تأثر قيمة ال HU بكمية وسيط التباين وحجم المريض.

من نتيجة التحليل يتبين ان الحقن الآلي يقلل من الجرعة الاشعاعية للمريض وهذه احدي المبادئي الاخلاقية في الوقاية من الاشعاع.

Table of contents

List of Figures

List of Tables

List of abbreviation

CAT Computed axial tomography

CT	Computed tomography
CTA	Computed tomography angiography
CM	Contrast media
CIM	Contrast induced nephropathy
F	Flow rate
G	Amount of contrast media
HU	Houndsfield unit
KeV	Kilo electron volt
MDCT	Multidetector Computed Tomography
MIP	Maximum Intensity Projection
PME	Peak of enhancement
Sig	Significant correlation
TARR	Contrast material arrival time
TCTT	Plus contrast material transit time
TIV	The sum of injection duration
T peak	Time to peak enhancement
T PME	Delay time to peak
3D	3 dimension image

Chapter One
Introduction

1.1 Introduction:

The machine CT scan makes use of computer-processed combinations of many X-ray images taken from different angles to produce cross-sectional (tomographic) images (virtual "slices") of specific areas of a scanned object, allowing the user to see inside the object without cutting. Other terms include computed axial tomography (CAT scan) and computer aided tomography. Digital geometry processing is used to generate a three-dimensional image of the inside of the object from a large series of two-dimensional radiographic images taken around a single axis of rotation. Medical imaging is the most common application of X-ray CT. Its cross-sectional images are used for diagnostic and therapeutic purposes in various medical disciplines. The term "computed tomography" (CT) is often used to refer to X-ray CT, because it is the most commonly known form. But, many other types of CT exist, such as positron emission tomography .

An abdominal CT scan helps the doctor see the organs, blood vessels, and bones in abdominal cavity. The multiple images provided give the doctor many different views of the body. Multi detector row computed tomography (MDCT) also known as multi slice , is the latest breakthrough in CT technology .it has transformed CT from trans axial cross sectional technique into truly 3D imagine modalities . (D. Karthikeyan et al., 2005)

Contrast materials also called contrast agents or contrast media, are used to improve pictures of the inside of the body element. These contrast materials can be injected into veins or arteries, within the disks or the fluid spaces of

the spine, and into other body cavities. Barium-sulfate is the most common contrast material taken by mouth, or orally with a concentration about 300 mgI/ml. It is also used rectally and is available in several forms, The types

of contrast include:- powder, which is mixed with water before administration, liquid, Paste and Tablet. Water soluble C.M chemically is.an iodinated contrast medium that is absorbed by the blood and excreted by the kidneys. When iodine-based and barium-sulfate contrast materials are present in a specific area of the body, they block or limit the ability of x-rays to pass through. As a result, blood vessels, organs and other body tissue that temporarily contain iodine-based or barium compounds change their appearance on x-ray or CT images. (Debabrata Mukherjee et al 2007)

1.2 Problem of study:

The variations in contrast parameters according to hospitals protocols, the difference between CT devices used in hospitals and their effect on parameters and variations between the technologist staff in one hospital .

1.3 Objectives of the study:

1.3.1 General objective:

To evaluate contrast media injection protocols in abdominal CT examinations and correlate between ct device using and contrast media parameter

1.3.2 Specific objective:

- To determine contrast parameter in different detector configuration .
- To study the variation in contrast media parameters.[volume- flow rate- scan delay]. With different method triggering
- To determine the influence of all previous parameters on the HU density of abdominal aorta.

1.4 Thesis over view:

This research will contain five chapters:

Chapter one include the introduction, problem and objective of the study. Chapter two contain the theoretical background and previous studies. Chapter three found to be discuss the materials and methodology use to collect the data. Chapter four contains the results achieved. Chapter five including discussion of the results, conclusion and recommendations.

Chapter Two

Theoretical Background

2.1 CT angiography

In clinical practice, contrast material is widely administered to improve image quality and diagnostic sensitivity .Currently, over 60% of total computed tomography (CT) examination routines performed in the United States are contrast enhanced. CT angiography (CTA) may be used to visualize arteries and veins throughout the body and is an attractive alternative to traditional catheter-based angiography in appropriate circumstances.

CTA uses contrast agents for the visualization of blood vessels. Many different contrast agents are available today, for CTA. Iodine, the main component of X-ray contrast media, has a high molecular weight which can be combined with larger molecules to form radio-opaque contrast agents.127I is the only stable isotope and is used in all iodinated contrast media. Iodine has a K-edge at 33.2 keV and therefore X-ray attenuation in blood vessels is enhanced compared to surrounding tissue. Iodinated contrast media may be divided into water-soluble, water-insoluble, and oily contrast media. (Bae KT et al 2003)

