

RADIATION EXPOSURE TO PEDIATRIC PATIENTS FROM CT

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INTRODUCTION

Computed tomography (CT) is an invaluable tool in the evaluation of a variety of disorders. Its inception in the 1970s revolutionized imaging. The introduction of helical technology in 1990 and the subsequent advancements in multidetector row CT (MDCT) technology have led to increased and more diverse CT applications. The annual number of CT examinations performed at US medical facilities has increased from approximately 3.6 million in 1980 to 13.3 million in 1990 to 33 million in 1998.¹⁻³

To realize the greatest benefit from the new CT technology, healthcare providers must merge sufficient technical understanding with appropriate application. Without this combination, CT may not be as useful and, given the radiation dose associated with CT examinations, may be potentially harmful.

In this article I first discuss the factors that have contributed to the growing concern about the risks associated with diagnostic CT examinations. I then outline unique considerations in the CT examination of infants and children. Finally, I present strategies for dose reduction in pediatric CT.

WHY THE GROWING CONCERN?

COMMONLY USED AND RELATIVELY HIGH RADIATION DOSES

CT scanning is a relatively high-dose procedure that contributes disproportionately to the overall radiation dose from all radiologic sources. According to the esti-

mates of Mettler and coworkers, CT examinations represented approximately 11% of all diagnostic radiologic procedures but accounted for 67% of the effective dose from diagnostic radiologic procedures.³ This unbalanced distribution of dose is simply because the dose associated with CT is higher than that from other radiologic examinations.^{3,4} To offer the reader a point of comparison, the radiation dose from one abdominal CT scan has been commonly reported to be equivalent to that of 100 to 250 chest radiographs.^{3,5,6}

Recent high-speed MDCT technology creates more defined images in shorter times and has allowed for new clinical indications such as CT angiography. In addition, the faster scan speed has reduced the need for sedation in pediatric patients, thus spurring this modality's use in that population. However, such advantages come with a price. Comparing MDCT to older, single-detector row helical scanners, *effective radiation dose* is estimated to be 27% to 35% higher with MDCT, whereas *organ dose* (ie, kidneys, uterus, ovaries, and pelvic bone marrow) is estimated to be 92% to 180% higher.^{7,8} Hence, new CT technology results in two concerns: (1) expanded technology resulting in more CT studies being performed and (2) higher radiation doses associated with the newer scanners.

NEW INFORMATION CONCERNING THE EFFECTS OF LOW-DOSE RADIATION

In the year 2000, new information concerning the effects of low-dose radiation on atomic bomb survivors who were irradiated as children prompted a change of thinking among both physicists and healthcare professionals. Research findings have shown that the effective doses with diagnostic CT have been shown to be similar to those received by Japanese survivors of the atomic bomb; these survivors had a small but statistically significant increased risk of developing cancer as a result of the radiation.⁹ On the basis of predictions from the aforementioned data, radiation doses from typical pediatric CT studies may cause the eventual cancer-related death of 1 in 1,000 children examined.^{10,11}

A NEED FOR EDUCATION

A number of papers have called attention to the need for additional education on the part of just about everyone involved in the healthcare of children. Parents, pediatricians, technologists, and even radiologists often lack basic information regarding the dose delivered during CT examinations. This problem was first brought to light by a 2001 study in which Paterson and coworkers evaluated the technical parameters used in outside CT examinations that were submitted to Duke University for a second opinion.¹² Technical parameters that can be adjusted to lower doses in children—such as tube current (mA) and pitch—were reviewed. The authors found that most children were routinely being imaged with parameters suited for adults and that adjustments were not being made to compensate for the smaller size of children. In their study population no adjustments were made on the basis of patient age or size; mA settings were no less for the youngest infants and children than those used for teenaged patients. In fact, Paterson and coworkers found that many infants were being imaged at a tube current greater than that used for adolescent patients for both chest and abdominal CT examinations. The mean tube current of the CT examinations in the study was 213 milliamperes (mA) with no adjustment for patient age.¹² The results suggested that pediatric patients were being exposed to unnecessarily high radiation doses from CT.

