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Evaluation of Radiation Exposure from Computed Tomography of the Head

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Evaluation of Radiation Exposure from Computed Tomography of the Head

A Capstone Scholarly Project Presented By:

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Abstract

In an effort to reduce radiation exposure from computed tomography (CT), practitioners and facilities need to monitor radiation exposure while delivering high-quality diagnostic exams. Computed tomography scanners have a range of pre-programmed protocols for different examination types, with set values for tube potential, tube current, and rotation time (American Association of Physicists in Medicine, 2007). One way to minimize a patient's exposure to radiation from CT is the use of an automatic exposure control (AEC) device. Current research is focusing on these devices and their actual benefits to patients. To assess the effectiveness of such a device, analysis of radiation doses per CT exam must occur. Machine-specific dose-length product (DLP) and or CT dose index (CTDI) are the only indicators of specific dose levels. This project compares current levels of radiation exposure to patients undergoing CT scans of the head, versus the national levels as evaluated by the Nationwide Evaluation of X-ray Trends (NEXT) program.

Key words: Computed tomography, radiation exposure, reducing radiation, monitoring radiation levels, automatic exposure control.

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Introduction and Background

Computed tomography is a non-invasive medical procedure that uses specialized X-ray equipment to produce a cross-sectional image representing a slice of the person being imaged (FDA, 2010). It can be performed on any area of the body for a multitude of reasons. CT images of organs, bones, soft tissues and blood vessels provide more details than conventional X-ray images (FDA, 2010). This medical imaging of the human body requires some form of energy that will produce an image only attainable by penetrating tissue (Bushberg, Seibert, Leidholdt, & Boone, 2001). As a result, there is absorption of the energy used to produce quality images. Exposure to radiation and the overutilization of imaging scans is a current healthcare quality concern. In the diagnosis of tumors, CT scans are essential tests. While not much study has been placed on the effects of such radiation emitting tools, there is a growing concern that it is too much. Focus has now turned to keep radiation doses as low as possible.

Although the exact risks of radiation exposure are difficult to quantify, it is inarguable that radiation exposure can be dangerous and is undesirable (American College of Radiology, 2009). Some studies of large populations exposed to radiation have demonstrated slight increases in cancer risk even at low levels of radiation exposure (ACR, 2009). According to recent estimates, the average person in the U.S. receives an effective dose of about 3 millisievert (mSv) per year from naturally occurring radioactive materials (Radiological Society of North America, 2012). As outlined by the Radiological Society of North America (2012) a CT scan of the abdomen will deliver approximately 10 mSv compared to a CT of the head delivering 2 mSv. Astonishing to realize a CT of the abdomen can deliver almost three years' worth of naturally occurring radioactive materials.

Problem Statement

Recent data suggest that increases in radiation exposure are associated with an increased health risk (Hall & Brenner, 2008). In an effort to monitor and limit radiation exposure from CT, tracking amounts of exposure along with utilizing devices to minimize exposure is central to the delivery of safe and good patient care. The American College of Radiology (2006) concept, "As Low as Reasonably Achievable (ALARA)" encompasses the need to minimize radiation dose to patients while maintaining the necessary diagnostic image quality.

Significance

Tube current is one of the key technical scanning parameters for adjusting radiation dose (Singh, Kalra, Thrall, and Mahesh, 2011). Automatic exposure control systems are designed to adjust the kilovoltage (Kv), milliamperage, or exposure time of a test in order to obtain an image of diagnostic quality (International Atomic Energy Agency [IAEA], 2008). Such systems detect the amount of radiation immediately in front of the image receptor and adjust the dose or dose rate to the patient in order to assure sufficient photons are reaching the image receptor (IAEA, 2008). Automatic exposure control techniques are available on most CT scanners from major vendors (Singh et al., 2011). It is up to the user to specify a desired image quality in terms of image noise or tube current (Singh et al., 2011). After the introduction of CT into clinical practice, a standardized metric of scanner radiation output, the CT dose index, was introduced and widely adopted, such as its inclusion into the Code of Federal Regulations Title 21, Volume 8 (Boone, Hendee, McNitt-Gray, & Seltzer, 2012). With every CT test a DLP or CTDI is calculated and specifies radiation dose delivered to the client. Managing the risks of CT procedures depends on two principles of radiation protection: appropriate justification for ordering and performing each procedure, and careful optimization of the radiation dose used during each procedure (FDA, 2010). Patients should be exposed to an optimal radiation dose to produce a high-quality image (FDA, 2010).

There will always be some level of radiation exposure because of these tests. The focus now is how to optimize patient exposure to radiation from certain types of medical imaging exams, as well as monitoring levels of radiation exposure; thereby reduce related risks while maximizing the benefits of these studies (FDA, 2010).

Objective

The aim of this project is to assess radiation exposure of clients undergoing head CT within a large metropolitan hospital and compare these dose levels to the national levels as reported by the 2006-2007 NEXT survey.

Evidence Based Intervention

The National Quality Forum [NQF] (2011) Board of Directors endorsed patient safety measures, addressing radiation dosing in computed tomography, targeting appropriate documentation and access of radiation doses to patients and providers. The measures endorsed by the NQF (2011) were a result of the National Council on Radiation Protection and Measurement's (NCRP) point that measuring and reporting dose information in a simple and consistent fashion would be an extremely important first step toward reducing variation, and thereby improving the safety and quality of CT imaging.

As a designated Evidence-Based Practice Center (EPC) by the U.S. Agency for Healthcare Research and Quality, the Emergency Care Research Institute (ECRI) joins applied scientific research to improve patient care. In an effort to help healthcare facilities ensure their CT radiation dosages are at a safe level, ECRI introduced a CT Radiation Dose Safety Review service (Emergency Care Research Institute, 2010). Its multidisciplinary experts, including medical physicists who specialize in diagnostic imaging, conduct a thorough assessment of a hospital's CT service, including current policy and procedures, staff, and technologies, then identify vulnerabilities in safety and quality, and help implement changes to minimize the likelihood of patient harm from excessive radiation dosage (ECRI, 2010). Similar to the ECRI, hospitals are establishing radiation safety committees to oversee radiology practices.

Review of Literature

Methods

The search of the literature for CT radiation overexposure included use of several databases: CINAHL, PubMed, and MEDLINE. The Medical Subject Headings (MeSH) used included: computed tomography radiation exposure; automatic exposure control device and reducing radiation exposure. Inclusion criteria included full-text articles written in the English language between the years of 2000 to present. While still an evolving and delicate subject matter, the search did not elicit many controlled or experimental studies. Non-experimental and few experimental studies as well as case reports and scholarly written reviews comprise the review of literature on decreasing radiation exposure. Initial online search yielded over 500 results. Closer analysis revealed lack of specified inclusion timeframe. Therefore, search criteria narrowed further to include data between the years of 2005 and present. Results then further limited to just fewer than 30 within CINAHL and MEDLINE. PubMed did not favor so well, it resulted over 1000 articles. As a result, CINAHL and MEDLINE became the search engines of choice.

Search on CINAHL delivered only 18 returns with MeSH search: radiation dose from computed tomography. With the same MeSH, search on MEDLINE, 26 results returned.

Unfortunately, PubMed provided too many articles. With the MeSH search: computed tomography of head, CINAHL resulted 37 articles. MEDLINE resulted 85 articles. The MeSH search: computed radiation overexposure, CINAHL resulted 7 articles. MEDLINE provided 20 results. In reading through the resultant articles, fewer still included information on both CT and AEC.

A review of ten articles on the prevention of radiation overexposure with use of AEC device yielded quantitative studies. Literature and expert opinions are prevalent on radiation overexposure from CT, yet experimental research on human subjects is not achievable. As a result, testing variable levels of radiation exposure are done via simulator studies. To control for radiation doses and exposure levels, studies identified use of phantom subjects. From pediatric to adult phantoms, variations of each were analyzed. The following represent the latest and most current data available.