The two major clinically important attributes of a contrast agent are its iodine dose (concentration X volume) and osmolality. To maintain good radiographic efficacy and safety, contrast agents must balance the somewhat paradoxical relationship between these two properties. Iodine dose refers to the amount of iodine delivered in an injected dose of contrast material. The iodine, delivered by iodinated benzene ring compounds, produces radiographic ‗contrast' by blocking X-rays. Visualization is typically

improved by increasing the iodine load, a function of the percentage of iodine and the concentration of the compound present upon injection. Increasing the

iodine load, however, results in increased 5 osmolality. Osmolality refers to the number of dis- solved particles in a solution, or the concentration. Ideally, contrast agents injected into the vasculature should have an osmolality as close to that of body fluids as possible. Solutions with osmolality greater (hypertonic) or less (hypo- tonic) than that of body fluids can cause cells to shrink or swell, respectively, contributing to hemodynamic, physiologic, and biologic adverse effects. The body also attempts to quickly dilute and excrete hypertonic solutions to maintain osmotic equilibrium. Therefore, the benefits gained from increasing the iodine load in contrast agents to improve radiographic efficacy may be offset by the adverse effects associated with higher osmolality solutions. The goal should be to use the lowest dose and volume of contrast necessary for adequate CTA. (Debabrata Mukherjee et al 2007)

2.2 The two major clinically important attributes of a contrast agent:

These are its iodine dose (concentration X volume) and osmolality. To maintain good radiographic efficacy and safety, contrast agents must balance the somewhat paradoxical relationship between these two properties. Iodine dose refers to the amount of iodine delivered in an injected dose of contrast material. The iodine, delivered by iodinated benzene ring compounds, produces radiographic ‗contrast' by blocking X-rays. Visualization is typically improved by increasing the iodine load, a function of the percentage of iodine and the concentration of the compound present upon

injection. Increasing the iodine load, however, results in and biologic adverse effects. The body also attempts to quickly dilute and excrete hypertonic solutions to maintain osmotic equilibrium. Therefore, the benefits gained from increasing the iodine load in contrast agents to improve radiographic efficacy may be offset by the adverse effects associated with higher osmolality

solutions. The goal should be to use the lowest dose and volume of contrast necessary for adequate CTA. (Debabrata Mukherjee et al,. 2007).

2.3 Fundamentals :

Currently used contrast agents are chemical modifications of a 2,4,6-tri-iodinated benzene ring and are classified on the basis of their physical and chemical characteristics.

For clinical purposes, categorization based on osmolality is widely used. Broadly, there are two types of agents, high osmolality ,and low-osmolality agents, with distinct advantages and disadvantages. Iso-osmolarity agents which have traditionally been included within low-osmolarity agents are now viewed as a separate class. In general, individuals with prior significant contrast reactions, active asthma, severe heart failure, aortic stenosis, severe pulmonary hypertension ,or significant renal dysfunction (serum creatinine _2mg/dl) should receive either a low-osmolar or preferably aniso-osmolar agent. Iso-osmolal agents have also been shown. (Debabrata Mukherjee et al,. 2007).

2.3.1 High-osmolar contrast agents :

The osmolality of these ionic agents in solution ranges from600 to 2100 mOsm/kg, versus 290 mOsm/kg for human plasma. Commonly used high-osmolar contrast agents are Renografin TM or HypaqueTM (diatrizoate anion) and Conray (iothalamate anion). The iodine content of diatrizoateis 370 mgI/ml and iothalamate is 400 mgI/ml. When injected for CTA, high-osmolar agents (Hypaque, Conray,Renografin) opacify blood vessels and are then rapidly carried the blood stream to the kidneys, where they areexcreted unchanged mainly by glomerular filtration, permitting visualization of opacified heart chambers and blood vessels. With these agents, the degree of enhancement is directly related to the amount of iodine administered. Peak

iodine blood levels occur immediately following rapid injection of the dose and fall rapidly within 5 to 10 minutes. The exact dose and rate of injection depend on the particular territory of interest, the particular CT scanner, and the number of detectors. It should be noted that very few clinicians currently use high-osmolarity contrast agents. (Debabrata Mukherjee et al 2007)

2.3.2 Low-osmolar non-ionic contrast Agents :

Common examples of low-osmolar and *non-ionic* monomersare iohexol (OmnipaqueTM), iopamidol (IsovueTM),ioversol (OptirayTM), and iopromide (UltravistTM). The respectiveiodine contents are iohexol: 140, 180, 210, 240, 300 and350 mgI/ml; iopadimol: 200, 250, 300 and 370 mgI/ml; ioversal:160, 240, 300, 320 and 350 mgI/ml; and iopromide: 150,240, 300 and 370 mgI/ml. Low-osmolar*non*-ionic contrast agents are

used in a broad range of intravascular diagnosticprocedures such as peripheral and coronary angiography, spinal cord imaging, and body cavity procedures including shoulder and knee joints. Immediately following intravascular injection, these agents reach peak plasma concentration andare then rapidly distributed throughout the extracellular fluid compartment. Low-osmolar agents do not normally cross the blood–brain barrier to any significant extent. It is excreted unchanged by the kidneys, mainly by glomerular filtration anda very small quantity (1 to 2%) is excreted via the bile. Typically these agents are injected intravenously through a 20 gaugeantecubitalangiocatheter with a power injector. The rate of injection and volume depend on the vascular bed. Low osmolar agents are the most commonly used contrast agents for CTA . (Debabrata Mukherjee et al,. 2007)

2.3.3 Iso-osmolar contrast agents:

The lower osmolality of iso-osmolar agents such as iodix- anol (VisipaqueTM, GE Healthcare) which is non-ionic iso- tonic with blood

causes fewer and less severe osmolality related disturbances, such as, pain, heat, and a burning sensation, upon injection. Iodixanol has approximately one-third the osmolality of the non-ionic media and one- sixth that of the monomeric ionic media of equi-8 iodine concentration. Visipaque is the only contrast medium cur- rently available for intravascular to use that is isosmolar to blood at all available iodine concentrations. In other words, it has the same osmolality as blood at the 270 mgI concentration and the 320 mgI concentration. (Debabrata Mukherjee et al,. 2007)

2.4 Contrast Administration:

2.4.1 Contrast material :

Non-ionic low osmolar such as iohexol (OmnipaqueTM),iopamidol (IsovueTM, NiopamTM), ioversol (OptirayTM), iopromide(UltravistTM), ioxaglate (HexabrixTM), or an iso osmolar agent, iodixanol (VispaqueTM) is typically used. The iodine concentrations of these agents are in the range of 300–400 mgI/ml.