It has been speculated that many of the healthcare providers directly responsible for CT imaging, that is, both radiologists and CT technologists, have been unaware of the *uncoupling effect* in CT.¹³ This effect makes CT physics somewhat different from that of conventional radiography. The uncoupling effect means that the final image is divorced from the radiation dose because of digital and electronic manipulation. In conventional radiography, when the radiation dose is too high, the image obtained is too dark; therefore, the technique (mA or peak kilovoltage [kVp]) is adjusted. With digital technology, the image is uncoupled from the dose, so even when an mA or kVp setting that is too high is used, a good image results. This effect can make it difficult to identify instances in which a dose that is higher than necessary is used.

A lack of attention to the technical parameters used in CT examinations can be profound. When the radiation doses used in adult protocols are used in neonates or young children, the effective dose is up to 50% greater.¹⁴ A more recent study in 2003 by Hollingsworth and coworkers showed that progress is being made.¹⁵ In this study it was found that most pediatric radiologists practicing in children's or university hospitals do practice age-adjusted helical CT. Another encouraging finding by Hollingsworth et al was a trend of using increased tube current with increased age as well as an overall tendency to use a lower tube current for chest CT compared

with abdominal CT in each age group. These practices are recommended for pediatric patients and were notably absent from the prior survey of techniques by Paterson and coworkers.¹² However, 11% to 26% of CT examinations performed on children younger than 9 years use more than 150 mA. Additionally, it was found that 20% to 25% of radiologist-respondents did not know the specific parameters used for their examinations. Hollingsworth and coworkers conclude that "Although the need for age-specific scanning is receiving more attention than it did previously, a substantial number of CT examinations in children are performed with relatively few adjustments. These data indicate the need for continued size-based scanning and education about the issues of radiation dose and pediatric CT techniques."¹⁵

Another concern recently brought to light is that of "extra" images contributing to the overall radiation dose of a CT examination. "Extra" images are defined as those images obtained beyond the desired area of interest. A recently published retrospective study was conducted to determine the number and usefulness of images acquired beyond the intended anatomic area of interest with abdominal and/or pelvic CT.¹⁶ Assuming other scanning parameters are held constant, the radiation dose is directly proportional to the scan volume. Therefore, restriction of the scan volume to the area of interest can help avoid unnecessary radiation. Researchers conducting this study found that a substantial number of extra images are acquired beyond the borders of the area of interest with abdominal and/or pelvic CT examinations. These extra images added approximately 10% to the patient's radiation dose from the examination. Study results showed that extra images are routinely obtained, both above the diaphragm and below the pubic symphysis regardless of the clinical indications, patient age, or patient sex. It is noteworthy that the researchers who conducted this study also found that most extra images acquired contributed no additional information. Findings from extra images affected diagnosis in only 1 of 106 (<1%) cases.¹⁶ However, the researchers did acknowledge factors that may, in some cases, justify the inclusion of images beyond the strict area of interest.

At the supradiaphragmatic level, the acquisition of extra images may be justified to ensure that the entire liver and spleen are included in one phase of contrast enhancement. However, in a small number of cases in our study, as many as 36 extra images were acquired, a fact that may suggest a lack of attention in the selection of scan volume. Infrapubic extension of routine abdominal and/or pelvic CT examinations without appropriate clinical request or reason, especially given the risks of radiation to the gonads, cannot be as easily justified. Likewise, although the acquisition of extra images might be acceptable in uncooperative or breathless patients, we found that it adds no diagnostic information to that provided by images in the area of interest for routine abdominal and/or pelvic CT and should be

restricted when not indicated or requested for specific clinical reasons. Indeed, it is important for radiologists and technologists to understand that the extension of image acquisition beyond the region of interest is associated with an additional radiation dose and that they share the responsibility of ensuring that scanning is restricted to the region of interest.¹⁶

Another study by Lee and coworkers was designed to determine the awareness level concerning radiation dose and possible risks associated with CT scans among patients, emergency department (ED) physicians, and radiologists.¹⁷ In this study each of the three groups (patients, ED physicians, radiologists) were surveyed and asked to estimate the radiation dose for one CT examination versus the dose for one chest radiograph (CR). Respondents could choose from the following categories: one CT examination is less than or equal to one CR examination; one CT examination is greater than one CR examination, but less than 10 CR examinations; one CT examination is greater than 10 CR examinations but less than 100 CR examinations; one CT examination is equal to from 100 to 250 CR examinations; one CT examination is equal to or greater than 500 CR examinations (Table 1). Researchers in this study referred to the category of 100 to 250 as the accurate range. Other questions were also asked that were specific to each group. For instance, patients were asked if the risks and benefits of the CT scan had been explained to them, and ED physicians were asked if they had outlined the risks and benefits of the CT scan to their patients. The results from this survey are surprising. Only 7% of patients reported being informed of the risks and benefits before their CT examinations. None of the estimates given by the patients were in the accurate range; all patients significantly underestimated the radiation dose delivered by a CT examination. Twenty-two percent of ED physicians surveyed reported dose estimates in the accurate range. Four per-

