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The Benefits and Risks of Computed Tomography

Assessment 3

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Assessment:

As diagnostic radiology has grown and improved as a field, so have the procedures that are commonly utilized. One of the most common methods of radiology, computed tomography (CT), has increased significantly in use over the past decade, now accounting for 13% of all radiologic procedures. CT scans are known by most of the general public as a quick, low-risk procedure that is very popular in emergency departments. CT procedures provide very quick and accurate results. However, CT scans expose patients to more radiology than 500 x-ray

procedures in some cases, and this risk can be decreased if radiology professionals are more aware of CTs effects and their solutions.

The major benefits of CT include faster scan times, faster image acquisition times, increased detail of scan results, the ability to collect images of smaller spaces in the body, and the lack of out of pocket expenses for insured patients. The large downside to the use of CT is the large amount of radiation exposure that patients are subjected to. While the benefits of CT may outnumber the downsides, they mostly concern the general convenience of radiologic procedures rather than patient welfare. In certain cases, faster image acquisition could save a patient's life, but the other benefits of CT are not nearly as important or impactful as the few downsides.

The main negative effect of CT is the increased radiation doses that patients are exposed to. The radiation exposure from CT procedures causes effects that are sorted into two categories: deterministic and stochastic. Deterministic effects increase in severity as the amount of exposure to radiation increases. Examples of these effects are the development of cataracts and fertility impairment. Stochastic effects are more likely to occur as the amount of radiation exposure increases. Examples of stochastic effects are genetic effects and carcinogenesis. Stochastic effects do not present themselves in the person who is exposed to the radiation, but rather their offspring.

One solution to protecting patients from the increased radiation exposure and following effects that result from CT is shielding. Shielding involves covering a patient with an apron containing lead to block the radiation from permeating the patient's body and causing negative effects. According to the article that I read for this assessment, CT technicians and other

radiology technicians often forget to shield their patients from the damaging rays that they are being exposed to. Therefore, there is a very simple solution to decreasing the exposure that patients are subjected to in certain situations. If technicians and radiologists are trained and reminded to shield their patients before performing procedures, there could be a decrease in the number of incidences of negative side effects from CT procedures.

Overall, when comparing the negative and positive aspects of computed tomography, the negative side effects outweigh the positives. Although CT is less expensive and faster than other radiologic procedures, the dose of radiation that it exposes patients to makes it dangerous and in my opinion, not worth the benefits that it includes. The positive aspects of CT primarily deal with convenience, which, when compared with negative effects that are life-threatening, are trivial matters. Researching the upsides and downsides of CT has helped me to gain knowledge about the dangers of radiologic procedures and how to prevent the dangers from affecting patients. This will be helpful in finding a mentor, as I will now be able to distinguish radiologists who value patient safety over costs and efficiency.

Computed tomography (CT) is one of the most powerful diagnostic tools available to physicians.

Rapidly developing technology has enabled visualization of smaller structures with ever-increasing detail. Results are available quickly, and there seem to be no visible side effects. Recently, these benefits have overshadowed the risk inherent in any examination involving exposure to ionizing radiation. Physicians and patients often are not aware of the elevated radiation dose associated with CT or the related risk of long-term biological effects. This paper addresses the risks associated with CT examinations, as well as avenues for minimizing these risks.

Benefits of CT

CT has many advantages over other diagnostic imaging modalities. It is used widely in the emergency department (ED) to quickly and accurately diagnose a variety of pathologies and injuries that often are not visualized with conventional radiographs. Multislice CT also has found use in coronary angiography. It is a noninvasive procedure with fast enough acquisition times that patients do not need to be medicated to slow their heartbeat.

In some instances CT has decreased the cost of medical imaging. Insured patients often do not have to pay out of pocket for a CT scan, and other options, such as magnetic resonance, can be much more expensive. Hospitals benefit economically from increased CT use as well, as reported by a level-I trauma center that studied costs associated with imaging facial traumas. In 2002 a CT head examination was estimated to cost the hospital \$121 per patient, while performing the same examination with conventional radiographs cost \$154 per patient. Using CT alone saved 22% in imaging costs, primarily due to the shorter time necessary for the CT scan.

