A Retrospective Study of MDCT Chest Examinations with Two Different Doses of IV Contrast Media

Thesis

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Abstract

**Purpose:** Chronic kidney disease (CKD), has been recognized as a global public health problem, and may affect up to 35% of the adult population worldwide. One method of lessening the occurrence of CKD is to decrease the incidence of Contrast Induced Acute Kidney Injury (CIAKI) which occurs when acute renal dysfunction is diagnosed after the intravascular injection of water soluble iodinated contrast media during radiologic examinations. Since CIAKI occurs in up to 15 percent of the general population receiving intravascular iodine-based contrast agents, recommendations include the use of the lowest possible dose of iso-osmolal or selected low-osmolal contrast. Based on these recommendations and guidelines, it is important to identify methods to decrease the dose of intravascular contrast for radiologic exams in order to lessen the possibility of adverse kidney events. The purpose of this study is to compare the quality and diagnostic capabilities for which two contrast-enhanced routine MDCT chest scans were performed, using two different doses of iodinated water soluble IV contrast media.

**Methods:** This was a retrospective study of an existing image database to compare image quality of two routine contrast-enhanced MDCT chest scans, each performed on the same patient using two different doses of water soluble IV contrast media, one with 100mL of high concentration iodinated IV contrast media, and one with 75mL of high concentration...
iodinated IV contrast media. The diagnostic image quality was evaluated based upon image contrast resolution as measured by regions of interest (ROI’s) in Hounsfield Units (HU’s) of the ascending aorta, the pulmonary root and the descending aorta; and an acceptable diagnostic image quality as subjectively interpreted by two radiologists, using a standardized 3-point image quality scale.

**Results:** When calculating for a statistical difference in contrast between the 75mL and 100mL contrast exams, the independent samples t-test results demonstrated that there is a statistically significant difference in the HU’s between the 100mL contrast dose and the 75mL contrast dose ($p < .05$). However, the results also demonstrated that the subjective radiologist readings of the CT chest scans utilizing 75mL doses, answered the clinical questions and were diagnostically satisfactory.

**Conclusions:** Therefore, this study suggests that CT chest protocols may be adjusted from 100mL to 75mL, by lowering the overall amount of high concentration iodinated contrast media by 25mL, utilizing similar updated CT scanners and patient weights of 210 kilograms or less without degrading the image quality or the ability of the radiologist to make a diagnostic interpretation. Future prospective studies should include iodinated IV contrast dosing based on individual patient needs and characteristics.
Dedication

This thesis is lovingly dedicated to my family: David, Christina, Jonathan, Stephanie and my mom, who supported and encouraged me throughout the process; and to my Lord and Savior Jesus Christ, who gave me the strength and the will to complete this great task through much adversity.
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Chapter 1 - Introduction

Background

Since the initial publication of guidelines from the Kidney Disease Outcomes Quality Initiative (KDOQI) in 2002, chronic kidney disease (CKD) has been recognized as a global public health problem (Uhlig & Levey, 2012). Experts estimate that CKD may now be affecting up to 35% of the adult population worldwide (Perkins, Kirchner, Hartle & Bucaloiu, 2013). According to a report from the U.S. Preventive Services Task Force in 2012, 11% of the United States general population of adults aged 20 or older have CKD, which is defined as kidney dysfunction or kidney damage continuing for at least three months (Fink, et al., 2012). Based on this knowledge, guidelines from the National Kidney Foundation now recommend screening for all Americans over the age of 60 (2013).

One method of lessening the occurrence of CKD is to decrease the incidence of Contrast Induced Acute Kidney Injury (CIAKI). CIAKI occurs when acute renal dysfunction is diagnosed after the intravascular injection of water soluble iodinated contrast media during radiologic examinations (Ronco, Stacul & McCullough, 2013). Since CIAKI occurs in up to 15% of the general population receiving intravascular iodine-based contrast agents, there is continuing concern about renal damage caused by these contrast agents (Ronco, Stacul & McCullough, 2013). In March of 2012, an
international group initiative, Kidney Disease: Improving Global Outcomes (KDIGO),
was formed to develop and implement clinical practice guidelines for treating patients
with kidney disease, and for the assessment and management of acute kidney injury
(Palevsky, et al., 2013). The National Kidney Foundation organized a group of
nephrology experts to review these guidelines and to make recommendations on the
relevancy for U.S. clinical practice. Topics covered included specific recommendations
for the prevention of CIAKI. The practice guideline recommendations were published in
the American Journal of Kidney Diseases including the practicality for use in the U.S.
Recommendations include the use of the lowest possible dose of iso-osmolar or selected
low-osmolal contrast in high-risk patients (Palevsky, et al., 2013). Specifically, these
recommendations refer to the lowest possible dose not only for those patients with
current abnormal kidney function, but for those individuals with risk factors such as
chronic kidney disease (CKD), diabetes mellitus, hypertension, congestive heart failure,
older age, anemia, and recent contrast enhanced exams (Roper and Abbuhl, 2011.) This
recommendation has also been adopted in other organizations including European-based
professional societies such as The Renal Association, British Cardiovascular Intervention
Society and The Royal College of Radiologists. (Lewington, Mactier, Hoefield, Sutton,
Smith & Downes, 2013.)

Based on these recommendations and guidelines, it is important to identify
methods to decrease the dose of intravascular contrast for radiologic exams in order to
lessen the possibility of adverse kidney events. Therefore, the purpose of this study was
to compare the quality and diagnostic capabilities for which two contrast-enhanced CT
chest scans were performed, one with 100mL of high concentration water soluble iodinated IV contrast media, and one with 75mL of high concentration water soluble iodinated IV contrast media.

**Problem Statement**

Water soluble iodinated intravascular contrast material utilized for radiographic exams such as CT studies, has the potential to result in contrast-induced acute kidney injury (CIAKI). Although CIAKI can be mild and temporary, it may result in severe injury. It is the third leading cause of acute kidney injury in hospitalized patients and has been shown to be the cause of the need for renal dialysis in approximately 9% of CIAKI patients (Kagan & Sheikh-Hamad, 2010). Nephrology experts, nationally and internationally, recommend the administration of the lowest possible dose of iodinated IV contrast for radiologic exams in patients with high-risk factors, thereby decreasing the possibility of CIAKI (Pavlevsky, et al., 2013). Therefore, the purpose of this study was to investigate use of less water soluble iodinated contrast media in obtaining diagnostic MDCT images of the thorax.

**Research Question**

The research questions for this study are:

1. Is there a significant difference in the diagnostic image quality of enhanced MDCT routine chest images between images obtained utilizing a 75mL dose versus a 100mL dose of high concentration iodinated water-soluble IV contrast agents as measured by:
a. Image contrast resolution as measured by regions of interest in Hounsfield Units (HU’s); and

b. Radiologist interpretation of blinded imaging using a standardized diagnostic image quality measurement tool.

