Al-Quds University

Deanship of Graduate Studies

Evaluation of Intravenous Contrast Agents Timing and Enhancement in Non-Traumatic Abdomen and Pelvis CT Exams

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M.Sc. Thesis

Jerusalem- Palestine

1441 / 2020

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A thesis submitted in partial fulfillment of requirements for the degree Master of Medical Imaging Technology/ Program of Functional Imaging Track/ Faculty of Health Profession/Al-Quds University.

Jerusalem- Palestine

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Thesis Approval

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Dedication

I dedicate my effort to my family and many friends. A special feeling of gratitude to my parents Hussein and Nofa Al-Makhamreh whose words of encouragement and push for tenacity ring in my ears. To my wife Amani Dababseh has never left my side and she is very special. To my children the secret of my happiness Ameer and Zaina who gave me the power to keep up.

I dedicate this work and give special thanks to my best friend Rami Quttaineh.

I dedicate this work to everyone I love..

Declaration:

I certify that this thesis submitted for the degree of Master is the result of my own research, except where otherwise acknowledged, and that this study (or any part of the same) has not been submitted for a higher degree to any other university or Institution**.**

Mo'ath Hussein Ismail Almakhamreh

Signed: 

Date: 19/12/2020

Acknowledgements

I’m grateful to the god for the good health and wellbeing that were necessary to finish this work. I would first like to acknowledge my supervisor Dr. Mohammad Hjouj who expertly guided me, for his patience, motivation, and immense knowledge.

I wish to acknowledge the support and great love of my mother, Nofa Aljundi; my wife, Amani Dababseh; they kept me going on and this work would not have been possible without their support.”

The collaboration of MITs and radiologist in Hebron governmental hospital, Al-Ahli hospital, PRCS, and Al-Yasmin radiology center is truly appreciated. Without their help this study could not have reached its goal.”

Abstract

Background: Among the advances that ensured better diagnosis in CT imaging is the use of contrast medium (CM). CM increase image quality by providing higher signal to noise ratio, contrast to noise ratio, and enhancing contrast between internal organs resulting in significant improvement in image quality and hence better diagnosis. Being advantageous means substantial use of the radiologic CM, nevertheless these chemical substances must be administered carefully in terms of timing, and other interrelated factors to improve image quality and to prevent or minimize any adverse effects. The CM used in CT exams is iodine-based that can be ingested or injected intravenously (IV). Awareness of iodinated CM regarding its effects is crucial since its effects can vary from low to life threatening. Even life threatening reactions are rare but they can happen and should be treated promptly.

Methods: A cross sectional prospective study was conducted from January 2020 to April 2020. 80 patients from different medical institutions underwent Abdomen, and Pelvis CT scans with IV CM were included; the process of CM timing and other CM related factors including volume, injection rate, injection duration, and concentration were evaluated by comparing the HUs that were a result of using different parameters to the recommended standards. The attenuation values in the Hounsfield Unit (HU) for liver and aorta were measured. The average HU was compared between the 4 groups of institutions.

Results: Variation was observed in CT contrast policies and procedures. Widely varying aortic and hepatic enhancement resulted from random use and wide range of timing and other CM factors. Aortic enhancement ranged from 98-361HU, and hepatic enhancement ranged from 13-76 HU, respectively. Mean± SD of maximal aortic enhancement was 264.25±60.23, 213.45±50.83, 200.85±39.2, and 164.2±48.27 .Mean ± SD of maximal enhancement of the liver was 53.4±10.3, 44.9±12, 45.8±10, 34.6±10.1 in institutions A, B, C and D, respectively.

Conclusion: Random use of CM timing and protocols will result in less patient safety and widely varying range of enhancement and peak parenchymal enhancement with less homogeneous enhancement.

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List of Abbreviations

Absorption Edge (K)

Abdomen and Pelvis (A/P)

AL-Ahli Hospital (AH)

Al-Yasmin Radiology center (YRC)

Arterial Phase (AP)

American College of Radiology (ACR)

Atomic Number (Z)

Attenuation Coefficient (μ)

Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI)

Computed Tomography (CT)

Computed Tomography Angiography (CTA)

Computed Tomography Contrast Team (CCT)

Contrast-Induced Nephrotoxicity (CIN)

Contrast Media (CM)

Cone-beam CT (CBCT)

Delayed phase (DP)

Electronic Medical Record (EMR)

Emergency Department (ED)

Estimated Creatinine Clearance (ECC)

Gastroesofageal Reflux Disease (GERD)

Gastrointestinal (GI)

Hebron Governmental Hospital (HGH)

Hounsfield Unit (HU)

Intravenous (IV)

Kilo-Voltage (KV)

Linear Attenuation Coefficient (μ)

Lean Body Weight (LBW)

Material Density (ρ)

Medical Imaging Technologists (MIT)

Milliampere-Second (mAs)

Multidetector Computed Tomography: (MDCT)

Non-Enhancement Computed Tomogrphy: (NECT)

Non-Governmental Organization :(NGO)

Nothing by Mouth (NPO)

Palestine red crescent society (PRCS)

Portal Venous Phase (PVP)

Post Bolus (PB)

Post Injection (PI)

Region of Interest (ROI)

Standard Deviation (SD)

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Chapter one

1. Introduction

1.1 Background

X-ray computed tomography (CT) is an imaging technique that is used in research and clinical purposes (Webb et al, 2005). CT with its high specifications has become an essential diagnostic technique due to being non-invasive, with its ability to initiate a high-resolution 3D reconstruction for a variety of organs. Besides allowing the application of many algorithms that ease the diagnostic evaluation of images such as segmentation in which the tissue of interest can be segmented. Along with so many other features making CT a widely spread medical imaging modality in terms of availability and use in hospitals and medical imaging centers (Perandini et al, 2010). Since the last 20 years, the frequency of CT scanners have rapidly increased in terms of use and spread, mostly in Europe (OECD, 2013). In Spain as an example, 4 million scans were performed in the year 2011 (Bosch de Basea et al, 2015). Yearly, more than 70 million clinical scans are performed in the U.S (Brenner et al, 2010). In Palestine, CT use is increasing as well, 76,360 CT scans were conducted in the year 2017, later increasing to 127,439 in 2018, and these numbers are only in governmental hospitals (Ministry of health, 2018).

Tomography comes from Greek (tomos) slice and (graphien) draw as a medical imaging technique that was utilized a few decades after W. C. Roentgen discovered the x-ray in 1895. A. M. Cormack, the South African physicist and G. N. Hounsfield was awarded the Nobel Prize in 1979 for inventing the modern and prosperous CT scanner in 1972 that resulted in improvements in CT imaging and diagnosis (Lindsten et al, 1992).

X-rays are electromagnetic radiations whose wavelengths lie between 0.01 nm and 10 nm. The production of x-rays is accomplished in a vacuum tube in which high voltage is used for accelerating electrons, which then are forced to collide the so-called anode, which is usually made of tungsten-alloy. Accelerated electrons are directed from the cathode, where they are produced to the target area on the anode, this is where they go under a sudden declaration and produce the electromagnetic radiations in the form of x-rays. The energy of the produced x-rays is dependent

upon the incident electron. Tube voltages of modern CT scanners range from 80 KV up to 150 KV.

X-rays possess an energy that can interact with matter in different manners. These interactions may include x-ray absorption in which energy is transferred from an energetic x-ray photon into absorbing material, or the interaction may include a scattering of these photons, which means a redirecting of x-rays in different directions by the scattering material.

The higher material density (ρ), or the atomic number (Z), the better the x-ray absorption. The following x-ray absorption coefficient formula explains the relationship between ρ, Z:

$$\mu \simeq \frac{\rho Z^4}{AE^3} \quad (1)$$

Where A is related to the target element relative to the atomic mass, and E is the energy of the x-ray. The absorption and atomic number are strongly dependent on each other, where Z^4 allows a contrast differentiation between the different types of tissues and contrast agents.

As the binding energy of the k-shell electrons are exceeded or are equal to an incident x-ray photon energy, the absorption coefficients would suddenly increase. This energy value is expressed as the absorption edge (K); the K value is higher for higher atomic number elements. Based on this fact, different types of contrast mediums are made up of elements with a high atomic number such as iodine and barium, which are commonly used as a radiologic contrast medium to enhance soft-tissue contrast as compared to surrounding tissues. Consequently, the use of these CM requires an adjustment of the kilo-voltage (KV) and the milliampere-second (mAs) of the x-ray source or an application of the automatic exposure control to closely match the K-edge of the different used contrast agents (Buzug et al, 2010) (Kalender et al, 2011) (Romans et al, 2010) (Seeram et al, 2009) (Hsieh et al, 2009).

1.1.1 CT of Non-Traumatic A/P CT Scan with CM

CT is the primary technique to be chosen in the case of a non-traumatic acute abdomen which happens by different causes. Patients presenting to the radiology department commonly undergo a CT scan with oral and intravenous (IV) contrast, which eases diagnosis to a great extent (Johnson

et al, 2006, Rosen et al, 2000, Stoker et al, 2009). The IV and oral contrast are usually used together at the same imaging session because using oral or IV alone will give uncertain results. Consequently, using both IV and oral will lead to more accurate findings that are sensitive and may be specific enough for diagnosing different diseases including bowel-related pathologies (Paulson & Coursey, 2009, Anderson & Soto, 2012).

Acute abdomen is the most typical complaint among patients who visit the emergency department (ED). In 2006 the United States had 119 million patients visit the ED, 7% (about 8330000) of the 119 million complained of abdominal pain (Pitts et al, 2008). This value has increased up to 8% of all ER visits in 2010 (Centers for Disease Control and Prevention, 2010). The term acute abdomen is related to a condition where patients suffer a sudden, severe abdominal pain that is usually accompanied with rigidity and tenderness and needs urgent attention and treatment (John & Dominique, 2019).

Although chronic abdominal pain is common in primary care, it is not always indicated in a CT (ex. Peptic ulcer disease); this pathological condition comes in the form of intermittent or continuous discomfort for at least six months. Origins of this pain may arise from the gastrointestinal tract or adjoining organs (ex. Pancreas and biliary duct); origins may also be related to gynecologic or genitourinary reasons (Mendelson et al, 2015).

A CT scan of A/P is also indicated for the progressive type of abdominal pain. Progressive abdominal pain is the kind that steadily gets worse with time and may have the symptoms of acute or chronic abdominal pain. This type is usually serious (Mayo clinic staff, 2019).

1.1.2 Indications of Non-Traumatic Abdomen and Pelvis (A/P) CT Scan with CM

1.1.2.1 Acute Abdomen

The causes of acute abdomen are broad and vary, ranging from simple self-limiting to dangerous, life-threatening disorders. There is a broad range of differential diagnosis of acute abdomen cases including gastrointestinal such as diverticulitis, bowel obstruction, ruptured hollow viscus, which may be caused from a complication of inflammatory bowel diseases or malignancy which in turn can result in peritonitis, appendicitis, cholecystitis and pancreatitis.. Urologic conditions that

include causes such as renal colic. Vascular events such as ruptured aneurysms, and mesenteric ischemia (Stoker et al, 2009).

1.1.2.2 Chronic Abdominal Pain

The causes of chronic abdominal pain are often difficult to determine. They are characterized by symptoms that come and go, some worsen but not necessarily get serious, these symptoms range from mild to severe. Some of the causes of chronic abdominal pain include conditions like gallstones, gastritis, hiatal hernia, gastroesophageal reflux disease (GERD), ovarian cyst, peptic ulcer and ulcerative colitis (Mayo clinic staff, 2019).

1.1.2.3 Progressive Abdominal Pain

Causes of progressive abdominal pain include Crohn's disease, lead poisoning, hepatitis, Uremia, splenomegaly, different types of cancers (stomach, liver, pancreas, kidney, and gallbladder) (Mayo clinic staff, 2019).

1.1.3 Location of Pain

The location of the pain is usually considered a starting point; this critical indicator may signal a specific localized disorder. The American College of Radiology (ACR) has defined evidence-based guidelines, where physicians can make the best imaging decisions and choose better imaging techniques for each specific process. Regarding imaging, the ACR appropriateness criteria are basically based on the location of pain, including different clinical variants for most locations (e.g. presence or absence of fever, leukocytosis, and pregnancy). For example, acute cholecystitis is usually linked with the right upper quadrant abdominal pain, while the acute appendicitis is linked with the right lower quadrant pain as the most common causes (Li PH et al, 2018).

1.1.4 X- ray computed tomography contrast Agent

CT exhibits an excellent contrast resolution, where most human body tissues are well visualized. The Hounsfield unit (HU) is a dimensionless unit that expresses the ability to attenuate x-rays. Different tissues have been given different values of the HU; the HU density value of 0 represents water, while -1000 represents air. For most soft tissues the HU density values range from 30 to -100 with the lungs being accepted because of the high air content (approaching -1000 HU), and mineralized bone with an HU density value of approximately 1000. Calibration in most CT scanners is carried out with water as reference material. The linear attenuation coefficient (μ) for the material is used to estimate the HU, where it can be calculated by:

$$\mathrm{HU} = \frac{(\mu - \mu_{\mathrm{water}})}{(\mu_{\mathrm{water}})} \times 1000 \quad (2)$$

Where μ water is related to the linear x-ray attenuation coefficient of water.

Although various bodily tissues show a contrast in CT, the contrast resolution of CT is limited in imaging as well as in the identification of interfaces for two adjacent tissues (e.g. liver/tumor), or imaging a clot in contact with blood. There must be a mechanism to differentiate such interfaces and soft tissues; here comes the magic of radiologic contrast media, which gives a difference of 50- 100 HU, enough to delineate and distinguish some tissue types of interest. The use of CM improves image quality through a signal to noise and contrast to noise ratio, which means better a visualization of the tissue of interest and hence a better diagnosis (Carterwright, S & Knudson, M, 2015). Accordingly, radiologic contrast media maximizes the ability to differentiate different tissues which increase CT sensitivity as well as gives information about the specific biochemical process of tissue and enables CT to act as a functional imaging modality where it can evaluate the function of the tissue/ organ (Lusic, & Grinstaff, 2012)

The most commonly used CM is iodine-based agents; these can be classified according to osmolarity (high, low, or iso). Moreover, they can be divided into ionic and non-ionic. Ionic agents have more side effects as compared to non-ionic agents; that's why non-ionic agents are recommended as they contribute to less discomfort in patients (Lusic & Grinstaff, 2012). The primary molecule forming the contrast is benzene, the contrast agents are then divided from it. All available CM are chemical modifications of a 2,4,6-triiodinated benzene ring (Singh & Daftary, 2009).

Clinical practice of CM is determined by two critical physicochemical properties, which are osmolality and viscosity. On one hand osmolality is linked with the adverse reaction of CM; on the other hand, delivery and enhancement of CM are greatly determined by viscosity, where it plays an important role. As the concentration of CM increases, an increase in viscosity is associated. Consequently, using CM with a high concentration at high rates may not increase iodine delivery to the vessels of the regions of interest and hence result in less desired enhancement. Temperature affects viscosity, where high temperature leads to less viscosity resulting in more efficient enhancement (Bae, 2010).

