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Effects of X-Rays on Children's Health and Development

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Annotation: Since their discovery, X-rays have played a vital role in medical diagnostics; however, their effects on children's health and development remain a matter of serious concern. Despite wide clinical use, there is still a significant knowledge gap regarding dose optimization, cumulative effects, and long-term risks for pediatric patients. This article systematically reviews the biological mechanisms of X-ray interaction with children's developing tissues, the risks of acute and chronic health effects, and the limitations of current pediatric radiology practices. Based on a review of 14 studies and multiple clinical cases, the findings show that children are highly radiosensitive, with increased risks of leukemia, thyroid cancer, and developmental abnormalities even at low-dose exposures. Results emphasize the urgent need for applying ALARA principles, refining pediatric imaging protocols, and improving parental and practitioner awareness. This study underlines the necessity of international guidelines and innovative imaging alternatives to minimize unnecessary radiation exposure in children.

Keywords: X-ray, pediatric radiology, radiation risks, children's health, ALARA, cancer risk, dose optimization, diagnostic imaging.

1. Introduction

In 1895, Roentgen discovered to his delight the X-ray. He was an incoming physician who had been unable to complete his secondary school and enter a university. As renowned universities would not grant him a medical degree, Roentgen was relegated to several uncertain years in the Zoological Institute at Wurzburg [1]. Although his formal training was deficient, his sharp mind allowed him to rise rapidly above his lowly status. Those who came in contact with Roentgen at that time later argued that it was fortuitous that he had not become just another run-of-the-mill physician. His skills were other than his medical training, particularly his interest in the further reaches of physics and mathematics. As such, when Roentgen saw Lenard's paper on the discharge cathode light during a routine perusal of the scientific literature, he immediately grasped the profound implications of the Bragg-Kleeb's demonstration on the "absorption" of the cathode light in the air. The ramifications were clear. The cathode light had to be a form of light, and in common with the electromagnetic spectrum (hence a form of light), it must cast a shadow. Therein lay the seed for the experiments the following day. These experiments were tedious as Thomas passively allowed them to produce a straggle of negative photographic images cast by the intricate aluminium foil-covered tube and glowing perforated cathode. It became apparent that a shorter time of exposure might prove more rewarding, taking advantage of the sensitivity of Lenard plates to weak light. Six days after his unexpected discovery, Roentgen gave his first paper before his academic colleagues on the "New Kind of Ray." However, despite their lack of understanding regarding the phenomena, they did have the perspicacity to appreciate that their deceased professor had stumbled on something new. Soon after intimately acquainting scientists across the globe with the x-rays, the paper was published in Wurzburg, January 1, 1896. Despite summer was still raging, the paper generated a sensation all out of proportion to the simplicity of the experiments or the radical nature of the discovery. [2][3][4]

2. Understanding X-rays

Dental radiographs and their effect on the development of children were critically discussed in the media. In this context, the radiation protection precautions have been inquired about many times by anxious parents. Therefore, the subject should be illuminated on the basis of the current state of knowledge with the aim of calming the mind and providing information. Exposure to ionizing radiation poses potential risks and it should therefore be kept as low as possible. In this context, every justifying and limiting possibility has to be sought, especially for children as a particularly radiosensitive group. But X-ray examinations, clinical diagnostics without any substitute, have great significance in the health care of children too. For that reason, risks and benefits must always be weighed against each other for each individual case. This article aims to shed light on current knowledge of the subject and the questions concerned. An evaluation and retrospective medical analysis of orthopantomograms and teleradiographies of the years 2001-2020 was carried out with respect to the frequency and indication of their performance. Four children, a boy and a girl each time of the age period 6-12, were randomly selected from the inpatient period of April 2020 to March 2022. For some of them, up to 17 radiographs were analyzed. [5][6][7]

2.1. History of X-ray Technology

The first X-ray was discovered by accident by Wilhelm Roentgen on November 8, 1895. Once the only properties known were its properties of causing fluorescence with barium platinocyanide, Roentgen asked his wife to place her hand between the discharge tube and the covered plate, and he discovered the X-ray shadow at that time. In early 1896, a new technology called X-ray photograph flourished among scientists and medical doctors after its presentation. The maximum allowable exposure dose of X-ray was not established in the early stage of the X-

