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# RADIATION DOSE REDUCTION STRATEGIES FOR CT

By: By Lesa Mohr, BSRT, RT(R) (QM)(BD), Mark A. Struthers, B.B.A., B.S.R.T., R.T. (R) (MR), Marilyn Sackett, MEd. RT(R), FASRT

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Objectives:

1. Identify the party responsible for creating radiologic appropriateness criteria.

2. Define and goals of the Alliance for Radiation Safety.

3. Discuss goals of the Image Gently Campaign.

4. Discuss radiation dose reduction strategies that can be implemented by the technologist to reduce patient exposure.

5. Discuss case studies as they relate to radiation induced injury

6. Identify risk associated with increased cancer incidence related to CT scanners

7. Discuss ALARA concepts in regards to head CT of the pediatric patients

### **RADIATION DOSE REDUCTION STRATEGIES FOR CT**

### Introduction

The discovery of X-radiation for medical purposes happened more than 120 years ago. Problems with overexposures and biologic effects have been a factor in the utilization since the beginning. As technology progressed, radiation dose became measured against the risk of exposure to radiation and the benefit of diagnosis. Overutilization in the practice of medicine enhanced the problem of increasing radiation dose. In addition, the "Burger King" mentality of "have it your way" and "we don't want to wait" attitude of our patients, increases pressure on the physician to over order exams to "cover his bases". Getting physicians to change their practice or to limit the number of procedures is difficult. Controlling the utilization procedure creep is like trying to get your arms around a bowl of Jello.

In the past decade there have been many documented cases of overexposures in computed tomography (CT). Also, the addition of CT scanners in all emergency rooms has produced a climate where almost all emergency room patients receive a CT scan as part of the ER protocol. The increased dose and the overutilization have led to an outcry to reduce dose. Our information on biologic effects has made it imperative to develop radiation dose strategies. Physicians and radiologic technologists using reduced dose strategies does lower patient risks.

### Who is working on the problem?

In order to give physicians the guidelines for ordering radiologic procedures, especially CT scans, the American College of Radiology (ACR) has developed appropriateness criteria. However, in spite of the guidelines, overutilization of CT continues to be a factor in overall increased dose to the public. The healthcare consumer has become increasing aware of the risks of radiation through the increased availability of information in the media. Increasing public pressure and coverage through the internet and printed media led to the establishment of The Alliance for Radiation Safety. The primary objective of the Alliance is to raise awareness in the imaging community to the need to adjust radiation dose when imaging children. **The ultimate goal of the Alliance is to change practice.** 

The Alliance chose to focus first on computed tomography (CT) scans. The dramatic increase in the number of pediatric CT scans performed in the United States in the past seven years and the rapid evolution, change, and availability of CT technology and equipment has justified this Alliance strategy. The campaign has grown to include: parent information, fluoroscopy, interventional radiology, nuclear medicine, and digital radiography. Dental information is the next area to be added.

The Alliance for Radiation Safety in Pediatric Imaging began as a committee within the Society for Pediatric Radiology (SPR) in late 2006. In 2007, The SPR leadership reached out to friends

and colleagues in sister societies representing the key members of the imaging team, ACR, American Society of Radiologic Technologists (ASRT) and American Association of Physicists in Medicine (AAPM), to form "the Writers Group." These organizations developed the concept of the Alliance and their representatives developed the campaign in the summer of 2007.



Logo designed to emphasize radiation safety

The Image Gently and other similar campaigns aid and encourage physicians and radiologic technologists to reduce radiation exposure. There are many technical tools available to the CT technologist to reduce radiation dose. Those include shielding options, parameter selections and hardware techniques, pitch effects in Helical CT, filters to attenuate low energy x-rays, and prepatient collimators. When these tools are used in a conscientiousness effort, the best possible patient protection from radiation dose is achieved.