2.4.2 Injection site :

For most peripheral applications contrast material may besafely administered in one of the forearm superficial veinsthat drain into the deep venous system of the upper extremity. For most applications involving the arch and thoracicaorta, the right upper extremity is preferred because of theshorter course of the right brachiocephalic vein that resultsin less _streaking‘ artifact. Additionally this allows unimpededevaluation at the internal mammary artery whenindicated. However, this may be irrelevant if the only accesssite available is the left upper extremity.(Debabrata Mukherjee et al 2007)

2.4.3 Intravenous access :

For most applications at least a 20 gauge access is recommended to allow faster injection rates. A smaller gauge iv cannula may require higher iodine-containing contrast agents to allow higher peak attenuation values.

2.5 Contrast arrival timing :

In CTA determination of the appropriate scan timing is important in obtaining satisfactory images. Determination of the appropriate time for image acquisition can be obtained by atest bolus sequence or by using bolus-tracking methods. The purpose of determining the appropriate scan delay is that patient-related factors, for example low cardiac output and other physiologic variables such as concomitant disease states ,will alter the time of the arrival of contrast agent in the vascular territory of interest.

Parameters affecting bolus geometry.

(a) The influence of contrast material (CM) volume. Increasing the volume of injected CM produces an increase in the peak of maximum enhancement (PME), and a delayed time to peak (tPME).

(b) The influence of CM injection rate. Increasing the rate of injected CM produces an increase in PME, and an earlier tPME.

(c) The influence of CM iodine concentration. Increasing the iodine concentration of the injected CM produces an increase in PME, without any influence on tPME.

(d) The influence of the saline chaser. The saline chaser pushes the injected contrast medium through the veins of the forearm, providing a result similar to the injection of a larger contrast volume. The example shows the effect of a 50 ml saline chaser (thicker curve), using a bolus with the same volume, rate, and iodine concentration. Moreover the saline chaser prevents the decrease of the CM in the arm veins, which may normally cause an increase in the CM concentration after the end of contrast injection.

(e) The influence of scan time are consistent, but with a shorter scan time, as with 16-row multi-slice CT, the importance of a lone plateau enhancement is reduced if compared to the impact of a very high PME. (Debabrata Mukherjee et al,. 2007).

2.5.1 Fixed delay :

This involves usage of an empirically derived delay to predict bolus arrival. As such this should be rarely used as it may result in inappropriate timing of contrast arrival and because there are better ways to predict bolus arrival. Practically however, usage of empiric delays has been used routinely in CTA with very good results in the majority of patients. (Debabrata Mukherjee et al 2007)

2.5.2 Test bolus technique :

In this method, a small test bolus (5 ml of iodinated contrast)is injected, followed by a saline bolus of the same volume and speed used in the actual CTA protocol (usually 50 ml of normal saline). The time to peak enhancement is calculated and is used to predict the true contrast arrival by using an empiric correction factor (usually 6–8 s). This is because the bolus geometry of the test bolus (being smaller) is different from the actual contrast injection (larger volume). The latter is going to be shifted to the right and thus one needs to add an arbitrary duration that corresponds to this delay. There is very poor correlation between the time to peak enhancement of the test bolus and the time to peak enhancement of the actual contrast injection. In contrast, there is good correlation between peak enhancement of the test bolus and attainment of a predetermined threshold such as 100 or 150 HU on the main injection protocol. Thus beginning the acquisition on the ascending limb of the contrast curve may be advantageous if the arterial bed is located in the mid portion of the scan range, which will actually correspond to peak arterial opacification.

In contrast, if the vessels are located at the beginning of the scan range, this may result in starting the scan too early. (Debabrata Mukherjee et al,. 2007)

2.5.3 Bolus tracking :

A better approach to timing the scan is the use of bolus tracking techniques. This involves a real-time tracking technique based on a user-defined area of interest within the lumen of the artery to be imaged. A threshold attenuation is chosen at which to trigger the actual CTA acquisition.

This arbitrary threshold can vary depending upon the application and the goals of the study. Thus, the scan is initiated on attainment of this empiric threshold. Furthermore, there is a small time delay dependent on the scanner, between detection of the threshold enhancement and actual initiation of scanning . (Debabrata Mukherjee et al,. 2007)

2.5.4 Bolus triggering protocol :

A region of interest is placed in the aortic arch image with a predefined threshold of 50–70 Hounsfield units (HU) to initiate the CTA acquisition. The contrast medium infusion and the scanner are activated at the same time, with monitoring scans starting after a scan delay of 6 10sin order to allow contrast to travel from the peripheral circulation to the central venous system. The CTA acquisition mode is automatically activated from the bolus tracking algorithm after a short pause (5–6 s, depending of the CT device). The breathing instructions are given to the patient during this pause. With 64-slice scanners it is possible to trigger from the left ventricle, with

coverage of the entire thoracic aorta and cervico-cranial circulation. (Debabrata Mukherjee et al,. 2007)

2.6 Limitation:

2.6.1 Adverse reactions:

Adverse reactions to contrast agents range from mild reactions such as itching associated with hives, to life-threatening emergencies such as laryngeal edema and even death. Renal toxicity is a well known adverse reaction associated with the use of any intravenous contrast material. Other forms of adverse reactions include delayed allergic reactions, an aphylactoid reactions, and local tissue damage. Prior history of allergic reactions to contrast material, asthma, and known multiple allergies are factors associated with an increased risk of developing an adverse reaction.