1.2 Problem statement

CT scans have become an essential tool for diagnosing patients and have become highly requested. In addition, CM application in procedures have rapidly increased, and the patients receiving these medications are continually rising (Bettman et al, 2004). The significant advances in CT such as introducing high-speed MDCT, results in clearly shorter scan time, leading to a constant adaptation of acquisition protocols to utilize these technological improvements.

The timing of IV CM requires special attention since short scan time needs enough timing of the IV injection and an individual bolus that is suitable, by taking into account variables like the CM concentration, volume, and flow rate because they are linked to individual physiology. For many individuals, physiological changes are out of control for the medical imaging technologists (MITs). This is true and applicable for angiography exams, and increasingly for parenchymal organs (Violon, 2012).

Achieving the optimal enhancement with the least adverse reactions is the desired goal of using radiologic CM. To achieve this goal, the examiner should avoid any mistakes that may result in non-diagnostic enhancement, like setting a threshold which can lead to examinations carried out too early in different phases of enhancements, as a result of high-speed CT scanners (Violon, 2012). Moreover, the bolus dynamics itself is complicated, significantly non-linear, and it is affected by different factors, including patient weight, vessel-related disease and the pattern of injection (Bai, 2008).

While fixed scan delay in which the timing of different phases is preset and highly dependent on an MIT's experience without considering individual differences, and hence the broad arrival time range values.

Non-traumatic A/P CT scan is a common procedure frequently associated with IV, oral and sometimes rectal contrast agents, where different phases of enhancement are used. Evaluating the use of CM in terms of timing, and other CM factors including volume, injection duration, injection rate, and concentration in this procedure (A/P CT) is essential because a diagnostic level of enhancement is required and that is based on the CM timing and other interrelated factors.

1.3 Justification

The purpose of this study is to examine IV contrast agents used in A/P CT scans. The preparations that were used were timing and injection-related factors. The availability of MDCT with their efficiency and flexibility in using contrast agents ensured maximum challenging benefits, and that includes scan time versus maximum diagnostic contrast enhancement and optimal delivery of the contrast agent. The examiner must balance these parameters for best results.

The data collected through this study has the potential to be used to raise the awareness of MITs, for optimal radiologic CM use as well as for providing information for medical institutions to create or improve CM and scanning protocols.

1.4 Objectives

1.4.1 General Objectives

This study aimed at evaluating the CM timing administration protocols in the Palestinian health system, including the governmental sector, NGOs, and the private sector in the Hebron governorate through A/P CT exams for patients (above 18 years old).

1.4.2 Specific Objectives

- To evaluate the preparations for patients who underwent an A/P CT scan with IV CM.
- To evaluate the IV CM administration timing and other CM factors (volume, injection duration, and injection rate, concentration).
- To quantitatively evaluate aortic enhancement.
- To quantitatively evaluate hepatic enhancement.

Chapter Two

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2. Literature Review

Contrast agents are substances that enhance the internal images of the body, produced in medical techniques such as computed tomography (CT). These substances are not dyes, but they influence the interaction between the imaging tools and the body cells. Different contrast agents are suitable for various body tissues. The agents also vary according to the route of administration, which can be oral, rectal, venous (Pua, Covey & Madoff, 2018). This literature review summarizes the different contrast agents used in the examination of a non-traumatic A/P CT scan, their deviations to the recommended standards, and their awareness among MIT's.

2.1 Intravenous Contrast Media

2.1.1 Phases of enhancement

Contrast enhancement is done in different phases in order to increase the contrast between the target tissue and the surrounding cells to highlight any pathological differences. As such, the target tissue could become hypovascular or hypervascular to the surrounding cells according to the type of enhancement required (Smithuis, 2014). Consequently, there are different types of enhancements which are applied to different target tissues. First, there is the non-enhancement CT (NECT), which is used to detect large tumors, calcification, and fat standings which can be common in inflammations associated with disorders such as diverticulitis, appendicitis and omental infarctions, among others (Smithuis, 2014). Second, the early arterial phase, a CT scan done immediately after the bolus tracking, about 15-20 seconds after the injection of the tracking agent, to enhance the arteries before the contrast agent reaches other tissues and organs in the body (Smithuis, 2014). Third, the late AP, which enhances all the structures that receive blood from the arteries, about 30-40 seconds after injection (Smithuis, 2014). Fourth, the hepatic phase, which enhances the renal parenchyma from the blood supply, approximately 70-80 seconds after injection (Smithuis, 2014). Fifth, the nephrogenic phase in which the renal parenchyma and medulla, which is enhanced for detecting renal carcinomas, approximately 100 seconds after injection. Lastly, the delayed phase (DP) enhancement, which occurs about 6-10 minutes after injection, allowing the contrast agent to wash out from all the abdominal structures except the fibrotic tissue (Smithuis, 2014). Hence, a CT scan is done at the appropriate time according to the targeted enhancement phase.

2.1.2 Timing and Injection Duration

The challenge of accuracy in the delay time required for CT scanning has led to the capturing of poorly enhanced images, which are taken too early or too late after the enhancement. Adibi and Shahbazi (2014) investigated the possibility of automated bolus tracking in abdominal CT scans and observed higher enhancement in the spleen and aorta in the portal phase; the liver, however, presented no effects. In addition, evidence from children posits show that bolus tracking also gives more homogenous enhancement in the liver than time-delay scanning, yet the contrast was enhanced (Adibi, & Shahbazi, 2014). Similar homogeneity has been observed in patients presenting various hepatic enhancements (Adibi, & Shahbazi, 2014). Hence, bolus tracking increases the quality of CT scanning technology as opposed to fixed time delay scans.

In CT scanning, in order to capture images at the correct enhancement phase, timing is critical. For instance, a patient could undergo two CT scans to retrieve an image at 18 seconds for the arteries, and the other at 35 seconds to enhance tumors in the arterial phase (AP) (Smithuis, 2014). It is crucial to adopt the protocol provided by the scanner underuse. For instance, a single slice scanner takes approximately 20 seconds to scan the liver (Smithuis, 2014). Therefore, if we intended to perform a late AP image whose optimal time is 35 seconds, we should complete the imaging between the 25th and 45th second. Using a more powerful scanner like the 64-slice takes only 4 seconds to complete liver imaging, one can start the imaging at the 33rd second (Smithuis, 2014). Similarly, the AP would take a shorter period, while the late portal venous phase (PVP) would start a bit later, about 75 seconds with any scanner (Smithuis, 2014). Thus, timing considers equipment as well as the targeted phase.

(Chung et al, 2006) used a fixed injection duration (47 seconds) to minimize its effect on the time to peak for parenchymal enhancement and 2 mL/kg Iodinated CM for patients with a weight less than 75 Kg and 150 mL for patients over 75 Kg with a flow rate varying from 1.6 mL/s (37 Kg patient) to 3.2 mL/s (75 Kg patients or more). They suggested that a delay of 50-60 seconds post-injection will achieve the peak parenchymal haptic enhancement while some patients' especially younger patients who showed earlier enhancement at 40 seconds, some patients with cardiovascular problems may have a peak enhancement at a longer portal-venous timing.

Injection duration is defined as the CM volume divided by the flow rate; this critical factor significantly affects both the magnitude and timing of the CM enhancement (Han et al, 2000).

Injection duration is determined according to the clinical objectives and scanning conditions. Injection duration must be selected appropriately since excessively short injection duration leads to insufficient enhancement and excessively long injection duration results in the wasting of CM and accordingly generates undesirable tissue and venous enhancement (Bae et al, 1998).

2.1.3 Total Amount of Contrast and Injection Rate

The dosing of the contrast agent is usually specified in the protocols. Weight doses recommend 100cc for patients with <75kg; 120cc for patients with 75-90kg; 150cc for patients with >90kg (Smithuis, 2014). Nonetheless, some CT scans require maximum doses of 150cc such as pancreatic and liver tumors, as recommended by the protocols (Smithuis, 2014). Hence, radiologists should follow the time recommended in the protocols.

The injection rate affects the enhancement of the images in CT. In gastrointestinal (GI) bleeding, pancreatic carcinoma, liver cancer, and pulmonary emboli, the recommended injection rate is 5 mL/s using an 18-gauge catheter (Smithuis, 2014). When this rate is impossible, or rather not needed, a 3-4 mL/s injection rate is employed using a 20 gauge pink venflon (Smithuis, 2014). Therefore, different target CT scans require different injection rates for better imaging.

Intravenous administration of an iodine contrast agent for A/P CT requires an injection of 100-150 mL, of a 350 mg iodine media at the rate of 3-4 mL/s. As the peak enhancement and the CM arrival are affected by the IV access site choice. When the forearm and hand are used, lower flow rate is desirable (Bae et al, 2010).

CM enhancement is dependent on iodine concentration in vessels and tissues. In vessels, this concentration is dependent on the flow rate in mg/s. Therefore, a concentration of 400 mg/mL injected at a flow rate of 3 mL/s will provide the same total amount of iodine with a concentration of 300 mg/mL injected at a flow rate of 4 mL/s. Even though both types produce a relatively equal enhancement, advantages and disadvantages are present for each concentration. Lower concentrations of CM require an increase in the flow rate and volume in order to maintain the same

vascular and organ enhancement, which in turn maintains the same iodine dose. On the other hand, injecting a CM of a higher concentration (≥350 mg iodine/mL) requires a lower flow rate for it to deliver the same amount of iodine. While using the same flow rate or higher, it provides a concentrated bolus that is suitable for examinations with short scan time such as CT angiography, mainly when MDCT is used (Williams et al, 2014).

(Awai et al, 2004) studied the effect of contrast material timing (duration and rate of injection) and its effect on aortic peak time and enhancement in which patient weight determined the dose of CM. The study included 199 patients, 115 men and 84 women with an age and weight ranging (30-92), (35-83), respectively. Included patients were diagnosed with various types of cancers (lung cancer, colon cancer, breast cancer, gastric cancer, angiocacinoma, bladder cancer, ovarian cancer, gallbladder cancer, etc.). These 199 patients were divided randomly into three protocol groups, A, B, and C, according to the contrast agent infusion protocol. A is a fixed 25-second injection duration with a flow rate of 4 mL/sec, B is a fixed 35-second injection duration, while C is a fixed injection rate of 4 mL/sec. The cannula used was a 20-gauge that was inserted into an antecubital vein, in addition to a power injector. The scanning began at the level of the third lumbar vertebra, in order to obtain a baseline attenuation value for the aorta. Then at an interval of 2 seconds and 10-60 seconds after the CM infusion, single-level serial shots were obtained at the same level. After single level shots, 70 seconds after the CM initiation, a routine abdomen CT scan was done at the PVP, and the following parameters were used (0.8- sec rotation time, 5 mm detector row width, 7 mm slice thickness, helical pitch of 3.0, 50 cm field of view, 120 KV, and 220-280 mAs). Results reveal that there was no significant correlation between any patient weight and aortic peak time, or injection rate and aortic peak time in A, and B groups in which the mean aortic peak times were 21.4 seconds ± 2.3, and 29.2 seconds ± 2.0, respectively. For the C group, the patient weight and aortic peak time had a significant positive correlation with a mean aortic peak time of 19.7 seconds ± 4.4. The study findings show that aortic peak times and aortic peak enhancement values can be reduced with the use of an injection protocol using a fixed injection duration. Accordingly, maximizing these values would be diagnostically advantageous in an AP CT scan of hepatic tumors and angiography. However, for adequate enhancement, considering the scanning duration according to the anatomical area scanned and the used scanning techniques, it's essential to ensure that injection duration is enough.

According to the recommendations of the American College of Radiology (ACR, 2018), the rate of intravenous delivery of contrast solution of up to 5mL/s can work in a 22-gauge catheter, but it is preferable to use a 20-gauge catheter or greater for flow rates of 3 mL/s or more significant. Standard procedures should be followed during these injections to prevent air embolism. It is also preferable to use an antecubital or a large forearm vein for the venous access site for the power injector as compared to peripheral sites such as the hand or wrist in which a lower flow rate is preferable if feasible to avoid extravasation.

Dosage of the contrast agent has been an issue of debate in CT scanning. On the one hand, there are concerns about the image quality associated with such reductions. On the other hand, there are concerns about the cost of the contrast agents applied in CT scanning. (Perrin et al, 2018) confirmed that the image quality of a weight-based dosage was similar to that of a fixed dosage. Accordingly, patients with body weights >76 kg could save some of the costs associated with the contrast agent (Perrin et al, 2018). They recommended that the weight-based protocol should be implemented in the portal-venous phase of the abdominal-pelvic CT scan for cancer patients with a normal renal function (<70ml/min/1.73m2) (Perrin et al, 2018). (Zanardo et al, 2018) asserted that a dosage of 0.63g of iodine/ kg of lean body weight (LBW) is appropriate for diagnostic abdominal CT. Since dosing is according to the total body weight (TBW), it can lead to doses more than needed for obese patients and less than needed for patients with higher LBW such as athletes.

The dosing of the contrast agent is usually specified in the protocols. Weight doses recommend 100cc for patients with <75kg; 120cc for patients with 75-90kg; 150cc for patients with >90kg (Smithuis, 2014). Nonetheless, some CT scans require maximum doses of 150cc such as pancreatic and liver tumors as recommended by the protocols (Smithuis, 2014). Hence, radiologists should follow the time recommended in the protocols.

(Yamashita et al, 2016) investigated the effect of different doses of CM (iopamidol 300). They assigned participants into four groups receiving 1.5, 2, and 2.5 mL/kg or a fixed dose of iopamidol 300. The result showed increased enhancement in the 2 and 2.5 groups as compared to the 1.5 and fixed-dose, but there was no significant difference among 2, 2.5 and fixed-dose in the arterial enhancement.

2.1.4 Intravenous Contrast Media Concentration

Another study investigated the effects of contrast concentration on the enhancement of CT images. They used two study groups with 62 participants each suffering from either liver cirrhosis or chronic hepatitis. One group was treated with a 350 mg/ml concentration of intravenous iodine-based contrast agent, while the other group was treated with a 400mg/ml concentration of the same contrast agent (Jo, Song, Shim, & Kim, 2016). The results confirmed that higher concentrations of iodine, precisely the 400mg/ml gives a higher hepatic enhancement in the portal and equilibrium phases of scanning using 128-slice multidetector computed tomography (MDCT) (Jo, Song, Shim, & Kim, 2016). They explained that the results were due to the high viscosity of the concentrated media, which allowed it to distribute evenly in the tissue rather than the less concentrated media.

2.2 Oral and Rectal Contrast Agent

The use of oral and rectal contrast media is commonly applied while examining suspected perforations or anastomotic leakage, using abdominal and pelvic CT imaging. Iodinated solutions are preferred as the oral and rectal agents since it distributes efficiently along the digestive tract and has minimal toxicity as compared to barium-based agents (Dias & Cunha, 2017). Accordingly, a dose of 1000-1500 ml of the contrast medium is administered in varying doses, about 45-60 minutes before the imaging (Dias & Cunha, 2017). Administration of 20mg of metoclopramide at the beginning of the ingestion helps in reducing the preparation time (Dias & Cunha, 2017). Rectal administration is facilitated by a catheter and an enema bag. About 200ml is sufficient for the rectum and sigmoid colon, while the entire colon requires about 900-1200 ml of the iodinated contrast solution (Dias & Cunha, 2017).