Definition of Terms

1) **Chest MDCT**- A Chest Multidetector Computed Tomographic scan includes computed generated, digital images of a section of the thorax beginning at the lung apex and extending through the lung bases (posterior costophrenic sulci) allowing adequate visualization of the lung parenchyma and intraparenchymal airways and vessels, as defined by the American College of Radiology (2013).

2) **Chronic Kidney Disease (CKD)**- A condition characterized by a gradual loss of kidney function over time in which the two main causes are diabetes and hypertension (National Kidney Foundation, 2014).

3) **Contrast Induced Acute Kidney Injury (CIAKI)**- An acute impairment of renal function that occurs after the intravascular administration of contrast material (for which alternative causes have been excluded.) The accepted definition of “contrast-induced nephropathy” has recently been updated by the Acute Kidney Injury Network to be a rise in serum creatinine (SCr) of more than 0.3mg/dL or an increase of more
than 50 percent in serum creatinine (SCr) from the baseline in which contrast induced acute kidney injury usually begins within 12-24 hours after the contrast media injection (Morabito, Pistolesi, Benedetti, Roma, et al., 2012).

4) **Contrast-to-Noise-Ratio (CNR)** - Contrast Resolution used to define quality of image. Calculation equation is CNR=[A-B]/SD where absolute A represents the mean signal in the region of interest (ROI) in the anatomy of interest, and absolute B represents the mean signal in the ROI outside the anatomy of interest (such as muscle) divided by the standard deviation (SD) which will be calculated by the ROI tool in PACS (American College of Radiology, 2013).

5) **Hounsfield Units (HU’s or CT number)** - Measurements or density values which quantify the degree that a structure attenuates an x-ray beam, related to the composition and nature of the tissue imaged. Examples include: Air = -1000, Fat = -100, Water = 0, Blood & Muscle = 40, Bone = 1000 (American College of Radiology, 2013).

6) **Noise** – undesirable image quality with appearance of graininess, usually caused in CT from substandard technical factors of kVp or mAs. Noise in CT is also referred to as the standard deviation of a CT number in a region of interest (ROI) (American College of Radiology, 2013).

7) **Water-Soluble Iodinated Contrast Media** – Intravenous (IV) contrast media are manufactured with different concentrations of iodine, the greater the concentration,
the higher the density of the organ imaged. The concentrations utilized in this study are Omnipaque 350 (GE Healthcare), in which there are 350mg of iodine per mL injected intravenously into the patient, and Visipaque 320, in which there are 320mg of iodine per mL. Omnipaque 350 is the standard contrast used at the Midwest hospital where the current research was performed, and is twice the osmolality of human blood. Visipaque 320 is administered when the patient’s kidney function (eGFR) is below the standard of 61mL/min/1.73m² since it has the same osmolality as human blood and is recognized as “easier” on the kidneys.

8) **Signal-to-Noise Ratio (SNR)**- calculation is derived from dividing the mean CT attenuation, which is the CT number in a region of interest (ROI) by the image noise (standard deviation-SD). \(\text{SNR} = \frac{\text{mean CT#}}{\text{SD}}\). (American College of Radiology, 2013).
**Chapter 2-Literature Review**

**Literature Review**

This literature review explored current research in order to demonstrate the significant contribution of multi-detector computed tomography (MDCT) chest scanning and to investigate methods of reducing iodinated contrast media and contrast induced acute kidney injury (CIAKI). It has long been an accepted practice to acquire and document the patient’s renal function laboratory values, such as the creatinine and the estimated glomerular filtration rate (eGFR) prior to the use of water soluble intravenous iodinated contrast material. This establishes confirmation of normal laboratory values, since healthy, well-functioning kidneys are less likely to incur renal injury from iodinated contrast media. Because of the necessity of iodinated IV contrast agents for certain diagnostic tests, research has been conducted to investigate methods to decrease contrast induced nephropathy (CIN), also known as contrast induced acute kidney injury (CIAKI.) This literature search was performed to incorporate information gleaned from previous research, such as methods that will ultimately provide a better alternative for patients’ renal health, while at the same time maintaining high image quality. This review focused on methods of reducing the amount of water-soluble iodinated contrast in MDCT studies in order to ultimately reduce patient kidney iodine load.
Multi-Detector Computed Tomography (MDCT) and Iodinated Contrast Media

For more than a decade, multi-detector computed tomography (MDCT) has been established as the “workhorse of radiology” due to greatly increased scanning speed and reconstruction times (Teague, Rosenblum, Olszewski, Dharalya & Popilock, 2009). Routine CT imaging of the thorax, abdomen, pelvis, brain, neck and spine make up greater than 85 percent of all annual CT scans while the remaining scans, CT angiography (CTA) studies (vascular imaging procedures,) more than doubled from 2004 to 2007 due to the faster rotation speeds, power, and larger detector coverage of MDCT scanning (Teague, et al., 2009). More specifically, concerning the thorax, chest CT has greatly improved and has increased considerably for indications such as pulmonary and mediastinal disease, hematologic and pulmonary malignancy, and pulmonary embolism, among other CT indications (Gondrie, Mali, Jacobs, Oen, van der Graaf, 2010). Some diagnoses, such as cancer, are found to cause other life-threatening maladies such as pulmonary embolism, requiring CTA/MDCT, where cancer and cancer-related therapies increase the risk of venous thromboembolism by six-fold when compared to cancer-free individuals (Faggioni, et al., 2012). Another indication of the importance and improvement of CT chest scans is found in the National Lung Screening Trial. The trial recommendations include a CT low dose lung cancer screening exam to specifically check for lung cancer in individuals aged 55-74 years who have a smoking history of 30 or more pack years and either currently smoke or have quit in the past 15 years (Pinski, Gierada, Nath, Kazerooni, Amorosa, 2013). Chest CT is a noninvasive imaging study which identifies disease both within and outside the chest, and provides anatomic detail
which better identifies tumor locations and their proximity to other chest structures, as well as demonstrating lymph node enlargement (Silvestri, Tanoue, Margolis, Barker, Detterbeck, 2003).