2.6.2 Contrast Nephropathy :

Patients should be well hydrated prior to a contrast enhanced study, and hydration should be continued for several hours after a contrast-enhanced procedure is performed. Other potentially nephrotoxic drugs should be discontinued when- ever possible prior to contrast administration. The minimal amount of contrast material, preferably a non-ionic, low-, or iso-osmolar agent, 13 needed to perform a diagnostic study should be used. If multiple studies are required, several days should be allotted between studies to allow the kidneys to recover fully from the first injection. N-Acetylcysteine with hydration may reduce the risk of contrast nephropathy in patients with chronic renal insufficiency and should be considered in appropriate patients.

2.6.3 Practical Pearls:

- The two major clinically important attributes of a con- trast agent are its iodine dose and osmolality.
- CTA requires tailoring the delivery of iodinated contrast by adjusting volume, concentration and rate, to optimize timing of the scan.

- There is poor correlation between the time to peak enhancement of test bolus and time to peak enhancement of the contrast injection while there is good correlation between peak enhancement of test bolus and attainment of a threshold such as 100 or 150 HU.
- The rate of injection and volume of injected contrast depend on the vascular bed being studied, the scanner, number of detectors and pitch.
- While bolus tracking the injection duration should at least equal the scan duration plus an additional time delay between detection of the threshold and initiation of scanning (2 to 9 seconds).
- Low osmolar agents are the most commonly used contrast agents for CTA.
- Injection speed, volume, and iodine concentration are the main factors that influence bolus geometry.
- Factors such as age, gender and hemodynamics do not affect geometry.

- The best approach to scan timing is usage of bolus tracking techniques which involves a real-time tracking technique based on a user-defined area of interest within the lumen of the artery to be imaged.

2.7 Intravenous Contrast Medium Administration and Scan Timing at CT :

2.7.1 Distribution of Concentration Medium within the Body :

After peripheral intravenous injection ,contrast medium travels to the right heart, the pulmonary circulation, and the left heart before reaching the central arterial system. Its circulation throughout the body is regulated by the cardiovascular system. Contrast medium rapidly redistributes from the

vascular to the interstitial spaces of the organs. Because iodinated contrast media consist of relatively small molecules that are highly diffusible, the transport of contrast media is predominantly ―flow limited‖ and far less ―diffusion limited.‖ In a flow limited process, the delivery of contrast medium through the circulatory system to an organ is a crucial determinant of contrast enhancement . Well-perfused organs such as the kidney, the spleen, and the liver show high contrast enhancement during the initial circulation (first pass) of contrast medium to the Organs . (Bae KT et al 2003)

As contrast medium circulates in the body, it is diluted by the blood, and the bolus disperses as it moves downstream through the circulatory system. The effect of dilution is greater in organs more distal from the injection site (typically antecubital vein)—progressively broadened contrast enhancement profile with a more flat tened peak. In addition, contrast material–enhanced blood recirculates and may contribute to the overall pattern of contrast enhancement achieved at CT imaging acquisition (2 , 17 – 19). For very long injections, the recirculation can even occur during the infusion of the contrast material. Recirculated contrast-enhanced blood does not reach a target organ simultaneously because of multiple circulatory pathways in the body. For example, blood in the cerebral circulation returns to the right heart and recirculates faster than blood in the portal circulation. (Bae KT et al 2003)

The transit time for normal recirculation may range 15–40 seconds depending on circulatory paths (faster for shorter paths). The recirculated contrast medium is 15 further diluted by intravascular and extracellular volume, and the bolus dispersion is largely governed by blood flow and tissue perfusion. The fractional contribution of recirculation to the overall magnitude of enhancement depends on the duration of injection and the time course of enhancement. For a short injection (, 15seconds), the contribution of

recirculated contrast medium to peak aortic enhancement is likely small. The aortic peak time-enhancement curve is similar to a Gaussian curve (a rapid initial rise followed by a short peak and rapid decline) . Conversely, when contrast medium is injected at a constant rate for a long injection, the new contrast media and the recirculated contrast media already in the body mix and accumulate, resulting in a more gradual increase in aortic enhancement over time. A typical aortic enhancement profile for long-injection duration then consists of a rapid initial rise, gradual increase, peak, and gradual decline. The contribution of recirculation to peak arterial

enhancement is likely 10%–20% for a typical clinical injection (. 15 seconds). In a theoretical physiologic model with no recirculation contribution, aortic contrast enhancement . (Bae KT et al 2003)

2.7.2 Mathematical Modeling of Contrast Enhancement in Humans

The large body of physiologic data available for the human cardiovascular system allows us to estimate the propagation and distribution of contrast medium throughout the human body. The distribution of contrast medium in an organ depends on the perfusion rate, tissue volume, tissue composition of the organ and permeabilities throughout the organ microvasculature and cellular interfaces. When contrast medium is considered a pharmaceutical injected intravenously, its in vivo distribution can be predicted by using mathematical techniques developed in pharmacokinetics. A physiologically based computer model of whole-body contrast enhancement was generated . (Bae KT et al 2003)

2.7.3 Factors Affecting Contrast Enhancement and Scan Timing :

Contrast enhancement at CT is affected by numerous interacting factors .These factors may be divided into three categories: patient, contrast medium, and CT scanning .