### The CT technologist sets the scanner exposure parameters

### **Radiation Dose Reduction Strategies for CT**

Radiation was first discovered on November 5, 1895 by Wilhelm Rontgen in a lab in Germany. He won the first Nobel Prize for the discovery. Advancements in the use of radiation in medicine to view what had previously been "unseen", flourished throughout the next 120 years since that first discovery. Technology has rapidly advanced since 1967 when Godfrey N. Hounsfield concluded that x-radiation could be passed through an object and recognition and reconstruction techniques could be used by a computer to produce an image (Seeram, 2009). The first CT scanners were designed to image the head only. Since the neuro system and brain are the most resistant to the effects of radiation exposure, concerns about the amount of dose received by the patient was minimal. However, the radiation dose to the patient in computed tomography has come under tough scrutiny over the past decade. One study estimated that as many as 0.4% of current cancers in the United States are due to CTs performed in the past and that this may increase to as high as 1.5 to 2% with 2007 rates of CT usage. CT scans in 2007 were estimated at 72 million. The estimates in 2012 were that one in ten Americans get a CT scan every year, and some more than one exam. In a 2011 report sponsored by Susan G. Komen, the Institute of Medicine concluded that radiation from medical imaging, and hormone therapy, the use of which has substantially declined in the last decade, was the leading environmental causes of breast cancer, and advised that women reduce their exposure to unnecessary CT scans.

There has been growing concern, and many questions asked from parents regarding the amount of radiation their child has received. In 2008, The Alliance for Radiation Safety in Pediatric Imaging developed an initiative called "The Image Gently Campaign" and the goal was to promote radiation protection, and reduce radiation exposure to children (Image Gently, 2011). This would be accomplished by educating parents about radiation, and providing a medical imaging record that the parent can use to keep track of the imaging studies their child has had including the date, the type of imaging study or studies that were performed, and the medical facility where the exams were performed. This is not only helpful to the parent, but is useful to the child's physician by informing them of studies performed. The physician may then decide if any further studies are needed. The Image Gently campaign has been a huge success. A website was established that provides further education and answers to frequently asked questions regarding children and radiation. The success of the Image Gently campaign has sparked more interest in the general public regarding radiation, and there have been several other programs such as "Image Wisely" that have evolved as a result. The creations of these programs have led to a major reduction in radiation doses to both the pediatric and adult population.

Excessive dose cases are often in the news, as in the case of 23-month-old Jacoby Roth who was subjected to 151 scans in 68 minutes at Mad River Hospital in Arcata, CA in 2008, exposing him to 2.8 – 11Gy and a calculated cancer death risk increase of 39% (AuntMinnie.com, 2013). This was one of the highest profile cases in recent history that stirred fear of radiation from CT scans throughout the nation and in California, where it occurred. In 2010, Gov. Arnold Schwarzenegger signed a bill that become law in 2012, making it a requirement to include radiation dose from CT scans in both the patients chart and on each image created (Diagnostic, 2013). Radiation dose reduction is critical for the safety of patients and personnel. We are trained, as technologists, to use radiation on patients as long as the dose remains ALARA, As Low As Reasonably Achievable. There are many dose reduction strategies that can be utilized by staff, physicians, and even patients. Other dose reduction strategies can be applied directly to the radiation emitting equipment used in the imaging department.



#### Jacoby Roth was burned with radiation from a CT scanner

One of the first steps that can be done to reduce the radiation dose to the patient is to determine whether there is a legitimate or diagnostic need for the CT study. It is also important to determine if the appropriate study has been requested by the patient's physician. Educating physicians plays a big role in helping to reduce radiation exposure and dosage to the patient. The American College of Radiology developed an appropriateness criteria designed to help physicians choose which imaging study, or modality would be the most effective (ACR, 2010). The criteria are also helpful in addressing clinical questions for the physician. There are multiple modern imaging technologies to choose for a diagnosis and it is important for the physician to have knowledge and awareness of the radiation doses associated with the various types of radiation emitting imaging equipment. It is also important that the physician understand the best use of the type of equipment to aid in diagnosis of a patient pathology. A recent study at one New York hospital found that nearly a third of its patients undergoing multiple cardiac imaging tests were getting a cumulative effective dose of more than 100 millisieverts of radiation ---equivalent to 5,000 chest X-rays. And last year, a survey of nuclear cardiologists found that only 7 percent of stress tests were done using a "stress first" protocol (examining an image of the heart after exercise before deciding whether it was necessary to take one of it at rest), which can decrease radiation exposure by up to 75 percent.