Automatic Exposure Control and Movement

A descriptive report completed by Gudjonsdottir, Svensson, Campling, Brennan, & Jonsdottir (2009) in Acta Radiologica on the AEC function of three different CT scanners looked to demonstrate the importance of operators understanding the relationship between AEC usage and movement. An oval-shaped acrylic phantom was scanned in various positions, using three different CT scanners, then the tube current was recorded and noise measured in the images (Gudjonsdottir et al., 2009). Correlation of tube current and noise with position was calculated using Pearson correlation (Gudjonsdottir et al., 2009). In CT, patient's alignment affects radiation dose and image (Gudjonsdottir et al., 2009). The researchers addressed various patient positioning methods. They did not however include testing site location or actual subject information. Applicable to practice, Gudjonsdottir et al. (2009) concluded that patient positioning could markedly affect AEC efficiency. Off-center patient positions cause errors in tube current modulation that can outweigh the dose reduction gained by AEC use, and image quality (Gudjonsdottir et al., 2009).

Automatic Exposure Control Function

Found in The Journal of Radiologic Technology, Gudjónsdóttir, Ween, & Olsen (2010) completed an international and national review of the literature just as Söderberg & Gunnarsson (2010) had done. The purpose of this review was to address the need for uniformity of AEC devices. A literature review was conducted to assess current knowledge regarding tube current modulation and AEC in CT from peer-reviewed journals and publications from national and international organizations involved in imaging and radiation protection (Gudjónsdóttir et al., 2010). This review included the expertise and judgment of multiple professionals. Four aspects of AEC use were identified, including interaction of user-selectable parameters with AEC, patient positioning, specific challenges with patient size groups and how to select appropriate input value (Gudjónsdóttir et al., 2010). Gudjónsdóttir et al. (2010) identified the importance of AEC on reducing radiation overexposure within all types of scanners. The inclusion of international data sources was the strength of this study. The researchers did not however provide the total number of sources or their specific credentials.

Söderberg & Gunnarsson (2010) performed an evaluation of systems from different manufacturers and the use of automatic exposure control in computed tomography. The authors conducted a literature review of journals and publications from national and international organizations and the use of AEC systems. Söderberg & Gunnarsson (2010) evaluated AEC systems from four different CT scanner manufacturers considering their potential for reducing radiation exposure to the patient while maintaining adequate image quality. The authors obtained the expertise and judgment of multiple professionals on AEC systems from General Electric, Philips, Siemens and Toshiba. Tube current modulation of each AEC system was investigated by scanning an anthropomorphic chest phantom using both 16- and 64-slice CT scanners from each manufacturer with the AEC systems activated and inactivated (Söderberg & Gunnarsson, 2010). The radiation dose was estimated and image quality was evaluated based on image noise and circular regions of interest situated throughout the spine region of the phantom (Söderberg & Gunnarsson, 2010). This study revealed the AEC systems available in modern CT scanners could contribute to a significant reduction in radiation exposure. The variation in image noise among images obtained along the scanning direction was lower when using the AEC systems compared with fixed tube current (Söderberg & Gunnarsson, 2010). Using a phantom chest representative of a 160cm tall male, researchers were able to get radiation readings and apply the findings to actual patients. Unfortunately, limiting the area scanned to only the chest also limits applicability of data to other body parts. The use of international sources of data presented strength of the study while omitting the total number of returned results was a weakness in the review. Söderberg & Gunnarsson (2010) concluded the AEC systems available in modern CT scanners could contribute to a significant reduction in radiation exposure to the patient.

Automatic Exposure Control Dose Reduction

From the European Society of Radiology, Lechel, Becker, Langenfeld-Jager, and Brix, (2008) assessed dose reduction by automatic exposure control in multidetector computed tomography. A comparison between measurement and calculation was completed. The researchers aimed to investigate the potential of dose reduction in multidetector CT by current-modulated automatic exposure control when an average tube current is used (Lechel et al., 2008).

In this experimental study, measurements of whole-body phantoms were conducted. Phantom measurements were performed at a CT system with 64 detector rows for four representative examination protocols, each with and without current-modulated AEC (Lechel et al., 2008). Lechel et al. (2008) resulted that the highest organ doses observed were for whole-body CT without AEC. A reduction of as much as 27%-40% was determined with use of AEC (Lechel et al., 2008). Although image quality was not addressed in this study, it was concluded that dose to patients undergoing an examination can be reduced considerably by applying a current-modulated AEC (Lechel et al., 2008).

From the American Journal of Neuroradiology, Namasivayam, Kalra, Pottala, Waldrop, and Hudgins (2006), compared diagnostic acceptability, noise, and radiation exposure from CT of neck performed with AEC and with fixed current. Two study groups of 26 patients each underwent CT of the neck using z-axis AEC and fixed-current technique (Namasivayam et al., 2006). The institution's governing Institutional Review Board approved the study at hand. Two radiologists evaluated the images for diagnostic acceptability (Namasivayam et al., 2006). Automatic exposure control systems from General Electric Healthcare Technologies with a range of 150-440 mA were utilized in the first subgroup of 26 subjects (mean age, 49 years) while the second subgroup of 26 subjects were exposed to a range of 75-440 mA (mean age, 53 years) (Namasivayam et al., 2006). A control group of 26 subjects underwent CT of the neck using a fixed tube current of 300 mA (Namasivayam et al., 2006). Namasivayam et al. (2006) concluded that all CT examinations of study and control groups were diagnostically acceptable, and there was no significant difference between AEC and fixed current diagnostic acceptability. The resultant dose reduction from AEC was significantly evident. The three scanning techniques resulted in overall mean tube current–time product reduction of 21% (range, 7%–51%) and 33%

(range, 11%–51%) when AEC used, compared with those scanned with fixed current technique (Namasivayam et al., 2006). Reducing tube current with the use of AEC is the most practical way to reduce CT radiation (Namasivayam et al., 2006).

Papadakis, Perisinakis, and Damilakis (2008), aimed to study AEC for dose reduction in pediatric and adult computed tomography. The authors of the study specifically used both pediatric and adult phantoms to assess the impact of AEC systems on radiation dose and image quality. Specifics to the pediatric phantom included representation of a 1-year old, 5-year old, and 10-year old child. The dose reduction ranged between 4.7 and 34.7% for neonate, 15.4 and 30.9% for a 1 year old, 3.1 and 26.7% for a 5 year old, 1.2 and 58.7% for a 10 year old, and 15.5 and 57.4% for adult phantom (Papadakis et al., 2008). With the specific attention given to the pediatric population Papadakis et al., (2008) were able to conclude that dose reduction was considerably inferior in children compared to an adult in some cases. Although, exact reasoning why was not indicated.

Automatic Exposure Control Image Quality

In the Journal of Medical Physics, Brisse et al. (2007) conducted an experimental assessment on pediatric phantoms. The objective by Brisse et al. (2007) was to assess an AEC system using pediatric phantoms by studying the effects of phantom transmission and resulting absorbed radiation dose and image quality. The study was performed with six phantoms of variable diameters (10-32 cm) and one equivalent to a 5-year-old pediatric anthropomorphic phantom (Brisse et al., 2007). Observed values were compared to expected values derived from known basic dose-quality relations (Brisse et al., 2007). This quantitative study focused its assessment of AEC devices only on the pediatric population. Unlike the common anthropomorphic phantoms used in previous studies, cylindrical phantoms were used as well.

From The Journal of Academic Radiology, Murazaki et al. (2012) conducted a non-experimental study observing image quality with use of exposure control devices. The researchers investigated variations in image noise and contrast using CT AEC on a hepatic phantom. Just as the study by Söderberg & Gunnarsson (2010), the researchers in this study exposed abdomen and pelvis phantoms to radiation entrance. Unlike the study by Söderberg & Gunnarsson (2010), this study did not identify specific make up of phantom model. Non-enhanced and iodine-enhanced simulated liver phantoms and automatic exposure control were used, with tube current automatically adjusted with noise index (Murazaki et al., 2012). Based on the findings by Murazaki et al. (2012), radiographers can reduce a patient's entrance skin exposure and maintain image quality by selecting specific AEC configurations. Results were limited as only abdominal and pelvic regions were tested. Applicability of such results to other regions of the body is limited. With AEC, image noise on iodine-enhanced images was higher than on non-enhanced images, as tube voltage decreased, contrast on iodine-enhanced images increased (Murazaki et al., 2012).