According to the American College of Radiology (ACR) Appropriateness Criteria (2013), because of the spatial resolution and lack of superimposition of structures, CT is more sensitive for detecting pulmonary nodules. However, even though spatial resolution and subject contrast in chest anatomy is inherently high, in which there is considerable contrast between the different structures of the chest such as lung (air) versus, soft tissue/mediastinum versus bone, there are still times when a chest CT exam requires iodinated IV contrast media for greater clarity of diagnosis (Romans, 2011). One of the major reasons for enhancing chest CT exams with IV contrast media is to help distinguish malignant from benign nodules since the vascularity of malignant nodules demonstrates distinct differences, and the absence of significant enhancement is strongly predictive of a benign process (Swensen et al., 2000). Iodine-enhanced CT scans of solitary pulmonary nodules provide information concerning the degree and pattern of enhancement useful in diagnosing the possibility of malignant nodules (Chae, Song, Seo, Krauss, Jang, Song, 2008). However helpful iodinated contrast media is in the interpretation of disease, it is also vitally important to keep the amount of IV contrast/iodine load to a minimum in order to maintain the health of patients’ kidneys.
Iodinated Contrast Material and the Kidneys

As stated in the previous section, multiple CT studies require intravenous (IV) water-soluble, iodinated contrast material injected quickly into a vein to enhance blood vessels and soft tissues of the body. Radiographic contrast agents for IV administration are tri-iodinated benzene derivatives as iodine is the element necessary for radio-opacity to better demarcate vascular structures (Seeliger, Sendeski, & Rihal et al., 2012; Roper & Abbuhl, 2011). In most instances, the contrast media is injected in the antecubital vein and travels to the right side of the heart, the lungs and the left side of the heart before it reaches the arterial system. It is then distributed throughout the organs, back to the venous system and reenters the right side of the heart before it enters the arterial system again (Fleischmann, 2003). Cho, Yu, Ahn, Kim, et al.(2012) advise the use of a high concentration of contrast media (350-370mgI/mL) to increase the vascular attenuation in CT angiography studies allowing better visualization of the vascular anatomy. However, these researchers also acknowledge that the use of an iodinated, intravascular contrast agent with a high osmolality and viscosity increases the risk of hypoxic injury to the medullary tissue of the kidneys and direct toxicity to the renal tubular cells, thus increasing the chance of contrast-induced nephropathy (CIN) (Cho, Yu, Ahn, Kim, et al.,2012).

Seeliger, Sendeski, Rihal, & Persson (2012) emphasize that iodinated contrast media can cause kidney damage by inducing cell damage and even cell death by reducing blood flow through renal structures, such as the outer medulla,
that are at risk for hypoxic damage. International concerns regarding the renal
toxicity of iodinated contrast agents led the Contrast Media Safety Committee of
the European Society of Urogenital Radiology to update their guidelines on
contrast media in 2011 (Stacul, van der Molen, Reimer, Webb, et al., 2011). The
published guidelines state that, “a ‘safe’ dose does not exist and even very limited
doses of contrast media may cause contrast induced nephropathy in high risk
patients,” so therefore, “in all patients, only the minimum amount of contrast
medium necessary to answer the clinical diagnostic question should be used”

**Contrast Induced Acute Kidney Injury**

The accepted definition of contrast-induced nephropathy has recently been
updated by the Acute Kidney Injury Network to be a rise in serum creatinine
(SCr) of more than 0.3mg/dL, or an increase of more than 50 percent in serum
creatinine (SCr) from the baseline in which contrast induced acute kidney injury
usually begins within 12-24 hours after the contrast media injection (Morabito,
contrast induced acute kidney injury is commonly mild and temporary; however
dialysis is required in about nine percent of patients who develop contrast induced
acute kidney injury. “Contrast induced nephropathy (CIN) is a common and
serious complication of radiocontrast administration used in imaging studies, and
is the third leading cause of acute kidney injury (AKI) in hospitalized patients”
(Kagan & Sheikh-Hamad, 2010, p. 62). Serum creatinine (SCr) is the most
frequent and least expensive laboratory test used to assess kidney function, (Imbasciati, Falbo, & Mariani, et al., 2013), however there is increasing evidence which indicates that serum creatinine is far from being a decisive marker for diagnosing and staging acute kidney injury due to several limitations (Bolignano, 2012). Creatinine is primarily defined as the end-product of muscle breakdown and is cleared by the kidneys at a normal rate of 85 to 135mL/min, which is considered the normal glomerular filtration rate (GFR) (Isaac, 2012). The level of kidney function is measured by determining the GFR, defined as the volume of blood filtered by the glomerulus in one minute (Isaac, 2012).

Considering the gravity of contrast induced acute kidney injury (CIAKI), or contrast induced nephropathy (CIN), there are a number of risk factors that have been identified which increase the possibility of development. Roper and Abbuhl (2011) list the risk factors as: chronic kidney disease (CKD), diabetes mellitus, hypertension, congestive heart failure, older age, anemia, hypotension and left ventricular ejection fraction of less than 40 percent. An individual is considered to have CKD when they have a GFR less than 60mL/min for six months or longer. In addition, the National Kidney Foundation recommends hemoglobin levels of 11 to 12g/dL and hematocrit levels to be 33 to 36 percent, since red blood cells transport oxygen and anemia creates a hypoxic state which is aggravated by intravenous iodinated contrast agents (Isaac, 2012). Patients who are at the highest risk of CIAKI are those with diabetes and chronic kidney disease. There is approximately a fourfold higher risk of contrast induced acute
kidney injury (CIAKI) in patients with diabetes and chronic kidney disease than in patients without those conditions (Roper and Abbuhl, 2011).

Taking into account both the necessity of IV water-soluble iodinated contrast media for many CT examinations and the detrimental effects iodinated contrast agents can have on renal function, (especially in individuals with reduced renal function and/or certain risk factors), certain precautions can be taken to decrease the chances of contrast induced acute kidney injury (CIAKI). Hydration is considered the gold standard in CIAKI prevention, and the preferred intravenous fluids are isotonic saline, or isotonic sodium bicarbonate, which lower the osmolarity of plasma and increases renal blood flow, thus decreasing direct nephrotoxic effects (Isaac, 2012). Another preventative therapy which acts as an antioxidant and helps to dilate the renal vessels and increase blood flow is N-acetylcysteine, more commonly known as Mucomyst, and is administered to patients prior to and after injection of contrast media (Isaac, 2012). Research conducted by Dr. Morabito, Pistolesi, Benedetti, Roma, et al. (2012), suggest the volume of intravenous contrast media is a strong modifiable risk factor which is related to the development of contrast-induced acute kidney injury (CIAKI). These researchers recommend the use of methods to reduce the amount of contrast agents used, especially in individuals with multiple risk factors (Morabito, Pistolesi, Benedetti, Roma, et al., 2012). Therefore, increased hydration plus a decreased contrast agent dose may result in a decreased likelihood of contrast induced acute kidney injury.
Recent Research Methods of Reducing IV Contrast for CT Scans