### CT parameters effecting dose rates

Computer tomography technologists have the abilities to aid in reducing or limiting radiation doses to the patient. There are several tools and techniques that can be used by the technologists to limit the radiation exposure. Before using any of the techniques or tools it is important that the CT technologist understands all the factors that affect radiation doses so they can use good judgment. One of the first and simplest steps a CT technologist can perform is to double check all of the patient information and the type of CT study that has been ordered by the patient's

physician. There are usually certain protocols established by the radiologists and the American College of Radiology that must be followed to justify the exam for reimbursement. This step alone can prevent a patient from receiving unnecessary radiation. Other dose reduction strategies that can be performed by a CT technologist include controlling the z-axis scan length, using appropriate shielding for different body parts, using dose reduction hardware techniques such as noise index, automatic tube current modulation, adjusting kilovoltage, and proper positioning, or precise centering over the body part (Duggans-Jahns, 2012).

Another practical way of reducing radiation dose is to reduce the tube current by 50%. The MA or tube current can be reduced and still maintain the image quality. MA or tube current is the characteristic in the generation of x-rays that determines the quantity of radiation or amount of exposure which is measured as radiation dose. The quantity of radiation also affects the number of photons received by the image detector. If there are not enough photons, then the image begins to shows the differences in receptor response to the lack of enough energy from the radiation. A pattern is produced on the image that is described as noise. Noise in the image can and will destroy image details. This affect is greater in the areas of the abdomen and pelvis where the atomic number of the tissues produce more secondary radiation. It is more difficult to image with reduced radiation dose in these body parts and maintain a high quality image.



CT image noise can make an image unacceptable

Despite the fact that there is a universal consensus that computed tomography (CT) can benefit patients if used under appropriate indications, there are still concerns regarding the risk of cancer induction from CT because of increased use. Since CT was introduced, it has gained a reputation as one of the primary diagnostic imaging modalities. After the introduction of helical scanning technique and the multi detector row technology, the impact and number of applications of CT continued to grow. The fast scanning speed and high resolution of CT makes it a favorite with the emergency room physician, the cardiologist, and the surgeon. CT has a fast scanning speed and spatial resolution at 0.3- 0.4 mm. This allows physicians to diagnose disease and injuries safely, quickly, and accurately compared to more invasive and less sensitive imaging methods. Reducing radiation dose may be achieved through manual or automatic methods of modifying several scanning factors. In the era before the advent of spiral computed tomography (CT), the

main parameters that radiologists considered when determining abdominal CT scanning protocols were scanning area, or range; section thickness; and interscan delay. With the introduction of spiral techniques, pitch became an additional important parameter because it affects scanning time and section thickness. Now, with the availability of multi-detector row CT, scanning protocols have become even more complex owing to the larger number of interacting factors.

The degree of patient exposure to x-rays also is influenced by the beam collimation because of the "overbeaming," or penumbra effect. With the best collimation, the x-ray beam is always slightly wider than the detector rows. In a multi–detector row CT, the incident x-ray beam is about 2 mm wider than the selected detector configuration. The wider the applied beam, the smaller the percentage of "wasted" radiation due to overbeaming. Another way of looking at this is that with overcollimation, overbeaming is reduced, but the scanner gantry will make more energized rotations to get the image.

For multi-detector row CT, pitch is generally defined as the table travel per rotation divided by the collimation of the x-ray beam. A beam-pitch of 1.0 would be used for an acquisition with no overlap or gap, a beam-pitch of less than 1.0 would be used for an overlapping acquisition, and a beam-pitch of greater than 1.0 would be used for an interspersed acquisition. Pitch has a smaller effect on image quality with use of multi-detector row CT scanners.