cent thought the dose to be higher than it actually was, whereas 73% underestimated the dose. Perhaps most surprising, of radiologists surveyed, only 13% reported dose estimates in the accurate range; 10% overestimated CT dose, whereas 76% underestimated dose. For both ED physicians and radiologists, there was no statistically significant relationship between years in practice and dose estimates. Lee and coworkers concluded that “patients are not given information about the risks, benefits, and radiation dose for a CT scan. Patients, ED physicians, and radiologists alike are unable to provide accurate estimates of CT doses regardless of their experience level.”

To summarize, the growing concern about the risks associated with diagnostic CT examinations can be linked to five main factors: (1) higher use; (2) new scanners that deliver higher radiation doses; (3) new information correlating the effects of low-dose radiation to a higher lifetime cancer risk; (4) lack of knowledge concerning the radiation dose among radiologists, technologists, attending physicians, and patients; and (5) studies showing that some facilities are not adjusting scanning parameters for pediatric patients, therefore exposing infants and children to a higher-than-necessary radiation doses.

PEDIATRIC RADIOLOGY: SPECIAL CONSIDERATIONS

There are three primary factors of special relevance to the use of CT in pediatric radiology: increased sensitivity, higher effective dose, and increasing use.

INCREASED SENSITIVITY

Children are much more radiosensitive than adults.^{9,10,13,18-21} For example, a 1-year-old infant is 10 to 15 times more likely than a 50-year-old adult to

TABLE 1. Dose Estimates for One CT Scan versus One Chest Radiograph*

Respondent Group	CT ≤ CR	CT > CR < 10 × CR	CT ≥ 10 × CR < 100 × CR	CT = 100 - 250 × CR [†]	CT ≥ 500 × CR
Patients (n = 67)	19 (28)	43 (64)	5 (7)	0 (0)	0 (0)
ED Physicians (n = 45)	3 (7)	20 (44)	10 (22)	10 (22)	2 (4)
Radiologists (n = 39)	2 (5)	22 (56)	6 (15)	5 (13)	4 (10)

*Numbers not in parentheses are the number of respondents. Numbers in parentheses are percentages.

[†]Accurate range.

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develop a malignancy from the same dose of radiation.⁹ There are two reasons for this increased sensitivity. One is that, because of their younger age, children have more time to develop cancer than do adults. Remembering that the latency time for cancer induction in the dose ranges used in CT is estimated to be between 10 to 30 years,²² it is clear why radiation exposure to a child is of greater concern than that to an adult. It is also worth recalling that exposure is cumulative; data have revealed that 30% of patients who undergo CT have at least three scans, 7% have at least five scans, and 4% have at least nine scans.²¹ Each CT examination (including multiple series per examination) contributes to the patient's lifetime (a newborn baby has an expected life span of more than 75 years) exposure. Radiation for older adults and the elderly does not carry the same cancer risk because many radiation-induced cancers, particularly solid malignancies, will not be evident for decades and thus would develop beyond the lifespan of many of these older persons. Also, children seem to be inherently more sensitive to radiation simply because they have more dividing cells and thus suffer more adverse radiation effects on dividing cells.²¹ Research shows that children are 10 times more sensitive to the effects of radiation than middle-aged adults and that girls are more radiosensitive than boys.^{23,24}

HIGHER EFFECTIVE DOSE

Even when machine parameters—most notably milliamperes-seconds (mAs) and kVp—are individualized, organ doses are larger in a child compared with an adult (assuming the adult is larger). To understand why this is the case, consider an organ located on the proximal side of the body relative to the x-ray source. This organ will get approximately the same dose in both an adult and a child. As the x-ray source rotates, that same organ will be on the distal side of the body relative to the x-ray source; now that organ is partly shielded by the body tissue proximal to it, thus reducing the organ dose. But this dose-reducing partial shielding will be much less for a thin individual, such as a child, compared with a thicker adult. Thus organ doses for children are generally larger than those for adults.²¹