Contrast medium pharmacokinetics and contrast enhancement are determined solely by the patient and contrast medium factors and are independent from the CT scanning technique. Nevertheless, CT scanning factors play a critical role by allowing us to acquire contrast enhanced images at a specific time point of contrast enhancement. The patient and contrast medium factors are highly interrelated, and all contribute to the distribution of contrast medium after injection and the resulting dynamics of contrast enhancement; some of the factors are more influential on the magnitude while others are more influential on the temporal pattern of contrast enhancement. (Bae KT et al 2003)

2.7.4 Patient Factors :

The key patient-related factors affecting contrast enhancement are patient body size (weight and height) and cardiac output (cardiovascular circulation time). Other patient factors that are important but considered to be less influential include age, sex, venous access, renal function, hepatic cirrhosis, portal hypertension, and various other pathologic conditions. Only limited data are available in the literature as for the effect of these seemingly less influential patient factors on contrast enhancement. Each patient factor and its effect on contrast enhancement are described in general in this section. Bae KT et al 2003)

2.7.5.1 Body Weight, Mass, Surface Area, and Mass Index :

The most important patient-related factor affecting the magnitude of vascular and parenchymal contrast enhancement is body weight. Numerous studies have been conducted to investigate the effect of body weight on contrast enhancement . This effect can be best described on the basis of the association of the body weight with the blood volume . Because large patients have larger blood volumes than small patients, contrast medium administered into the

blood compartment dilutes more in a large patient than in a small patient. The result is a reduced iodine concentration in the blood and lower contrast enhancement. (Bae KT et al 2003)

2.8 Previous Studies :

Bae KT et al 2003 found The continuing advances in computed tomographic (CT) technology in the past decades have provided ongoing opportunities to improve CT image quality and clinical practice and discover new clinical CT imaging applications. New CT technology, however, has introduced new challenges in clinical radiology practice. One of the challenges is with intravenous contrast medium administration and scan timing. Contrast medium pharmacokinetics and patient, contrast medium, and CT scanning factors associated with contrast enhancement and scan timing are presented and discussed. Published data from clinical studies of contrast medium and physiology are repeated. Computer simulation data are analyzed to provide an in-depth analysis of various factors associated with contrast enhancement and scan timing. On the basis of basic principles and analysis of the factors, clinical considerations and modifications to protocol that are necessary to optimize contrast enhancement for common clinical CT applications are proposed. Schindera, S. T et al 2008 study Contrast medium (CM) administration for multidetector computed tomography angiography (CTA) requires using a power injector.

Power injectors deliver viscous CM at different flow rates up to a maximum pressure of 300 lb per square inch (psi), provide features that benefit patient safety, improve arterial and parenchymal opacification ,and allow flexible and complex injection protocols to be administered .The use of power injectors not only includes contrast but also saline, which is primarily responsible for

reducing the overall volume of contrast administration while maintaining peak vessel opacification over a longer duration during the CTA acquisition.

CTA faces multiple challenges with advanced scanner hardware. There is an increased need to inject small volumes of CM at fast injection rates over a short duration. This technical overview is to increase the understanding of parameters that influence optimal contrast enhancement and bolus geometry, and to enable the user to modify and optimize scanner and contrast protocol sat peak arterial contrast enhancement. This is achieved with bolus shaping accompanied with calculating bolus arrival time with either bolus tracking technique or test bolus technique. New effective methods evolved to reduce radiation dose including the use of body habitus indices and the automated tube voltage and 21current. Despite all of these new techniques in and scanning protocols and CM delivery, none, has been universally applied in renal CT .

Anna Seehofnerováa et al 2014 Using smaller volumes of contrast media (CM) in CT angiography (CTA) is desirable in terms of cost reduction and prevention of contrast-induced nephropathy (CIN). The purpose was to evaluate the feasibility of low CM volume in CTA of the aorta .Methods*:* 77 patients referred for CTA of the aorta were scanned using a standard MDCT protocol at 100 kV. A bolus of 50 ml CM (Iopromide300 mg Iodine/ml) at a flow rate of 6 ml/s was applied (Iodine delivery rate IDR = 1.8 g/s; Iodine load 15 g) followed by a saline bolus of 40 ml at the same flow rate. Scan delay was determined by the test bolus method. Subjective image quality was assessed and contrast enhancement was measured at 10 anatomical levels of the aorta .Results *:* Diagnostic quality images were obtained for all patients, reaching a mean overall contrast enhancement of 324 ± 28 HU. Mean attenuation was 350 ± 60 HU at the thoracic aorta and 315 ± 83 HU at the

abdominal aorta. Conclusions*:* A straightforward low volume CM protocol proved to be technically feasible and led to CTA examinations reaching diagnostic image quality of the aorta at 100 kV. Based on these findings, the use of a relatively small CM bolus can be incorporated into routine clinical imaging.

.