Table travel speed is another and maybe the most important parameter that radiologists have to manipulate when they are setting up scanning protocols. Beam collimation, pitch, and gantry rotation time define table speed according to the following relationship: Table speed equals beam collimation x pitch x number of gantry rotations per second. Hence, an acquisition performed with a detector configuration of  $16 \times 1.5$  mm scanned at a pitch of 1.0 and at a 0.5-second gantry rotation time will result in a table speed of 48 mm/sec (16 data channels x 1.5-mm detector row thickness per data channel x pitch of 1.0 per rotation x two rotations per second).

Another tool to control radiation dose is the appropriate utilization of filters added to the x-ray beam. Filters underneath the tube in x-ray selectively attenuate low-energy x-rays that have no contribution to image formation (Rajiha, et. al 2012). Filtered beams have higher mean energy and lower intensity, but the potential energy is not altered. This has the effect of hardening the beam and removing radiation dose that would enter the skin, but would not contribute to the image formation. Dependent upon the size of the patient, the radiographer may select small, medium, or large bow tie filters. The choice of filter size impacts the acquisition field of view as well as the radiation dose. The smallest filter which allows the entire region of interest in the field of view should be used. Similarly, cardiovascular technologists may use pre-patient z-collimators to reduce the amount of radiation that reaches the patient (Nievelstein, et. al 2010). The pre-patient collimators are placed close to the x-ray tube. This location allows the width of the collimator to be altered. This also limits the x-ray radiation to the thick section that is

intended at the target area in the z-axis. This avoids unnecessary radiation exposure under and to adjacent tissues.

Despite the potential risks associated with CT scans, the benefits still outweighs the risks. We are all exposed to radiation on a daily basis from background sources such as cosmic, terrestrial, and internal sources from air and food. Researchers, radiologists, imaging professionals and other physicians make decisions intended to balance the benefit and risks. Radiation dose varies widely depending on the type of exam performed. The value of a quick diagnosis may outweigh the risk associated with a CT scan dependent upon the situation, such as the trauma patient in the emergency department. CT used to assist surgeons in localizing trauma and pathology may be a critical factor in the patient's treatment. A CT procedure will allow the cardiologist to review a 3 dimensional image of the arteries without an invasive procedure.

CT is a good tool for performing procedures on patients with medical devices. Most patients with electronic medical devices undergo CT scans without any adverse consequences. However, the FDA has received a small number of reports of adverse events in which CT scans may have interfered with electronic medical devices, including pacemakers, defibrillators, neurostimulators, and implanted or externally worn drug infusion pumps. It is possible that this interference is being reported more frequently now because of the increased utilization of CT, the higher dose-rate capability of newer CT machines, an increase in the number of patients with implanted and externally worn electronic medical devices along with better reporting systems.

### **Common CT dose rates**

According to ECRI Institutes, new CT models with dose saving technologies (built-in) are now in use in some facilities but are very expensive (ECRI, 2010). To ensure proper functioning, all radiation producing equipment is evaluated annually for performance to manufacturers' specifications as a safety measure. This performance review is part of the annual physics certification. Radiation dose is directly related to scanning protocols. Protocols vary for medical facilities, especially for those performing pediatric procedures. Therefore, there is no dose standardization between facilities.

CT radiation doses have increased as the technology increases. In a recent magazine article the following radiation doses were reported from CT Scans:

CT scans of abdomen and pelvis	15,000 microsieverts
Virtual Colonography	10,000 microsieverts
Environmental exposure	3,000 microsieverts
Mammogram	400 microsieverts
Chest X-ray	100 microsieverts

#### Dental x-ray

5 microsieverts

Despite the usefulness of CT, awareness of the side effects is not always properly discussed with patients by their physicians in terms of alternative treatment. Some physicians are routinely quick to order CT scans which can be very expensive and sometimes unnecessary. Alternative treatment such as ultrasound, MRI, biopsies and blood tests may be underutilized in medical guidance for diagnosis due to CT overuse. "Among young and middle-aged patients, more women than men have had CT scan; nearly one in five women (19 percent) ages 45-64 have had at least one CT scan in the past year. That's up from 13 percent in 2004—a 46% jump" (Petersen, 2013). It is clear that specific guidelines need to be set to control the protocols used by physicians for ordering CT procedures in order to protect the patient.