INCREASING USE

The use of helical CT is increasing even faster in children than in adults.³ This trend is probably due to improved scanner capabilities, a general increased reliance on imaging, and the malpractice environment. However, these factors can lead to the temptation to use CT as a screening procedure.⁹

PERCEPTION OF RISK

As mentioned earlier, there is a small but statistically significant increase in cancer deaths over the lifetime of individuals who undergo CT examinations in childhood. The estimated lifetime cancer mortality risk attributable to a pediatric radiation exposure (one person in one thousand people scanned during childhood) is greater than that found in a similar study of adult exposure.⁹ The data now available only examines cancer deaths, not cancer occurrence. Many people who develop cancer are successfully treated and do not die from their cancer. Therefore, the incidence of cancer will most likely be shown to be greater (perhaps double) than the mortality figures, but these data are not yet fully available.^{9,20}

It is important to put the increased risk that pediatric radiation exposure poses into perspective so that we are better able to effectively communicate with patients and their families. Inherent in the discussion of risk is an understanding that the public may have a different perception of risk than that of scientists or researchers. In general, scientists define risks according to the language and procedures of science itself. They consider the nature of the harm that may occur, the probability that it will occur, and the number of people who may be affected. In contrast, the general public is less aware of probabilities and the size of a risk and much more concerned with broader, qualitative attributes, such as whether the risk is voluntarily assumed, whether the risks and benefits are evenly distributed, whether the risk is controllable by the individual, whether a risk is necessary and unavoidable, and whether there are safer alternatives.²⁵ Some of the factors identified by experts as influencing the public's perception of risk are as follows:

- **Catastrophic potential**—People are more concerned about incidents that kill many people at the same time (eg, airplane crashes) than about fatalities and injuries that are scattered or random in time and space (eg, automobile accidents).
- **Familiarity**—People are more concerned about unfamiliar risks (eg, ozone depletion) than familiar risks (eg, household accidents).
- **Understanding**—People are more concerned about poorly understood activities (exposure to radiation) than those that may be understood (eg, slipping on ice).
- **Scientific uncertainty**—People are more concerned about risks that are scientifically unknown or uncertain (eg, recombinant DNA) than risks that are well known to science (eg, car crashes).
- **Controllability**—People are more concerned about risks that are not under personal control (eg, pesticides on food) than those that are under personal control (eg, driving a car).

- **Voluntariness of exposure**—People are more concerned about risks that are imposed (eg, residues in food) rather than voluntarily accepted (eg, smoking cigarettes).
- **Impact on children**—People are more concerned about risks that are perceived to disproportionately affect children.

Recognizing these factors can help us understand that our judgment of risk is often not particularly rational. For example, many individuals are afraid of flying for which the risk of death is one in a million on a commercial airline flight; yet these people will readily accept a hundred times greater risk by driving a car every day.

Taking into account that the perception of risk is greatly affected by many circumstances, some generalizations can still be made. A yearly risk of death of one in a million is generally ignored (eg, being struck by lightning), whereas a risk of death of one in a hundred is totally unacceptable (eg, accident and disease in coal miners at the turn of the century). The risk level associated with pediatric CT falls into the more ambiguous intermediate level. This level of risk can be considered acceptable if, (1) the individual is aware of the risk; (2) the individual receives some commensurate benefit; and (3) everything reasonable had been done to reduce the risk.⁹

These general principles of risk are applied to the specific case of pediatric CT through the following recommendations:⁹

1. The patient—or the parent in the case of a patient who is a child—should be told of the small risk involved.
2. The procedure should be restricted to cases in which it is specifically indicated and conveys a commensurate diagnostic benefit that is difficult to obtain by any other means. Pediatric CT involves too large a dose to be used indiscriminately as a screening procedure.
3. Every effort should be made to decrease the radiation dose by adjusting the kVp and mAs to a suitable level according to the size of the child being scanned. “One size fits all” is no longer appropriate now that the risks have been identified.

STRATEGIES FOR REDUCING DOSE

Strategies for reducing the dose involve two components: appropriate patient selection and appropriate technical parameters that will minimize the dose without compromising diagnostic quality. These strategies are summarized in Table 2. Although technologists play an essential role in dose-reduction strat-

egies for CT scanning of infants and children, it is ultimately the responsibility of the radiologist to see that such strategies are implemented.