Hawking & Elmore (2009) conducted a study in the Journal of Radiologic Technology to determine whether manipulation of the standard AEC chamber selections reduce a patient's entrance skin exposure (ESE) without compromising image quality. Data for density and radiation for this study was gathered at two clinical locations. Hawking & Elmore (2009) exposed abdomen and pelvis phantoms to radiation using three AEC chamber selection configurations. Optical density and exposure indicator remained within acceptable ranges and image quality was maintained using this chamber configuration (Hawking & Elmore, 2009).

Radiographers can reduce patients' entrance skin exposure and maintain image quality (Hawking & Elmore, 2009). Study results are limited as they are only applicable to abdomen and pelvis CT scans. Further research on AEC chamber selection needs to be conducted for additional anatomical regions. Positive findings were the resulted lowest exposure dose while maintaining image quality.

Exposure Levels

From The Journal of Digital Imaging, a case-control observational study conducted by Thakur et al. (2012) highlighted the dose variation in common CT examinations throughout a large health region. RadChex was the device used to measure radiation exposure on patients already undergoing computed radiography. An analysis of exposure levels yielded reports based on the specific body part scanned. Patients undergoing CT scans in twenty different CT rooms throughout seven hospitals were included in the study. Thakur et al. (2012) identified up to 30% of a patient's radiation dose may be reduced with standardization of AEC device. Within a large health region, variation in exam protocols can occur, leading to unnecessary patient dose from the same type of examination (Thakur et al., 2012). Quality control programs must monitor exam protocols and AEC chamber calibration in CT to ensure consistent, minimal, patient dose, regardless of hospital or CT vendor (Thakur et al., 2012). Strength of the study was its use of various CT scanners in multiple hospitals. This minimized biases based on specific devices. Unfortunately, the radiation exposure was only specific to chest radiographs, as opposed to a variation of many types of radiographic tests. Yet, it is one of few studies to provide data based on human participants and not just phantoms.

Synthesis

The consensus on the research reviewed identifies radiation exposure levels from CT a subject matter requiring ongoing attention. The literature identified use of AEC device as favorable in managing levels of radiation from computed tomography. The reviewed articles on the prevention of radiation overexposure with use of AEC device suggests that its proper use does provide significant decreases in radiation dosage. The ongoing theme amongst each reviewed work consistently acknowledged proper use and application of an AEC device delivers high quality diagnostic images while reducing needless radiation levels and averting potentially damaging effects. The literature review was comprised of mostly expert opinions and non-experimental studies, as experimental research on human subjects is not achievable. As a result, levels of radiation exposure were simulator studies. To control for radiation doses and exposure levels, seven of the studies identified use of phantom subjects.

The spectrum on subjects varied from single organ models, such as a hepatic phantom in the study by Murazaki et al. (2012) to a complete chest phantom as seen in the study by Söderberg & Gunnarsson (2010). Brisse et al. (2007) were the only researchers to conduct an experimental assessment on the effects of radiation transmission, absorbed radiation dose, and resulting image quality. Brisse et al. (2007) and Papadakis et al. (2008) solely identified use of pediatric phantoms, while the other studies employed the use of phantoms replicating the adult anatomy. Thakur et al. (2012) and Namasivayam et al. (2006) were the only to produce results from actual human subjects. Although, the studies on human subjects were limited to the radiation exposure of only torsos and necks, the findings were significant as the outcomes from both the studies reflected comparable results obtained from the studies that utilized phantom subjects.

Gudjonsdottir et al. (2009) addressed automatic exposure control function. The researchers not only addressed the function of AEC devices on multiple types of scanners, but it was the only study to focus on operator knowledge and proper positioning methods and its effect on AEC function leading to the least level of radiation. The identified subject was an oval-shaped phantom of acrylic material, but no size configuration reported. It is unclear whether the phantom was representative of a pediatric or adult human. To account for manufacturer differences, the researchers did utilize multiple types of CT scanners to record tube current and assess resulting images. Gudjónsdóttir et al. (2010) addressed the need for standardization of AEC devices for optimal function. A substantial amount of data on the usefulness of AEC devices came from this single article. Gudjónsdóttir et al. (2010) comprised the expertise and judgment of multiple professionals to address the matter of AEC device uniformity. Patient positioning and size along with user knowledge and proper selection of input level on scanner were closely examined. Gudjónsdóttir et al. (2010) did not exclude data sources, but they did not identify number of or qualifications of sources. Söderberg & Gunnarsson (2010) evaluated AEC function from different CT manufacturers and their potential for reducing radiation exposure levels while still maintaining satisfactory image quality. While use of phantom models was appropriate, as they were representative of an adult male chest, the study omitted to illustrate how and who evaluated image quality. The overall conclusion from the study was the resultant reduction of radiation exposure to the patient.

Lechel et al. (2008) solely addressed overall dose reduction. They were the only researches to identify measurements of whole-body phantoms and not merely phantom parts. Actual dose measurements with and without AEC resulted in reductions in radiation levels. Once again, this study utilized phantom parts to test a hypothesis that is applicable to human beings. Papadakis, Perisinakis, and Damilakis (2008), employed the use of phantoms, but they incorporated both adult and pediatric models. A significant finding they made was that dose reduction in the pediatric model was lower compared to the adult model. Namasivayam et al. (2006) did analyze radiation exposure levels on actual patients, but they failed to incorporate whole body analysis. Their results were limited to only exposures of the neck. It becomes difficult to quantify the significance of results when such a narrow area is studied.

Image quality with use of AEC was evaluated by Murazaki et al. (2012), and Hawking and Elmore (2009). Yet, the researchers did not identify how and who judged the quality of images produced, as Namasivayam et al. (2006) acknowledged the expertise of radiologists in assessing image quality from performed CT scans. Each study identified use of abdomen and pelvic phantoms as their subjects. This, their limitation as study results could only be applicable to CT scans of the abdomen and pelvis. Hawking and Elmore (2009) conducted their studies at two separate clinical sites, but it is unclear what role if any location played in their testing and results.

Analysis of exposure levels were addressed by multiple studies, but Thakur et al. (2012) specifically measured exposure levels with use of an identified AEC device, RacChex. It is also the only study to identify multiple hospital sites and their individualized exam protocols. Protocols vary by institution and exam type, and incorporating this factor into result analysis is paramount in the overall significance of findings. Although exams were limited to only chest radiographs, the researchers looked at an aspect not examined by others.

Implications

The FDA (2011) currently regulates CT scanners as radiation-emitting electronic products under the Radiation Control for Health and Safety Act and as medical devices. The regulations place controls on the manufacturers of the CT systems rather than on the users of the CT systems (2012). To optimize radiation dose in CT, it is up to the user to adjust tube current either with manually selected values or with the application of the AEC (Singh, 2011). Therefore, system operator plays a significant role in the proper utilization of AEC. Any single device is only as good as its operator. These radiation emitting systems can result in high patient doses, especially with digital image receptors, without the knowledge of the imaging staff (IAEA, n.d.). As well, although most AEC techniques are based on similar principles of physics, there are some differences in features from different vendors (Singh, 2011). Söderberg & Gunnarsson (2010) outlined this fact.

In 2011, the FDA issued a patient safety warning as it became aware of approximately 365 patients who received overdoses from CT scans of the brain. The investigation conducted by the FDA (2011) revealed that the scanners used did not produce overexposures when they were used according to the manufacturers' specifications, and that the manufacturers did not modify their protocols to cause the overexposures. Therefore, it was most likely that the overexposures resulted from errors by radiology personnel. Technologists must be trained on the specific scanner and for the specific imaging protocol they are using, and should understand the meaning of the dose index reported on the CT control screen, as well as the expected ranges for each imaging protocol and body scan region (FDA, 2011). The FDA (2011) recommends that health care professionals and hospital administrators work to reduce radiation exposure to patients by discussing the rationale for the examination with the patient and making sure, they understand the benefits and risks, as well as justify the exam. Each practitioner must make sure the CT is necessary to answer a clinical question, must consider other examinations that deliver less radiation, and check the patient's medical imaging history to avoid duplicate examinations (FDA, 2010). Ultimately, continued testing on human subjects would reveal most accurate and applicable results.