Trends in Use

Use of CT has increased steadily during the past 2 decades. Between the mid-1980s and the mid-1990s, CT use grew by more than 500%. CT now accounts for approximately 13% of all diagnostic imaging procedures in the United States. Sixty five million scans were performed in 2002, compared with 33 million in 1998.

Emergency Department Use

Table 1 Emergency Department CT Use, 2000–2005⁵	
CT Examination	% Increase*
Head	51
C-spine	463
Chest	226
Abdomen	72
Miscellaneous	132

*Compared with a 13% increase in the number of patients

The use of CT has increased at an even higher rate in many EDs. One ED reported a patient increase of 13% between 2000 and 2005, with a disproportionately higher increase in the use of CT over the same period (see Table 1). The increase in CT use is driven by ever-increasing detection capabilities, as well as by the increasing availability of CT scanners. Additionally, many departments consider CT the first test for many conditions. Physicians might be replacing clinical judgment and time-consuming physical examinations with a "let's do a quick CT" approach to emergency medicine. A trauma patient in the Yale University Medical Center ED might have his or her entire body scanned.

Defensive Medicine

Perhaps one of the greatest factors contributing to the rise in CT use is the practice of defensive medicine. Physicians are looking for certainty in diagnosing patients' conditions and often order unnecessary procedures to avoid potential malpractice lawsuits. For example, the American College of Radiology reported that defensive medicine accounts for 5% to 9% of the annual health care

budget in the United States, with a corresponding 5% to 9% decrease in medical costs in states that have enacted tort reform. Studies in these states show no adverse changes in patient outcome and an increase in the availability of subspecialty care.

Radiation Dose and Effects

Although CT is often beneficial, the rapid expansion in its use comes at a cost because it exposes patients to more ionizing radiation than most other modalities. CT accounts for only 13% of all radiologic procedures performed, yet it results in 70% of patients' radiation exposure. While patient dose has been decreasing for radiologic examinations as a whole, the dose from CT increased by 35% from 1990 to 2000. Many equipment manufacturers claim reductions in dose due to shorter scan times, but the inclusion of larger volumes of tissue in each scan causes the reverse effect. Patients accumulate dose from CT, as well as conventional radiography, across their life spans; multiple exams have a cumulative effect. The increasingly liberal use of this technology results in patients receiving many more CT scans in shorter periods of time. During an 18-month study, several patients received more than 100 CT scans. One patient underwent 341 examinations, averaging 2 scans every 3 days. This resulted in a dose of more than 992 mSv.

The relatively high dose associated with even a single routine CT examination can be illustrated through a comparison with the effective dose of a posteroanterior (PA) chest radiograph. A PA chest radiograph has an effective dose of 0.02 mSv. An abdominal CT scan can result in an effective dose from 10 to 20 mSv; at 10 mSv it is equivalent to receiving 500 chest x-rays in succession. CT examinations of the head result in an effective dose of 2 mSv, which is equivalent to 100 consecutive chest x-rays.

Pediatric Dose

Pediatric patients are exposed to potentially higher doses than adults. The same abdominal CT scan described above results in an effective dose of 11 mSv for pediatric patients. The elevated radiation dose received by children is due to 2 factors: the size of the patient and the state of body development. Because pediatric patients are smaller than adults, more of their anatomy is likely to be irradiated. Even when proper collimation is used, the small size of their organs results in a greater dose to that organ even at lower levels of exposure.

Neonates provide the CT technologist with another dilemma. Red bone marrow, a highly radiosensitive tissue, is found throughout the neonate's body. Children's rapidly dividing cells are also less efficient than adult cells at repairing the mutations that might be caused by exposure to ionizing radiation. These differences account for a sensitivity more than 10 times as great as most adults. Despite this information, pediatric CT examinations have increased in frequency at an even faster rate than adult CT scans. In the mid-1980s pediatric examinations accounted for only 4% of all CT scans performed. By the mid-1990s, that proportion had increased to 11%.