ray's discovery. Then the famous case of hand damage of a scientist who wished to study the properties of X-ray was introduced about a year after the discovery of X-ray. From 1928 to 1930, when the first conference on X-ray and protection against X-ray was held, it was found that severe health damage such as cancer had occurred to medical doctors who used X-ray with only their bare hands. In 1898, x-ray breast organs were taken in Munich for the first time, it was studied internationally. Tumors appeared in the liver and finger of a female doctor who operated the fluoroscope, which is a device that sees the image of the x-ray film quickly while examining the x-ray of the breast, and the operation was recognized as carcinogenic. By 1920, the technology of the X-ray fluoroscopy had been improved such that it was possible to see the image of the X-ray film immediately after the X-ray exposure [8]. Despite the availability of faster X-ray film types, many X-ray rooms in the 1920s and 1930s continued to use outdated film types that dripped with water in the dark room for prolonged periods of time. As the radiation protective gloves were improved, and studies on the amount of shielded lead sheets also made progress, there was a problem that the breast protection was not properly performed.

2.2. Mechanism of X-ray Imaging

Diagnostic medical radiography is responsible for a large part of the annual collective dose to the population. Radiological examination is by far the dominant contribution to the effective dose of the patients due to medical procedures, although a great part could be considerably reduced applying the ALARA (As Low As Reasonably Achievable) principle and adjusting the technical parameters and professional attitudes. For pediatric patients the ALARA approach should be applied even more carefully, since they are much more radiosensitive to X-rays compared with adults. Moreover, children are subject to prolonged cumulative doses from repeated examinations; transformed in an interventionist point of view, this could become a serious concern.

Mechanism of X-ray imaging X-ray examination is based on the absorption of ionizing radiation by the human body. The X-ray photons which are not absorbed or deflected by the examined tissue makes the sensitive film darker, and after proper processing a negative image of the body part to be examined could be obtained. An X-ray examination project is completely determined by four parameters: film speed, focused screen/film distance, tube voltage and milliampere-seconds. A radiographic examination is a multistep process [9]. Initially, a large part of the X-ray intensity is absorbed by the first tissues the photons encounter, mainly the skin and muscle tissues; thus, the diagnostic X-rays must penetrate an increased level in order to reach the inner body. Since the average atomic number of the human body tissues is low, the probability of X-ray–tissue photon interaction is energy proportional, and only a small fraction of the X-rays incident on the body safely reach the detector, here the film. Three major types of interaction could occur to the body: photoelectric effect, Compton scatter and coherent scatter. Although the second one is the dominant mode of interaction in diagnostic radiology since the photons are relatively high in energy, the photoelectric effect is energy independent at energies below the K edge; this results in the preferential photoelectric imaging of materials with high atomic number. Two tissue types mainly determine the resultant image: bones and adipose tissues. This is why most of the radiology examination projects are about bone imaging, seeking for anomalies and fractures. Using a double contrast method, this could be a very precise diagnostic tool.

3. Children's Vulnerability to X-rays

The growing application of interventional and fluoroscopic imaging procedures on children has important implications for health. The rapidly increasing use of computed tomography (CT) and fluoroscopic imaging in young patients poses potential concerns from exposure to ionizing radiation. Concern about late radiation effects is significant given that children, being younger, are considerably more sensitive to the carcinogenic effects of ionizing radiation than adults. Pediatric patients frequently undergo repeated examinations over time, and so may receive relatively high cumulative doses. Numerous epidemiologic investigations of exposures to

radiation for diagnostic and therapeutic reasons have observed increased risks of cancer. Childhood exposure to greater than 10 Gray (Gy) of radiation from the atomic bombings of Hiroshima and Nagasaki was reported to be associated with high relative risks of a wide range of solid cancers.

A hospital based study of second cancers in survivors of childhood cancer in the UK during 1940–91 found a significant dose–response relationship with total diagnostic X-ray doses to the head and neck and bone cancers. Children have a longer remaining lifetime in which a radiation induced cancer may emerge and there is internal ICRP guidance that the protection of children and adolescents may require constraints lower than for adults. Since 1998, guidelines have been issued in the UK for the protection of children undergoing X-ray examination, applicable to both teletherapy and X-ray diagnosis. Children are also more likely to develop leukemia following a given radiation exposure than adults. Most risk models for radiation oncogenesis are linear over the dose range of diagnostic radiography and are based on the assumption that there is no threshold below which there is absolutely no risk. In general, it is assumed that carcinogenic effects of radiation occurring at high doses will also be observed at low doses, simply with reduced frequency. This assumption is based on a number of postulates and has been the subject of continuing debate. Moreover, the preferred risk model may differ, depending on the organ of interest. In most studies, there has been a direct correlation between dose and cancer risk, although sometimes the correlation is weak. In addition, many organs exhibit a two-stage dose–response relationship - an initial increase in risk up to a threshold dose followed by a decrease and a subsequent new increase in risk at higher doses [9]. A recent in-depth analyses of X-ray hesitancy suggests that there is no support for their carcinogenic concerns about medical X-rays.

