Review Article

Radiation-induced Risk in Pediatric Dentistry - A Review

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ABSTRACT

This study aim is to know the radiation risk in pediatric dentistry, especially using ionizing radiation in computed tomography. Imaging studies that use ionizing radiation are an essential tool for the evaluation of many disorders of childhood. Ionizing radiation is used in radiography, fluoroscopy, angiography, and computed tomography scanning. Computed tomography is of particular interest due to its relatively high radiation dose and wide use. Statements on radiation risk suggest that it is reasonable to act on the assumption that low-level radiation may have a small risk of causing cancer. The best available risk estimates suggest that pediatric computed tomography (CT) will result in significantly increased lifetime radiation risk over adult CT, both due to the increased dose per milliampere-second and the increased lifetime risk per unit dose. Lower milliampere-second settings can be used for children without significant loss of information. Although the risk-benefit balance is still strongly tilted toward benefit, because the frequency of pediatric CT examinations is rapidly increasing, estimates that quantitative lifetime radiation risks for children undergoing CT are not negligible, and may stimulate more active reduction of CT exposure settings in pediatric patients.

KEY WORDS: Children, Computed tomography, Ionizing radiation, Risk

INTRODUCTION

Nowadays, dentist depends heavily on diagnostic imaging methods, especially radiographs. Radiographs are taken to confirm or supplement the clinical examination done in cases such as dental caries and other diseases. It has been established that children are significantly more susceptible to radiation-induced carcinogenesis than adults.[1,2]

Computed tomography (CT) is a useful and essential addition to the arrangement of imaging modalities for children. CT used X-rays that provide rapid, consistent, and detailed information about virtually any organ system in infants and children. Since X-rays were an part of the image formation with CT, there was an obligatory radiation exposure during the CT examination. Ionizing radiation has been exhibited to increase the risk of cancer in children exposed to high doses of radiation. Moreover, recent reports have discussed the potential risk of cancer that results from the lower radiation exposure from CT examinations. These articles have raised concerns on the part of pediatricians, patients, and families. There are many different statements on ionizing radiation risk present in the literature; one principle has been supported routinely by the authors of articles to which this report refers: Any estimated risk of a CT scan is far less than the likely benefit to the patient for indicated examinations. This paper will attempt to review the effects of X-radiation as a carcinogen and to produce proper clinical diagnostic radiologic utilization with minimal exposure to the pediatric patients.

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X-radiations and Exposure

Radiation is energy that is radiated or transmitted in the form of waves or particles. These radiations are classified into two types; ionizing and non-ionizing radiation. Ionizing radiation is defined as high-energy radiation that has capacity of producing ionization in the tissues through which it passes and can be absorbed. 1 gray (Gy) is absorption of 1 joule (J) of radiation energy by 1 kg of matter. 1 Gy equals 100 radiation absorbed doses (rads). The Sievert (Sv) accounts the biological effects of radiation and was identified by multiplying the gray by a quality factor.

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It is important to realize that ionizing radiation is regularly resent in our environment. These radiation exposures are termed "background radiation" and include natural and manmade sources. Natural sources of radiation include cosmic rays, radon, radiation from terrestrial rock, and natural radionuclides. Those sources account for most of the radiation exposure received by all inhabitants of the United States. The amount of background radiation varies depending on various locations. Residents of Denver, Colorado, for example, receive approximately twice the annual background radiation absorbed by those who live at sea level. The reason for high radiation exposure may be because of more cosmic rays at the higher elevation as well as increased terrestrial radiation from the rock in the surrounding mountains. In the United States, the average background radiation is approximately 3 mSv/year per person. Man-made radiation includes that of industrial and medical origins. Medical radiation can be measured several different ways. For example, the exposure to radiation from diagnostic radiologic procedures can be described like the dose that strikes the surface of the body or entrance dose. However, the entrance dose was higher than the average dose to which the entire body would have been exposed.

X-rays are electromagnetic radiation which has no mass or no charge. Hence, X-rays are ionizing type of radiation which is a known carcinogen which can cause damage, especially to children.[3] The harmful effects produced by the radiation depend on the amount of dose received by the patients and the amount of time the dose being received. Some review of literature suggests that dental diagnostic X-rays produce whole body radiation of up to 73 mrem/year.[4] Threshold dose is the minimum dose that will produce a detectable degree of any given effect. In dentistry, radiations used for treating cyst or tumors, or in cases of particular diagnosis, there is no particular threshold dose.[5,6]

Exposure is the measure of ionization produced in air by X-ray. The unit of exposure is Roentgen. Exposure to radiation by patient is in two ways.