Chapter Three

Material and Methods

3.1Methodology :

3.1 Study Design:

Descriptive study (statistical research)

3.2 Study Area :

Khartoum state

3.3 Data Collection:

The data was collected from radiology department of Yastbshiron Hospital, Omer SawiHospital , ALSAHA HOSPITAL , Alzaytoona Hospital and Alia .

3.4 Variables :

The data of patients obtained from work sheet is used to collect data on 6 variables these variables were include: Age , gender ,HU density ,amount of volume , flow rate, configuration device .

3.5 Data Collection Tools :

The data were collected using CT abdomen with contrast media using all above variables data.

3.6 Analysis :

By SPSS and Excel

3.7 Materials :

Data collection sheet.

3.7.1 Accessories Instrumentations Used:

Configuration devices128 ,64,16 slice CT.

Automatic injector and Manual injector(NEMOTO , NEOSOFT)

Contrast media (OMINOPAQUE) 40-150ML

Flow rate 1.6-4 ML/SEC

3.7.2 Study Subjects:

The study was performed in 100 CTA abdomen scan. 24

The measurement of AP diameter and LT to RT diameter , measure HU from at the level of the celiac trunk in the abdominal cavity .

The study include Sudanese group of patients.

Chapter Four

- **Results**

4.1 Results:

Table 4.1 show frequency distribution of gender for all patients:

Gender	number	Percent
Male	83	76 %
Female	26	24 %
Total	109	100 %

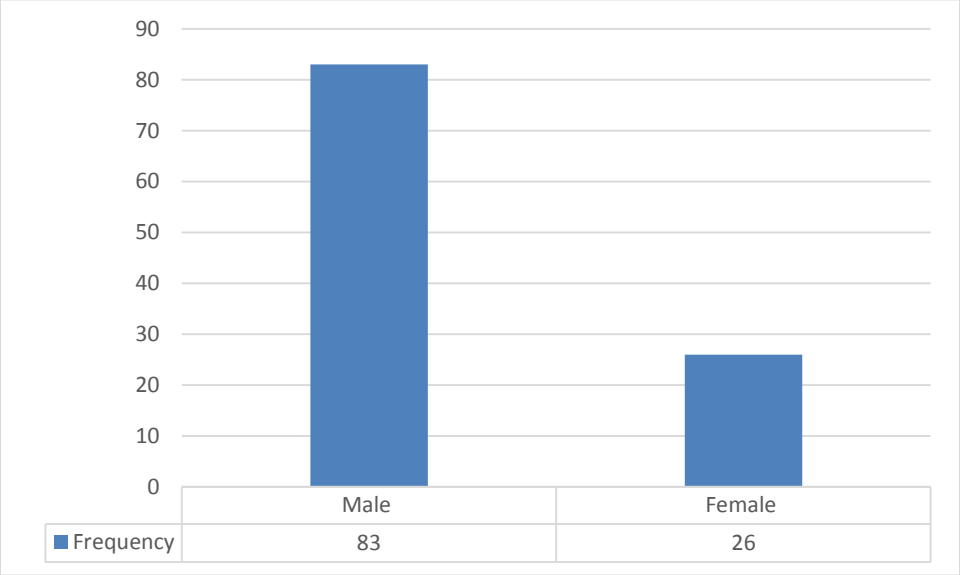

Figure 4.1 show frequency distribution of gender for all patients

Table 4.2 show age group frequency among all the patients:

Age	Frequency	Percent
0-10	4	3.7%
11-20	7	6.4 %
21-30	11	10 %
31- 40	19	17.4 %
41 -50	18	16.5 %
51-60	21	19.3 %
61-70	18	16.5 %
71-80	9	8.3 %
81-90	2	1.8 %
Total	109	100 %