The technologists' role utilizing all of the parameters available and the inherent factors designed into CT systems can significantly reduce radiation risk to the patient. The responsibility is shared amongst the ordering physician, the radiologist, and the technologist performing the procedure. When that responsibility is combined with knowledge and skill, the desired radiation dose reduction is achieved.

### The ALARA Concept for Performing Pediatric Head Computed Tomography

In 2008, The Alliance for Radiation Safety in Pediatric Imaging developed an initiative called "The Image Gently Campaign" with the goal of promoting radiation protection, and reducing radiation exposure to children (Image Gently, 2011). The campaign parameters include informing parents about radiation exposure, educating radiologic technologists and physicians about pediatric dose concerns, and suggesting methods to lower pediatric doses.



Radiation Protection for Children: One size does not fit all and one strategy does not fit all

The key concerns include common indications for head CT for pediatric patients, optimizing scan performance, and lowering radiation dose by using protocols and techniques (Image Gently, 2011). Head CT has become one of the most beneficial methods used to diagnose pediatric conditions over the past thirty years (Image Gently, 2011). The increase in CT usage in pediatrics has led to concern over the long term effects of cancer risk. Children are more sensitive to ionizing radiation and absorb more radiation than adults (Image Gently, 2011). It is estimated that the lifetime cancer mortality risks attributable to the radiation exposure from a head CT in a 1-year-old is 0.07% which is much higher than the adult risk (PubMed, 2013).

Other imaging modalities, such as MRI and ultrasound, cause no ionizing radiation dose to patients and are safer to use for pediatric imaging. However, the spatial resolution that enables visualization of soft tissue densities is superior with CT (Image Gently, 2011). Additionally, MRI takes longer to perform than CT, making it difficult to perform without sedation on small children (Image Gently, 2011).

Physicians have to make critical decisions concerning the use of CT on patients according to presenting signs and symptoms of the patient. Indications for head CT procedures must be understood by ordering physicians. When an exam is ordered that does not meet the known indications, the Radiologist should consult with the ordering physician (Image Gently, 2011). Sometimes it is concluded that "watchful waiting" is the best action to take (Image Gently, 2011). "One of the most effective ways to change the risk of radiation-related mortality is to decrease CT scanning, especially in children, and especially in cases where CT is not absolutely indicated" (ACEP, 2008).

Out of the 85 million CT scans per year performed in this country, 8-11 percent are performed on children. In fact, CT is reported to be 12.8 percent of all imaging procedures in childhood. Overall, 7.9 percent of children receive at least one CT scan and 3.5 percent receive 2 or more scans. A problem exists with this utilization frequency because many facilities are not familiar with pediatric protocols and the imaging techniques default to more common adult protocols. Compounding this incorrect imaging protocol is the lack of familiarity with pediatric disorders and disease. Additionally, the CT area may be removed from direct radiology supervision which could correct the protocols based on the different size ranges of the pediatric patients.

The first direct association between CT scans and cancer was published online by Lancet in June, 2012. The following is a reprint of some of their findings.

"Radiation exposure from CT scans in childhood could triple the risk of leukaemia and brain cancer

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Children and young adults scanned multiple times by computed tomography (CT) have a small increased risk of leukaemia and brain tumours in the decade following their first scan.

The findings, published online today in <u>The Lancet</u>, from a study of more than 175,000 children and young adults was led by researchers at Newcastle University and at the <u>National Cancer Institute</u>, part of the National Institutes of Health, USA.

The researchers emphasise that when a child suffers a major head injury or develops a life-threatening illness, the benefits of clinically appropriate CT scans should outweigh future cancer risks.

In the study, the researchers estimate that for every 10,000 head CT scans performed on children 10 years old or younger, one more case of leukaemia and one more brain tumour would occur than would normally be expected."