Besides, Williams (2014) recommends the use of water-soluble iodine or dilute barium agents in bowel opacification. Accordingly, Williams posits that 1 liter of a dilute oral contrast media is sufficient for general abdominal-pelvic CT. The contrast medium should be ingested in doses that are divided with the last dose of 150-200 mL ingested immediately before a patient is positioned on the CT scanner couch, and the administration should begin approximately one hour before the scan (Williams, 2014). Studies limited to the upper abdomen require lower doses of the contrast media, about 500 mL. In addition, Williams (2014) recommends that small doses of oral contrast

media, about 5 mL in 150-200 mL of water to be taken 4-12 hours before the scan can be useful in contrast opacification of the colon and rectum. Williams (2014) adds that rectal contrast media can help in diagnosing pelvic disease. Accordingly, 100 mL of the contrast media is followed by 50 mL of air to push the agent to the sigmoid colon. Furthermore, water and CO2 can also work as contrast agents in esophagus and stomach examinations (Williams, 2014). These agents have worked in the visualization of abdomen and pelvic diagnostics.

Water is a negative contrast agent used in the visualization of the stomach and proximal small bowel because once it gets to the colon; it is absorbed in the body. Other scholars have investigated the potential of milk as a contrast agent in an abdominal CT scan which found positive results. In their experiment, 50 patients received 1000-1500 mL of whole milk from an oral contrast agent one hour before the scan (Badawood et al, 2015). Their findings revealed that the resultant images were rated as good and excellent by expert radiologists. However, additional research is needed to enhance the accuracy of protocols using milk as a contrast agent (Lee et al, 2016). In 2015, another novel oral contrast agent was approved by the FDA in the US. The substance is ORALTAG (iohexol), produced by Otsuka Pharmaceutical Co. Ltd. It comes in a powder form and can be prepared into a variety of beverages for medical purposes (Otsuka Pharmaceutical Co, 2016). These are some novel contrast agents used in abdominal and pelvic imaging.

According to the recommendations of the American College of Radiology (ACR, 2018), it recommends a dose of 85% -100% w/v suspension of barium sulfate concentration diluted in 1000 mL – 2000 mL is appropriate for GI opacification (ACR, 2018). These doses vary according to the purpose of the investigation. The recommended concentration of iodated contrast agents is 367 mg/ml, which is diluted in water for delivery. In the oral administration, it recommends a dose range of 4-48 mgI/mL, but 13-15 mgI/mL is sufficient for oral and rectal administration in adults (ACR, 2018). Doses for barium-based contrast agents are specified in their respective kits. In addition, it recommends the use of other neutral oral contrast agents, including water, electrolyte solution, lactulose solution, methylcellulose, polyethylene glycol, and mucofalk (ACR, 2018). These agents should be preloaded in the patient at least twice before the imaging takes place. The doses reviewed in this study are closer to the global standards of contrast agents in CT scanning.

2.3 Kidney Function Test

Kidney function tests are laboratory tests that are used to estimate both contrast-induced nephrotoxicity (CIN) before administering a CM or to test if acute kidney injury has occurred post-contrast injection. Serum creatinine concentration is considered the most common test lab to evaluate and measure the renal function. According to (Band RA, Gaieski DF, Mills AM, et al, 2007) serum creatinine alone is not sensitive for evaluating a renal function, because creatinine is affected by various factors including patient's sex, muscle mass, nutritional status, and age. As a result, GFR has gained attention as a potentially preferred marker of CIN. However, calculating the GFR rely on serum creatinine and therefore making eGFR estimation a subject to some limitations as well. Although both serum creatinine and eGFR have limitations, using eGFR as renal function indicator, an estimation from the serum creatinine concentration is recommended, because it still provides as compared to the serum creatinine alone, as a more sensitive and specific measure of the renal function.

Regarding the serum creatinine (Tippins et al, 2000) suggests that routine creatinine testing is not necessarily indicated for all patients. Instead, suggested indications for the lab testing (serum creatinine concentration and the eGFR) are listed in Table 2.1. However, according to (ACR, 2018) the risk factors listed, showing that they are not definitive or a blend of published data .According to expert opinions, a patient who does not have one of these risk factors and happens to undergo a CT scan with IV contrast does not require creatinine testing, before IV administration(Tippins et al, 2000, Choyke et al, 1998).

Table 2.1: suggested list of risk factors that may require renal function testing

- Age above 70 years old. - History of kidney disease, including kidney transplant, tumor. - Family history of kidney failure. - Diabetic patient using insulin or other prescribed medications.

- Paraproteinemia syndromes or diseases (eg, myeloma).
- Hypertension.
- Patients undergoing chemotherapy.
- Chronic use of nonsteroidal anti-inflammatory medications.
- Metformin or metformin-containing drug combinations.

Chapter Three

3. Methodology

3.1 Study Design

A prospective cross-sectional study on 80 subjects with abdominal pain (non-traumatic) who got subjected to A/P CT with contrast. The preparations, timing, volume, flow rate, injection duration, and enhancement of contrast agent used were recorded and compared to the recommended standards. The duration of this study was from January to April 2020.

3.2 Study Population and Sample

The study population included 80 patients who are above 18 years old and have undergone an abdominal-pelvis CT scan (non-traumatic) with CM in the mentioned medical institutions. 20 patients from the governmental sector, 20 patients from each NGO, and 20 patients from the private sector in the inclusion criteria who underwent the A/P CT with IV CM examinations.

3.3 Inclusion and Exclusion Criteria

All patients age 18 and above who underwent A/P CT with contrast (non-traumatic) in the chosen governmental, NGOs, and private institutions in Hebron governorate. While patients under 18 years old and patients who have contraindicated to CM in whom contrast study are indicated were excluded.

3.4 Data Collection

Data collection form (Appendix I), and (Appendix II) were data collection sheets prepared after the literature review. Standard demographic questions were used to assess age, sex, other background and clinical variables, CM parameters including injection rate and duration, timing of AP, PVP, DP, and CM volume and type. Patient preparation and safety were assessed by a kidney function test, solid food and fluid fasting, and the use of a CM questionnaire.

3.5 Comparison of CT Scanners

4 CT scanners were included to evaluate the CT scanning factors associated with the contrast enhancement and scan timing. These scanners are located as follows: one in a governmental hospital, two in NGOs, and one in a private radiology center. Table 3.1 shows four CT scanner used in Hebron governorate medical institutions.

Table 3.1: CT Units used in Hebron governorate medical institutions.

Medical Institution	Institution symbol	Sector	Manufacturer/ Year of installation	Scanner Model
Hebron Governmental Hospital	A	Governmental	Philips Brilliance/2009	16 Slices
Al-Ahli Hospital	B	NGO	Siemens Somatom Perspective / 2015	32 Slices
PRCS	C		Philips Ingenuity Elite/2017	64 Slices
Al-Yasmin Radiology center	D	Private	Philips Brilliance/2019	16 slices

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3.6 MDCT Technique and Application of Contrast Agent

In all the medical institutions included, the patient was in the supine position with feet first protocol or headfirst protocol according to the MIT's preference. Arms raised above the patients head and the abdomen, centered with gantry. A single non-enhanced breath-hold CT (NECT) was done first, from the level of the diaphragm through the symphysis pubis. Then, a water-soluble non-ionic IV contrast agent was given in different volumes, and a flow rate (according to the institution) through power injectors and post-contrast arterial. Arterial, venous and delay phases were taken by bolus tracking or by a fixed time delay at different timings, extending from 18 -25 seconds post-injection or 4-12 seconds PB, 40-75 seconds PI or 38-92 seconds PB, and 3-24 minutes PI or PB, respectively. In inconclusive cases, rectal contrast was given while the patient was on the imaging couch. Oral contrast was given 1-2 hours prior to the procedure in urgent cases, 15-25 mL of different types of ionic and non-ionic water-soluble iodinated contrast (according to institution) in 1500 cc water.

KVp were controlled manually and set to be from (120 to 140 KVp), institution A used 120 KVp with a fixed mA, a rotation time of 0.75 and 0.938 pitch. Institution B used 130 KVp with the mA being automatically controlled by the machine with a 0.5 second rotation time and 0.7 pitch. Institution C used 120 KVp with an automatic mA selection and a rotation time of 0.5 seconds and a 0.859 pitch. Institutions D used 120-140 KVp, with a fixed mA, and a 0.75 second rotation time

and a 1.2 pitch. Raw data is acquired at 3 mm slice thickness in all institutions except institution B, which used a 5mm slice thickness.

3.7 Quantitative Assessment

Three radiologists with 5, 10, and 10 years experience, respectively, worked for interpreting body CT scans) measured the mean HU values of Aorta in the unenhanced and the AP images, and HU of the liver in unenhanced and PVP images on a commercially available DICOM by placing a region of interest (ROI) that is circular with an area of approximately 2 cm^2. All possible hepatic lesions, artifacts, bile ducts, and blood vessels that are visible were excluded from the area of interest. In every patient, a hepatic mean HU value was calculated from three different hepatic hepatic segments—right lobe, medial segment, and left lobes of the liver—at each CT section. (ΔHU) used to express the quantitative degree of CM enhancement and was calculated by subtracting CT numbers on unenhanced images from those on the PVP. For the aorta, we measured attenuation values by placing a circular ROI of 1 cm^2 for all patients where the CT values placed were measured in areas just above the level of the diaphragmatic dome, and contrast enhancement of the Aorta was calculated as the absolute difference in HU between the non-enhanced image and the contrast-enhanced CT images of the A phase.

3.8 Statistical Analysis

After being encoded, collected data was used as input in SPSS version 20. Descriptive statistics were carried out for all variables. Frequencies (percentages) were calculated for socio-demographic variables. Continuous variables were expressed as mean ± standard deviation, while categorical variables were given as frequencies and percentages.

"T" test for independent samples (a T sample independent test) was used to determine the variance according to the gender variable, and one-way analysis of variance (ANOVA) to determine the variance in ages, weights, injection rate, Δ HU of the liver and Δ HU of Aorta was done according to the institution.

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3.9 Ethical Consideration

Approval from Research Ethical Committee (REC) at Al-Quds University (Appendix 3) Palestinian Ministry of Health, (Appendix 4), Al-Ahli hospital (Appendix 5), PRCS (appendix 6), and Al-Yasmin radiology center (Appendix 7) were taken before the study initiation. All required patients information was recorded after receiving consent form that confirms their willing to participate (Appendix 10).

Chapter Four

4. Results

4.1 Demographic Information of the Patients

Eighty patients underwent an A/P CT with a CM in 4 different medical institutions related to three sectors, governmental, NGO, and private. 25% were from the governmental sector, Hebron governmental hospital(HGH), 50% from NGOs, Palestine red crescent Society (PRCS), and AL-Ahli hospital (AH), and 25% from the private sector, Al-Yasmin radiology center (YRC) (Figure 4.1).

Forty-three of the patients were females (54%) (Figure 4.2). Mean ± standard deviation of the sample age equals to 46 ± 18 years, ranging from 18-95 years.

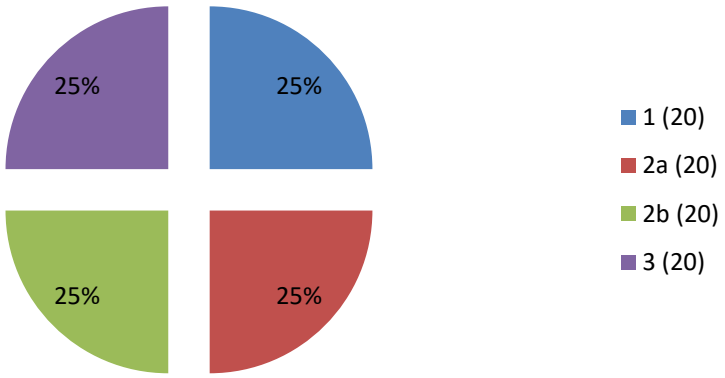

Figure 4.1: Number of patients underwent A/P CT scan with IV CM from medical institutions included in the study

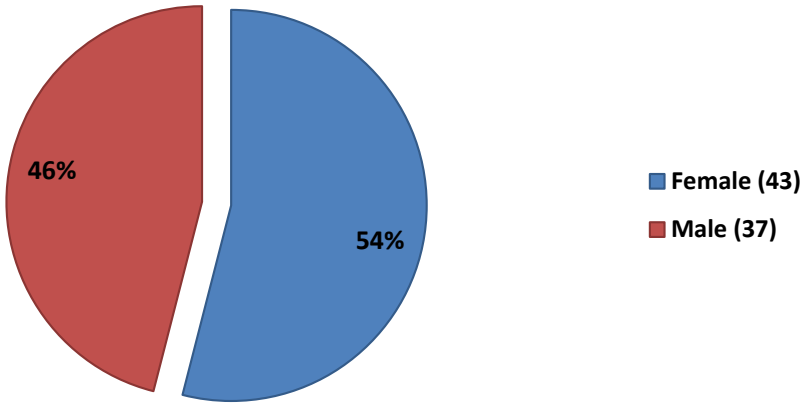

Figure 4.2 Number and percentage of male VS Female patients underwent A/P CT scan with IV CM from medical institutions included in the study

It is noted through Table 4.1 that the level of significance (α> 0.05) indicates that there are no statistically significant differences between the average ages of cases according to the type of institution.

Table 4.1: Analysis of variance of age between the 4 institutions

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups (institutions)	52.638	3	17.546	0.053	0.984
Within Groups	25011.250	76	329.095		
Total	25063.888	79			

Patient's weights mean ± SD and range in institution A, B, C, and D are shown in Table 4.2.

Table 4.2: patient's weight mean ± SD, and range in the four institutions

	Institution			
Score	**A**	**B**	**C**	**D**
Mean ± SD	73.1±12.34	80.7±17.28	78.15±13.37	81.85±11.29
Range	55-93	40-110	65-110	60-100

It is noted through Table 4.3 that the significance level (α> 0.05) indicates that there are no statistically significant differences between the averages of the weights of cases according to the type of institution.

Table 4.3: Analysis of variance of patient's weight between the four institutions

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups (institutions)	902.238	3	300.746	1.589	0.199
Within Groups	14383.450	76	189.256		
Total	15285.688	79			

4.2 Patient Safety and Preparations

All institutions instructed patients to have nothing by mouth from midnight till just before the day of the A/P CT scan with IV CM. One institution (25%) out of the four included, used a pre-contrast patient questionnaire, while 3 institutions (75%) only asked patients orally about possible allergies to iodine or seafood (Figure 4.3).