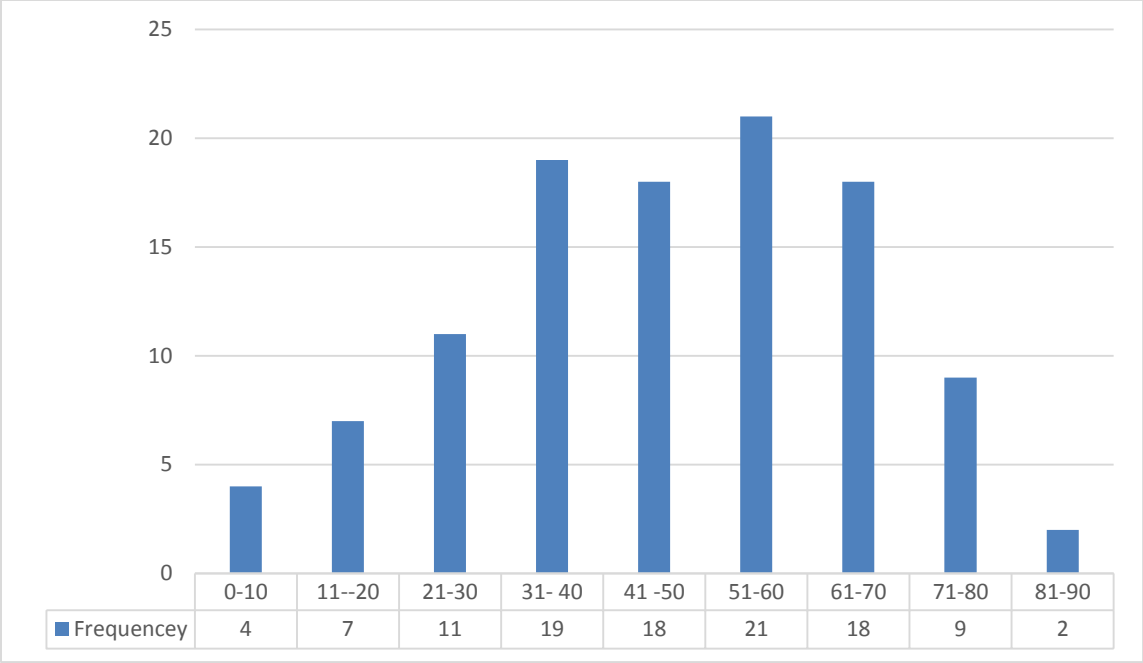

Figure 4.2 show age group frequency among all the patients

Table 4.3 show the device modality that used in this study

Device configuration	**Frequency**	**Percent**
16	6	60 %
64	1	10 %
128	3	30 %
Total	10	100 %

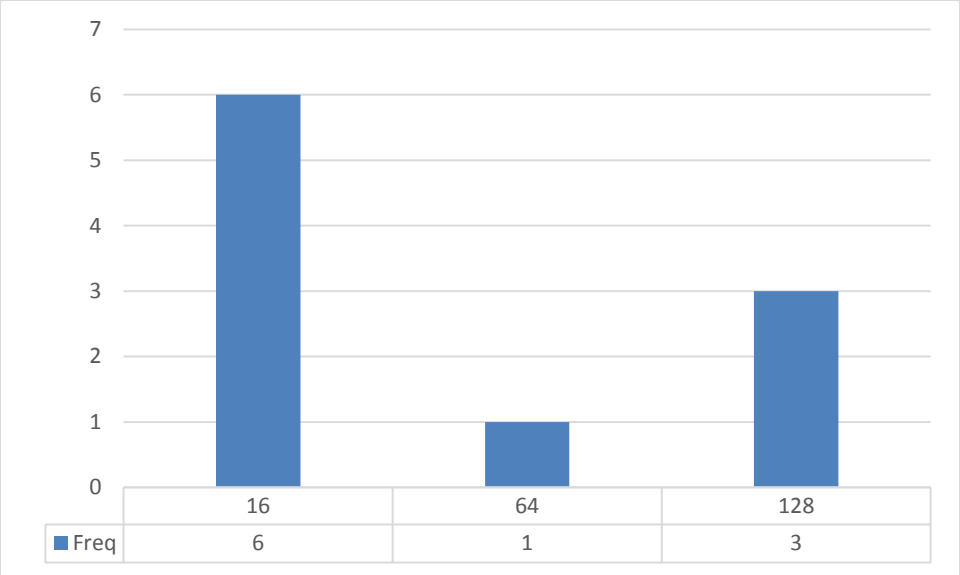

Figure 4.3 show the device modality that used in this study

Table 4.4 show compare of mean for HU density, flow rate and amount of CM for all devices configuration

	16	**64**	**128**
HU	201.08	200.5	315.4
Flow rate	2.68	3.21	4.00
Amount of CM	69.6	73.03	100

Table 4.5 show compare between the mean of HU density, flow rate and amount of CM for automatic and manual injector:

	Manual injector	Automatic injector
HU	242.5	201.2
Flow rate	3.22	2.84
Amount of CM	74.8	73.26

Table 4.6 compare between number of configuration device with type of injector:

	Automatic	**Manual**
16	44	16
128	30	-
64	-	10

Chapter Five

Discussion, Conclusion &Recommendation

5.1 Discussion:

Table 4.1 represent frequency distribution of gender for all patients where the female was 26 with percent 24% as shown in figure 4.1. Table 4.2 and figure 4.2 age group frequency among all the patients were the most patients age was in range 31-40 and 41-50 years with 18 and 19 patients, while the patients in range 0-10 and 81-90 years was lower frequency with 4 and 2 patients.

Be seen from table 4.3 that represent device modality that used in this study where the machine with slice 16, 64 and 128 give 6, 1 and 3 respectively, as shown in figure 4.3.

Table 4.4 compare of mean for HU density, flow rate and amount of CM among all devices configuration where HU was higher at 128 (315.4) slice and lower at 64 (200.5), the flow rate was higher at machines with 128 (4) and lower at 64 (3.21), while the Amount of CM was higher at 128 (100) and lower in 16 (69.6)

Table 4.5 show compare between the mean of HU density, flow rate and amount of CM, the manual injector give HU, Flow rate, Amount of CM was 242.5, 3.22 and 74.8 respectively while the automatic injector give 201.2, 2.84 and 73.26 respectively. Table 4.6 compare between number of configuration device with type of injector, for automatic and manual injector, where the automatic injector 44 patients from 16 slice and 30 from 128 slice, while the manual 16 patients from 16 slice and 10 from 64 slice.

From the previous studies is clear that the results agree that the focus of the value of an intermediary contrast affected by effectively with weight and age and gender of the patient and also the length and width patient (Bae KT et al 2003).

(Bae KT et al 2003) agree also one of previous studies on the device configuration 128 one of the best devices to improve the maximum

enhancement at CTA. The best modality to improve enhancement of CTA are (70. 128. 162) and the best modality in Sudan CT scanner configuration 128.