Theoretical Framework

To address radiation exposure from diagnostic tests, process change and patient focus are necessary. Two theories support this proposal and final capstone. Spradley's change theory, an adaptation of Lewin's theory of change guides the DNP(c) with the needed steps for effective reform. Hall's care, cure, and core theory places emphases on the person as patient, and the nurse caring for him.

Spradley's theory is composed of an eight-step process for planned change (Swansburg, 1995). The steps include recognizing the symptoms, diagnosing the problem, finding alternative solutions, selecting change, planning change, implementing change, evaluating change and stabilizing change (Swansburg, 1995). The problem at hand, applicable to the project is the identification of radiation exposure from computed tomography. The next step provides a diagnosis of radiation overexposure from CT. The third step outlines solutions to monitor for radiation overexposure. The fourth step or resolution to decrease radiation overexposure is use of automatic exposure control device. Documenting and monitoring levels of radiation dose are also necessary to address any overexposure. This is followed by a detailed plan outlining how to bring about change; which includes use of an AEC device, and random review of radiation doses from CT exams. Implementation is the sixth step in Spradley's change theory. Documenting and analysis of current radiation doses versus the national findings becomes the basis for implementation of change. The seventh step evaluates the change. The DNP(c) will evaluate for radiation levels at practicum site and compare to the national documented levels of 2006-2007. Maintaining and stabilizing the change is the eighth step (Swansburg, 1995). The problem solving process is an aspect within several change theories. While there are multiple theories readily available, Spradley's eight-step process clearly outlines and addresses all aspects of change applicable to this project.

Hall's three independent yet interconnected concepts of core, care, and cure represent nursing care at all levels (George, 2002). According to Hall's theory, the nurse is present and influences all three circles of the theory. The DNP(c) will influence the three circles by following the nursing process, and maintaining the ALARA program. Assessment and diagnosis of the individual is the core, while implementation, outcome and planning are the cure and care of Hall's theory. The core in this project is the population of patients receiving head CT. DNP (c) along with radiologists, neurologists, and technicians make up the medical group working on "curing" the patient. Multiple members of various healthcare services come together to treat an illness. The care provided by the DNP(c) is the monitoring of radiation levels to prevent overexposure. It also includes education on radiation overexposure from CT. The DNP(c) takes on the role of caring for the circle where she is the professional in helping the patient (George, 2002).

Project and Study Design

In an effort to improve the quality of American healthcare, the NQF builds consensus on national priorities and goals for performance improvement; endorses national consensus standards for measuring and publicly reporting on performance; and promotes the attainment of national goals through education and outreach programs (University of California San Francisco, n.d.). In following the NQF, data from a specialized cancer institution was used to develop a database of radiation dose information per patient undergoing head CT. These values were compared to the national DLP values (Table 1.0). Currently there is no database of recorded dose levels at the practicum facility. As a result, levels of radiation exposure were inputted into excel spreadsheet with formula to calculate actual DLP (Appendix A).

Setting and Resources

The project setting was a specialized cancer center located in a large metropolitan city. The center is equipped with five CT scanner rooms available for testing, all with GE scanners, models ranging from: Lightspeed 16, Lightspeed VCT (64-slice), Discovery CT750. All scanners are equipped with automatic exposure control, although for head CTs, the facility does not prescribe AEC. As per CT Department Supervisor, manual technique is used to ensure optimal image quality and remain within ACR guidelines

DNP(c) received guidance and assistance from The Radiation Safety Team Physicist, CT Department of Radiology Supervisor, Neuroradiology Radiologist, and Program Manager to Radiology Research Department. Collaboration with the various departments and staff as well as the clinical experience alongside a Neuro-Oncology DNP was most valuable in data examination.

Study Population

The population consisted of adult patients with known or suspected malignancies of the brain undergoing CT scans of the head with and without contrast. Sample included random number of subjects admitted under the neurology service that underwent CT of head between the months of December 2013 and March 2014. The final number of CT scans during that period totaled 114.

Sources of Data

Computed tomography tests of adult patients resulted within the picture archiving and communication system (PACS) (Appendix B) of the electronic health record at the institution provided DLP doses for review. Dose-length product results were then calculated as effective dose. These doses were compared to the expectant dose measurements (Table 2.0) as specified by the Conference of Radiation Control Program Directors Inc. (CRCPD) (2007), and the national average levels reported by the NEXT survey of 2006-2007.

Data Analysis

The Plan Do Study Act (PDSA) model clearly identified the means of managing this issue. The plan addressed decreasing a patient's exposure to radiation while receiving adequate diagnosis. All in-hospital patients undergoing CT scan of any kind received adequate tests with the lowest radiation exposure. Percentage of final reports for CT examinations performed with documentation of use of appropriate radiation dose reduction devices for appropriate moderation of exposure were reviewed (ACR, 2007). Data collection on radiation exposure for each CT in the form of dose–length product was used. The overall radiation burden associated with a CT examination was examined (Smith, Dillon, Gould & Wintermark, 2007).

The ACR created a CT Dose Index Registry (CTDIR) in an effort of tracking patient doses by collecting data across a large number of sites. The tracking allows participating sites to compare their own values to those observed at other sites and to determine if values typically used are higher or lower than those used by others (Boone et al., 2012). Use of the registry is costly and therefore likely deters organizations such as this one from purchasing it. For this reason, the expertise of a Radiation Safety Officer is used to oversee CT quality assurance. Many facilities now employ the expertise of a Radiation Safety Officer and establish radiation safety teams to oversee CT quality assurance. My review of this current institution's doses has allowed me to compare their values to those of the national standards without an added institutional expense. In following the NEXT guideline (Appendix C), data obtained provided an organized and systematic inquiry of material.

Plan

Managing the risks of CT procedures depends on two principles of radiation protection: appropriate justification for ordering and performing each procedure, and careful optimization of the radiation dose used during each procedure (FDA, 2010). Patients should be exposed to an optimal radiation dose to produce a high-quality image (FDA, 2010).

In an effort to maintain this, the FDA has launched an initiative. The Initiative to Reduce Unnecessary Radiation Exposure from Medical Imaging takes steps to promote safe use of medical imaging devices; support informed clinical decision-making; and increase patient awareness (FDA, 2010). Through this initiative, the FDA will take steps directly and in collaboration with others to mitigate the factors contributing to unnecessary radiation exposure from medical imaging modalities (FDA, 2010).

There will always be some level of radiation exposure because of these tests. The focus now becomes how we can optimize patient exposure to radiation from certain types of medical imaging exams, and thereby reduce related risks while maximizing the benefits of these studies (FDA, 2010). The project encompassed a timeline of four months, to gather, analyze, and document radiation doses per patient per CT.

Table 1.0 – Common DLP Values for Neuroradiology CT Scans

	Minimum DLP (mGy-cm)	Maximum DLP (mGy-cm)
Brain W/ & W/O	**483**	**2873**
Brain W/O	**355**	**1341**

Table 1.0 Computed Tomography effective doses by examination type.
Adapted from the Journal of Radiology (2008).

Table 2 – Effective Radiation Doses

Examination	Typical Dose (mSv)
CT Adult Head	2.0
CT Adult Abdomen	8.0
CT Adult Chest	7.0

Table 2.0 Common DLP Values for Neuroradiology CT Scans.
Adapted from the Journal of Radiology (2008).

Ethics

The evaluation of radiation doses from computed tomography did not require IRB approval. While human subjects were included, there were no risks to the subjects, and no identifiable data collected. Each scan was identified by date and time only, no medical record number or any other data linking patient to exam is present. Only those CT scans of patients under direct care of DNP(c) were reviewed. Therefore, no violations of Health Insurance Portability and Accountability Act (HIPAA) resulted.

Budget

The monetary cost of CT tests can total exorbitant amounts of money. The cost to an individual's health detriment is invaluable. The only part radiation consideration plays in the cost benefit analysis is the cost of radiation protection and the cost of well-being resulting from exposure of individuals to radiation (Ahmed & Daw, n.d.). There is no cost to review already calculated DLP doses. It is difficult to compare human well-being with supply cost. Therefore, value judgments have to be introduced into the analysis (Ahmed & Daw, n.d.). The effects of radiation overexposure can prove more problematic. Increases in cancer because of radiation overexposure can prove more costly in the long term as cancer treatment modalities would prove more costly. In cost-benefit analysis, ethical problems are involved in trying to assign a monetary value to human life (Ahmed & Daw, n.d.).