TABLE 2. Strategies for Reducing CT Radiation Dose

Appropriate Patient Selection
<ul style="list-style-type: none"> • Confirm CT is necessary • Consider alternative modalities
Appropriate Technical Parameters
<ul style="list-style-type: none"> • Limit the region covered • Minimize the use of multiphase examinations • Adjust mAs based on size • Adjust mAs based on region • Adjust mAs based on clinical indication • Consider an increase in pitch • Limit the use of thin slices • Use new equipment options that automatically adjust dose during scanning • Consider patient shielding

USE CT ONLY WHEN CLINICALLY INDICATED

The first step in minimizing radiation exposure in children is to decide that CT is in fact the best method of answering the specific clinical question. Perhaps 40% of all pediatric CT examinations are not clearly indicated.²⁰ Communication between pediatric healthcare providers and radiologists is critical in deciding whether a CT examination is appropriate. Technologists play a critical role in this communication process by bringing to the radiologist’s attention any order that seems inappropriate or unnecessary. Armed with sufficient clinical information, radiologists may offer an alternative such as ultrasonography or magnetic resonance imaging (MR) that does not use ionizing radiation. In some institutions a lack of accessibility poses a barrier to the use of other imaging methods. If modalities such as MR are to be viable alternatives they must be as easy to schedule as CT exams. If it is decided that CT is indeed the best modality, the clinical information provided can help in customizing the CT scan.

CUSTOMIZE THE CT EXAMINATION

One way of tailoring the examination to the specific diagnostic need is for the radiologist to limit the examination to the region in question. For example, routine scanning of the pelvis as part of an abdominal CT is not always necessary;

in this way, exposure to the gonads will be reduced or eliminated.²⁶ There are many potential situations wherein limited CT could be used. For example, in follow-up examinations, the region scanned could be limited to just the area of interest (eg, pseudocyst, lung, or abdominal abscess).

Limiting the use of multiphase examinations is another important consideration. Essentially, every additional phase increases the radiation dose by the multiple of the total number of phases. In body scanning, it has been reported that multiphase scanning is used in approximately 30% of children, many times with three phases.¹² Justification for the routine use of multiphase examinations in infants and children has been questioned.^{19,26} Frush reported that “the indications for scanning through a region more than once are few,” and “if the use of multiphase examinations were limited, the overall radiation would be at least 15% lower.”¹⁹ In the rare instance (< 3% of body scans)²⁶ for which multiple phases are necessary, scan parameters—including length of scan, slice thickness, and tube current—should be adjusted to minimize the additional radiation received.

TECHNICAL PARAMETERS

Because a combination of factors is responsible for the total radiation dose delivered to the patient during a CT examination, a variety of methods for reducing dose are available. The following options can be used in any combination according to the specific clinical situation. Ideally, appropriate strategies are chosen and used together to reduce the dose as much as possible without sacrificing the image quality necessary to answer the clinical questions posed. It is in the mastery of the issues associated with the adjustment of each technical factor that technologists can play a unique and vital role in limiting the radiation dose to pediatric patients.

Adjust mAs. The relationship between the mAs setting and dose is linear. That is, if mAs settings are halved, the dose (and therefore the risks) are halved. If the mAs settings are doubled, the dose (and the risks) are doubled.

At this point in the discussion of radiation dose, the need to adjust mAs to suit individual patient size should be apparent. Small bodies require a lesser dose, and large bodies require a greater dose. Although some facilities use the patient’s weight to adjust mAs, others prefer using the diameter of the patient to determine optimal mAs setting. Both approaches have been proven to be successful.

The mAs setting selected should also be based on the region scanned. Lower tube currents are adequate in evaluating lung parenchyma.^{19,26,27} Because bone intrinsically has high contrast, the tube current should be lowered when a bone is of primary interest.¹⁹

The cost of reducing mAs below a threshold point is that the signal-to-noise ratio decreases because the number of image-forming photons decreases. The resulting noisier

images have decreased spatial resolution. In many cases, this decrease in image quality will affect diagnosis, but in some cases the reduction may be acceptable. For example, in a child for whom a large abnormality is being evaluated, such as a retroperitoneal hematoma or an abscess, the noisier image will probably be sufficient. Therefore, tube current should be adjusted for patient size, region scanned, and scan indication.