Subsequently, since reducing the contrast agent dose may result in a decreased likelihood of contrast induced acute kidney injury (CIAKI), many studies have been performed to find an appropriate method to decrease the amount of contrast media for CT scans while retaining image quality. A frequently utilized means of reducing the iodine load and maintaining image quality that could be found at the time of this literature search, has been to decrease the kilovoltage for CT studies to 80kVp. Holmquist, Hansson, Pasquariello, Bjork and Nyman (2009) give credit to an article written in Radiology in 2004 by “Sigal-Cinqualbre, et al.,” as the first to propose that performing CT pulmonary embolism studies with 80kVp protocols might be advantageous in terms of renal protection due to the fact that the contrast media can be decreased. Reducing the tube voltage from the standard 120kVp down to 80kVp, results in higher CT attenuation due to the increased contrast-to-noise ratio (CNR) of iodinated contrast containing vessels, since the x-ray output energy at these low tube voltages is closer to the iodine k-edge of 33keV (Nakura, et al., 2011). Cho, et al., (2012) confirmed that when the tube voltage is reduced, there is an increase of the photoelectric effect and a decrease in Compton scattering which contributes to a higher mean attenuation in the iodine value. However, even though this has been a widely used approach in CT angiography, the byproduct of low tube voltage is image noise, which can be a serious imaging problem, especially in abdominal imaging (Nakura, et al., 2011). This is due to the fact that
image noise tends to increase when patient body weight increases (Kristiansson,
Holmquist & Nyman, 2010).

Because of this, most of the studies investigated have a patient weight
limit of 80-90 kilograms, or approximately 176-198 pounds. In order to decrease
image noise with the lower kVp, tube current time product, (milliampere seconds
or mAs) must be increased, and it has only been recently, with advances in
technology, that the capacity of the x-ray tubes has been increased enough to
compensate for the increased noise and permit imaging at 80kVp. (Kristiansson,
Holmquist & Nyman, 2010). A roughly four-fold decrease in radiation intensity to
the detectors that occurs when the x-ray tube potential is decreased from 120- to
80-kVp must be compensated with an almost four-fold increase in effective mAs
to balance for the increased noise. The upper weight limit for obese patients in a
study conducted by Kristiansson, Holmquist and Nyman in 2010 was about 90kg;
however the researchers believed that the use of a recently developed, more
potent x-ray tube design and dual-energy CT may overcome this limitation.

In 2012, Cho, Yu, Ahn, Kim, Chung, Lee and Lee conducted a prospective
study in order to evaluate the possibilities of using a moderate concentration of
contrast media (CM) such as 300mg I/mL (as opposed to 370mgI/mL) and
utilizing an effective mAs of 585 for renal artery CTA studies. The researchers
concluded that the use of 80kVp with a moderate concentration of iodinated CM
for renal artery CTA examinations significantly improved arterial enhancement,
showing similar SNR and CNR when compared with the high concentration CM
images acquired by using the 120-kVp protocol, despite the fact that the iodine
dose was reduced by 18.9% (Cho et al., 2012).

Another means of decreasing the patient iodine load is to individualize
contrast media dosing by weight. Results of a study conducted by Bae (2010)
stated that, “the most important patient-related factor affecting the magnitude of
vascular and parenchymal contrast enhancement is body weight” (p. 38). The CT
imaging technique most widely used today to obtain consistent contrast
enhancement is to base the iodinated dose of contrast media on the patient’s body
weight (Onishi, et al., 2011). Benbow and Bull (2011) conducted a study in order
to develop a weight-based protocol that was easy to use in a busy clinical practice
of a high throughput CT department. In that same article, they stated that the
majority of abdominal MDCT exams are performed using IV contrast and that a
fixed dose technique may not be optimal since there is evidence that liver
parenchymal enhancement with a fixed dose of iodinated contrast media varies
with body weight. The articles of Benbow and Bull (2011) and Bae, (2010) both
state that weight tailored dosing will reduce enhancement variations, creating a
consistent contrast enhancement important for organ imaging. This consistent
weight-based contrast medium volume dosing decreases the potential risk of
lighter patients being “overdosed” which could have the potential risk of contrast
induced nephropathy (Benbow and Bull, 2011). By asking patients for their
weight prior to scanning, and by utilizing a practical weight-based table for the
technologists to follow, the demands of the scanner throughput pressures were
met (Benbow and Bull, 2011). Their “look-up table” was based on delivering 450mg of iodine/kg (or 1.3mL/kg using 350mg Iodine/mL of contrast medium), in which Benbow and Bull stated was preprogrammed into the contrast injector to facilitate easy weight-based dosing (2011). Bae (2010) suggested a base dose for a routine chest CT in a 70kg (156lb) patient to be 70mL of 300-350mgI/mL at a rate of 2-3mL/sec with a fixed scan delay of 40-60 seconds. Bae also goes on to mention that a study was reported that contrast enhancement tended to be greater in elderly patients (ages 60 and older) for a given iodine load and that iodine dose and injection rate could be reduced by 10 percent to achieve the same degree of enhancement in elderly patients (2010).

In conclusion, many studies have been performed over the years, and several techniques have been investigated to find the best method of decreasing the amount of water-soluble iodinated contrast media injected into patients for enhancement during CT scans, while maintaining image quality. The methods suggested are: lowering the tube potential from 120kVp to 80kVp; using a moderate concentration of iodine (300mgI/kg instead of 370mgI/kg); and measuring dosage by body weight, which above all entails lower doses for smaller patients (Kristiansson, Holmquist & Nyman, 2010; Cho et al., 2012; Benbow & Bull, 2011).
Chapter 3-Methods

Research Design

This was a retrospective study of an existing image database to compare chest MDCT image quality of two routine contrast-enhanced chest CT scans, each performed on the same patient using two different doses (75ml and 100ml) of water soluble iodinated contrast media. No direct patient identifiers were retained in the research database. The purpose of the study was to determine if a significant difference exists in the diagnostic image quality of enhanced MDCT routine chest images utilizing a 75mL dose versus a 100mL dose of high concentration iodinated water-soluble IV contrast agent. The diagnostic image quality was evaluated based upon image contrast resolution as measured by regions of interest (ROI’s) in Hounsfield Units (HU’s) of the ascending aorta, the pulmonary root and the descending aorta; and an acceptable diagnostic image quality as subjectively interpreted by two radiologists. The images were blinded and evaluated using a standardized diagnostic image quality measurement tool.

Subject Selection

The sample of convenience included the first 39 patients who underwent a routine enhanced chest CT with 100mL during the time period of July 2013 through March 2014, and whom also had previously underwent a routine chest CT with 75mL prior to July 2013. Patient examinations were accessed through the radiology information systems
(RIS) database from a mid-sized suburban hospital in the Midwest United States. The limited number of patient examinations selected was due to limited radiologist availability for interpretation and was estimated to be 66% of the existing population at the time of the study. Patient images were retrieved from the Picture Archiving and Communications System (PACS) and the examination images were compared in order to examine the effect of contrast media dose on image quality. All patients were scanned in the cranio-caudal direction and positioned supine on the CT table.