5.2 Conclusion :

Evaluation of contrast media injection protocols in computed tomography at Khartoum state in period from January to July 2020, where the samples

collected from different four hospitals. Where the results of this study show that Comparing of mean for HU density, flow rate and amount of CM among all devices configuration where HU was higher at 128 (315.4) slice and lower at 64 (200.5), the flow rate was higher at machines with 128 (4) and lower at 64 (3.21), while the Amount of CM was higher at 128 (100) and lower in 16 (69.6)

Correlate between mean of HU density, flow rate and amount of CM, the manual injector give HU, Flow rate, Amount of CM was 242.5, 3.22 and 74.8 respectively while the automatic injector give 201.2, 2.84 and 73.26 respectively.

While compare between number of configuration device with type of injector, for automatic and manual injector, where the automatic injector 44 patients from 16 slice and 30 from 128 slice, while the manual 16 patients from 16 slice and 10 from 64 slice.

5.3Recommendation:

- On each hospitals that have a CT scanner 128 slice configuration to use less amount of contrast with increasing the flow rate to minimize the time of examination and hence underestimated the dose of radiation.
- On each hospitals that have CT scanner should agreement on criteria and proportions standardized to ensure the quality and reduce the dose of radiation patient.
- The seller will all hospital identifying weight and the length and width the patient to determine the amount of contrast, taking into account the expense of the cardiac output.
- And is advisable to all hospitals in particular the government of them to get on the device 128 configuration to keep the image quality and save the patient of dose of radiation . Must also note the factors that affect the HU density and is the amount contrast and the rate of cardiac output and the speed of the machine .

References :

Anna Seehofnerováa, Madeleine Koka,b, Casper Mihla,b, Dave Douwesc, Anni Sailera,b,Estelle Nijssena,b, Michiel J.W. de Haana,b, Joachim E. Wildbergera,b, Marco Dasa, 22 August 2014

Bae KT . (Kyongtae T. Bae , MD, PhD) Technical aspects of contrast delivery in advanced CT . Appl Radiol 2003 ; 32 (suppl): 12 – 19 .

D. Karthikeyan and Deepa chegu - 16 july 2005 (Step by step CT scan - chapter 7 - contrast issues - page 161 – 162)

Debabrata Mukherjee and Sanjay Rajagopalan - 2007 (CT and MR Angiography of the Peripheral Circulation- chapter 5 contrast agent and contrast timing consideration -page 64 – 72)

Schindera, S. T., Nelson, R. C., & Howle, L., et al. (2008). Effect of varying injection rates of a saline chaser on aortic enhancement in CT angiography: phantom study. Eur Radiol 18, 1683–1689

www.ncbi.nlm.nih.gov/pubmed/20574084/

Appendix

Figure CT scanner machine

Figure Automatic injector (dual head injector)

Figure automatic injector (single head injector)

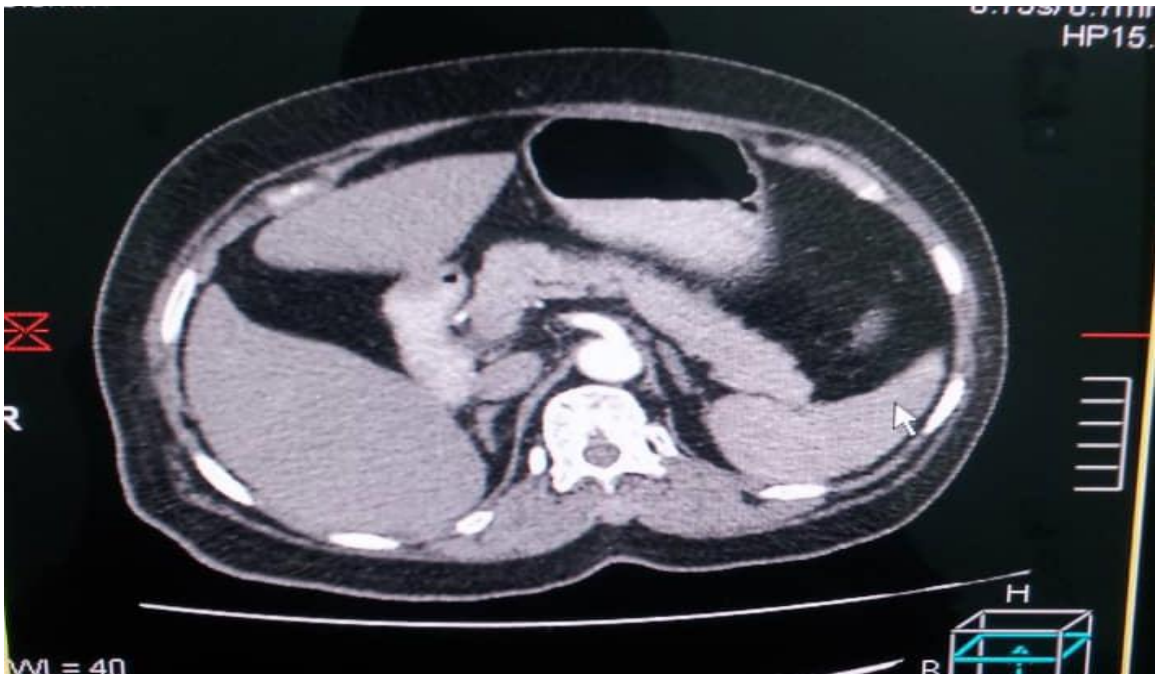

Figure CT scan axial cut for abdomen at the level of celiac trunk using CM