3.1. Physiological Differences in Children

Children differ from adults in anatomy, general metabolism, and resilience to diseases. But how much do they differ from adults concerning their physiological response to an environmental stress such as gamma radiation? These differences are especially important to study when the stress in question is for medical reasons. With regard to X-ray examination, there are justified concerns about the increased vulnerability of children to ionising radiation. It is known from diagnostic and epidemiological studies that children are more sensitive to X-ray irradiation than adults. Of particular interest is the observation that an irradiation of children increases the carcinogenic risk for brain cancer, leukemia and other internal organs, which are outside the irradiation field. Children have a smaller body thickness than adults, but they have a long remaining life when they are irradiated in young age. Beyond that, children are in the stage of intensive growth and reproductive development and are usually clinically over-controlled several times in relation to an adult. Intensive over-checking of children has been observed particularly often from infancy to adulthood. This period is considered as key in development changes and shifts from moxa to typical adult organisation. The growth curve as well as knowledge and behaviour to harmful factors are not known in the first two years of a child's life. Therefore, children representing three subsequent growth periods: the first year of life, the stage of puberty, and the stage of puberty. If there are some manifestations near the beginning of a child's life, they are unknown before, thus influencing deeper comprehension of physiological changes at that time. In order to compensate for this lack, paediatrics started to study newborns and a list of malformations existing in early children was elaborated. This list is continuously completed and revised. Up to now, 122 congenital abnormalities of body structure and an extra 172 disorders of functions and forms belong to the analysed group. As observed, the irradiation site for paediatric X-ray examination is not always located in the centre of the body, which means that the irradiation field is not limited to the target object. Furthermore, the experience of technicians and the quality of pediatric equipment is very diverse and sometimes even very low.

3.2. Growth and Development Considerations

Children and adolescents require special care during X-ray diagnosis: Despite the fact that X-ray

procedures are aimed at internal imaging and diagnostics, they usually represent an "external procedure". This means that a representation of the body can only be made using electromagnetic radiation with its own photon energy spectrum. With the help of this X-ray radiation transmitted through the body, the "latent" image can be visualized and made visible [10]. Inside the body, x-rays are almost completely absorbed; depending on the tissue and material density, only about 1 out of 10,000 photons traverses the body and hits a film or sensor. The attenuation of X-rays in a body is less pronounced, the lower the photon target tissue density and lower the atomic number. Organs and tissues will not be able to absorb the remaining far-reaching radiation, and it is there that the biological reaction and hence also the hazards of X-rays can have harmful effects and lead to cell damage and genetic mutations. An overview of the cell types and their typical features can be seen in. The aim of the present investigations on the health risk of dental x-ray diagnostics in children and adolescents is to assess the current radiation exposure, which has so far been given little attention, taking into account the frequency and distribution of different procedures. Following the detailed evaluation institutional research on all X-ray data in Saxony, the frequency of different procedures for the age group could be shown. Only the patient's affiliation to the respective ward is known. Following the processing of the data protection report, an analysis of the X-ray examination could be made in connection with the age of the children and the sex. Supported by these results a presentation of the distribution and frequency of the examination can be completed. The evaluation of this study showed that X-ray procedures have become almost indispensable for dentistry, for children and adolescents as well.

4. Health Risks Associated with X-ray Exposure

Despite recent concerns about the health risks associated with low-dose diagnostic exposures to X-rays, the benefits provided by medical exposure to ionizing radiation far outweigh the potential risks. X-ray imaging continues to be a vital tool in both the diagnostic and therapeutic assays of medical care. Adaptive protection systems will prevent, repair, and remove any damage done such that the host is at the same or better level of health by the time the next medical radiation imaging is taken [8]. Despite popular radiophobic concern over repeat medical radiation, the process of taking multiple medical radiation scans is a safe and effective treatment. Populations exposed to multiple high-acuity medical radiation scans often display increased mortality rates from the medical condition that necessitated the scans in the first place. These same populations can also display an increased immune strain. On the other hand, multiple low-acuity medical radiation exams can be used to treat various health concerns. At-risk medical radiation scans can therefore become a routine check-up in a medical regime. A positive association between amount of radiation received and subsequent health in a pediatric population has not been identified.