Timeline

Figure 1.0: Project Timeline

	September	October	November	December	January	February	March	April	May
Project development	X	X							
Securing project site			X						
IRB review									
Team selection			X						
Sample selection, project initiation/completion			X	X	X	X			
Data analyses			X	X	X	X	X		
Distribution project findings								X	
Presentation to Neurology Service									X

Findings

Since 1973, NEXT has been conducting surveys on examinations related to the adult chest, abdomen, lumbosacral spine, upper gastrointestinal fluoroscopy, mammography, and computed tomography of the head, amongst other radiology exams (CRCPD, 2007). Today NEXT surveys capture comprehensive data on radiation exposure and quality assurance associated with the practice of selected radiographic examinations (CRCPD, 2007). The FDA specifically (2012) mandates justification of test as well as dose optimization of individual imaging exam.

The data collected was compared to the standards effective doses as outlined in the Journal of Radiology (2008) (Table 1.0). Common DLP values for head CT are displayed (Table 2.0). The average radiation dose from a total of 114 CT scans of the head performed at facility (Table 3.0) compared to standard effective doses and national projected doses of approximately 226 participating facilities (Table 4.0) of which New York State is not a participant. Four-month facility dose trends outlined (Graph 1.0), along with national trend from 2006-2007 survey (Graph 2.0).

The FDA's Center for Devices and Radiological Health (CDRH) radiation safety programs involve enforcement of mandatory requirements in addition to partnerships and voluntary programs that promote the safe use of radiation-emitting products (FDA, 2012). At the conclusion of the project, reviews of the primary facility strategies for CT dose radiation safety and resultant radiation doses analyzed and met FDA mandatory requirements. Further efforts to monitor and manage radiation will require individualized facility guidelines and personnel qualifications, education and communication, appropriate use of and equipment safety features, along with tracking radiation safety metrics (FDA, 2012). Each of these areas requires coordinated efforts by regulatory, professional and industry partners to achieve common goals. Enhancing safety further within the project facility will require new goals and objectives for successful achievement. Outlined (Table 7.0) are current facility policies along with future goals and proposed strategies as recommended by the ECRI (2012) and the ACR (2009).

Table 3 –Facility Radiation and Effective Dose over Four-Month Span

Examination	**Mean Facility Dose (DLP)**	E/DLP Conversion Coefficient*	**Effective Dose (mSv)** **DLP xE/DLP**
CT head	1070.88	0.0023	2.46

*Conversion Coefficients for Use in Radiological Protection Against External Radiation. Adapted from the ICRP Publication (1996).

Table 4.0 – NEXT Data Results

Variable	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**	**Sample Size (n)**
DLP (mGy-cm)	791	333	186	1914	83
E (mSv)	2.0	1.1	0.6	6.2	73

Table 4.0 Nationwide Evaluation on Xray Trends Tabulation and Graphical Summary of 2000 Computed Tomography Survey for Hospitals Only. Adapted from CRCPD (2007).

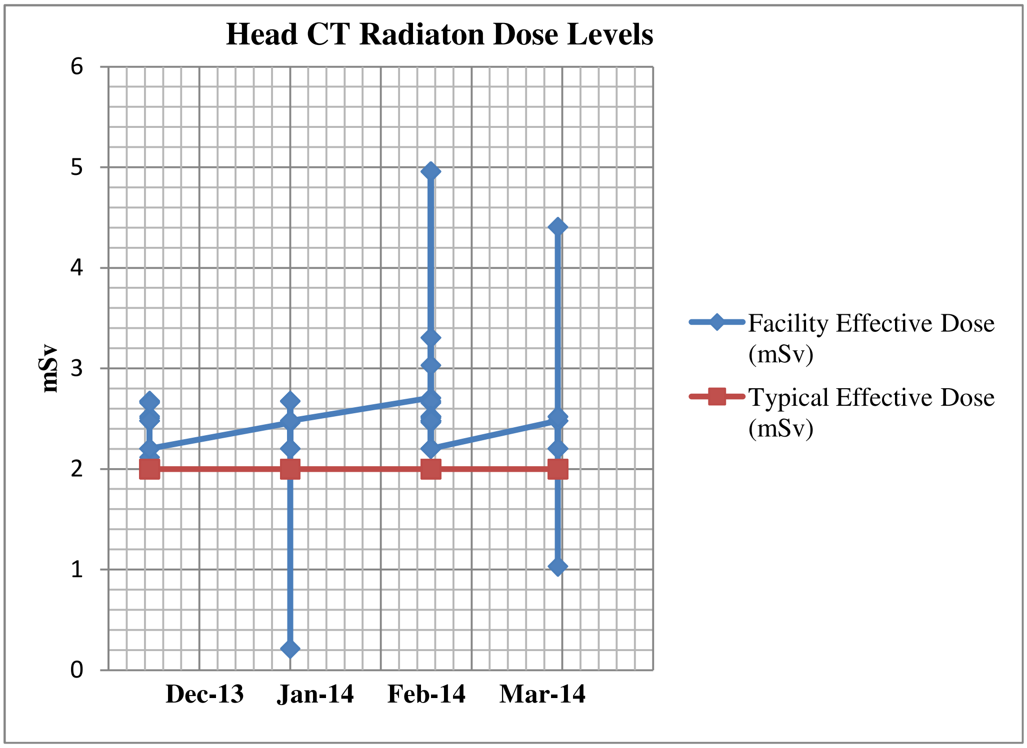
Table 5.0 – Test Facility Data Results

Variable	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**	**Sample Size (n)**
DLP (mGy-cm)	1070.88	220.02	93.24	2156.04	114
E (mSv)	2.46		0.21	4.95	114

Table 6.0 - Radiation Dose Comparison

Head CT	National Mean	Facility Mean
Projected Dose (DLP)	791	1070.88
Standard Effective Dose (mSv)	2.0	2.46