Technologists and physicians must have a good understanding of the radiation doses that children receive during any CT exam and keep the dose as low as reasonably achievable. The protocols used for each head CT exam can be altered to adjust technical factors to lower the dose to the patient. In many radiology departments, the Radiologist in charge provides protocols that are designed for pediatric CT patients; however, sometimes the technologist sets the protocols (Image Gently, 2011). For a technologist to create the best possible protocol, they must have a very good understanding of the factors that affect patient dose. Guidance for protocol selection is available on the Image Gently website, but protocols vary according to the equipment manufacturer (Image Gently, 2011). Lowering patient dose can compromise the resolution of the exam, so protocols have been established under the Image Gently, 2011). This allows the technologist to lower the resolution on repeat exams or exams that don't require high resolution to obtain the needed information. Physicians and technologists must keep up-to-date as technologic changes occur in the field in order to make the best choices and balance the need to reduce dose to the patient with the need to obtain diagnostic images.

In an article from *Radiologic Technology* in 2011 that surveyed CT technologists, the authors reported that:

• Although 85 percent reported having pediatric-specific protocols, only 58 percent indicated that they always used them.

- In that same report, only 29 percent or CT respondents reported that they use all methods of shielding at their disposal.
- The report stated that 54 percent of the CT respondents stated they were very knowledgeable about anatomy and 41 percent stated they were knowledgeable about anatomy, 80 percent reported overscanning the area of interest with some regularity.

After the study that linked the CT scans to increased risk of cancer, more questions were asked about the relationship to other cancers, in particularly in girls and the risk of breast cancer. In 2013, an additional study was published in the *Journal of American Medical Association Pediatrics*. The following is a reprint of some of their findings.

## *"Study Examines Cancer Risk from Pediatric Radiation Exposure From CT Scans*

#### EMBARGOED FOR RELEASE: 3 P.M. (CT), MONDAY, JUNE 10, 2013

Media Advisory: To contact Diana L. Miglioretti, Ph.D., call Phyllis Brown at 916-734-9023 or email Phyllis.Brown@ucdmc.ucdavis.edu. To contact editorial author Rita Redberg, M.D., call 312-464-5262 or email mediarelations@jamanetwork.org.

CHICAGO – According to a study of seven U.S. healthcare systems, the use of computed tomography (CT) scans of the head, abdomen/pelvis, chest or spine, in children younger than age 14 more than doubled from 1996 to 2005, and this associated radiation is projected to potentially increase the risk of radiation-induced cancer in these children in the future, according to a study published Online First by *JAMA Pediatrics,* a JAMA Network publication.

The projected lifetime attributable risks of solid cancer were higher for younger patients and girls than for older patients and boy. The risks were also higher for patients who underwent CT scans of the abdomen/pelvis or spine than for patients who underwent other types of CT scans, according to the results.

The estimates also suggest that for girls, a radiation-induced solid cancer is projected to potentially result from every 300 to 390 abdomen/pelvis scans, 330 to 480 chest scans, and 270 to 800 spine scans, depending on age. The potential risk of leukemia was highest from head scans for children younger than 5 years of age at a rate of 1.9 cases per 10,000CT scans, the results show."

Other key areas of concern for the technologist performing head CT exams for pediatric patients are parent education (Image Gently, 2011). Technologists can direct parents to the parent portal on the Image Gently website, where medical imaging forms can be obtained to record procedures that a child receives. This helps the parent, and can be used by the patient's physician in making decisions about future scans.

Image Gently website does discuss most of the methods used to lower pediatric dose during head CT scans. CT technologists should benefit from the information, but there are additional technical steps that help lower patient dose. For example, the technologist may use hardware techniques such as noise index, automatic tube current modulation, adjusting kilovoltage, and controlling z-axis scan length (Duggans-Jahns, 2012). Tube current may also be reduced by 50%.

Patient communication is a vital factor in reducing repeat exams. Repeat exams increase patient exposure by 100% for each repeat. In pediatric CT, the communication level depends on the age of the patient. If the patient is an infant or toddler, then sedation is often necessary. Good communication with the patient's parents eases parent apprehension, which may also lessen the patient's fear.

If a patient is under age five, the immobilizer should be used to secure their arms and reduce movement (Seeram, 2009). Immobilizer use is common in older patients as a reminder to hold still during a CT scan (Seeram, 2009). For head CT, it is common to use thin Velcro straps across the patient's forehead to help them hold the precise position needed for the scan. Again, communication is key in getting patient cooperation from patients over the age of four or five years old.