Patients with routine MDCT chest exams utilizing 75mL of iodinated IV contrast media were acquired with one of three scanners: the Toshiba Aquilion 64 slice scanner, the Toshiba Aquilion 32 slice scanner and the GE 750 HD (64 slice equivalent). Patients with MDCT chest exams utilizing 100mL of iodinated IV contrast media were acquired with one of two scanners: GE 750 HD (64 slice equivalent) and the GE Optima 660 (64 slice scanner). The GE 750 HD is a dual energy scanner; however the GSI dual energy technique was not utilized for these scans. Each patient received the standard protocol IV contrast iohexol 350 (Omnipaque, GE Healthcare) unless their eGFR was less than 61mL/min/1.73m², in which case the patient received iodixanol 320 (Visipaque, GE Healthcare) as the IV contrast agent for proper enhancement because iodixanol is believed to be better tolerated by the kidneys.

Indications for routine CT chest exams include: pulmonary disease, pulmonary nodules, mediastinal disease, hematologic malignancy, metastasis from other types of cancer and pulmonary malignancy (Gondrie, et al., 2010). Patient examinations excluded from the study were: a) CT chest exams other than routine chest CT, such as CTA or
pulmonary embolism studies, b) patients weighing greater than 110 kilograms per the recommended protocol of 70mL of 300-350mgI/mL contrast media for CT chest patient’s with weight of 70 kg or greater (Bae, 2010), c) patients with unsatisfactory suspension of breathing causing motion artifact, d) patients with a marked reaction to the contrast medium which interfered with image acquisition, and e) patients with an extravasation of contrast medium.

Data Collection Procedures

Patient examinations were accessed using the Radiology Information System and PACS databases following approval from the Institutional Review Boards from both The Ohio State University and from the midwestern hospital where the research took place. A list of eligible cases was compiled from the PACS. The examinations were stripped of all identifiers, assigned a unique identification number, and 78 examinations were randomly assigned to the 2 radiologists. These 78 de-identified examinations were placed into a separate folder in the PACS system for the radiologists to access. This process was to assure that the radiologists providing the subjective ratings were blinded not only to the dose delivered for the examinations (75mL or 100mL), but also to patient identifying information. Each radiologist was oriented to the Data Collection Form-Image Quality Scale (Appendix A) prior to reading any exams, with an explanation of the 1, 2, 3 ratings and was informed to read each CT chest exam as to whether contrast enhancement was sufficient for routine chest CT’s (not CTA exams.) Both radiologists read from their customary radiology department PACS monitors with normal lighting conditions and
following standard reading procedures. Each radiologist read a total of 42 exams; five exams were read by both doctors for inter-rater reliability.

**Instrumentation-Diagnostic Quality Imaging Tool**

Two radiologists evaluated and interpreted the images for diagnostic purposes using a standardized 3-point image quality scale (Appendix A) adapted from a tool developed by Muhlenbruch, et al. (2008) for evaluation of contrast enhanced chest CT imaging. The Muhlenbruch, et al. diagnostic quality image tool was originally designed to measure the radiologists’ subjective interpretation of MDCT chest image quality comparing enhancement with three different concentrations of iodinated contrast media. However, the imaging tool was easily adaptable to one or two iodine concentrations such as in this current study, utilizing the “anatomical depiction” section of the tool only. No changes were required except to omit the “vessel edges” and “image artifacts” columns in order to be utilized for this current study.

**Contrast Enhancement Measurement**

Contrast enhancement was measured on all sets of images in the study. The HU’s of the predetermined vessels and muscles were measured and recorded in order to numerically determine the contrast differences in the vessels enhanced with 75ml of contrast agent in comparison to the vessels enhanced with 100mL of contrast agent. One region of interest (ROI) was placed in the three designated contrast enhancing patient anatomy areas- ascending aorta, pulmonary root and the descending aorta to obtain a HU measurement for each area, which is similar to the Muhlenbruch, et al. (2008) study,
adding the descending aorta for measurement as well. Hounsfield Units (HUs) measurements were obtained using rectangular regions of interest with the PACS image tools for three consecutive mediastinal images at the level of the carina for each of the 78 CT chest exams in the study. Exclusion from measurements included visible artifacts such as beam hardening from pacemaker leads and vessels in close proximity to the dense contrast in the superior vena cava. The rectangular shaped ROI was utilized since it was simpler to retain the same size ROI for more consistent measuring, and therefore enabled easier measurement of the muscle HU due to the elongated shape of the erector spinae and trapezius muscles. The muscle readings were utilized as the non-enhancing region for calculating the level of contrast enhancement. The data was collected and documented by the researcher on the Contrast Enhancement Data Collection Form. (Appendix B.)

**Data Analysis**

Data analysis was performed using the commercially available software IBM SPSS version 22. To assure inter-rater reliability, the two radiologists each reviewed the same 5 patients to determine inter-rater reliability. The radiologist diagnostic quality scale interpretations were calculated and analyzed using descriptive statistics since chi-square analysis was unobtainable. The contrast enhancement was calculated by comparing the HU values of muscles and 3 vessels for both examination sets, one with 75mL IV contrast enhancement and one with 100mL IV contrast enhancement. The contrast enhancement calculations were as follows: Ascending Aorta HU = mean (A1,A2,A3) – mean(M1, M2, M3); Pulmonary root = mean(PR1,PR2,PR3) –
mean(Mus1, Mus2, Mus3); Descending aorta = mean (D1,D2,D3) – mean(M1, M2, M3).

Contrast enhancement for the vessels was compared using a t-test.
Chapter 4-Results

Descriptive Statistics

The study included 39 eligible patients, totaling 78 examinations in which 34 patients (43.6%) were male and 44 patients (56.4%) were female. The ages ranged from 25 years of age to 81 years, with a mean age of 60.4 years. The patient body weights ranged from 52 kilograms to 105 kilograms with a mean of 76.72 kilograms. Of the 78 MDCT chest examinations, 84.6% (n=66) were completed using Omnipaque 350 and 15.4% (n=12) were conducted using Visipaque 320.

Research Question 1a:

Is there a significant difference in the diagnostic image quality of enhanced MDCT routine chest images between images obtained utilizing a 75mL dose versus a 100mL dose of high concentration iodinated water-soluble IV contrast agents as measured by regions of interest (ROI’s) measuring the Hounsfield Units (HU’s) of the ascending aorta, the pulmonary root and the descending aorta?

Independent samples t-tests were used to compare the image contrast resolution between the 75mL and 100mL contrast exams. The image contrast resolution values were based on the mean of the three contiguous slices of the ascending aorta minus the muscle HUs (where M is the value of muscle HUs). These proxy calculations were
performed due to the inability of acquiring the standard deviation (SD) within the region of interest (ROI) of each vessel measurement on the PACS system in order to obtain the originally planned CNR and SNR calculations. The proxy calculations for image contrast resolution were:

- Ascending Aorta HU = mean (A1,A2,A3) – mean(M1, M2, M3)
- Pulmonary root HU = mean(PR1, PR2, PR3) – mean(Mus1, Mus2, Mus3)
- Descending aorta HU = mean (D1,D2,D3) – mean(M1, M2, M3).