1. External exposure which can be whole body exposure, partial body exposure, and localized exposure.
2. Internal exposure which can be due to inhalation (air and water vapor) ingestion (contaminated food and water), skin (external radioactive contamination), wounds (fall out), parenteral (nuclear medicine), and transplacental (maternal contamination).

Children can be exposed to radiation by any of the above-mentioned ways.

Harmful Effects of Radiation

Radiation produces two types' of effects in the tissues.

Deterministic Effects

These effects occur above a threshold dose which results in tissue destruction and cell loss, for example, acute radiation sickness and developmental damage during early exposure.

Stochastic Effects

In this, the cells are not killed but are modified. In this, the cells are not killed but are modified, which can lead to something termed as probable effect. e.g.: Transformation of somatic cells into a cancer Effects of whole body irradiation depend on the dosage, the whole body receives which is measured in gray (Gy). When the Gy is above 20, it produces cardiovascular and central nervous system and if the Gy is <0.5, the damage occurs later in life.[7] Children are more vulnerable to ionizing radiation resulting in hypersensitivity to radiation exposure and higher cancer risks. Although only a small percentage of individuals are "hypersensitive" to radiation, health professionals prescribing or using radiation in children should be aware of these conditions such as Fanconi anemia, systemic sclerosis, Behçet disease, and Down syndrome.[8] Pediatric cancer patients with a family history of cancers could also be predisposed to radiation-induced second cancers and clinical hyper-radiosensitivity (Bourguignon *et al*., 2005).

Children and Radiation

Children are more highly prone to get affected by radiation when compared to adults.

Leukemia

The risk of leukemia may be higher in children exposed to diagnostic radiation *in utero* than in unexposed children. In a study of childhood cancer mortality, Monson and MacMahon found that children exposed prenatally to diagnostic X-rays had 1.5 times higher risk of dying of leukemia than unexposed children.[9]

However, other similar studies of prenatal radiation have not found the risk of leukemia to be higher than that associated with childhood exposure.[10]

Breast Cancer

Breast cancer rates were higher among female atomic bomb survivors who were 10–19 years of age when exposed to the bomb than those who are older at that time.[11] The latent period for a radiogenic breast cancer is a minimum of about 10 years. Radiation-related breast cancer has age distributions and histopathological characters similar to those of breast cancer from other causes are known or unknown.[12]

Hence, breasts should be shielded when providing any therapeutic or diagnostic type of radiation.

Brain Cancer

It has been found that individuals exposed to therapeutic medical radiation do show an increased risk of brain tumors. In addition, there is evidence that the risk is higher in those exposed before 20 years of age.[13] Most brain tumors associated with ionizing radiations are benign.

Thyroid Cancer

Irradiation in childhood for benign conditions including enlarged thymus, enlarged tonsils, and acne, and others have been shown to increase risk for thyroid cancer. Thyroid gland tissue is highly susceptible to radiation during childhood. In Hiroshima survivors, a significant linear association was found between dose and increased risk of thyroid cancer, predominantly in those exposed at ages <19 years.[14] A large increase in thyroid cancer has been reported in children exposed to fall out at Chernobyl in the former USSR.[15]

Mental Retardation

A smaller increase in frequency of mental retardation was seen in those exposed at 16–25 weeks of gestation. However, no mental retardation was observed in children prenatally exposed to ionizing radiation after the week 25.[16] Hence, it is recommended to avoid exposure to radiation of pregnant woman as much as possible. If the procedure is necessary and justified, the protection should be optimized to reduce the fetal dose as much as reasonably achievable, according to the medical purpose.

Secondary Cancer

Children who have received radiotherapy for cancer are at risk of secondary cancer later in life. Some of the risk appears to be associated with the combination of radiation exposure and or genetic predisposition. Leukemia, thyroid cancer, and sarcomas of bone and soft tissue are common secondary cancers.[17]

Radiation Effects on Oral Cavity

Oral mucous membrane

The oral mucous membrane consists of basal layer of radiosensitive rapidly dividing stem cells. At the end of 2nd week of radiation therapy, some of these cells die and the mucous membrane begins to show areas of redness and inflammation resulting in Muscovites.

Taste buds

Taste buds are sensitive to radiation. Patients notice loss of bitter and acid flavors when posterior thirds of the tongue are affected and salt and sweet taste when anterior one-third of the tongue is affected following the 2nd or 3rd week of radiation therapy.

Salivary glands

A marked and progressive loss of salivary secretion (hyposalivation) is seen usually in the 1st few weeks after initiation of radiotherapy. The mouth becomes dry resulting in xerostomia which later leads to difficulty in swallowing and pain.