Graph 1.0 – Facility Monthly Radiation Dose Levels



Graph 2.0 – CT Head with and without contrast

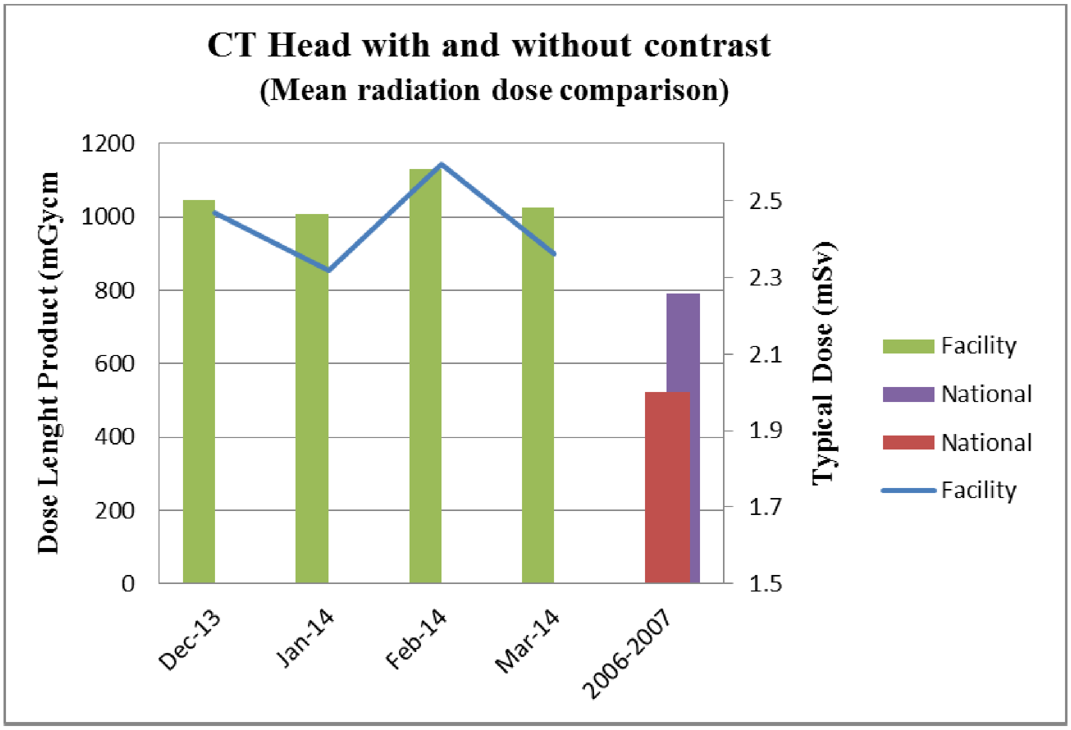


Table 7.0 Facility Goals and Objectives

Goals	Objectives
1. Standardize radiology order requisition to include "reason for CT study" (ECRI, 2012)	Facility currently has this policy in place. Reason for test is always displayed on PACS results. • Policies require patient history information and reason for test as this allows technologist to confirm reason for scan order (ECRI, 2012).
2. Perform real time random audits of CT scan orders for appropriateness criteria (ECRI, 2012).	Facility currently does not perform such audits. It is expected reason for test is verified and confirmed by the radiology technician. • Estimating % of CT scan orders not meeting criteria, will designate responsibility to appropriate physician for possible alternative imaging studies to CT scans (ECRI, 2012).
3. Develop CT protocols to ensure that radiation doses are as low as reasonably	Facility currently has dedicated protocols for head CT. • There is written policy (Appendix D) on protocol including:

achievable (ECRI, 2012).	1) Established criteria for setting and revising CT protocols 2) Limit ability to modify protocols to authorized individuals 3) Review of protocols as needed when new CT applications and technologies are adopted 4) Process for assessing image quality that includes the radiologist, medical physicist, and technologist
4. Implementation of dose control tools/new technologies as appropriate (ECRI, 2012).	Facility scanners currently are GE and equipped with AEC for dose control. • All facilities are to include dose control tools/new technologies in equipment planning and acquisition (ECRI, 2012) • Include technologist training programs with vendor equipment (ECRI, 2012)
5. Actively monitor CT radiation doses (ECRI, 2012).	Radiation Safety Team monitors scanners and any reported unexpected radiation levels. There is no system in place to screen every CT scan and the radiation emitted. NYS did not participate in the last NEXT survey. • Imbedded dose calculation and recording into workflow monitors doses (ECRI, 2012) • Employ dose monitoring software • Report radiation doses to dose registry. The ACR (2009) dose registry does all the work for a facility by tracking each CT scan and the radiation emitted
6. Provide education and training in CT imaging and scanner operations to all technologists (ECRI, 2012).	The Department of Radiology conducts on-going monthly in-service training program for all members of the department. • Hire American Registry of Radiologic Technologists (ARRT) CT certified technologists or require certification within 1 year after hire (ECRI, 2012) • Incorporate staff training into CT vendor contracts (ECRI, 2012)

7. Attain accreditation for all CT devices (ECRI, 2012).	Facility currently holds ACR accreditation of CT scanners through 10/2015 • Meet or exceed accreditation requirements for CT scan services (ECRI, 2012)
8. Aim for organizational commitment to improving CT radiation dose safety (ECRI, 2012).	The Radiation Safety Team is in existence to fulfill this commitment. • Commitment of the medical executive committee and chief of radiology and/or chair of radiology or imaging services committee (ECRI, 2012)
9. Educate medical and technical staff on the CT dose safety strategies (ECRI, 2012).	The Department of Radiology conducts on-going monthly in-service training program for all members of the department. • Education on defined roles, responsibilities, and processes in the reduction of CT radiation doses (ECRI, 2012) • Support an understanding by patients of potential risks of excessive radiation that is balanced with benefits of CT scan use for diagnostic purposes (ECRI, 2012)

Conclusion

Delivery of medical care in the safest manner with the least harmful effect reflects what every practitioner strives to achieve. Addressing the overexposure of radiation from diagnostic tools such as CT scans is vital in patient care. These valuable advances in technology also generate harms not fully known. As a result, research remains an ongoing process.

The risk from a medically necessary imaging exam is small when compared to its benefit (FDA, 2010). When used appropriately, the benefits of a CT scan exceeds the risks, as they can provide essential information necessary to diagnose, plan treatment and evaluate disorders (FDA, 2010). With the CT scanner, cancers are discovered at a treatable stage, the intracranial hemorrhage from a traumatic brain injury is managed immediately limiting permanent neurologic deficits and death. While the three components of manufacturer, machine operator and AEC device are imperative in controlling radiation overexposure, the need for continued monitoring and documenting of radiation doses becomes the next stride in maintaining radiation levels as low as reasonably achievable.

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Appendix A: Sample Picture Archiving and Communication System

02/14/2014 18:40	CT	1 or More Final Results Ancillary ID: R9767581

CT — Final — Updated

CT BRAIN W/O CON
February 14, 2014 CT head

CLINICAL STATEMENT: Gastric cancer with dizziness.

TECHNIQUE: CT head without intravenous contrast, protocol #1, using axial images.

RADIATION DOSE (DLP): 1078.02 mGy-cm

COMPARISON: Multiple priors including MR brain dated October 9, 2013.

FINDINGS:

BRAIN:

There is moderate cerebral volume loss with sulcal prominence and proportional ventricular dilatation. There is no midline shift or evidence of mass effect. There is no intra-axial or extra-axial hemorrhage or fluid collection. There is no evidence of acute infarction. There are moderate centrum semiovale, subcortical and periventricular white matter low-attenuation areas which are nonspecific but likely secondary to chronic microvascular ischemic changes.

Appendix B: Radiation Dose per Head CT Spreadsheet

Date of Head CT	DLP	Conversion Coefficient	Facility Effective Dose (mSv)	Typical Effective Dose (mSv)
12/1/2013	1090	0.0023	2.507	2
12/1/2013	1098	0.0023	2.5254	2
12/1/2013	1160	0.0023	2.668	2
Dec-13	920.48	0.0023	2.117104	2
Dec-13	958	0.0023	2.2034	2
Dec-13	958	0.0023	2.2034	2
Dec-13	1078.02	0.0023	2.479446	2
Dec-13	1078	0.0023	2.4794	2
Dec-13	1078.02	0.0023	2.479446	2
Dec-13	958	0.0023	2.2034	2
Dec-13	1078	0.0023	2.4794	2
Dec-13	1163	0.0023	2.6749	2
Dec-13	958	0.0023	2.2034	2
Dec-13	1163	0.0023	2.6749	2
Dec-13	958	0.0023	2.2034	2
Dec-13	1156	0.0023	2.6588	2
Dec-13	958	0.0023	2.2034	2
1/1/2014	1070.01	0.0023	2.461023	2
1/1/2014	1078.02	0.0023	2.479446	2
1/1/2014	1078	0.0023	2.4794	2
1/1/2014	1163.08	0.0023	2.675084	2
1/1/2014	1078	0.0023	2.4794	2
1/1/2014	1078	0.0023	2.4794	2
1/1/2014	1163	0.0023	2.6749	2
1/1/2014	93.24	0.0023	0.214452	2
1/1/2014	1078	0.0023	2.4794	2
1/1/2014	958.24	0.0023	2.203952	2
Jan-14	1163.08	0.0023	2.675084	2
Jan-14	958.24	0.0023	2.203952	2
Jan-14	1078	0.0023	2.4794	2
Jan-14	958.24	0.0023	2.203952	2
Jan-14	1163.08	0.0023	2.675084	2
1/1/2014	958.24	0.0023	2.203952	2
1/1/2014	958	0.0023	2.2034	2
1/1/2014	1078	0.0023	2.4794	2
2/1/2014	1177	0.0023	2.7071	2
2/1/2014	1071.01	0.0023	2.463323	2
2/1/2014	1078.02	0.0023	2.479446	2