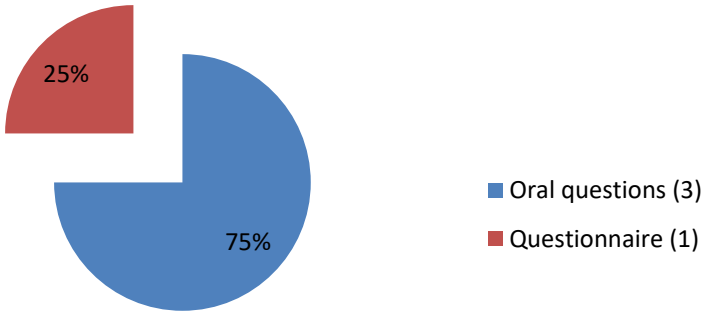

Figure 4.3: Frequency of institutions used pre-contrast IV CM questionnaire

Serum creatinine laboratory test was done to all patients prior to the IV CM administration, mean ± SD of the sample serum creatinine equals 0.85 mg/dL ± 0.2 mg/dL, and ranged from 0.5-1.4 mg/dL.

4.3 Cannula and Injection Site

Antecubital vein was used in all patients from the four institutions. The 20 gauge pink cannula was the most used in the total population (67.5%), followed by the 18 gauge green cannula (22.5%), and finally the 22 gauge blue cannula (10%), Table 4.4 Shows the different cannulas used among the institutions.

Table 4.4: Cannulas used in the four institutions

Institution	Cannula Gauge	Frequency	Percent
A	18 G	1	5.0
	20 G	19	95.0
	Total	20	100.0
B	18 G	3	15.0
	20 G	16	80.0
	22 G	1	5.0
	Total	20	100.0
C	18 G	2	10.0
	20 G	18	90.0
	Total	20	100.0
D	18 G	12	60.0
	20 G	1	5.0
	22 G	7	35.0
	Total	20	100.0

4.4 Saline Flush

Saline flush has been used in three out of the four institutions (75%) in the range of 25-30 mL, with an injection rate of 2.5 -2.8 mL/s, while one institution did not use saline in its CT contrast exams, (Figure 4.4)

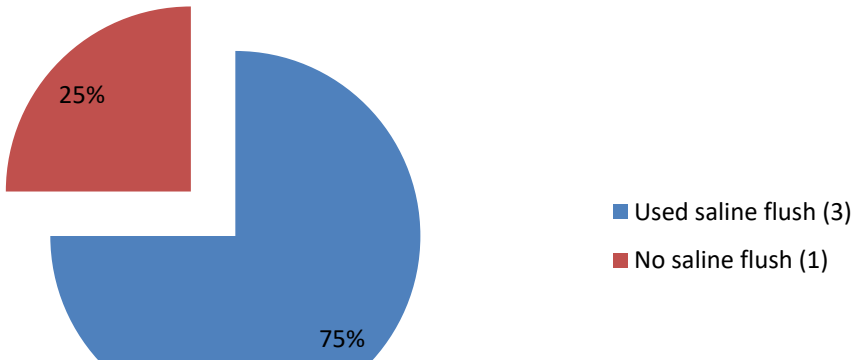

Figure 4.4: Frequency of institutions used saline flush

4.5 Arterial, Portal Venous, and Delayed phases Time Delay

4.5.1 Arterial Phase Time Delay

AP was used in two institutions as a routine phase, while other institutions escaped the A phase according to the institutional policy. Institution 1 used the A phase in 9 (45%) out of 20 patients (Table 4.5).

Table 4.5: AP usage and time delay in institution A

	Score	
AP timing used	**Frequency**	**Percent**
8 PB	6	30
9 PB	3	15
none	11	55
Total	20	100

Institution B and C generally use the A phase as a routine phase in the A/P CT scan with IV CM, thus, the A phase was used in all their included CT exams (Table 4.6 & 4.7)

Table 4.6: AP usage and time delay in institution B

Score

AP timing used	Frequency	Percent
3 PB	1	5
4 PB	12	50
5 PB	3	15
8 PB	3	15
9 PB	1	5
Total	20	100

Table 4.7: A phase usage and time delay in institution C

	Score	
AP timing used	**Frequency**	**Percent**
7 PB	3	15
8 PB	16	80
9 PB	1	5
Total	20	100

Institution 3 used a fixed time delay for the A phase which was used for 10 (50%) out of 20 patients, (Table 4.8)

Table 4.8: AP usage and time delay in institution E

	Score	
Ap timing used	**Frequency**	**Percent**
18 PI	2	10.0
20 PI	2	10.0
25 PI	6	30.0
none	10	50.0
Total	20	100.0

Mean ± SD of the A phases time delay is shown in (Table 4.9).

Table 4.9: AP time delay mean ± SD and range for the institutions

	Institution			
Score	**A**	**B**	**C**	**D**
A phase usage N (%) for bolus timing group	9 (45%)	20 (100%)	20 (100%)	-----
A phase usage N (%) fixed time delay group	-----	-----	-----	10(50%)
Mean A timing ± SD for bolus timing group	8 ± 0.5	5 ± 1.76	8 ± 0.45	-----
Mean A timing ± SD for fixed time delay group	-----	-----	-----	22.6 ± 3.2
Range for bolus timing group	8-9	3-9	7-9	-----
Range for fixed time delay group	-----	-----	-----	18-25

4.5.2 Portal Venous Phase Time Delay

The second phase after the AP is the PVP. All institutions performed the PVP. There were two groups of the PVP in institution A the first is the PB group which was part of the triphasic A/P CT exams and was done for 9 (45%) patients. The second was done as a PVP only, where a fixed time delay was used for 11 (55%) patients (Table 4.10).

Table 4.10: PVP phase usage and time delay in institution A

	Score	
PVP timing used	**Frequency**	**Percent**
62 PB	8	40
70 PI	11	55
72 PB	1	5
Total	20	100

Institution B used the PVP as part of the triphasic A/P CT exams for all patients where the PB mechanism has been used as routine (Table 4.11).

Table 4.11: PVP phase usage and time delay in institution B

Score

PVP timing used	Frequency	Percent
38 PB	2	10
40 PB	1	5
44 PB	1	5
45 PB	1	5
47 PB	2	10
48 PB	1	5
51 PB	1	5
52 PB	1	5
53 PB	1	5
58 PB	1	5
60 PB	2	10
63 PB	1	5
72 PB	1	5
74 PB	1	5
82 PB	1	5
90 PB	1	5
91 PB	1	5
Total	20	100

Institution C used the PVP as part of the triphasic A/P CT exams for all patients where the PB mechanism was used as routine (Table 4.12).

Table 4.12: PVP phase usage and time delay in institution C

	Score	
PVP timing used	Frequency	Percent
61 PB	1	5
64 PB	1	5
68 PB	2	10
70 PB	2	10
71 PB	3	15
72 PB	3	15
74 PB	1	5
75 PB	1	5
77 PB	1	5
78 PB	1	5
80 PB	1	5
81 PB	1	5
82 PB	1	5
85 PB	1	5
Total	20	100

Institution D used PVP as part of triphasic A/P CT exam for 10 (50%) patients with a delay time ranging from 56-82 seconds PI. For the rest of patients (50%), one-phase or two-phase studies (PVP only, or PVP and DP) were used with a delay time ranging from 50-65 seconds PI (Table 4.13).

Table 4.13: PVP phase usage and time delay in institution D

	Score	
PVP timing used	**Frequency**	**Percent**
50 PI	2	10.0
52 PI	1	5.0
53 PI	1	5.0
55 PI	3	15.0
56 PI	1	5.0
60 PI	1	5.0
63 PI	1	5.0
65 PI	2	10.0
66 PI	1	5.0
68 PI	2	10.0
74 PI	1	5.0
76 PI	2	10.0
81 PI	1	5.0
82 PI	1	5.0
Total	20	100.0

Mean ± SD of the PVP phase time delay and range for the four institutions are shown in Table 4.14.

Table 4.14: PVP phase time delay mean ± SD and range for the institutions

	Institution			
Score	**A**	**B**	**C**	**D**
PVP phase usage N (%) for bolus timing group	9 (45%)	20 (100%)	20 (100%)	-----
PVP phase usage N (%) for fixed time delay group	11(55%)	-----	-----	20 (100%)
Mean A timing ± SD for bolus timing group	63 ± 3	57 ± 16	73 ± 6	-----
Mean A timing ± SD for fixed time delay group	70 ± 0	-----	-----	63.5 ± 10
Range for bolus timing group	62-72	38-91	51-85	-----
Range for fixed time delay group	70	-----	-----	52-82

4.5.3 Delayed Phase Time delay

DP is the last phase and was subject to the institutional policy. Institution A used the DP for eight patients (40%) (Table 4.15)

Table 4.15: DP usage and time delay in institution A

	Score	
DP timing used	**Frequency**	**Percent**
4.42 PB	1	5
4.47 PB	1	5
4.48 PB	1	5
4.6 PB	2	10
4.6 PI	1	5
4.7 PB	1	5
7.33 PB	1	5
none	12	60
Total	20	100

Institution B used DP as a routine phase for different abdominal indications where DP was done for 19 (95%) patients (Table 4.16)

Table 4.16: DP usage and time delay in institution B

	Score	
DP timing used	**Frequency**	**Percent**
10 PB	1	5
4.38 PB	1	5
5.10 PB	1	5
6.27 PB	1	5
6.45 PB	1	5
6.52 PB	1	5
6.59 PB	1	5
7.42 PB	1	5
7.46 PB	1	5
7.50 PB	1	5
7.8 PB	1	5
7.9 PB	1	5
8.12 PB	1	5
8.27 PB	1	5
8.37 PB	1	5
8.38 PB	1	5
9.12 PB	1	5
9.38 PB	1	5
9.8 PB	1	5
none	1	5

Institution C used DP for 11(55%) patients (Table 4.17).

Table 4.17: DP usage and time delay in institution C

	Score	
DP timing used/Score	**Frequency**	**Percent**
04:42 PB	1	5
09:42 PB	1	5
10 PB	3	15
10.18 PB	1	5
12.10 PB	1	5
24 PB	1	5
4:54 PB	1	5
5 PB	1	5
8.43 PB	1	5
none	9	45
Total	20	100

Institution D used DP for 17 (85%) patients (Table 4.18)

Table 4.18: DP usage and time delay in institution D

	Score	
DP timing used/Score	**Frequency**	**Percent**
10.49 p i	1	5.0
12 p i	1	5.0
13.2 p i	1	5.0
3.46 p i	1	5.0
4.1 p i	1	5.0
4.16 p i	1	5.0
4.2 p i	1	5.0
4.29 p i	1	5.0
4.3 p i	1	5.0
5.14 p i	1	5.0
5.26 p i	1	5.0
5.27 p i	1	5.0
5.28 p i	1	5.0
6.25 p i	1	5.0
6.9 p i	1	5.0
7.3 p i	1	5.0
8.32 p i	1	5.0
none	3	15.0
Total	20	100.0

Time delay mean ± SD of the DP is shown in Table 4.19.

Table 4.19: DP time delay mean ± SD and range for the institutions

	Institution			
Score	**A**	**B**	**C**	**D**
DP usage N (%) for bolus timing group	8 (40%)	19 (95%)	11 (55%)	-----
DP usage N (%) for fixed time delay group	1(5%)	-----	-----	17(85%)
Mean DP timing ± SD for bolus timing group	4.9 ± 0.98	7.6 ± 1.5	9.3 ± 5.9	-----
Mean DP timing ± SD for fixed time delay group	-----	-----	-----	6.47 ± 2.93
Range for bolus timing group	4.42- 7.33	4.38-10	4.42-24	-----
Range for fixed time delay timing group	-----	-----	-----	3.46-12

4.6 Injection Rate

Administration of CM was done at different injection rates, and no fixed injection rate was used in the included institutions except for institution A which use a fixed injection rate of 2.5 mL/s for the PVP group only, and 4 mL/s for the triphasic group except for one patient who had an injection rate of 3 mL/s, while other institutions used a fixed injection rate for some patients (Table 4.20).

Table 4.20: Injection rate used in institution A

	Score	
Flow rate	**Frequency**	**Percent**
2.5 mL/s	12	60.0
3 mL/s	1	5.0
4 mL/s	7	35.0
Total	20	100.0

Institutions B, C, and D used a varied injection rate that was fixed for some patients according to the MIT working (Table 4.21-4.23).

Table 4.21: Injection rate used in institution B

	Score	
Flow rate	**Frequency**	**Percent**
2.7 mL/s	6	30.0
2.8 mL/s	4	20.0
2.9 mL/s	1	5.0
3 mL/s	8	40.0
3.3 mL/s	1	5.0
Total	20	100.0

Table 4.22: Injection rate used in institution C

	Score	
Flow rate	**Frequency**	**Percent**
2.5 mL/s	2	10.0
3 mL/s	15	75.0
4 mL/s	3	15.0
Total	20	100.0

Table 4.23: Injection rate used in institution D

	Score	
Flow rate	**Frequency**	**Percent**
2.5 mL/s	8	40.0
2.7 mL/s	1	5.0
2.8 mL/s	1	5.0
3 mL/s	1	5.0
3.2 mL/s	9	45.0
Total	20	100.0

Table 4.24 summarizes mean ± SD, and range of flow rates used in the institutions.

Table 4.24: Injection rate mean ± SD and range used in the four institutions

Institution

Score	A	B	C	D
Mean ± SD	3.1±0.72	2.87±0.14	3.1±0.42	2.87±0.33
Range	2.5-4	2.7-3.3	2.5-4	2.5-3.2

It is noted from Table 4.25 that the significance level (α> 0.05) indicates that there are no statistically significant differences between the injection rate averages for cases according to the type of institution.

Table 4.25 Analysis of variance of injection duration between institutions

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.886	3	.295	1.425	0.242
Within Groups	15.757	76	.207		
Total	16.644	79			

4.7 CM Volume

Institution A used a fixed volume of CM (100 mL) regardless of patient weight, except for one patient who received 80 mL/Kg while random amounts of CM were used in the rest of institutions in which patients received 1-1.2 mL/Kg randomly according to MIT working.

4.8 Contrast Media Concentration

For all patients at each institution, A and B Omnipaque 350 mgI/mL was used, while in institution C Visipaque 320 mgI/ mL was used, and finally in institution D Omnipaque 300 mgI/ mL was used.

4.9 Injection Duration

As institution A used a fixed injection rate and volume in the two groups, bolus tracking and fixed time delay, this resulted in a fixed injection duration for both groups, except for one patient. Other

institutions neglected the injection duration, which was clear in the greatly varying injection durations used (Table 4.26).