Deterministic Effects

Deterministic effects, also referred to as nonstochastic effects, increase in severity as exposure to ionizing radiation increases. Such effects are believed to have a threshold, which is a level of exposure below which the effect will not be induced. There are several deterministic effects of interest to radiologic technologists, including cataract formation in the lens of the eye and fertility impairment. The threshold doses of these 2 effects are displayed in Table 2. A patient would require the equivalent of 500 CT abdomen examinations across his or her lifespan to reach the level of exposure required to induce cataracts. Although that seems like an unreasonable number, the increasing use of CT described earlier indicates a need for concern.

The dose required for men to suffer permanent sterilization is similar to the threshold for cataractogenesis. Women should not have concerns about permanent infertility, as CT is unlikely to

provide a high enough dose to surpass the threshold even after repeated examinations. Even though CT exposes patients to much more ionizing radiation than other diagnostic imaging modalities, the exposure is still relatively quite low. Therefore, CT does not appear to be a major cause of deterministic effects, except after excessive patient exposure.

Table 2
Deterministic Effects and Their Thresholds^a

Effect	Threshold (Gy) ^a
Cataract formation	2-5
Temporary infertility	0.15
Permanent infertility (male)	3-5
Permanent infertility (female)	6-20

^aThe first number given applies to acute doses. The second number applies to fractionated doses.

Stochastic Effects

Stochastic effects differ from deterministic effects in that an increase in radiation dose increases the probability of the effect occurring rather than the severity of the effect. Stochastic effects are considered nonthreshold; that is, there is no level of radiation exposure that does not contribute to increasing the probability of the effect. [degrees] Two stochastic effects concern radiographers: genetic effects and carcinogenesis.

Genetic effects are caused by damage to DNA located within the germ cells. Such effects are not expressed in the individual receiving the radiation, but instead by his or her offspring. Small doses of radiation often have no effect on either the patient or the patient's children, but mutations caused by exposure during radiologic examinations do affect the human gene pool. Though rarely discussed, this result makes increasing use of CT a public health concern.

Carcinogenesis is the effect of most concern to CT technologists. The risk of cancer accumulates with the patient's lifetime accumulation of radiation exposure. Due to the disproportionately high amount of radiation used, CT accounts for more probable induced cancers than any other medical imaging modality. Scientists have associated a dose as low as 10 mSv with an increased risk of

developing cancer. Therefore, a single abdominal CT examination can elevate a patient's risk for cancer.

Children are at the greatest risk of developing cancer due to medical imaging for several reasons. As previously stated, children's rapidly dividing, relatively undeveloped cells are not able to repair the mutations caused by radiation exposure. Furthermore, children also are more likely to develop cancer as a result of medical radiation exposure due to their long life expectancy. They simply have more time to manifest the effects of the mutations.

Reducing Patient Exposure:

Shielding

Shielding is one of the fundamental methods used to reduce patient dose during radiologic examinations, yet it is often forgotten when positioning a CT patient. Shielding radiosensitive tissues drastically lowers the effective dose received by the patient. Lead shielding absorbs 90% to 95% of the x-rays that interact with it. To be effective, lead aprons must be at least 0.5 mm lead equivalent thickness, and they should be checked regularly for holes and weak areas. Appropriate shielding during a head examination can reduce the thyroid dose by 45% and breast dose by 76%. Shielding other radiosensitive organs, such as the testes and lens of the eye using bismuth-lined shields that do not obscure deeper anatomy, has been reported to decrease the dose to those tissues by 50% during certain CT examinations. CT technologists must remember that, unlike traditional radiography, CT requires 360[degrees] shielding due to the rotating tube (Kerry Krugh, Ph.D., lecture at Toledo Hospital, January 2007).

Protocols

Technologists can reduce patient dose significantly by selecting proper exam protocols. Most manufacturers now provide built-in protocols for pediatric imaging, although many CT technologists are not aware of this. Using adult protocols subjects pediatric patients to more radiation with no

diagnostic benefit. Some facilities still use older scanners without pediatric protocols. In his lecture at Toledo Hospital in January 2007, Dr. Krugh advocated the creation and use of pediatric technique charts based on the patient's weight and diameter. He also stated that the automatic mA setting on many scanners often results in higher doses for abdomen and pelvis examinations. This happens because automatic settings typically raise mAs beyond the necessary level. CT technologists should become less dependent on the scanners' default protocols so they can minimize the radiation exposure for each individual patient.