Teeth

Children receiving radiation therapy to the jaws may show defect in the permanent dentition such as retarded root development, dwarfed teeth, or failure to form one or more teeth. If exposure precedes calcification, irradiation may destroy the tooth bud, but if irradiation occurs after calcification, it results in arresting cellular differentiation causing malformations and retarding general growth.

Radiation Caries

Radiation caries is a rampant form of dental decay that may occur in individuals who receive a course of radiotherapy that includes exposure of the salivary glands.[18] Patients with xerostomia presented with dental caries are mostly due to radiation.[19]

Protection from Ionizing Radiation

Two ways to achieve this reduction are to use radiation doses that are as low as reasonably achievable (ALARA), which means that no more radiation should be used than is required to achieve the necessary diagnostic information and to perform these studies only when they are necessary. This study investigated the organ and effective doses for pediatric dental cone-beam CT (CBCT) using anthropomorphic phantoms. Even though the pediatric effective doses were considerably lower than they were for head and neck multislice CT, it was found that they were higher than those for conventional dental X-ray imaging and similar to those for adult CBCT doses. This study has shown that the lowest effective doses were calculated for units that offered small fields of view and "small patient size" settings. Therefore, dose reduction can be achieved using the pediatric small size settings. Small and medium fields of view should be used for mandible and/or maxilla imaging, while for CBCT units which offer only large fields of view, vertical and horizontal collimation should be offered. Taking into account the higher radiosensitivity of children, it is imperative that the use of CBCT in children is fully justified over conventional X-ray imaging. A study discusses the importance and the potential use of CBCT as a diagnostic tool in the identification of the second mesiobuccal canal (MB2) in primary second molar. This three-dimensional imaging technique overcomes the limitations of conventional radiography that is intraoral radiographs and is a beneficial to the pedodontist armamentarium. However, the effective radiation dose of CBCT is higher than in conventional intraoral radiography. To justify this, any benefit to the patient of CBCT scans should overcome the potential risks of the procedure. The radiation should be ALARA. However, the decision to prescribe CBCT in the management of endodontic problems must be based on a case-by-case basis and only when sufficient diagnostic information is not attainable from other diagnostic tests.[20]

Protection from ionizing radiation depends on several factors.[21]

1. Time - Decrease exposure time.
2. Distance - Increasing distance from source.
3. Shielding - Introducing shield.
4. Developing norms and standard - Inspection and enforcement.
5. Several voltage equipment gives way for the use of the highest possible kVp for the required clinical result, thus reducing the exposure of the skin and superficial structures. A latest arrived machine alternative to the variable kilovoltage machine is the fixed 70 kVp machine with samarium filtration and small focal spot size which permits higher contrast radiology than 80–90 kVp units while delivering a significantly reduced radiation dose to the patient.
6. Fast speed film (speed group “E”) combined with high milliamperage machines allow the minimal exposure time with a reduction in exposure and motion distortion.
7. Wrap-around leaded apron and thyroid shields reduce exposures to critical body sites and relieve patient concern regarding gonadal exposure.
8. Optimal processing chemicals eliminate the need for overexposing and underdeveloping films which only adds to the patient’s radiation burden and results in poor film quality.
9. A daily quality assurance program for optimal machines and processing chemicals performance should be instituted in every pedodontic office. Degradation of machine or chemical performance can result in increased exposure in variety of ways.
10. The use of beam-guiding, field-size-limiting, and film-holding instruments for intraoral radiology would probably the most significant advantage in patient dose reduction, film quality improvement, and attainment of routine successful films in recent decades. Federal regulations state that for medical diagnostic radiology, the X-ray beam size must not exceed the receptor (X-ray film) size. Although intraoral dental radiology is not included in these regulations, the technology to control the occasional beam to the size of the film is readily available in the market. Such devices should be used to reduce radiation doses to marrow, thyroid, and other tissues outside of the area being examined.

CONCLUSION

Radiations are an essential component of a CT examination. The amount of radiation that a CT examination produces is low-level radiation. The cause and effect relationship between low-level radiation, such as with CT, and cancer is not certain, but expert panels that have examined this question have suggested that there is a small risk that increases with increasing dose. No direct connection between CT examinations and subsequent development of cancer has been demonstrated, so the risks of CT scans must be estimated, and these estimates vary depending on the information used.[22] The amount of radiation that CT provides depends on many factors, especially the protocols used and equipment settings for the individual examination. In general, properly performed CT examinations of children should expose a child too much lower exposure than those for the same procedure on an adult. The potential benefit from an indicated CT examination is clinically recognized and documented and is far greater than the potential cancer risk. Radiologists are specialists in CT who are trained to use the least amount of radiation necessary.

The risk of cancer associated with most diagnostic radiation is low, and its use should not be restricted when needed for correct diagnosis. Any medical procedure has a risk and diagnostic radiography is no exception.

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