From these calculations, a t-test was performed. As illustrated in Table 1, the t-test demonstrated a statistically significant difference in HUs between the 100mL contrast dose and the 75mL contrast dose.

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Dose</th>
<th>Mean HUs</th>
<th>SD</th>
<th>t</th>
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<tbody>
<tr>
<td>Ascending Aorta</td>
<td>75</td>
<td>176.68</td>
<td>43.40</td>
<td>-3.061*</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>206.80</td>
<td>43.51</td>
<td></td>
</tr>
<tr>
<td>Pulmonary Root</td>
<td>75</td>
<td>181.13</td>
<td>68.33</td>
<td>-2.034*</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>214.13</td>
<td>74.81</td>
<td></td>
</tr>
<tr>
<td>Descending Aorta</td>
<td>75</td>
<td>166.96</td>
<td>42.87</td>
<td>-2.458*</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>191.58</td>
<td>45.57</td>
<td></td>
</tr>
</tbody>
</table>

* p<.05

Table 1: Image Contrast Resolution
Research Question 1b:

Is there a significant difference in the diagnostic image quality of enhanced MDCT routine chest images between images obtained utilizing a 75mL dose versus a 100mL dose of high concentration iodinated water-soluble IV contrast agents as measured by the radiologists’ blinded diagnostic image quality interpretation using a standardized measurement tool?

A total of 78 enhanced CT chest exams were randomly assigned and evaluated by two radiologists. Chi-square analysis was planned to analyze nominal data in order to compare the doses (Ary, Jacobs, & Sorenson, 2010). The analysis was not possible due to the small number of ratings in the “3” category. However, one can see that there were very few studies that were rated as a 3 in both dosage categories. The ratings of 1, 2 or 3 were subjectively assigned by the radiologists, one rating per each exam for all exams. The results, as illustrated in Table 2, illustrate that of the 75mL scans, 23 exams were given a “1” rating, 15 with a “2” rating and 1 having a “3” rating. The 100mL chest CT scans demonstrated 25 scans rated as “1,” 14 scans as a “2” rating and zero “3” ratings. Table 2 demonstrates that 100% of the 100mL exams and 38 out 39 (97%) of the 75mL exams were diagnostic according to the subjective radiologist ratings. Each radiologist read a total of 42 exams. Five CT exams were read by both physicians to determine inter-rater reliability. Two out of the five exams were given the same ratings and three were assigned different ratings. This resulted in a moderate inter-rater reliability rate of 40% (Marques & McCall, 2005).
<table>
<thead>
<tr>
<th>Dose</th>
<th>Radiologist Ratings</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>75</td>
<td>23</td>
<td>15</td>
</tr>
<tr>
<td>100</td>
<td>25</td>
<td>14</td>
</tr>
</tbody>
</table>

Table 2: Radiologist Ratings
Chapter 5- Discussion

This study explored whether a significant difference exists in the MDCT diagnostic image quality of the two intravenous (IV) contrast doses. Iodinated IV contrast, which is used to differentiate objects, or different parts of anatomy on CT images from adjacent objects, creates a temporary density difference between the objects, since it is of a higher density material (Romans, 2011). Hounsfield units (or density values) also called CT numbers are utilized in order to measure the degree of attenuation of the x-ray beam. The range of Hounsfield units of anatomic structures which are naturally occurring is 1000 to -1000, where dense bone is assigned up to 1000 HUs, zero represents distilled water, blood and muscle equal approximately 40 HUs, and air is assigned HUs as low as -1000 (Romans, 2011). Even though there can be a great difference in attenuation between anatomic structures, low attenuating abnormalities can be visualized on CT scans with at least as low as only 20 HUs difference, when comparing certain pathologies such as myxomas (tumors in the heart) and adjacent unopacified blood (Shin, Choe, Kim, Song & Kim, 2014). The greater the iodine concentration injected for a CT study, the greater the vascular attenuation and Hounsfield Unit (HU) values, creating images with greater vascular and soft tissue enhancement. These greater attenuation images appear brighter to the
human eye, allowing better visualization of vascular anatomy. This was made evident during this study when the images with the 100mL dose of iodinated IV contrast registered not only greater Hounsfield numbers, but also demonstrated to be statistically significant. Further, this study explored whether a difference exists in the diagnostic image quality between the two different doses of contrast injected for the MDCT chest images, since one possible method of lessening the occurrence of chronic kidney disease (CKD) is to decrease the incidence of contrast induced acute kidney injury (CIAKI) by administering the lowest possible dose of iso-osmolal or selected low-osmolal contrast in high-risk patients (Palevsky, et al., 2013). Stacul, et al., further states that a “safe dose” of contrast media does not exist, and that only the minimum amount of contrast media necessary to answer the clinical diagnostic question should be used in all patients (Stacul, et al., 2011).

Subjective Ratings

The subjective portion of this study was one in which the radiologists interpreted and rated the same CT chest scans on a diagnostic quality scale of 1 to 3. To determine inter-rater reliability, five of the CT chest examinations (a mixture of both 75mL and 100mL contrast exams) were rated by both radiologists in order to establish regularity in interpreting the studies. Two of the five patient exams were rated the same, leaving only a moderate 40% agreement, which had equivalent ratings when examining the ratings. Interestingly, even though the reliability calculations were only moderate in agreement, the findings for the
study demonstrated there was only one exam which resulted in a radiologist’s rating of 3. This was an important finding since it demonstrated that the diagnostic quality of the MDCT chest images with the lower contrast dose was sufficient (rated as a 1 or 2) for radiologist image interpretation. A “2” rating is adequate for routine enhanced CT chest scans since vascularity changes is not the primary focus or reason for the scan. By determining that there is no difference in the diagnostic quality (as rated by the radiologists) of contrast enhanced CT chest images between the two doses, the lesser of the two doses would be the better choice in order to reduce patient kidney iodine load and lessen the possibility of adverse kidney events.