2/1/2014	1078.02	0.0023	2.479446	2
2/1/2014	1078	0.0023	2.4794	2
2/1/2014	1078	0.0023	2.4794	2
2/1/2014	958	0.0023	2.2034	2
2/1/2014	1078	0.0023	2.4794	2
2/1/2014	958.24	0.0023	2.203952	2
2/1/2014	1156	0.0023	2.6588	2
2/1/2014	1078.02	0.0023	2.479446	2
2/1/2014	1094.67	0.0023	2.517741	2
2/1/2014	1078	0.0023	2.4794	2
2/1/2014	958.24	0.0023	2.203952	2
2/1/2014	1437.36	0.0023	3.305928	2
2/1/2014	958.24	0.0023	2.203952	2
2/1/2014	1094.67	0.0023	2.517741	2
2/1/2014	958	0.0023	2.2034	2
2/1/2014	1078	0.0023	2.4794	2
2/1/2014	1437.36	0.0023	3.305928	2
Feb-14	958.24	0.0023	2.203952	2
Feb-14	1318	0.0023	3.0314	2
Feb-14	1078.02	0.0023	2.479446	2
Feb-14	1078	0.0023	2.4794	2
Feb-14	1078.02	0.0023	2.479446	2
Feb-14	1078.02	0.0023	2.479446	2
Feb-14	1078.02	0.0023	2.479446	2
Feb-14	1163.08	0.0023	2.675084	2
Feb-14	1078.02	0.0023	2.479446	2
Feb-14	2156.04	0.0023	4.958892	2
Feb-14	1437.36	0.0023	3.305928	2
Feb-14	1078	0.0023	2.4794	2
Feb-14	958	0.0023	2.2034	2
Feb-14	1078.02	0.0023	2.479446	2
Feb-14	1078.02	0.0023	2.479446	2
Feb-14	1078.02	0.0023	2.479446	2
Feb-14	1078.02	0.0023	2.479446	2
Feb-14	2156.04	0.0023	4.958892	2
2/1/2014	1078	0.0023	2.4794	2
2/1/2014	1098	0.0023	2.5254	2
2/1/2014	958	0.0023	2.2034	2
2/1/2014	1098	0.0023	2.5254	2
2/1/2014	958.24	0.0023	2.203952	2
2/1/2014	1078.02	0.0023	2.479446	2

2/1/2014	958	0.0023	2.2034	2
2/1/2014	1078.02	0.0023	2.479446	2
2/1/2014	1090	0.0023	2.507	2
2/1/2014	1078	0.0023	2.4794	2
2/1/2014	958	0.0023	2.2034	2
3/1/2014	1078.02	0.0023	2.479446	2
3/1/2014	1078	0.0023	2.4794	2
3/1/2014	958	0.0023	2.2034	2
3/1/2014	958.254	0.0023	2.2039842	2
3/1/2014	1916	0.0023	4.4068	2
3/1/2014	449	0.0023	1.0327	2
3/1/2014	958.24	0.0023	2.203952	2
3/1/2014	1098	0.0023	2.5254	2
Mar-14	958	0.0023	2.2034	2
Mar-14	1078.02	0.0023	2.479446	2
Mar-14	958	0.0023	2.2034	2
1-Mar	1078.02	0.0023	2.479446	2
Mar-14	1078.02	0.0023	2.479446	2
Mar-14	1078.02	0.0023	2.479446	2
1-Mar	1094.67	0.0023	2.517741	2
Mar-14	1078.02	0.0023	2.479446	2
Mar-14	1078	0.0023	2.4794	2
Mar-14	958	0.0023	2.2034	2
Mar-14	958.24	0.0023	2.203952	2
Mar-14	958	0.0023	2.2034	2
Mar-14	958.24	0.0023	2.203952	2
Mar-14	958.24	0.0023	2.203952	2
Mar-14	1078.02	0.0023	2.479446	2
Mar-14	958.24	0.0023	2.203952	2
Mar-14	1078.02	0.0023	2.479446	2
Mar-14	958	0.0023	2.2034	2
Mar-14	958	0.0023	2.2034	2
Mar-14	958	0.0023	2.2034	2
3/1/2014	1090	0.0023	2.507	2
3/1/2014	958	0.0023	2.2034	2

Appendix C: NEXT Survey Form

Statistics are provided for a subset (N=40) of surveyed sites. These values are preliminary findings pending publication of final values for the entire surveyed population. Values for $CTDI_{vol}$, $CTDI_{free-in-air}$, dose-length product (DLP), and effective dose were calculated for the surveyed CT scanner, typically the most frequently used one. Facilities also completed a questionnaire that gathered additional information about adult and pediatric scan protocols. For CT systems that routinely employ an automatic-exposure control feature, the product, tube current - gantry rotation time (mAs) is an estimate for the average mAs over the course of the CT scanning sequence.

	Adult Head	Adult Abdm + Pelvis	Ped Head (5 Yr)	Ped Abdm + Pelvis (5 Yr)
Survey Parameter	25th / median / 75th	25th / median / 75th	25th / median / 75th	25th / median / 75th
CT scanner weekly exam workload	12 / 30 / 69	11 / 25 / 74	1 / 2 / 3.5	1 / 2 / 2
Selected kVp	120 / 120 / 140	120 / 120 / 120	120 / 120 / 120	120 / 120 / 120
Tube current- time product (mAs)	300 / 340 / 400	178 / 223 / 303	126 / 184 / 240	74 / 95 / 135
Gantry rotation time (seconds)	1.0 / 1.5 / 2.0	0.5 / 0.75 / 1.0	0.8 / 0.9 / 1.0	0.5 / 0.5 / 0.9
Acquisition slice thickness (mm)	2.5 / 4.5 / 5.0	1.5 / 2.8 / 5.0	2.3 / 4.1 / 5.0	1.1 / 1.5 / 5.0
Pitch*	1.0 / 1.0 / 1.0	0.9 / 1.0 / 1.4	1.0 / 1.0 / 1.0	1.0 / 1.0 / 1.4
Percentage of exams with 2 phases	3 / 10 / 23	5 / 10 / 30	0.0 / 0.0 / 0.04	0.0 / 0.0 / 0.3
$CTDI_{free-in-air}$ (mGy)	69 / 88 / 103	35 / 53 / 75	34 / 47 / 58	21 / 26 / 32
$CTDI_{vol}$ (mGy)	55 / 64 / 80	12 / 18 / 24	24 / 31 / 40	12 / 15 / 21
DLP (mGy-cm)	782 / 894 / 1145	426 / 660 / 904	300 / 383 / 499	299 / 382 / 543
Effective dose (mSv)	2.1 / 2.5 / 3.0	8.9 / 11.8 / 20.6	**	**

* For exams of the head, axial rather than helical scanning was predominantly used. In this case "pitch" was evaluated from the ratio of the patient-table increment per rotation to the overall width ($N \times T$) along the axis of rotation of the multiple (N) tomographic sections of acquisition thickness (T) simultaneously acquired per rotation.

** Insufficient data.

Annual Workload Projections

	Hospitals	Sites other than Hospitals
Number of sites with at least one CT unit	4707	3253
Average facility no. of adult exams per week	258.0	59.8
Average facility no. of pediatric exams per week	16.7	3.67
Total U.S. annual CT exam workload (millions):		
Adult	63.2	10.1
Pediatric	4.1	0.62
All CT exams (millions)	78.0	

Use the space below to enter your facility's values for the CT scanner frequently used to perform the indicated exams

	Adult Head	Adult Abdm+Pelvis	Pediatric (5 yr) Head	Pediatric (5 yr) abdm+pelvis
CT scanner / room no.				
Exams per week				
kVp				
mAs				
Pitch				
$CTDI_{vol}$ (mGy)				
$CTDI_{free-air}$ (mGy)				
DLP (mGy-cm)				
Percentage w/ two phases				

Appendix D: Capstone Power Point Presentation

Evaluation of Radiation Exposure from Computed Tomography of the Head

A CAPSTONE SCHOLARLY PROJECT PRESENTED BY:
NELLY VEGA-WOO,
DNP(C), MSN, FNP-BC

Objectives

- Introduction
- Problem Statement
- Background
- Objective
- Project and Study Design
- Findings
- Discussion
- Resources
- Conclusion
- References

Introduction

- Computed tomography (CT): non-invasive medical procedure producing a cross-sectional image (FDA, 2010)
- Requires some form of energy to produce an image only attainable by penetrating tissue (Bushberg, Seibert, Leidholdt, & Boone, 2002)
- There is absorption of the energy used to produce quality images
- Exposure to radiation and the overutilization of imaging scans is a current healthcare quality concern

Background

Recent data suggest that increases in radiation exposure are associated with an increased health risk (Hall & Brenner, 2008). In an effort to monitor and limit radiation exposure from CT, tracking amounts of exposure along with utilizing devices to minimize exposure is central to the delivery of safe and good patient care.