Avoid Increasing kVp. Increasing the x-ray tube potential increases both the radiation dose and penetration of the x-rays through the body. In general, increases beyond 120 kVp should be avoided.²² However, an increase in kVp could be accompanied by a reduction in tube current to offset the increase dose.

Increase Pitch. For single-detector row helical CT (SDCT), table speed, collimation, and tube rotation time all determine pitch. The concept of pitch is more complex with MDCT wherein the beam collimation is a combination of all the detector thicknesses. However, for both SDCT and MDCT, the higher the pitch, the lower the radiation dose. Vade and coworkers showed that increasing the pitch on an SDCT scanner from 1.0 to 1.5 decreased the dose by 33% without any apparent loss of diagnostic information.²⁸

Limit the Use of Thin Slices. Using a large number of thin adjacent CT slices results in a radiation dose that is 30% to 50% greater than using fewer thicker slices to scan the same anatomy.^{22,29} Although it is not always possible to avoid using thin slices, technologists and radiologists should be aware of the consequences.

NEW EQUIPMENT OPTIONS

Manufacturers are developing new technologies to assist in the challenge of reducing radiation exposure to children. One new option involves automatic changes in tube current based on the estimated attenuation of the patient at a specific location. These estimates are derived from scout views done in both the anteroposterior and lateral projections. From these views, the mA is programmed to vary by location along the length of the patient. The exact details of the option vary by manufacturer.

PATIENT SHIELDING

Although lead shielding is standard in general radiography, it is less beneficial in CT. Due to narrow collimation, radiation to areas outside that of the selected scan area is minimal and usually attributable to the internal scattering of photons that are unaffected by surface shielding. However, a recent investigation suggested that shielding of the breast tissue and thyroid gland can be a valuable dose-reduction strategy.³⁰ Perhaps what is more important is that patient shielding may play a role in the perception of risk; that is, it would assure the child’s family that every effort was being taken to reduce the radiation dose.

CONCLUSION

CT is a valuable imaging modality for infants and children. Because CT is associated with a relatively high radiation dose, it therefore involves some risk. In cases in which CT is positively indicated, the risk is far outweighed by the potential benefit. However, given the increasing use of CT in the pediatric population, children's greater sensitivity, and the accumulating data about the risks of cancer development after low-level radiation, healthcare providers must do everything in their power to avoid delivering excessive radiation. Strategies include appropriate patient selection; adjusting the scan protocol to meet the clinical needs; and adjusting the technical factors based on the size of the patient, the region being scanned, and the indication.