Table 4.26: Injection duration used in the four institutions

	Score		
Institution	**Injection duration**	**Frequency**	**Percent**
A	25 sec	7	35.0
	26.7 sec	1	5.0
	40 sec	12	60.0
	Total	**20**	**100.0**
B	20 sec	1	5.0
	23 sec	2	10.0
	26 sec	1	5.0
	27 sec	1	5.0
	28 sec	2	10.0
	29 sec	2	10.0
	30 sec	4	20.0
	33 sec	1	5.0
	34 sec	1	5.0
	35 sec	1	5.0
	36 sec	1	5.0
	37 sec	2	10.0
	38 sec	1	5.0
	Total	**20**	**100.0**
C	23 sec	4	20.0
	25 sec	4	20.0
	27 sec	4	20.0
	28 sec	2	10.0
	29 sec	1	5.0
	30 sec	1	5.0
	31 sec	1	5.0
	33 sec	1	5.0
	37 sec	1	5.0
	38 sec	1	5.0
	Total	**20**	**100.0**
D	22 sec	2	10.0
	23 sec	2	10.0
	25 sec	1	5.0
	26 sec	1	5.0
	27 sec	1	5.0
	28 sec	3	15.0
	29 sec	2	10.0
	30 sec	1	5.0
	32 sec	1	5.0
	36 sec	1	5.0
	38 sec	2	10.0
	40 sec	3	15.0
	Total	**20**	**100.0**

The shortest and longest injection durations were 20, and 40, Table 4.27 Summarizes mean ± SD, and range of the used injection duration in the four institutions.

Table 4.27: Injection duration mean ± SD and range in the four institutions

	Institution			
Score	**A**	**B**	**C**	**D**
Mean ± SD	34±7.4	30.2±5	27.7±4.3	30.2±6.3
Range	25-40	20-38	23-38	22-40

4.10 Quantitative Assessment

4.10.1 Aortic Enhancement

The mean ± SD of unenhanced attenuation of the aorta is shown in (Table 4.28)

Table 4.28 Unenhanced attenuation of the aorta mean ± SD and range in the four institutions

	Institution				
Score	**A**	**B**	**C**	**D**	**Total population**
Mean ± SD	31.15±6.7	38.75±6.02	36.9±9.82	34.1±10.1	35.32±8.7
Range	18-45	27-49	18-50	16-61	16-61

The mean ± *SD* of maximal aortic enhancement was calculated (post-contrast attenuation minus pre-contrast attenuation), and the range is shown in (Table 4.29). It is noted through Table 4.30 that the level of significance ($\alpha \leq 0.05$) indicates that there are statistically significant differences between the averages of maximal aortic enhancement according to the type of institution between institution A and B and between institution A and D, in which maximal aortic enhancement is shown to be greater in institution A.

Table 4.29: Maximal aortic enhancement during AP mean ± SD and range in the four institutions

Institution

Score	A	B	C	D
Mean ± SD	264.25±60.23	213.45±50.83	200.85±39.2	164.2±48.27
Range	192-361	149-354	136-292	98-273

Table 4.30 Analysis of variance of maximal aortic enhancement between institutions

(I)Institution	(II) Institution	Mean Difference (I-II)	Std. Error	Sig.
A	B	50.8	20.09699	0.107
	C	63.40000*	20.09699	0.027
	D	100.05000*	22.78784	0.001
B	A	-50.80000-	20.09699	0.107
	C	12.6	15.1919	0.876
	D	49.25	18.6062	0.084
C	A	-63.40000-*	20.09699	0.027
	B	-12.60000-	15.1919	0.876
	D	36.65	18.6062	0.286
D	A	-100.05000-*	22.78784	0.001
	B	-49.25000-	18.6062	0.084
	C	-36.65000-	18.6062	0.286

4.10.2 Hepatic Enhancement

The mean unenhanced attenuation of the liver is shown in (Table 4.31). One patient from institution A, three from institution B, three from institution C, and three from institution D were excluded because of fatty liver.

Table 4.31: mean unenhanced attenuation of the liver mean ± SD and range in the four institutions

	Institution				
Score	**A**	**B**	**C**	**D**	**Total population**
Mean ± SD	49.6±6.7	56.1±5.9	54.5±7.1	50.1±6.4	52.4±6.9
Range	40-66	43-66	40-65	40-61	40-66

The mean peak maximal enhancement of the liver (post-contrast attenuation minus pre-contrast attenuation) was calculated. The mean maximal enhancement of the liver during PVP as well as the SD and range for each institution is shown in (Table 4.32)

Table 4.32: Maximal hepatic enhancement mean ± SD and range in the four institutions

	Institution			
Score	**A**	**B**	**C**	**D**
Mean ± SD	53.4±10.3	44.9±12	45.8±10	34.6±10.1
Range	33-76	25-69	32-62	13-49

Table 4.33 Analysis of variance of maximal hepatic enhancement between institutions

Multiple Comparisons			
Dependent Variable: maximal			
(I)Institution	(II) Institution	Mean Difference (I-II)	Sig.
A	B	8.4309	.149
	C	7.6037	.212
	D	18.7802*	.000
B	A	-8.4309-	.149
	C	-.8272-	.997
	D	10.3493	.058
C	A	-7.6037-	.212
	B	.8272	.997
	D	11.1765*	.030
D	A	-18.7802-*	.000
	B	-10.3493-	.058
	C	-11.1765-*	.030

There were statistically significant differences between Institution A and Institution D, where hepatic enhancement was greater for institution A, and greater for institution C as compared to D ($\alpha \leq 0.05$) (Table 4.33).

Chapter Five

5. Discussion

The continuous advances in CT technology have provided an excellent opportunity for improving clinical practice, image quality, and the discovering of new CT imaging Applications regarding CM administration. However, such new technology has introduced challenges in clinical practice. (Berlin et al, 2011) suggests alternatives that would provide the same or even better diagnostic information which might replace the CT scan with the IV CM, the risk-to-benefit should also be considered by the referring physician and radiologists.

To the best of our knowledge, this study is the first of its type in Palestine to assess a IV contrast timing and its interrelated factors and effects on enhancement. This study provides MITs and radiologists with factors that are entirely neglected and severely affect the magnitude of peak enhancement and the temporal window for CT scanning.

Patient preparations, arterial, portal Venous, delayed phase timing, injection duration, CM concentration, and quantitative enhancement were assessed in three Palestinian medical sectors: governmental, NGOs, and private. The protocols in use are somewhat random, in which institutions have no clear guidelines and policies regarding patient preparations and safety. Some institutions only use the PVP, as compared to others which use a triphasic A/P CT scan with a CM as a routine exam for different abdominal indications with greatly varying parameters including injection duration. Injection duration is one of the most critical injection-related factors that significantly affect the timing of different phases because it has a direct effect over the time to peak enhancement in organs and vessels (Bae et al, 2010). That fact resulted in different enhancement levels of different phases which varied greatly among these institutions, as a result of hugely varied injection duration. The variation in enhancement was a result of neglecting essential parameters such as different phases timing, injection duration, flow rate, CM volume.

5.1 Patient Preparation for A/P CT Scan with IV CM

CM is considered safe, and generally, side effects are mild and self-limiting, but life-threatening emergency side effects are possible (Andreucci et al, 2014). Medical institutions follow a specific protocol for patient preparations to avoid as much as possible any adverse reactions of the CM, which could happen. Referring physicians and radiologists should consider the risk-to-benefit profile of the CM IV enhanced exams and consider potential alternatives that can provide the same or even better diagnostic information, and confirm a convincing clinical indication for the use of IV CM enhanced CT exams (Berlin, 2011).

5.1.1 Nothing by Mouth (NPO)

It is considered typical for patients not to eat or drink for hours before the CT exam with a IV CM. This preparatory procedure made sense in the past, taking into account the reasonably high rate of emetic complication associated with the use of high osmolar and ionic CM (4.58% of nausea and 1.84% for vomiting) (Bush, 1991). However, after the introduction of non-ionic low osmolar CM (Gomi et al, 2010) indicated that emesis has markedly declined (0.3%) which led them to suggest the lessening of the rationale of dietary restriction.

The large number of patients undergoing a CT scan with IV CM every day makes it a necessity for asking whether a preparatory fast is necessary. (Lee et al, 2012) mentioned in his study about the preparatory fast necessity, that current fasting policies were noticeably variable at the national level. Korea and Egypt have used more prolonged fasting compared to Germany, which used shorter fasting. Two thirds (14 of 21) [66.8%] of the investigated French and German hospitals had no restriction on both fluids and solid food while Australasian hospitals varied about fluid intake in which no restrictions in 8 out of 10 hospitals included [80%]. It also varied on fluids in Korea, the United States, and Egypt, their restrictions, 0-8 hours for Korea, 0-4 hours for the United States, and 0-6 hours for Egypt. Solid policies also varied among these countries, restriction time before a CT exam with IV CM in Korea was 0-8 hours, 0-6 for United States hospitals, 0 to 4-6 hours for Australian hospitals, and finally 0-midnight for the Egyptian hospitals.

They also suggested that drinking clear fluids such as water, tea, or decaffeinated black coffee should be allowed with no restrictions or until at least one hour before the CT exam, where the stomach empties 90% of the fluids within one hour and 100% in two hours. Their recommendation regarding solid food was less of a short-cut, as some radiologists may prefer to follow the European countries and use no dietary restrictions, others still believe that vomiting after food intake may cause minor problems in the patient's handling.

All institutions included in our study have restrictions on solids, and they instruct all patients to have nothing by mouth in which the fasting period used in these institutions was overnight for the solids which are consistent with some Egyptian hospitals that used a fasting period over the night. Fluids were allowed 2 hours before the A/P CT exam with IV CM in all the institutions included, as this agrees with the fact that two hours is the time needed for the stomach to empty 100% of the ingested fluids (Lee et al, 2012).

5.1.2 Serum Creatinine lab test

(Elicker et al, 2006) surveyed radiologists to identify the accepted practice guidelines for the screening and prevention of contrast nephropathy for patients who undergo a CT scan with IV CM. They found that serum creatinine was the most common lab test for patients receiving IV CM to assess renal insufficiency with a wide variation of practice patterns since 143 out of 410 of the radiologists use 1.5 mg/dL as the threshold of serum creatinine, while 111 use 1.7 mg/dL and 127 use 2.0 mg/dL which in some cases conflicts with other pieces of literature (Tippins et al, 2000) and (Davenport et al, 2013). (92%) of radiologists use a serum creatinine for inpatients as the initial screening test for patients undergoing a CT with IV CM. In outpatients, serum creatinine was still used (65.6%), because respondents used clinical history alone (29%) in the evaluation of occult renal insufficiency. This was also suggested by (Tippins et al, 2000) and (Olsen et al, 1996) where they suggest that most patients with renal insufficiency can be identified without the need for a laboratory test. (97-99%) of outpatients or ER department patients can be identified by a simple questionnaire. Only (2%) use an estimated creatinine clearance (ECC). Although it is easy to calculate the ECC, very few use it. It can be easily calculated by the Cockcroft-Gault equation and is considered more predictive for renal insufficiency as compared to serum creatinine (Cockcroft

et al, 1976), (Campens et al, 1997), (Levey et al, 1999) or by using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation, which is currently the most accurate method for estimating a GFR for diverse populations and can be used for routine clinical use (Levey et al, 2010).

Our results indicate that the institutions in our study consider the serum creatinine lab test an essential preparatory part for patients before the A/P CT with an IV CM. Few radiologists, 21 out of 410 do not use serum creatinine because they only use clinical history, and this number increased to 120 (28.6%) radiologists when evaluating only outpatients . (Tippins et al, 2000) also suggests that routine serum creatinine is not indicated for every patient as they listed risk factors indicated for serum creatinine and/or eGFR. They also consider a threshold of less than 1.5 mg/dL where the highest value of serum creatinine. In our study threshold was 1.4 mg/dL which agrees with 143 out of 410 radiologists surveyed by (Elicker et al, 2006). Even ECC can be easily calculated, but none of the institutions has considered EEC even in non-conclusive cases.

5.1.3 CM Questionnaire

We found a variation in the CM policies, since one institution (25%) used a CM questionnaire, while the rest of the institutions only used oral questions about possible allergies to iodine or seafood. Proper dealing with the CM requires good knowledge of patient risks. Moreover, it requires clear standards for identifying, recording, and adequately responding to those risks. Based on that fact, different CT CM policies and procedures can lead to different and varied CT CM practices and administration, which in turn results in decreased patient safety. The patient's contrast reaction information before a CT is of great importance. Inability to track such information can lead to a CT CM reaction recurrence which can lead to decreased patient safety and satisfaction and might be associated with increased costs of managing the resultant reactions (Morcos et al, 2005, Namasivayam et al, 2006, Powe et al, 1993).

(Kahlon et al, 2009) by their systemwide computed tomography contrast team (CCT) began examining already implemented and existing practices of CT CM by surveys, interviews, and site visits at sizeable integrated health care systems composed of 6 hospitals. They have found variations in CT CM policies and procedures. The majority of the institutions (83%) had screening

forms to identify the risk of CM reactions in patients. All the intended forms were different, and no consistent CM administration guidelines were being followed. Accordingly, they have described their experience implementing uniform procedures for CT CM administration and the impact on patient safety after standardizing these practices. Their results led them to formulate standard CT CM policies and procedures. Their CCT first standardized the CT CM reaction definition according to the ACR's classification for CM reactions. They also incorporated individual hospitals and their best practices along with ACR's CT CM administration policy in order to develop a systemwide standardized electronic medical record (EMR) policy for CT CM administration. Screening and classification of reactions approach for responding to CM-induced nephropathy in addition to exceptional clinical circumstances, including metformin therapy, diabetes, sickle-cell anemia, and pheochromocytoma are all addressed in the policy. CCT also worked to develop a standard CT IV CM patient questionnaire, along with an adverse drug event form. It was designed to include the patient's history of allergic and idiosyncratic reactions, premedication regimen, in order to reduce contrast reactions, and patient current medications. It also included questions with information about conditions such as kidney disease, diabetes, sickle-cell anemia, pheochromocytoma, multiple myeloma, cardiac disease, and collagen vascular diseases (such as lupus). Pregnancy and breastfeeding questions were added for female patients.

5.2 Cannula and Injection Site

According to the recommendations of the (ACR, 2018), it is preferable to use the 20-gauge cannula or higher for the flow rates of 3 mL/s and above with antecubital or large forearm veins as the preferable venous access site. In our study, 67.6% (54 patients) of the used cannulas were the 20-gauge pink, and the larger size 18-gauge green cannula was used by 22.5% (18 patients), while the 22-gauge cannula which can be used for flow rates of lower than 3 ml/sec, used with eight patients with flow rates less than 3 ml/sec. The venous access site in all patients included was the antecubital vein. (Smithuis, 2014) suggests that flow rate of 5 mL/s is needed in some abdominal indications, including GI bleeding, pancreatic carcinoma, liver cancer. When this rate is impossible or not needed, a lower flow rate of 3-4 mL/s should be used with a 20-gauge cannula.

5.3 Arterial, Portal Venous, and Delayed Phases Time Delay and Injection-Related Factors

5.3.1 Arterial Phase Time Delay and Injection-Related Factors

The early AP which occurs immediately post bolus (PB) tracking or 15-20 seconds post-injection (PI). This early AP is used to enhance the arteries before contrast enhances other body organs. Late A phase occurs 30-40 seconds PI, or 15-20 seconds PB, where the organs that receive blood from arteries will be enhanced (Smithuis, 2014). Institutions included a mean A phase timing delay of 8 ± 0.5, 5 ± 1.76, 8 ± 0.45 PB, and 22.6 ± 3.2 PI timing. This timing used will mostly result in the AP, that is not early nor late (Figures 5.1-5.5).