**Comparison with Related Literature**

After comparing the Multidetector Computed Tomography (MDCT) routine chest scans with two different doses of high concentration water soluble iodinated IV contrast without any adjustment of the kilovoltage peak (kVp) or the milliamperage (mA), the results demonstrated in this study showed that there was diagnostic quality as evidenced by the radiologists’ ratings of studies enhanced with a 100mL dose of an iodinated IV contrast agent and a 75mL dose of iodinated IV contrast agent in patients with a maximum weight of 110 kilograms, undergoing a routine MDCT chest scan. It is interesting to note that there was only a 25 to 33 mean Hounsfield Unit (HU) difference in the vascularity enhancement between the mediastinal vessels in the CT chest exams of the 100mL dose and the 75mL dose, including the ascending aorta, the pulmonary root and the descending aorta. This is not considered a substantial visual difference given that
the total range of Hounsfield values is greater than 2,000, the CT monitors are only able
to display 256 shades of gray, and since the human eye is only able to differentiate fewer
than 40 shades of gray (Romans, 2011). Therefore, this study suggests that CT protocols
may be adjusted from 100mL to 75mL, by lowering the overall amount of high
concentration iodinated contrast media by 25mL, utilizing similar updated CT scanners
and patient weights of 210 kilograms or less without degrading the image quality and the
ability of the radiologist to make a diagnostic interpretation.

When comparing this current study with the prospective study of Muhlenbruch, et al. (2008), which compared the differences between CT chest scans obtained with three IV contrasts containing differing amounts of iodine, there are some similarities, such as a set amount iodine load. In the Muhlenbruch study, although there were three different iodine contrast concentrations administered, each patient, all 300 of them, received a total iodine load of 33g of iodine at an equal iodine delivery rate of 1.3g/sec. In the current research study, each patient received a designated amount of contrast, 75mL or 100mL of the same contrast, Omnipaque 350, at a designated rate of 2mL/sec in which the fixed scan delay was 37 or 50 seconds, depending on the amount of contrast being delivered and the group assignment. Neither of these studies, the Muhlenbruch study nor the current research study, were weight based injections. Although both studies speak of measuring the averaged “attenuation values” or Hounsfield units (HUs) of mediastinal vessels from three consecutive images by ROI’s, the Muhlenbruch study did not list any specific HU numbers that can be compared with the current study. Since Muhlenbruch et al., (2008) was a prospective study, they were able to obtain the standard deviation for
those attenuation values directly from the CT scanner, however, this current research could not calculate or analyze a difference in the Contrast-to-Noise ratio (CNR) or Signal-to-Noise ratio (SNR) values since standard deviations (SD) are not obtainable from within the ROI placed in the vessel from the PACS system utilized in this study. The Muhlenbruch study did conclude however, that there were no statistically significant differences in their CT chest contrast enhancement of three concentrations of contrast media with an identical iodine load and delivery rate (Muhlenbruch et al, 2008). However, even though the current research study concluded that there was a statistically significant difference in the image contrast resolution as measured by regions of interest in HUs, the subjective interpretation of blinded imaging by an experienced radiologist and a fourth year resident was diagnostic when utilizing a 75mL dose instead of a 100mL dose of high concentration iodinated IV contrast media. Therefore, this current study helps to support the findings of Muhlenbruch et al (2008), since 38 out of the 39 exams (or 97%) injected with 75mL of contrast were considered diagnostic according to the subjective radiologist ratings.

When compared with other previous studies which attempted to decrease the amount of iodine load for CT patients, no studies were found which only decreased a specific amount of IV contrast agent. Varying the amount of contrast agent in other studies was paired with another alteration in the examination protocol. For instance, in the study conducted by Cho, et al. (2012), decreasing the kVp to 80 allowed the researchers to decrease the amount of iodine contrast. But further limitations to this approach include a patient weight limit of less than 200 pounds due to the fact that as
patient weight increases, decreasing kVp increases image noise, especially if an increase in mA cannot be made to compensate for the kVp reduction. Studies conducted by Bae (2010), and Benbow and Bull (2011) were weight-based studies in which the amount of IV contrast agent used was varied according to patient weight. This approach decreases the patient IV contrast dose for smaller patients based on the assumption that the magnitude of vascular and parenchymal contrast enhancement is primarily a function of patient weight (Bae, 2010).

In comparison to the research conducted by Benbow and Bull (2011) whose patients received 1.3mL/kg (not 1.3mL/sec), to the Muhlenbruch, et al., 2008 study, there was considerably less iodine load since the dose was based on patient weight. They developed an easy to read dose chart which was based on delivering 450mg of iodine/kg (or 1.3mL/kg) using 350mg Iodine/mL of contrast medium, in which the researchers stated was preprogrammed into the contrast injector to facilitate easy weight-based dosing (Benbow and Bull, 2011). Bae (2010) suggested a base dose for a routine chest CT in a 70kg (156lb) patient to be 70mL of 300-350mgI/mL at a rate of 2-3mL/sec with a fixed scan delay of 40-60 seconds.

**Further Investigation**

An area of further investigation would be to conduct a prospective study comparing CT chest contrast enhancements in order to acquire the standard deviations (SD) from the ROI’s of the vessels by utilizing the actual CT scanner console tools. This would be so that calculations for the contrast-to-noise ratios (CNR) and signal-to-noise
ratios (SNR) may be performed since the PACS tool was not sensitive enough to calculate the small standard deviations of the vessels.

Another area of further investigation relates to the particular brand of iodinated contrast utilized. In this study, 15% of the patient CT examinations were conducted using Visipaque 320, which contains 30mg of iodine less than Omnipaque 350, as the contrast of choice due to a decreased patient GFR. This difference in iodine concentration should affect the attenuation values resulting in a lesser opacification of the vessels; however, the ROI measurements obtained in this study did not demonstrate a significant HU difference when comparing the two types of contrast, only the two amounts of contrast. If this is a consistent finding, perhaps it may be viable to decrease both the dose and iodine concentration to reduce the likelihood of CIAKI.

An additional area for further investigation relates to investigation of the use of even lower iodine doses based on patient weight and age. This is especially crucial for smaller patients. The current protocols at the mid-western hospital where this research took place utilize a set amount of iodinated IV contrast media for each examination, regardless of weight or age. This means that a 100 pound patient receives the same iodine load as a 400 pound patient, and an 80 year old patient receives the same iodine load as a 30 year old patient. Besides weight, age is also important to consider since contrast enhancement tends to be greater in elderly patients (ages 60 and older) for a given iodine load and that the iodine dose and injection rate could be reduced by 10 percent to achieve the same degree
of enhancement in elderly patients (Bae, 2010). A possible suggestion could be a system in which the contrast dose is individualized for each patient.

Of interest to note is the dosage recommended per the Omnipaque contrast package insert which is in every case of IV contrast media. When administering Omnipayque 350 for CT scanning of the body, which is 350mg of organic iodine per mL, (the highest iodinated concentration of intravascular contrast media that GE manufactures in the Omnipaque brand,) GE Healthcare Inc. recommends the adult dosage as 60mL to 100mL, which is equivalent to 21grams of iodine (gI) to 35gI (GE Healthcare, 2009, p.9).