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RADIATION EXPOSURE TO PEDIATRIC PATIENTS FROM CT POST TEST

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1. **When considering radiation dose from all radiologic sources, CT contributes**
 - a. a very low percentage of the total dose.
 - b. a proportional amount—that is, CT examination represents approximately 11% of all diagnostic procedures and accounts for approximately 11% of the total dose.
 - c. a disproportionately high percentage of the total dose.
 - d. almost 98% of the total dose.
2. **The radiation dose from one abdominal CT scan is estimated to be equivalent to that of _____ chest radiographs.**
 - a. 2
 - b. 10–50
 - c. 100–250
 - d. 300–500
3. **Comparing multidetector row CT (MDCT) scanners to single-detector row helical CT (SDCT) scanners, effective radiation dose is estimated to be**
 - a. 5–10% lower with MDCT.
 - b. 15–25% lower with MDCT.
 - c. 5–10% higher with MDCT.
 - d. 27–35% higher with MDCT.
4. **The lifetime risk of an eventual cancer-related death due to pediatric CT is approximately 1 in**
 - a. 100.
 - b. 1,000.
 - c. 10,000.
 - d. 100,000.
5. **Which statement best describes the uncoupling effect?**
 - a. When technical parameters are set too high, the resulting image will be dark.
 - b. When technical parameters are set too low, the resulting image will look grainy.
 - c. Even when technical parameters are set higher than necessary, there is no associated loss in image quality.
 - d. The mAs and kVp settings are entirely independent of each other and have no effect on the radiation dose from a CT examination.
6. **When the same technical parameters used in adult CT are used for infants or small children, the effective dose is up to _____ greater.**
 - a. 10%
 - b. 20%
 - c. 30%
 - d. 50%
7. **Concerning patient education regarding the risks and benefits of CT examinations, research has shown that**
 - a. nearly all patients are well-informed.
 - b. the majority of patients are well-informed.
 - c. only approximately half of patients are well-informed.
 - d. few patients are well-informed.
8. **Which of the following is a TRUE statement regarding emergency department (ED) physicians' and radiologists' estimates of CT dose?**
 - a. Both ED physicians and radiologists give accurate dose estimates.
 - b. Although most ED physicians are unable to provide accurate dose estimates, nearly all radiologists provide accurate estimates.
 - c. Most ED physicians overestimated dose; only experienced radiologists provided accurate estimates.
 - d. Most ED physicians and most radiologists are unable to provide accurate estimates of dose.
9. **The latency time for cancer induction in the dose ranges used in CT is estimated to be between**
 - a. 1 and 5 years.
 - b. 69 years.
 - c. 10 and 30 years.
 - d. 30 and 40 years.
10. **Children are more radiosensitive than adults for all of the following reasons EXCEPT which of the following statements?**
 - a. Children have more time to express a cancer than do adults.
 - b. In children the latency time for cancer induction is only a few months.
 - c. Radiation exposure is cumulative, and children may undergo more than one CT examination in their lifetimes.
 - d. Children have more dividing cells, and adverse effects of radiation act on dividing cells.
11. **Which is a TRUE statement concerning our perception of risk?**
 - a. People are more concerned about risks not under personal control than those that are under personal control.
 - b. People are more concerned about scattered injuries and fatalities than those that are grouped in time and place.
 - c. People are more fearful of risks that they are familiar with than those they do not understand well.
 - d. People are mainly concerned with the risks they voluntarily accept rather than those that are imposed on them.
12. **In general, the risk of death of one in a million is**
 - a. ignored.
 - b. considered intermediate and may be acceptable if there is adequate associated benefit.

- c. only acceptable if the benefit is substantial and there are no alternatives.
- d. totally unacceptable.
- 13. What are two main components in a dose-reduction strategy?**
- Use of only MDCT and elimination of localizer scout images
 - Appropriate patient selection and appropriate technical parameters
 - Decrease in mA and increase in scan time
 - Decrease in kVp and increase in mAs
- 14. The relationship between mAs and dose is**
- inversely proportional; the higher the mAs, the lower the dose.
 - linear; the higher the mAs, the higher the dose.
 - represented by the equation: $\text{dose} = 1 / \text{mAs} \times \text{kVp}$.
 - highly variable and impossible to quantify.
- 15. Which of the following is a TRUE statement concerning mAs settings for pediatric CT?**
- Patient weight cannot be used as a basis for adjusting mAs.
 - The indication for a scan will never have a bearing on mAs setting selected.
 - Lower tube currents are adequate in evaluating lung parenchyma.
 - Increased mAs must be used when bone is of primary interest.
- 16. For an SDCT scanner, table speed, collimation, and tube rotation time will determine**
- filtration.
 - algorithm.
 - kVp.
 - pitch.
- 17. Increasing the pitch from 1.0 to 1.5 will have what effect on the dose?**
- An increase in dose of approximately 20%
 - No effect
 - A decrease in dose of approximately 8%
 - A decrease in dose of approximately 33%
- 18. Compared with using wider slices, using a large number of thin adjacent slices results in a**
- 5% to 10% less radiation dose to the patient.
 - 15% to 20% less radiation dose to the patient.
 - decrease in image quality due to the partial volume effect.
 - 30% to 50% higher radiation dose to the patient.
- 19. Some newer CT systems may have an option that will adjust the tube current based on**
- the operator's selection of desired dose.
 - published tables of the average dose necessary to examine a specific anatomic area.
 - the estimated attenuation of the patient at a specific location.
 - previous scans of the patient.
- 20. Why is lead shielding less beneficial in CT than it is in general radiography?**
- Because of the narrow collimation, not much radiation is scattered to regions outside the selected scan area.
 - Because of the high kVp used in CT, photons will penetrate a lead shield.
 - Scatter radiation is excessive in CT and is not controlled by shielding.
 - Radiosensitive organs such as the thyroid gland can never be shielded without impairing the scans.



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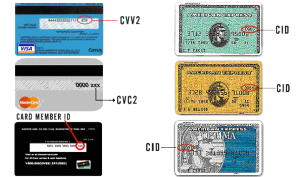
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