Education

Patients and physicians often are unaware that there are risks associated with exposure to low levels of ionizing radiation, such as those used in radiologic examinations. One study showed that neither patients, ED physicians nor radiologists could estimate the relative doses of a chest x-ray and a CT scan accurately. Only half of the radiologists and almost none of the patients or ED physicians surveyed believed CT examinations might increase a patient's risk for cancer. There is an obvious need to educate the general public and medical professionals about the risks associated with CT scans. Several methods for educating children and their families are already available, including instructional videos and coloring books. Continued professional development is crucial for CT technologists. The American College of Radiology maintains that specific skills, knowledge and training are essential, and it highly encourages continual training and education. Specific training in pediatric imaging might help reduce doses to the most vulnerable segment of the patient population.

Communication

Communication and teamwork are perhaps the most useful skills for protecting patients. Requesting physicians often do not know whether their patients have had excessive radiation exposure. Such knowledge could affect their decision to order an examination. Patient records should include information not only on recent examinations performed, but also on the estimated received dose.

The patient's medical history also can track lifetime exposure. This would aid in monitoring patients who are receiving higher doses than recommended, as well as provide a tool for epidemiological studies on the effects of varying levels of exposure to ionizing radiation. Health Level 7 currently is drafting standards for document format and transmission that might enable such cooperation.

Radiologic technologists often review a patient's history before starting the examination. At this time, they might find recently performed diagnostic imaging procedures. Such information should not be ignored and can be used to make sure the ordered procedure is in the patient's best interest.

Communication between the technologist and the physician can eliminate many unnecessary repeat examinations. If a recent exam was negative, a repeat examination might not be worth the risk of additional exposure. Technologists also might discuss with physicians other modalities that do not expose the patient to ionizing radiation, such as ultrasound and MR. As MR becomes faster and less expensive, it should be suggested as a replacement for CT for follow-up examinations, as well as those that are not time-sensitive.

CT technologists also must communicate with their patients. Although 93% of patients are never told about relevant risks, some patients approach CT with apprehension due to conflicting information about the safety of the procedure. Technologists should take the time to answer all of their patients' questions completely. This will help ensure full cooperation during examinations.

Whole-body Computed Tomography

CT has found a new use as an annual health-screening examination. Whole-body CT scans, sometimes referred to as "Oprah body scans," are marketed to potential patients as a harmless way to screen for various diseases. However, there is no scientific evidence that these scans provide any benefit or extend patients' lives. The American College of Radiology has taken a position against recommending such procedures.

Whole-body CT scans result in a very high dose, as shown in Table 3. The 15.5 mGy dose to lung tissue is particularly concerning, because lung cancer is the primary cause of death due to radiation exposure. It is not surprising that repeated whole-body scanning is associated with an increased lifetime risk of cancer mortality. According to Brenner, a 45-year-old patient who plans on receiving 30 annual whole-body scans has a 1 in 50 risk of cancer mortality. This risk is 25 times higher than for a person of the same age who has had none of these scans.

Conclusion

CT is an important diagnostic technology. The benefits provided by this modality usually outweigh any risk to the patient. Recent technological advances, standards of practice, and other radiation protection measures have decreased the risk of adverse effects. However, it must be understood that no procedure using ionizing radiation is without risks. CT exposes patients to more radiation than most other examinations, and it is the radiologic technologist's responsibility to protect all patients appropriately.

Providing adequate shielding and selecting the proper protocols for each exam are crucial, but patient protection should begin before starting the examination. Technologists should be encouraged to check the patient's history to be certain that recent radiation doses have not been excessive. They also must communicate with the referring physician in a collaborative effort to provide the best care possible. The most effective step we can take as professionals is to educate our patients, physicians and peers about CT. Only then can enlightened decisions be made.