### Summary

Much of the success of the Image Gently program is that it has initiated discussion amongst technologists, supervisors, administrators, physicians, medical physicists, other healthcare professionals and patients. Discussion leads to improved communication, which leads to improvement in the process of providing the best possible care to the patient. Since Image Gently was first started, other campaigns have begun because of its success, such as the Image Wisely Campaign.

Continued quality processes to find new ways reduce radiation dose need to be on-going between technologists, physicians, and equipment engineers. Medical technology changes so rapidly, that quality care must be sought during development to ensure that all new technological advances, whether software related or equipment are safer than what we currently have as we will continue to move in the direction of improvement.

### **Powerpoint Study Guide**

### Slide 9

With multislice CT, everything is better. For a given protocol, multislice is better by the number of detector rings. For this example we will use a typical single-slice protocol, 40 second continuous spiral run, one second per rev scan time, 5mm slice thickness, 200 mA and 200cm total anatomic coverage using an Mx8000 quad-slice scanner.

For multislice, using four as the number of rings, the same protocol would equal either Better resolution — Nominal Slice Thickness of 5mm divided by four with the same total coverage, scan time and mAs

More Speed — 40 second continuous spiral run divided by four with the same nominal slice thickness, scan coverage and mAs

or

or

Greater volume coverage — 20cm times four with the same nominal slice thickness, scan time and mAs  $\,$ 

or

Power Effective mA — 200 mA times four with the same nominal slice thickness, scan time and coverage

### Slide 30

Figure 1. Chart shows the basic dose parameters (as determined with an AEC system) displayed on the console of a Siemens multidetector CT scanner. Note that the reference milliamperage has been set at 100. From the volume CT dose index and dose-length product (DLP), the effective dose can be roughly calculated as  $DLP \times$  conversion factor. cSL = section collimation (not section width), mAs = average applied milliamperage, ref. = quality reference milliamperage, TI = rotation time, Total DLP = DLP value of the entire examination, Total mAs = actual value of the entire examination in milliamperes.

### Slide 48

- Take the time to position the patient in iso center- you will get better image quality and speed up your post processing times

- Use different tilt positions when scanning the head

For Sinuses and F/B tilt chin up

Brains and PTB tilt chin down to avoid orbits and reduce the scan volume, directly reducing DLP and Dose

- Make sure the patient is flat in the Z plane as this gives optimal dose modulation and image quality. It also reduces potential high skin doses

### Slide 49

- Correct patient alignment can reduce dose by up to 56% - from a paper by banghart 2006 Centered *Correctly* the body will be truly representative of its actual size.

-Centered *Too High in the gantry* the body will be magnified and therefore create *higher mA's* -Centered *Too Low in the gantry* the body will be reduced and therefore will create *lower mA's*.

### Slide 61

- Rotation time is related to dose in a linear fashion

Decreasing RT from 1s per rotation to 0.5s per rotation = a 50% dose reduction

- However the trade off is image noise (demonstrated in these images)
- BY using short rotation times we

produce a linear decrease in patient dose

- Faster scan times
- And less motion artifact
- I recommend using short rotation times for paediatrics

### Slide 62

Graph shows dose reductions in cardiac CT angiography. Cardiac spiral CT was introduced into clinical practice around 2000 after the introduction of the four-section scanner. Electrocardiographically controlled milliampere (mA) modulation was introduced to clinical practice in about 2002, the step-and-shoot mode for cardiac imaging was introduced in about 2006, and dual-source spiral CT with high pitch was introduced in around 2009. For cardiac examinations that do not require images of the heart throughout the entire cardiac cycle, the radiation can be turned down with the use of tube current (milliampere) modulation, or off in the case of nonspiral scans. This is often done for phases of the cardiac cycle where the heart is moving fastest, when motion blurring or artifact would be most severe.

### Slide 69

Comparison of simulated lower-dose images obtained from a routine-dose CT examination. CT images obtained with the original dose, 70% of the original dose, 50% of the original dose, and 25% of the original dose were compared to determine the lowest acceptable dose level for each type of CT examination.

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