The package insert also states that the “lowest dose of Omnipaque necessary to obtain adequate visualization should be used,” and that “a lower dose may reduce the possibility of an adverse reaction.” (GE Healthcare, 2009, p.7) The insert continues by stating: “The combination of volume and concentration of Omnipaque to be used should be carefully individualized accounting for factors such as age, body weight, size of the vessel and the rate of blood flow within the vessel.” (GE Healthcare, 2009, p. 7)

**Limitations of the Study**

There were several limitations which may have impacted the results of this study. First, patients in this retrospective study were scanned by multiple technologists. In most instances, CT technologists adhere to a standardized enhanced CT chest protocol, however, protocol adjustments, such as but not limited to, decreasing the IV contrast media injection rate, may have been made for patients experiencing difficulty in tolerating the CT procedure.
New CT scanning equipment was installed in 2012 and 2013, resulting in the use of different scanners in obtaining some CT images. Patients with MDCT chest exams utilizing 75mL of iodinated IV contrast media were acquired with one of three scanners: the Toshiba Aquilion 64 slice scanner, the Toshiba Aquilion 32 slice scanner and the GE 750 HD (64 slice equivalent). Patients with MDCT chest exams utilizing 100mL of iodinated IV contrast media were acquired with one of two scanners: GE 750 HD (64 slice equivalent) and the GE Optima 660 (64 slice scanner). The GE 750 HD is a dual energy scanner; however the GSI dual energy technique was not utilized for these scans. Additionally, the patient CT chest exams in which 100mL of contrast was administered were scanned at a 50 second delay, and the patient CT chest exams which received 75mL of contrast were scanned at a 37second scan delay, both set to scan at the time it took for the entire amount of contrast to be injected at 2mL per second.

Another possible limitation of this study was in reference to the availability of only one board certified radiologist who had completed the IRB approved CITI human research training and was permitted to participate in this study. Due to this circumstance, the second physician participating in the project was a fourth year radiology resident who met the IRB qualifications and has experience in interpreting MDCT examinations. Even though the radiology resident had read at least 330 contrast-enhanced MDCT chest exams prior to the research conducted in this study according to the hospital’s Radiology Information Systems (RIS), the researcher was unable to control for a potential difference in CT interpretations due to the differences in professional experience between the resident and the attending radiologist who had 15 plus years as an attending physician.
The Picture Archiving and Communications System (PACS) was unable to obtain and display the image standard deviation (SD), therefore, a true Contrast-to-Noise Ratio (CNR) could not be calculated. A proxy calculation of image contrast resolution was obtained by measuring regions of interest (ROI’s) using Hounsfield Units (HU’s) of the ascending aorta, the pulmonary root and the descending aorta. Lastly, the standard protocol IV contrast, iohexol 350 (Omnipaque, GE Healthcare), could not be used in patients with an eGFR less than 61mL/min/1.73m². This high risk patient population received an IV injection of iodixanol 320 (Visipaque, GE Healthcare) which has a lower iodine content and therefore has the potential to demonstrate a decrease in Hounsfield unit measurements. Iodixanol is used in this patient population because it may be better tolerated by the kidneys.

**Conclusion and Implications for Clinical Practice**

In conclusion, chronic kidney disease (CKD) has been recognized as a global public health problem and experts estimate that CKD may now be affecting up to 35% of the adult population worldwide. Since water soluble iodinated intravascular contrast material utilized for radiographic exams such as CT studies, has the potential to result in contrast-induced acute kidney injury (CIAKI) and since it is the third leading cause of acute kidney injury in hospitalized patients and has been shown to be the cause of the need for renal dialysis in approximately 9% of CIAKI patients; it is imperative to administer the lowest dose of iodinated IV contrast material needed to create a diagnostically satisfactory CT exam (Uhlig & Levey, 2012; Perkins, Kirchner, Hartle & Bucaloiu, 2013; Kagan & Sheikh-Hamad, 2010; Stacul, van der Molen, Reimer, Webb, et
This is essential in order to decrease the possible incidence of contrast induced acute kidney injury (CIAKI). Additionally, since according to Stacul et al (2011) a “safe dose” of contrast media (CM) does not exist, the minimum amount of contrast media necessary to answer the clinical diagnostic question should be used in all patients.

The results of this research study demonstrate there is a statistically significant difference in the image contrast resolution as measured by regions of interest in HUs, but the subjective interpretation of blinded imaging by an experienced radiologist was diagnostic when utilizing a 75mL dose instead of a 100mL dose of high concentration iodinated water-soluble IV contrast agent. Therefore, the examinations with the lesser amount of patient iodine load were sufficient for diagnostic purposes and should be utilized for best patient care practices. Future prospective studies should include iodinated IV contrast dosing based on individual patient needs and characteristics. This includes but is not limited to individualizing by the weight and age of each patient. Since lower patient iodine doses may decrease the possibility of contrast-induced acute kidney injury (CIAKI), which in return may reduce the problem of chronic kidney disease (CKD) estimated to be affecting up to 35% of the adult population worldwide, then it is well worth the effort.


Appendix A

Radiologist Data Collection Form—Image Quality Scale

Image Quality Rating Scale

1 (Distinct anatomic detail, high degree of vascular opacification)
2 (Anatomic detail clear, most images display high degree of vascular enhancement)
3 (Obscured anatomic detail, enhancement not sufficient for diagnosis)

<table>
<thead>
<tr>
<th>Patient ID#</th>
<th>Image Quality Rating from 1-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) ID#_______</td>
<td>Rating #________</td>
</tr>
<tr>
<td>2) ID#_______</td>
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</tr>
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<td>Rating#________</td>
</tr>
<tr>
<td>10) ID#_______</td>
<td>Rating#________</td>
</tr>
</tbody>
</table>
Appendix B

Researcher Data Collection Form

ID#________________________  ________75mL  ________100mL

Patient weight_______________  Age_________  Male___Female___

Type of Contrast: Omnipaque 350 ______  Visipaque 320 _________

Radiologist Rating of Enhanced MDCT Chest Exams (circle one)

___1___ (Distinct anatomic detail, high degree of vascular opacification)
___2___ (Anatomic detail clear, most images display high degree of vascular enhancement)
___3___ (Obscured anatomic detail, enhancement not sufficient for diagnosis)

ROI Attenuation values (HU’s) from 3 consecutive slices at the carina:

Ascending -  ROI#1_________ ROI #2_________ROI #3_________
Pulm. Root-  ROI#1_________ ROI#2_________ROI #3_________
Descending- ROI#1_________ ROI#2_________ROI #3_________
Muscle.-    ROI#1_________ ROI#2_________ROI #3_________

Mean (Ascending 1, 2, 3)  = ___________
Mean (Pulm Root 1, 2, 3) = ___________
Mean (Descending 1, 2, 3) = ___________
Mean (Muscle 1, 2, 3)    = ___________