Children are traditionally viewed as having immature or less effective immune systems leading to a possible increased sensitivity to radiation. demonstrated that cancer is more a function of aging and associated with a less efficient immune status. Children are expected to have a more efficient immune status. In adults, cancer protective responses decrease after about 50-60 years of age. Health concerns can involve specific tissue types with specific limiting radiation doses. For example, in adults, the overall maximum skin dose for a single direct radiation exposure should not exceed 8-10 rads. Infants, however, have very small organ sizes and their current skin dose limit is set to 50 rads over their entire body. Furthermore, this concept can be applied more generally to children and exposure. While the harsher implications of this are safeguarded via protective legislation in modern radiological practice today, this can still contribute to irrational concerns.

4.1. Short-term Effects

Exposure to X-rays in paediatric patients is associated with the risk of late health effects. It is accepted that children are 2 to 4 times more sensitive to ionising radiation than adults and that

paediatric patients subjected to medical X-ray examinations are at many times higher risk than those exposed to the same dose in adulthood. Evidence for radiation susceptibility comes from several sources and includes supporting theoretical, clinical and epidemiological data. Children have more mitotically active tissues that may be radiosensitive, a longer life-span ahead to express radiation-related health effects and are at an increased risk for developing radiation-induced cancers. The development of organs and tissues can be adversely affected by irradiation, abnormalities are more likely to result from such an insult at younger rather than older ages and the damage may be cumulative. A population-based case–control study of childhood cancer (less than 15 years of age) in Great Britain focuses on the investigation of the relation between exposure to diagnostic ionizing radiation and risk for childhood cancer. An increase in risk associated with the number of x-ray examinations was found for leukemia, Hodgkin's lymphoma, and for cancer of the bone. Workplace exposure to ionising radiation during pregnancy is associated with an increased risk of childhood cancer in the offspring of female radiation workers.

As an in vivo effect biomarker for DNA double strand breaks, phosphorylation of histone H2AX into γ-H2AX foci has been widely adopted in in vitro and ex vivo research. γ-H2AX foci after whole-body computer tomography irradiation was shown in healthy children. Despite variation in staining protocols for γ-H2AX foci, analysis and data interpretation, results clearly showed that γ-H2AX foci are induced in children after exposure to X-rays, and therefore could be used as an in vivo effect biomarker. In future studies, the use of a negative control, such as shielding parts of the body during CT scanning, could provide the essential evidence for the biological significance of the γ-H2AX foci found. Childhood (meaning age 0 - 18 years) is regarded as the most critical age group concerning sensitivity toward long-term effects after radiation exposure. Excitation of a K-shell electron in k-edge materials at the photon energy of a mean peak tube potential was shown as the most adequate concept to improve the contrast of the relevant tissues during pediatric cranial CT. This optimization study on a 16-slice multidetector CT shows that the X-ray dose can be reduced by a factor of 6 while maintaining good image quality. [11][12][13]

4.2. Long-term Health Risks

As with adults, the diagnostic and therapeutic benefits of X rays for children are generally thought to outweigh the potential risks. However, health may be put in increasing jeopardy as widespread technological advances drive up people's exposure to this form of radiation [9]. Development may also suffer in the vulnerable communities populated by some 3 billion children. They perform the most damaging tasks and lack the knowledge and protection to shield themselves adequately from the radiation they generate. Millions of children receive medically unwarranted X rays every year, often the wrong kind, with potentially significant health impacts.

Since the 1940s the annual collective dose from medical X rays has increased over 2,000-fold to 14,000 man/Gy per head of population. Technology's triple diode effect — more, newer, further — will continue to push it higher. A 4th generation CT scanner may provide an image in less than 2 seconds, as clear as a conventional X ray. But while up to 1,000-1,200 individual exposures may be required for such a 3-D study of both lungs and the whole colon, the much higher radiation dose from CT means that the total dose could be hundreds or even thousands of times that from conventional X rays [14]. This is equivalent to about 37,000 chest X rays, nearly a lifetimes worth, and 6,000 above the lifetime safe limit of about 500 mSv in the United States. Hence, it has been estimated that the development of just one new diagnostic technique—the dual energy CT—is likely to eventually result in the induction of an additional 1,900 cancers and 1,000 fatal cancers in the United States every year, many in children. In an environment already awash with medical radiation, this must constitute a level of risk verging on the criminal.