The American College of Radiology (2006) concept, "As Low as Reasonably Achievable (ALARA)" encompasses the need to minimize radiation dose to patients while maintaining the necessary diagnostic image quality.

IMAGE WISELY™
Radiation Safety in Adult Medical Imaging

Background

In an effort to reduce radiation exposure from CT, practitioners and facilities need to monitor radiation exposure while delivering high-quality diagnostic exams.

CT scanners have a range of pre-programmed protocols for different examination types, with set values for tube potential, tube current, and rotation time (American Association of Physicists in Medicine, 2007).

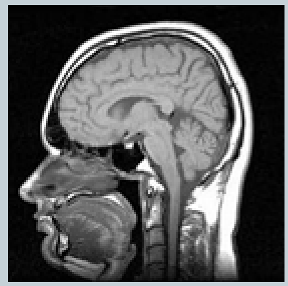
Background

One way to minimize a patient's exposure to radiation from CT is the use of an automatic exposure control (AEC) device. To assess the effectiveness of such a device, analysis of radiation doses per CT exam must occur. Machine-specific dose-length product (DLP) and or CT dose index (CTDI) are the only indicators of specific dose levels.

Objective

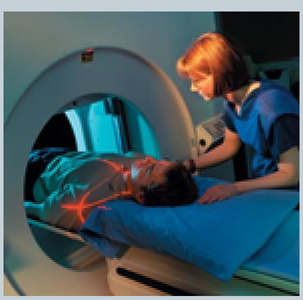
The aim of this project is to:

- Assess radiation exposure of clients undergoing head CT within a large metropolitan hospital and compare these dose levels to the national levels as reported by the 2006-2007 Nationwide Evaluation of X-ray Trends (NEXT) survey.



Project and Study Design

- Setting
- Population
- Data sources
- Data analysis

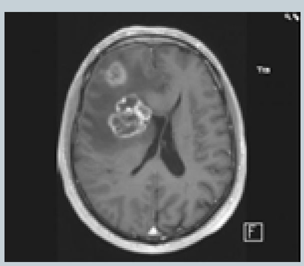


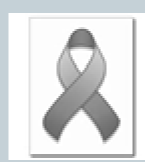
Setting

- Large specialized cancer center in urban community
- Five CT scanner rooms with GE scanners, models ranging from: Lightspeed 16, Lightspeed VCT, Discovery CT750
- All scanners equipped with AEC

Population

- Adult patients with known or suspected malignancies of the brain undergoing CT scans of the head
- Random sample admitted under the neurology service





Data Sources

- CT scans resulted within the picture archiving and communication system (PACS) of the electronic health record provided DLP doses for review

Sample PACS Report

02/14/2014 18:40 **CT** **1 or More Final Results**
Ancillary ID: R9767581

CT Final Updated

CT BRAIN W/O CON
February 14, 2014 CT head

CLINICAL STATEMENT: Gastric cancer with dizziness.

TECHNIQUE: CT head without intravenous contrast, protocol #1, using axial images.

RADIATION DOSE (DLP): 1078.02 mGy-cm

COMPARISON: Multiple priors including MR brain dated October 9, 2013.

FINDINGS:

BRAIN:

There is moderate cerebral volume loss with sulcal prominence and proportional ventricular dilatation. There is no midline shift or evidence of mass effect. There is no intra-axial or extra-axial hemorrhage or fluid collection. There is no evidence of acute infarction. There are moderate centrum semiovale, subcortical and periventricular white matter low-attenuation areas which are nonspecific but likely secondary to chronic microvascular ischemic changes.

Data Analysis

- Timeline of four months, to gather, analyze, and document radiation doses per patient per CT
- Data collection on radiation exposure for each CT in the form of dose–length product
- Values compared to those of the national standards without an added institutional expense.
- Following the NEXT guideline, data obtained provided an organized and systematic inquiry of material

Effective Radiation Doses

Examination	Typical Dose (mSv)
CT Adult Head	2.0
CT Adult Abdomen	8.0
CT Adult Chest	7.0

Computed Tomography effective doses by examination type.
Adapted from the Journal of Radiology (2008).

Common DLP Values for Neuroradiology CT Scans

	Minimum DLP (mGy-cm)	Maximum DLP (mGy-cm)
Brain W/&W/O	483	2873
Brain W/O	355	1341

Common DLP Values for Neuroradiology CT Scans.
Adapted from the Journal of Radiology (2008).

Findings

- Data collected compared to the standard effective doses as outlined in the Journal of Radiology (2008)
- Average radiation dose from a total of 114 CT scans of the head performed at facility compared to standard effective doses and national projected doses of approximately 226 participating facilities
- Reviews of the primary facility strategies for CT dose radiation safety and resultant radiation doses met FDA mandatory requirements

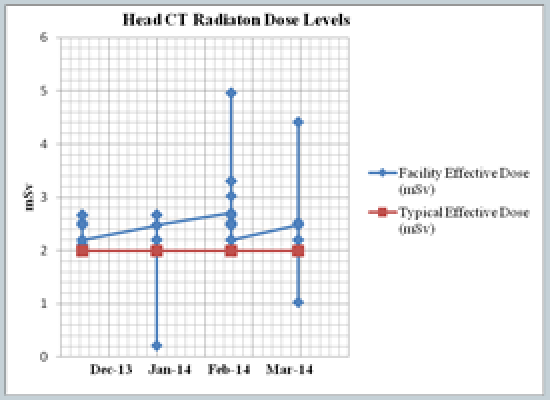
NEXT Data Results

Variable	Mean	Standard Deviation	Minimum	Maximum	Sample Size (n)
DLP (mGy-cm)	791	333	186	1914	83
E (mSv)	2.0	1.1	0.6	6.2	73

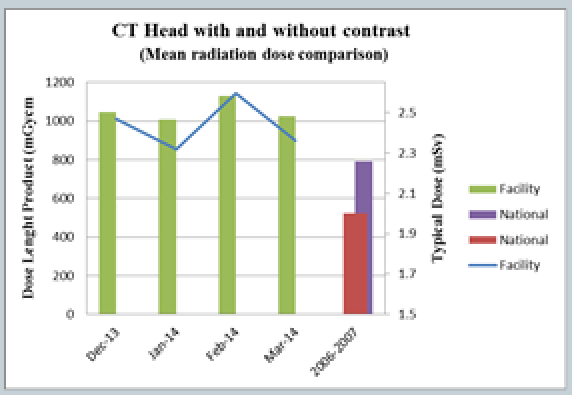
Test Facility Data Results

Variable	Mean	Standard Deviation	Minimum	Maximum	Sample Size (n)
DLP (mGy-cm)	1070.88	220.02	93.24	2156.04	114
E (mSv)	2.46		0.21	4.95	114

Facility Monthly Radiation Dose Levels



CT Head With and Without Contrast



Discussion

The FDA's Center for Devices and Radiological Health (CDRH) radiation safety programs involve enforcement of mandatory requirements in addition to partnerships and voluntary programs that promote the safe use of radiation-emitting products (FDA, 2012).

At the conclusion of the project, reviews of the primary facility strategies for CT dose radiation safety and resultant radiation doses analyzed met FDA mandatory requirements.

Conclusion

Delivery of medical care in the safest manner with the least harmful effect reflects what every practitioner strives to achieve. Addressing the overexposure of radiation from diagnostic tools such as CT scans is vital in patient care.

The benefits of a CT scan exceeds the risks, as they can provide essential information necessary to diagnose, plan treatment and evaluate disorders (FDA, 2010).

While manufacturer, machine operator and AEC device are imperative in controlling radiation overexposure, the need for continued monitoring and documenting of radiation doses becomes the next stride in maintaining radiation levels as low as reasonably achievable.

Questions

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Wear Gray for Brain Cancer Awareness