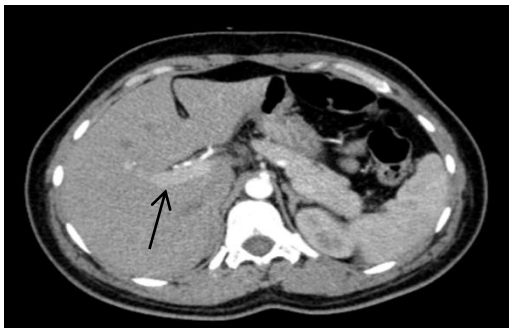

Figure 5.1 : 48 years old female, 65 Kg. 70 mL of CM was administrated at flow rate of 3 mL/s and injection duration of 23 seconds with AP time delay of 4 seconds PB showing enhancement in the portal vein (black arrow) indicating end of early A phase.

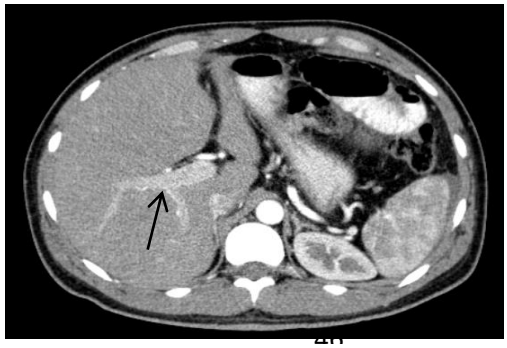

Figure 5.2 : 39 years old male, 80 Kg. 85 mL of CM was administrated at flow rate of 3 mL/s and injection duration of 23 seconds with A phase time delay of 8 seconds PB showing enhancement in the portal vein

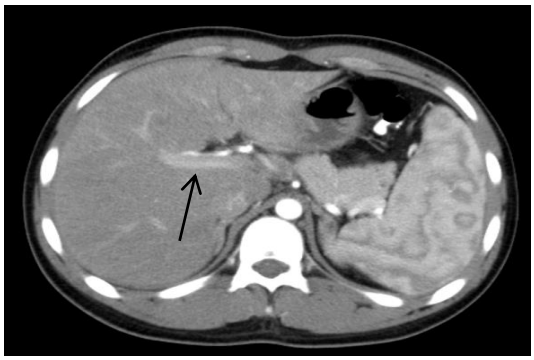

Figure 5.3 : 18 years old male, 60 Kg. 65 mL of CM was administrated at flow rate of 3 mL/s and injection duration of 22 seconds with A phase time delay of 25 seconds PI showing enhancement in the portal vein (black arrow) indicating end of early A phase.

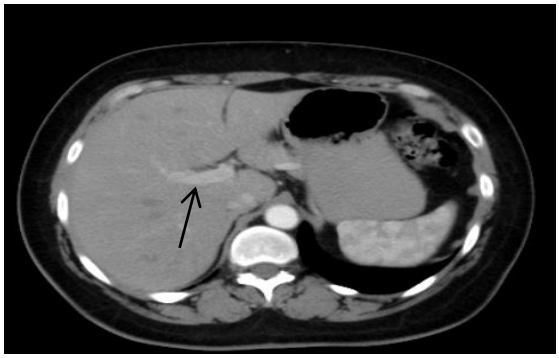

Figure 5.4 : 40 years old Female, 75 Kg. 75 mL of CM was administrated at flow rate of 3.2 mL/s and injection duration of 22 seconds with A phase time delay of 23 seconds PI showing enhancement in the portal vein (black arrow) indicating end of early A phase.

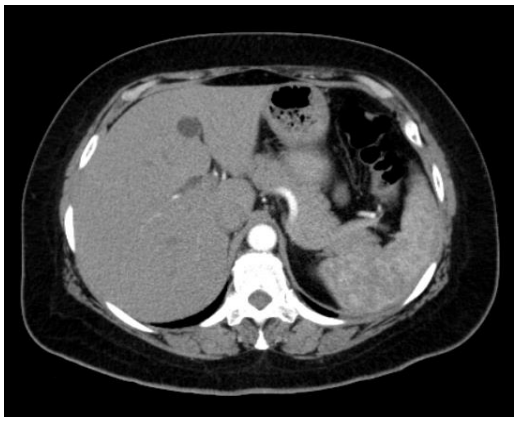

Figure 5.5 : 48 years old Female, 110 Kg. 110 mL of CM was administrated at flow rate of 3 mL /s and injection duration of 37 seconds with A phase time delay of 4 seconds PB showing the portal vein unenhanced indicating early A phase.

Early AP begins when CM arrives hepatic arteries and ends before portal vein enhancement (Bae et al, 2005). This is primarily has a great role in imaging pure arterial data for studies such as CT angiography (CTA). But AP has a limited role in imaging the liver. Late AP is preferred for radiologists to diagnose different liver and abdominal abnormalities (Awai et al, 2002, Hollett et al, 1995, Kanematsu et al, 2005).

The resulted images in our study mostly reveal that the AP time delay used along with other CM factors made an AP that can be described as an intermediate AP which represents the end of the early AP and the beginning of the late AP. Injection duration used has a great effect on CT scan timing and actually considered the most important injection-related factor. MITs should determine the scan timing with consideration of injection duration (Bae, 2010). Results mentioned in table 4.26 reveal a great variation of the injection duration timing used which confirms unawareness of this critical injection related factor. (Yanaga et al, 2010) used in his study contrast material injection protocol with the dose adjusted to the body surface area for MDCT Aortography a fixed injection duration of 15 seconds to reduce inter-patient variability in aortic enhancement in addition to the effect of short injection duration on arterial enhancement which is greatly desired for arterial enhancement. Therefore using short injection durations (i.e using a high injection rate or low CM volume) this will result in earlier peak arterial and parenchymal enhancement (Bae et al, 2005). This fact is consistent with our results, CT images shown in (Figures 5.1-5.5) show that the injection durations used are 23, 23, 22, 22, and 37 seconds respectively and theses injection durations are considered a relatively short injection durations which means earlier arterial

enhancement and also parenchymal enhancement which explains that at A phase timing delay of 4-8 seconds PB or 20-25 seconds PI used in our study resulted in earlier enhancement of the portal vein and escaping the early AP while (Figure 5.5) shows an injection duration of 37 seconds, longer injection duration resulted in the early A phase in which more A phase timing delay is needed with longer injection duration. But for larger patients sometimes higher flow rate is used intentionally to shorten injection duration to increase arterial enhancement. The first factor will result in delayed peak arterial and parenchymal enhancement and that explains the resulted early A phase even flow rate, and even A phase timing delay was the same as previous patients, but the injection duration has a great effect on scan timing. For pure early A phase short injection duration and A phase timing delay of 15 -20 seconds PI, or immediately after bolus tracking should be used.

5.3.1 PVP Time delay and Injection-Related Factors

The hepatic parenchymal phase or the PVP occurs when the peak contrast bolus has returned to the portal venous system after travelling through splanchnic circulation, which results in maximum hepatic parenchymal enhancement, and this typically occurs 25-40 seconds after completion of the CM injection (Bae et al, 2005). Regarding the timing for the PVP, it occurs 60-80 seconds PI, and it is usually obtained using a fixed time delay for those studies targeting the hepatic venous phase (Johnson & Fishman, 2012). (Smithuis, 2014) suggested that the PVP occurs 70-80 seconds after the CM initiation or PI, and 50-60 seconds after bolus tracking. (Ronot et al, 2017) in his triphasic A/P CT with the IV CM study used to detect neuroendocrine liver metastasis, with a PVP timing delay of 60-70 seconds PI with a flow rate of 4 mL from a nonionic contrast medium at 350 mgI/mL without specifying the injection duration. (Chung et al, 2006) recommended a delay time of 50-60 seconds post bolus tracking which can be translated into 70-80 seconds PI as an optimal delay time for a PVP delay time, and a slow injection rate when the study is targeted at the hepatic venous phase. They used a slow injection rate of less than 2 mL/s in 12 patients (5 patients received 300 mgI/mL CM with a PVP delay of 60 seconds, and 7 received 370 mgI/mL with a PVP delay of 70 seconds) each patient received a dose of 2 ml/Kg of CM and an injection duration of 47 seconds. They had no significant differences between these 12 patients, and the other 118 patients included in the study had injection rates from 2-3.2 mL/s and a PVP delay of 50 and 60. The PVP

delay used in our study for institution A was 70 seconds PI for the studies that targeted the hepatic venous phase and 62 seconds PB for the multiphasic phase which is consistent with (Smithuis, 2014, Chung et al, 2006). Flow rates used in institution A were 4 mL/s for multiphasic CT exams, and 2.5 mL/s for those targeted at the hepatic venous phase, these flow rates used are considered suitable. 2.5 mL/s alone in the PVP is enough since increasing the flow rate to more than 3 mL/s will not increase the hepatic enhancement because slower, but longer injection duration will generate a prolonged vascular enhancement which is recommended and more appropriate for lengthy procedures with long scan durations (Bae, 2010). Accordingly, injection duration such as 47 seconds which is considered a long injection duration is preferred when targeting at the hepatic venous phase, and such is used by (Chung et al, 2006). Injection duration used in the PVP for institution A was 40 seconds, which is close to that used by (Chung, 2006); however, they used a CM volume of 2 mL/Kg compared to the 100 mL fixed-dose, whatever the patient weight may be. The 100 mL fixed-dose should not be used for all patients; instead, they should be classified like the ones used by the studies such as (Chung, 2006, Smithuis, 2014, Bae, 2010) or even using a fixed weight adapted amount for all patients such as 2 mL/Kg as used by (Ronot et al, 2017, Kanematsu et al, 2005)

Institution B used a PVP timing delay that ranged from 38-91 seconds PB. While institution C, and 3 used a range of 61-85 seconds PB, and 50-82 seconds PI. This wide range will result in the PVP that would be classified as an early PVP, late PVP, or nephrogenic phase, indicating a random use of the timing according to the working MIT. Also, they neglected the injection duration which ranged from 25-40, 20-38, 23-38, and 22-40 seconds in institutions A, B, C, and D, respectively; which may change the optimal scan delay (Kanematsu, 2005). (Bae, 2010) recommended a shorter injection and faster injection rate for multiphasic visceral organs, because shorter injection duration results in greater temporal separation, and also a more extensive degree of enhancement between the A-phase and the PVP of the visceral parenchymal enhancement.

(Bae, 2010) suggested that flow rates of less than 3 mL/s will increase hepatic enhancement much more gradually, and this is apparent only at relatively low injection rates (<3 mL/s). The flow rate used in institution A and D for studies that targeted the hepatic venous phase was only 2.5 mL/s which was accepted, but other factors may alter the time delay used and accordingly visceral enhancement. For multiphasic imaging studies of the visceral organs, the use of a 4 mL/s injection

duration with a 25 second injection duration is reasonable and would result in maximal enhancement because relatively short injection duration with faster injection rate has been used.

The effect of using a different timing delay and other injection-related factors on CT images (Figures 5.6-5.10)

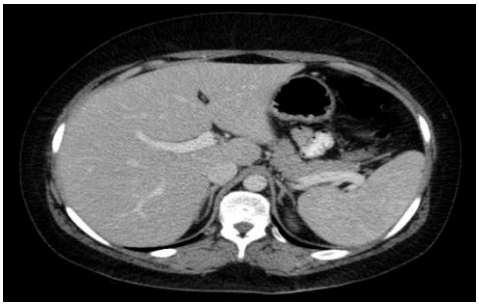

Figure 5.6: 18 years old male, 70 Kg. 100 mL of CM was administrated at flow rate of 2.5 mL /s and injection duration of 40 seconds with PVP time delay of 70 seconds PI showing intensive enhancement of the portal vein and homogenous appearance of the spleen indicating late PVP.

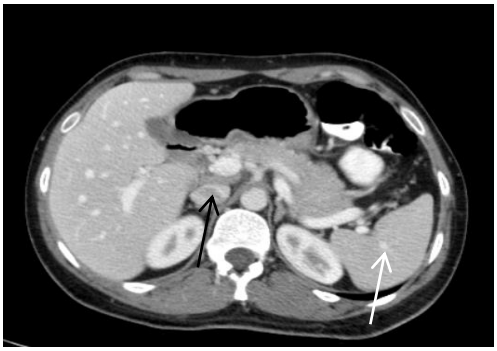

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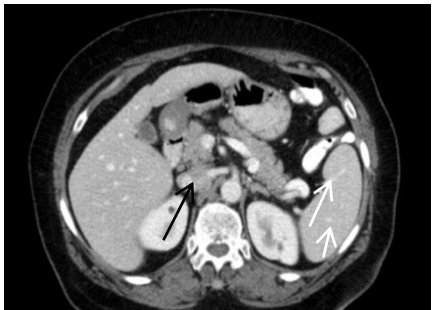
Figure 5.7: 31 years old female, 55 Kg. 100 mL of CM was administrated at flow rate of 2.5 mL /s and injection duration of 40 seconds with PVP time delay of 70 seconds PI showing an artifact of mixed blood with CM and non- opacified blood (swirl-like) which is a feature of early PVP that could be confused with thrombus (black arrow), in addition to inhomogeneous appearance of the spleen (white arrow).



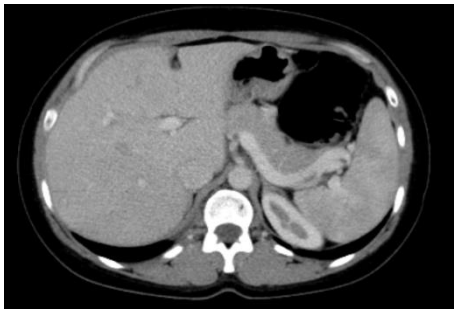


Figure 5.9: 35 years old female, 65 Kg. 75 mL of CM was administrated at flow rate of 2.7 mL /s and injection duration of 28 seconds with PVP time delay of 38 seconds PB showing heterogeneous appearance of spleen indicating early PVP.

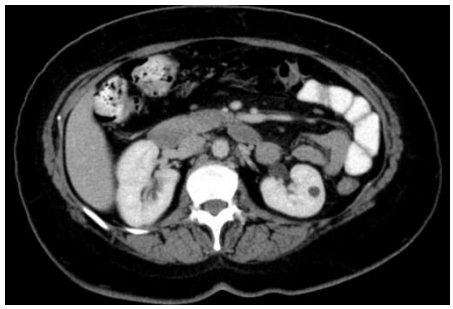


Figure 5.10: 48 years old female, 110 Kg. 110 mL of CM was administrated at flow rate of 3 mL /s and injection duration of 37 seconds with PVP time delay of 91 seconds PB showing homogeneous appearance of kidneys indicating nephropgenic phase.

In (Figure 5.7, & 5.8) the use of PVP time delay of 70 seconds PI was consistent with the literatures, but there was signs of early PVP even time delay used was 70 seconds PI, that was a result of a relatively long injection duration (40 seconds) which was suitable for prolonged procedures with long scan duration such as those studies targeting hepatic venous phase. As timing, now it's well known that longer injection durations results in later peak enhancement, and accordingly longer scan delay is preferable (Bae, 2005). To avoid sings of early PVP longer injection duration than 70 seconds PI should be used with this long injection duration.

The same timing, CM volume, and flow rate was used with the patient as shown in Figure, 5.6. But the difference was that patient age (18 years old). Younger patients are always associated with increased cardiac output which is the most important patient-related factor affecting CM timing (Bae, 1998). And that explains why patient has reached the late PVP even same parameters were used.

A/P CT image shown in Figure 5.9 shows too early timing delay for the PVP, 38 seconds PI resulted in early PVP. Injection duration used was 38 seconds which will further increase time delay needed for both A phase and PVP, in which shorter injection duration and faster injection rate are recommended for multiphasic CT exams.

Figure 5.10 shows nephrogenic phase, which was a result of using too long delay for the PVP. 91 seconds PB is too much timing for late PVP. The timing used with all patients was not based on clinical indication but rather on MITs working.

5.3.2 Delayed Phase

The DP in the triphasic A/P CT scan can be of added value in certain clinical applications such as abdominal trauma, evaluation of known renal, adrenal, hepatic, or pancreatic mass, and to assess patients who had undergone endovascular aortic aneurysm repair for possible endoleaks (Chan et al, 2014). DP can also increase the confidence, diagnosing active arterial extravasation in cases of active bleeding or trauma; it can also act as a supplementary phase of the A-phase of stent-graft, and thus confirm urinary leaks. Also, DP can increase the accuracy of lesion characterization (Vasanawala & Desser, 2006). However, if there is no indication known to do the DP, routine

addition of this phase may be a waste of resources and results in additional radiation to patients (Guite et al, 2011). Institution A, B, C, and D used this phase in (40%), (95%), (11%) and (85%) of the patients, respectively. Institution B and D use this phase as a routine due to the institutional policy, while A and C use this phase selectively, which can be decided by a radiologist or an experienced working MIT.

For the evaluation of the urinary system, 7 to 10 minutes after the PVP is required (Romano et al, 2015). The DP occurs about 6-10 minutes PI of the CM, in order to wash out from all the abdominal structures except for fibrotic tissues (Smithuis, 2014). Delayed imaging times of a few minutes up to 15 minutes are considered typical, the most common indications for DP, include kidney evaluation, collecting system (ureters and bladder), and specific kidney, liver, and adrenal lesions (Boland, 1997, Lacomis et al, 1997). According to previous reports, excretory phases have been obtained between 2.5 and 16 minutes PI (Caoili et al, 2002, Silverman et al, 2006, Meindl et al, 2006, Van Der Molen et al, 2008, Metser et al, 2012, Juri et al, 2013). (Meindl at al, 2006) suggested that a longer delay time of 10-16 minutes is feasible for opacification of the distal ureter. (Juri et al, 2017) reported that a 15 minutes delay time for the DP is necessary for complete opacification, and a much longer time may be useful for further improvements of the opacification of the urinary bladder. The range of the DP time used in the institutions A, B, C, and D was 4.42-7.33, 4.38-10, 4.42-24, and 3.46-12 minutes, respectively. Sometimes the DP is much dependent on the indication; for example, 15 minutes delay is required for adenomas washout to reach 40 % or higher so that a diagnosis can be made (Chan et al, 2014). Opacification of the ureters and bladder is needed, Figures 5.11-5.13 show the results of using a different DP time.

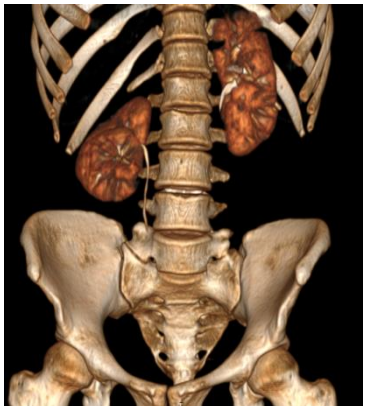


Figure 5.11: 3D image of DP of 29 years old female, 65 Kg. 75 mL of CM was administrated at flow rate of 4 mL /s and injection duration of 25 seconds with DP time delay of 4.42 minutes PB showing incomplete opa

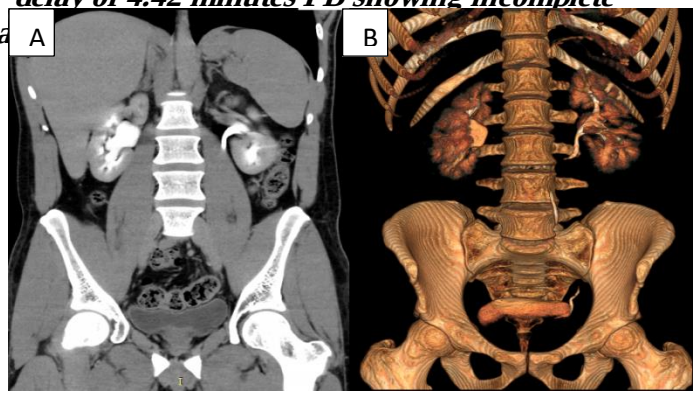


Figure 5.12: Coronal (A) & 3D (B) images of DP of 29 years old male, 80 Kg. 80 mL of CM was administrated at flow rate of 4 mL /s and injection duration of 25 seconds with DP time of 10 minutes PB showing non-opacification of right ureter and intermittent (incomplete opacification) left ureter.

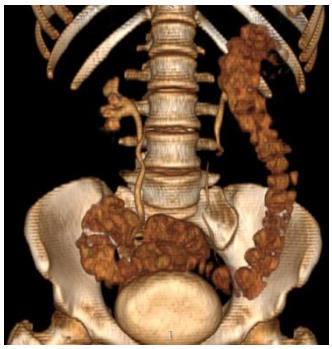


Figure 5.13 3D image of DP of 38 years old female, 73 Kg. 75 mL of CM was administrated at flow rate of 3mL /s and injection duration of 25 seconds with DP time delay of 24 minutes PB showing opacification of the right ureter and intermittent or incomplete opacification of the left ureter due to narrowing and ureteric peristalsis, while the bladder is showing full opacification.

5.4

Quantitative Assessment

5.4.1 Aortic Enhancement

If CM is injected at a fixed injection rate, the patient weight may considerably change the aortic peak enhancement. Therefore, using a protocol in which CM is injected at a fixed rate; the time of the A phase should be optimally tailored specifically to each patient, while using a protocol with a fixed injection duration means that the A phase time may remain unchanged, and thus the scanning protocol can be easily specified as the aortic peak time and the period during which contrast enhancement is 200 HU or greater are almost constant (Awai et al, 2004). They also considered 200 HU as adequate for aortic enhancement. (Mitsuzaki et al, 1996, Kim et al, 1998, Yamashita et al, 2000) reported that maximum enhancement of aorta was more significant than 238 HU when an injection rate was 3 mL/s or higher. Institution A used a fixed CM volume, fixed injection duration, and a flow rate of 4 mL/s in the triphasic A/P CT scans, the maximal aortic enhancement mean ± SD for institution A was 264.25±60.23 ranged from 192-361. This explains why the highest values were included in institution A. There was a significant difference between institution A and B, and between A and D, in which maximal aortic enhancement was more exceptional in institution A, and this is because when the injection duration is fixed, both the delivery rate and the total delivered amount of CM would be increased when faster injection rate is used which in turn results in a higher magnitude of vascular and parenchymal enhancement (Bae, 2010). In addition, the use of saline flush improves CM enhancement and CM efficiency

use. This effect will be particularly efficient when the total amount of CM is small (Bae, 2010). In our study, institutions used a relatively small amount of CM as compared to other reports, and this also explains why institution D which had no saline flush in its A/P CT exams, as well as having the least aortic enhancement when compared to institution A, and the least hepatic enhancement when compared to institution A and C.

5.4.2 Hepatic Enhancement

During the PVP, the most crucial factor affecting hepatic enhancement is the CM volume. At the same time, patient's weight or size is the most important physiologic parameter affecting the liver enhancement (Bae et al, 2010, Rengo et al, 2011, Wald et al, 2013), (Chung et al, 2006) mentioned in his study the optimal delay time for the hepatic parenchymal enhancement at the multidetector CT examination, results revealed an increase of hepatic enhancement when a higher concentration of the CM is used at the same volume. Also, at a given injection rate as the dose of iodine increases, the magnitude of the peak for hepatic enhancement increases linearly (Yamashita et al, 2000). The volume of CM used in institution B, C, and D was weight adapted, and the highest volume used was 1.2 mL/Kg with a range of 1-1.2 mL/Kg which was used randomly according to the MIT working, and the volume used was even variable for the same working MIT. Institution A used a fixed CM volume, regardless of the patient size or weight. There was no significant difference among institution A, B, and C for the maximal hepatic enhancement. (Yamashita et al, 2000, Fujigai et al, 2012, Eddy et al, 2017) considered maximum hepatic enhancement more significant than 50 HU to be adequate for diagnosis. In our study, the mean maximal hepatic enhancement was 53.4±10.3, 44.9±12, 45.8±10, 34.6±10.1 which ranged from 33-76, 25-69, 32-62, and 13-49 for institution A, B, C, and D, respectively. There was even no significant difference between institution A, B, and C, but it's noted that the highest numbers were included in institution A due to the use of the fixed 100 mL/Kg CM volume in which some patients who weigh 50 Kg for example, received about 2 mL/Kg as compared to other institutions which ensured that maximal hepatic enhancement is greatly affected by CM volume and concentration.

(Chung et al, 2006) in his study mentioned the optimal delay time for hepatic parenchymal enhancement at the multidetector CT examination, results revealed increasing hepatic

enhancement when a higher concentration of the CM is used at the same volume. In our study, hepatic enhancement was significantly higher in all scans using a contrast medium dose of 350 mgI/mL compared with the 300 mg I/mL, in which maximal hepatic enhancement was significantly higher in institution A when compared with D, and more significant for C when compared to D. Institution A used more CM volume when compared to institution D; also, institution C used a CM dose of 350 mgI/mL as compared to the 300 mgI/mL used in D with a random weight adapted CM volume that ranged from 1 mL/Kg – 1.2 mL/Kg which was used in both institutions.

Chapter Six

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6. Conclusions and Recommendations

6.1 Strengths and limitations

Major strengths of this study include: This is the first study of its type conducted in Palestine and the region to assess CM administration timing and enhancement in non-traumatic A/P CT scans. It provides baseline data about the CM administration process (safety, timing), as well as the effects of using different injection-related parameters on the delay time of different phases and enhancement.

Study limitations

Our study had notable limitations. Foremost, the study was based on a comparison between relatively small size-matched subgroups; each consisted of 20 patients, where the total study population was 80 patients.

6.2 Conclusion

Multiphasic CT scans with IV CM are very important for detecting and characterizing certain conditions. At the same time, A/P CT scan with IV CM should not be generalized and handled as a routine study. However, unindicted multiphasic CT scans of the A/P with IV CM are an important source of radiation that contributes to increased patient dose. When CM is indicated, consistent CM administration guidelines should be followed for more patient safety.

Our results show a wide range of the parameters used. The random use of time delay, CM volume, injection rate, and injection duration resulted in a wide varying range of enhancement and peak parenchymal enhancement. In order to achieve maximum benefits of the MDCT, MITs must be aware that the CM administration and scan timing need to be optimized by considering multiple interrelated factors affecting CM timing and enhancement as well as the purpose of each A/P CT scan with CM.

6.3 Recommendations

1. The need to develop a standard CT contrast IV patient questionnaire and an adverse drug event form that is consistent between institutions in Palestine.

2. Well-defined CM protocols should be identified, in addition to specify CM protocol according to indication and to the nature of the CT exam.

3. Further studies should be implemented using defined CM protocols to assess CT images qualitatively to identify the best CM protocol with maximal and optimal enhancement.

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Appendix 1

DATA COLLECTION SHEET (I)

Data collection sheet of demographic information & CM Injection parameters	**Δ HU of the liver**																				
	Mean contras enhancement of hepatic parenchyma in PVP (HU)																				
	Mean unenhanced attenuation of																				
	Δ HU of the Aorta																				
	Mean contrast enhancement of Aorta in A phase																				
	Mean unenhanced attenuation of																				
	Injection duration																				
	HFU for Bolus tracking																				
	Locator position																				
	DP time delay																				

	PVP time delay																				
	AP time delay																				
	Volume																				
	IV CM used																				
	Injection rate																				
	Cannula used																				
	Weight																				
	Sex																				
	Age																				
	Pt. code																				

Appendix 2

DATA COLLECTION SHEET (II)
PATIENT PREPARATION & SAFETY PROCEADURES

Pt. code	Serum creatinine	(NPO)	CM questionnaire

Appendix 3

Al-Quds University
Jerusalem
Deanship of Scientific Research

بسم الله الرحمن الرحيم

جامعة القدس
القدس
عمادة البحث العلمي

Research Ethics Committee
Committee's Decision Letter

Date: 22 February 2020
Ref No: 108/REC/2020

Dear Dr. Mohamad Hjouj, Mr. Mo'ath Al-Makhamreh

Thank you for submitting your application for research ethics approval. After reviewing your application entitled **"Contrast Agent Timing and Enhancement Evaluation in non-traumatic Abdomen and Pelvis CT Exams ".** The Research Ethics Committee confirms that your application is in accordance with the research ethics guidelines at Al-Quds University.

We would appreciate receiving a copy of your final research report/ publication. Thank you again and wish you a productive research that serves the best interests of your subjects.

PS: This letter will be valid for two years.

عمادة البحث العلمي
Scientific Research Deanship

Nuha El Sharif, PhD
Research Ethics Committee Chair

Cc. Prof. Imad Abu Kishek - President
Cc. Members of the committee
Cc. file

Abu-Dies, Jerusalem P.O.Box 20002
Tel-Fax: #970-02-2791293
research@admin.alquds.edu
بوديس، القدس ص.ب. 20002
لفاكس: #970-02-2791293

Appendix 4

Appendix 5

05-01-'20 08:45 FROM- T-696 P0001/0001 F-041

State of Palestine
Ministry of Health
General Directorate
of Paramedical Services

دولة فلسطين
وزارة الصحـــــة
الإدارة العامة
للخدمات الطبية المساندة

الاخ الدكتور نجي نزال المحتـــــــرم
ق.أ مدير عام الادارة العامة للمستشفيات

الموضوع: تسهيل مهمة

GDPS 4
5/11/2020

تحية طيبة وبعد،،،

نرجو تسهيل مهمة الطالب معاذ حسين مخامرة تخصص ماجستير تكنولوجيا التصوير الطبي من جامعة القدس مسار التصوير الطبي لعمل بحث تحت عنوان:

(MSc Medical Imaging Technology – Functional Imaging Track)

وذلك من خلال تقييم زمن استخدام المادة الملونة في عمل فحوصات البطن والحوض حيث سيقوم الطالب بجمع البيانات بعينة ممثلة للنظام الصحي الفلسطيني من قسم التصوير الطبقي في مستشفى الخليل الحكومي مع العلم بأنه سيتم التعامل مع كافة المعلومات بسرية تامة وتستخدم لأغراض البحث العلمي فقط.

وتفضلوا بقبول فائق الاحترام،،،

لخوكم
أسامة النجار
مدير عام
الإدارة العامة للخدمات الطبية المساندة

Ministry of Health – Ramallah
Ministry of Health - Nablus

TelFax: 022964402 تلفاكس
e-mail : labs_bb@hotmail.com
TelFax: 09-2335821 تلفاكس

وزارة الصحة برام الله
وزارة الصحة – نابلس

Al Quds University
Faculty of Health Professions
Department of Medical Imaging
Jerusalem –Abu Dis

جامعة القدس
كلية المهن الصحية
دائرة التصوير الطبي
القدس – أبو ديس

2019\11\15

حضرة الدكتور يوسف التكروري المحترم \ مدير مستشفى الاهلي\ الخليل

تحية طيبة وبعد،

الموضوع :تسهيل مهمة باحث

ارجو العلم بان الطالب معاذ حسين المخامرة طالب دراسات عليا في برنامج ماجستير تكنولوجيا التصوير الطبي \ مسار التصوير الطبي الوظيفي (MSc Medical Imaging Technology – Functional Imaging track) في دائرة التصوير الطبي/ جامعة القدس.

يقوم الطالب معاذ بعمل بحث بعنوان تقييم زمن استخدام المادة الملونه (الصبغة) في عمل فحوصوت البطن والحوض باستخدام لتصوير الطبقي المقطعي

Evaluation of Intravenous Contrast Agents timing and Enhancement in Non-Traumatic Abdomen and Pelvis CT Exams

حيث سيقوم الطالب معاذ بجمع البيانات بعينة ممثلة للنظام الصحي الفلسطيني بمختلف القطاعات (الحكومي والاهلي والخاص).

وعليه أرجو من حضرتكم التكرم بالايعاز للمعنيين بتسهيل مهمته.

وتفضلوا بقبول الاحترام والتقدير

د. محمد حجوج
رئيس دائرة التصوير الطبي
جامعة القدس

Tel. + 02 2799753 - +02 2791243 E-Mail: البريد الالكتروني: + 02 2799753 -+ 02 2791243 :تلفون
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Appendix 6

Appendix 7

Al Quds University
Faculty of Health Professions
Department of Medical Imaging
Jerusalem –Abu Dis

جامعة القدس
كلية المهن الصحية
دائرة التصوير الطبي
القدس – أبو ديس

2019\11\15

حضرة الدكتور وليد التميمي المحترم/ رئيس قسم الاشعة - مستشفى الهلال الاحمر الفلسطيني/الخليل.
تحية طيبة وبعد،

الموضوع :تسهيل مهمة باحث

ارجو العلم بان الطالب معاذ حسين المخامرة طالب دراسات عليا في برنامج ماجستير تكنولوجيا التصوير الطبي \ مسار التصوير الطبي الوظيفي
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وعليه أرجو من حضرتكم التكرم بالايعاز للمعنيين بتسهيل مهمته.

وتفضلوا بقبول الاحترام والتقدير

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جامعة القدس
كلية المهن الصحية
دائرة التصوير الطبي
القدس – أبو ديس

2019\11\15

حضرة السيد احمد عواد المحترم/ مدير مركز الياسمين للاشعة المحترم

تحية طيبة وبعد،

الموضوع :تسهيل مهمة باحث

ارجو العلم بان الطالب معاذ حسين المخامرة طالب دراسات عليا في برنامج ماجستير تكنولوجيا التصوير الطبي \ مسار التصوير الطبي الوظيفي
(MSc Medical Imaging Technology – Functional Imaging track) في دائرة التصوير الطبي/ جامعة القدس.

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وعليه أرجو من حضرتكم التكرم بالايعاز للمعنيين بتسهيل مهمته.

وتفضلوا بقبول الاحترام والتقدير

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Appendix 8

Notification of Acceptance to ICMHI 2020

Address: Unit 1112, 11/F, Wing On Plaza, 62 Mody Road, Tsim Sha Tsui East, Kowloon, Hong Kong, Email: admin@cbees.org
Tel: +852-3500-0137(HK), +86-28-88220101 (Chegndu)

Notification of Acceptance of the ICMHI 2020

Kamakura City, Japan, August 14-16, 2020

http://www.icmhi.org/

Paper ID : K1029

Paper Title : Evaluation of Intravenous Contrast Agents timing and Enhancement in Non-Traumatic Abdomen and Pelvis CT Exams

Dear Mo'ath Makhamreh, Murad M. Abusamra MD, Hjouj Mohammad,

First of all, thank you for your concern. 2020 4th International Conference on Medical and Health Informatics (ICMHI 2020) review procedure has been finished. We are delighted to inform you that your manuscript has been accepted for presentation at 2020 4th International Conference on Medical and Health Informatics (ICMHI 2020) will be held in Kamakura City, Japan during August 14-16, 2020.Your paper was tripling blind-reviewed and, based on the evaluations. The reviewers' comments are enclosed.

The conference received papers from about 12 different countries and regions during the submission period. And there are about 70 papers accepted by our reviewers who are the international experts from all over the world.The selected papers could be published in the international conference proceeding with high quality. According to the recommendations from reviewers and technical program committees, we are glad to infrom you that your paper identified above have been selected for publication and oral presentation. You are invited to present your paper and studies during our ICMHI conference that would be held in Kamakura City, Japan during August 14-16, 2020.

The ICMHI 2020 is co-sponsored by Hong Kong Chemical, Biological & Environmental Engineering Society (HKCBEES).

This paper of ICMHI 2020 will be published in International Conference Proceedings Series by ACM, which will be archived in the ACM Digital Library, and indexed by Ei Compendex and submitted to be reviewed by Scopus and Thomson Reuters Conference Proceedings Citation Index (ISI Web of Science).

(Important Steps for your registration): Please do finish all the 5 steps on time to guarantee the paper published in the proceeding successfully:

1. Revise your paper according to the Review Comments in the attachment carefully. (Five authors at most each paper)

Address: Unit 1112, 11/F, Wing On Plaza, 62 Mody Road, Tsim Sha Tsui East, Kowloon, Hong Kong, Email: admin@cbees.org
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2. Format your paper according to the Template carefully.

http://www.icmhi.org/template.docx

3. Download and complete the Registration Form.

http://www.icmhi.org/reg.doc (English)

4. Finish the payment of Registration fee by Credit Card. (The information can be found in the Registration form)

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5. Send your final papers (both .doc and .pdf format), filled registration form (.doc format) and the scanned payment (in .jpg format) to us at icmhi@cbees.net. (Before June 15, 2020 (Very important)

ICMHI 2020 will check the format of all the registered papers and send e-mail confirmation to the authors. After the registration, we will send all qualified papers to the publish house and index organization for publishing directly.

We are looking forward to meeting all the authors in our conference. But if you and your co-author(s) could not attend ICMHI 2020 to present your paper for some reasons, please inform us. And we will send you the proceeding in electronic version and the scanned receipt after ICMHI 2020

Please strictly adhere to the format specified in the conference template while preparing your final paper. If you have any problem, please feel free to contact us via **icmhi@cbees.net.** For the most updated information on the conference, please check the conference website at **http://www.icmhi.org/.** The Conference Program will be available at the website in **the late of July, 2020**.

Yours sincerely,

ICMHI 2020rganizing Committees

http://www.icmhi.org
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Appendix 9

Registration Form of ICMHI 2020

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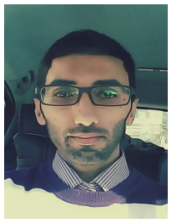
Registration form of ICMHI 2020

Kamakura City, Japan, August 14-16, 2020

www.icmhi.org

ICMHI 2020 will be held during August 14-16, 2020, Kamakura City, Japan. Please note that it is essential for all participants to send in a completed Registration Form (DOC), Final Papers (DOC and PDF), Payment Voucher (JPG) to icmhi@cbees.net before June 15, 2020.

1. PERSONAL INFORMATION

First Name: **Moath**		Family Name: **Almakhamreh**	
Whether attend the Conference: (Please choose √)			
The Attendee's Name: **Moath Almakhamreh**		Presentation Type: Oral √□	
(All the materials of participation will be prepared under this name. Only one author could come with one registration.)			
Position: Prof. □ Associate Prof.□ Assistant Prof.□ Lecturer□ Ph. D □ Master √□ Others □			
Organization or University: Al-Quds University			
City: Yatta	State: Hebron	Country: Palestine	Postcode:00972
Telephone:	Fax:	Mobile: **0595440550**	Email:**Moathhusseinnew@gmail.com**
Special Needs or Dietary Requirements:			
Student ID Number of Your University: **21712509**			
HKCBEES Member Number:			
Paper ID Code (For author only): **K1029**			
Paper Title (For author only): **Evaluation of Intravenous Contrast Agents Timing and Enhancement in Non-Traumatic Abdomen and Pelvis CT Exams**			
Authors' Names (For author only): Moath Al-Makhamreh			
Paper Pages:		Additional Page:	
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2. REGISTRATION FEE

	Registration Fee	Please fill√
ICMHI Tutorial	50 USD/360 CNY	

Online Presentation	400 USD/2860CNY	
ICMHI reviewer (Full paper)	450 USD/3220 CNY	
CBEES member (Full paper)	500 USD/3575 CNY	
Student Authors (Full paper)	500 USD/3575 CNY	√
Normal Authors (Full paper)	560 USD/4000 CNY	
Listeners	350 USD/2500 CNY	
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Additional Paper(s)	320 USD/2300 CNY each paper	
Additional Page	30 USD /215 CNY each page	
Extra Proceeding	50 USD /360 CNY each proceeding	

Good News! All authors can join the CBEES member for free right now, then you can register the conference as "CBEES Member"(500 USD). Please visit the following website for more information. (http://www.cbees.org/list-34-1.html)

* One regular registration can cover a paper within 8 pages, including all figures, tables, and references.
** One regular registration with one or more additional papers has only one proceeding book.
*** For the authors who have difficulties paying US Dollars, such as Iran, please pay Euros.
**** If you would like to register the conference and publish your paper as the reviewer, please send email to icmhi@cbees.net . (Only Ph.D holder can apply)

3. PAYMENT INFORMATION

A. Credit Card Payment Information (No handling fees)

http://confsys.iconf.org/online-payment/18131

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ADDRESS OF THE BANK: 83 DES VOEUX ROAD CENTRAL, HONGKONG

Please fill in the following form for us to check your payment

Appendix 10

PARTICIPANT CONSENT FORM

استمارة موافقة مشارك

انا المريض .....أوافق على المشاركة في هذا البحث العلمي الذي تم شرح أهدافه وغايته لي من قبل الشخص المقابل والذي يهدف الى تقيم توقيت إعطاء المادة الملونة في فحص التصوير الطبقي الخاص بمنطقة البطن والحوض، وبذلك أوافق بالسماح للطالب معاذ حسين إسماعيل المخامرة الذي يحمل هاتف رقم 0595440550 وهو يجري بحث لرسالة الماجستير من جامعة القدس بتخصص تكنولوجيا التصوير الطبي ويهدف البحث الى تقييم دقة توقيت إعطاء المادة الملونة عن طريق الوريد للمرضى الذي يقومون بإجراء صورة طبقية للبطن والحوض مع مادة ملونة ومقارنتها مع المعايير الموصى بها.

أدرك أن أخذ المعلومات سيكون بشكل سري وبالطريقة التي تم وصفها لي، وأعلم أن معلوماتي ستبقى طي الكتمان، وأنا بكامل حريتي وإستطيع الانسحاب وعد السماح بمشاركة معلومات التصوير الخاصة البي.

التوقيع.....

الملخص

المقدمة: من بين التطورات التي ضمنت تحسينا للتشخيص في التصوير الطبقي المحوسب استخدام المادة الملونة، حيث تعمل على زيادة جودة الصورة من حيث تقليل ظهور اي اشارات غير مرغوب بها وتعزيز التباين بين الاعضاء الداخلية مما يوثر ايجابا على جودة الصور. نتيجة لايجابيات المادة الملونة ادى ذلك إلى استخدامها بشكل كبير، واستخدام هذه المواد الكيميائية بهذا الشكل الكبير بحاجة إلى عناية كبيرة وانتباه شديد فيما يتعلق بتوقيت اعطائها والكمية المطلوبة ومعدل ضخها ، واستعدادات المريض لضمان الحصول على الجودة ودرجة تعزيز المادة الملونة بالشكل المطلوب و لمنع او تقليل اي اثار جانبية. المادة الملونة المستخدة في التصوير الطبقي هي مادة كيميائية تحتوي على اليود يمكن ان تستخدم عن طريق الحقن في الأوردة ، او عن طريق الفم. المعرفة الجيدة بكيفية استخدامها واثارها مهم جدا وذلك لانه الاثار الجانبية قد تتروح من بسيطة إلى خطيرة تهدد حياة المريض وبالرغم من ان الأثار الجانبية المهددة لحياة الإنسان نادرة الحدوث إلا أنها قد تحدث.

الأساليب: أجريت دراسة مستعرضة من كانون الثاني / يناير 2020/ إلى نيسان / أبريل 2020. شملت الدراسة على 80 مريضا خضعوا لفحص تصوير البطن والحوض مع المادة الملونة. تم تقييم عملية توقيت المادة الملونة والعوامل الأخرى المرتبطة بها بما في ذلك الكمية ومعدل الحقن ومدة الحقن والتركيز من خلال مقارنة الـ (HUs) التي كانت نتيجة لاستخدام هذه العوامل المختلفة مع المعايير الموصى بها .تم قياس قيم التعزيز(Enhancement) بوحدة Hounsfield Unit (HU) للكبد والشريان الأورطي .تمت مقارنةمتوسطات الـ (HU) بين المجموعات (المؤسسات) الأربع.

النتائج: كان هنالك تباين واضح في بروتوكولات المادة الملونة. وكان هناك تباين في تعزيز المادة الملونة نتج عن الاستخدام العشوائي والمدى الواسع لقيم الوقت والعوامل الأخرى المؤثرة. فقد بلغ مدى تعزيز المادة الملونة للشريان الأورطي (98-361) HU، بينا بلغ مدى التعزيز للكبد (13-76) HU. بلغ المعدل والانحراف المعياري لأقصى تعزيز للمادة الملونة للشريان الأورطي 264.25 ± 60.23، و 213.45 ± 50.83، و 200.85 ± 39.2، و 164.2 ± 48.27 بينما بلغ للكبد 53.4 ± 10.3، و 44.9 ± 12، و 45.8 ± 10، و 34.6 ± 10.1 لكل من المؤسسات A، و B، وC، وD على التوالي.

الاستنتاج: سيؤدي الاستخدام العشوائي لتوقيت وبروتوكولات المادة الملونة إلى تقليل سلامة المرضى ونطاق متنوع وواسع من التعزيز(Enhancement) والذي سيكون أقل تجانسًا.