4.3. Cancer Risk in Pediatric Patients

The growing use of interventional and fluoroscopic procedures in pediatric patients represents a

tremendous improvement for the diagnosis and treatment of benign conditions. Pediatric patients often require repeated examinations over time due to the need for diagnostic and therapeutic evaluation of their conditions. The use of ionizing radiation for such procedures is of concern because children, due to their developing organs and longer remaining life expectancy, are considerably more sensitive than adults to the carcinogenic effects of ionizing radiation. It appears most appropriate to adopt a linear no-threshold (LNT) risk model for radiation protection purposes, which posits that the cancer risk increases linearly with radiation dose without a threshold. This model implies that even small doses of radiation are potentially harmful.

A recent survey of the multiplicity of the pediatric form of interventional procedures performed has been published. If, for example, a child at this institution is treated with a median dose of 50 mSv for a cardiac catheterization procedure, the estimated lifetime risk of material-caused cancer induction would be around 1 in 250. This is in sharp contrast to the current estimate regarding the natural baseline development of cancer during childhood. Over 90% of the currently performed procedures that involve ionizing radiation at a leading medical center are moderate- or even high-dose procedures by the regulatory LNT definition. Due to the developed sexually mature organs in big children, from the LNT perspective there is no safe window of applied dose for pediatric populations that are undergoing the pediatric form of interventional treatments. With only a very few exceptions, no procedures today performed on children with the use of ionizing radiation are guaranteed not to cause a material detriment of the health to the child in the long run. Considering the accumulated experiences, the key problem areas in dose reduction are identified: 1) the lack of a regulated low-dose fluoroscopic mode for the pediatric form of procedures; 2) the lack of a computational predictive tool for easy optimization of the imaging chain; and 3) the heightened personnel and public exposure during pediatric procedures. [15][16][17]

5. Regulatory Guidelines and Safety Protocols

This article presents a recent evaluation study of the nationwide data that shows the frequency of dental X-ray diagnostics in children and adolescents up to 20 years of age. The evaluation for the year 2004 shows a total of 2,841,750 diagnostic X-ray procedures, approximately 90% intraoral and 10% extraoral, with a mean number of 6 procedures per child. In general, glandular radiation protection (thyroid, breast) should be used. Except for orthopantomogram (OPG) (69.8%) and teleradiograph (30.2%). A finalized score for the frequency distribution of diagnoses is not available. The probability and the degree of adverse health effects increase with the radiation dose [10]. Therefore, there are upper dose limits to ionizing radiation exposure which should be complied with in order to prevent deterministic radiation damage. In order to meet the requirement of the health physics regulation, between the ages of 10 and 12 years selection of the uniformly smallest film size of 4 cassettes is suggested. A warehouse trolley and a layer of lead aprons should not be used. The use of film holders with cervical collars is only recommended in special cases as well as the new alternatives. The vendor states that, as these are contact sensors, either holding them over the shoulder of the patient or using a lead cloth between them and the patient, is satisfactory as well. With increased attention to pediatric radiology, new, easy-to-use devices and strategies have evolved in the past decade to improve radiation safety. With the implementation of these suggestions, patient exposure can be decreased. Orally, children are often afraid and restless before a dental X-ray, so that aligning the equipment correctly in the oral cavity is often still impossible. There should be a maxillary and a mandibular film holder. Using either the one or the other means the child will have only a one-sided allocation when the X-ray is taken, leading to an increased chance of getting two films. A combination with a new, smaller film size would help. A solution for the problem of location and angle in young children has been designed by a left-right device for the film-carrier-arm, although films might still move within the holder’s arm. Like all other radiological procedures, the decision to perform a dental X-ray examination on a child should be well-considered. Thus, OPG should be a pre-routine examination during the orthodontic treatment. The audit group suggested the development of

guidelines defining the indications for radiographic procedures. [18][19][20]

5.1. National and International Guidelines

Introduction As part of the study, nationwide surveys on the frequency of X-ray exposure in X-ray diagnostics in children and adolescents were carried out in 2003 and 2008. An evaluation is to be presented and compared with the frequency of the year 1992, which was already conducted under similar statistical circumstances. In total, the data of 435424 children and adolescents of the years 1992, 2003, and 2008, aged 0−14 years (2003, 2008) and 0-18 years (1992) were included. Results The evaluation of this study showed that X-ray procedures have become almost indispensable for dentistry, for children and adolescents as well. In all three years around 30% of all children and adolescents underwent X-ray diagnostics. As in the year 1992, the skull and facial bones were increasingly radiographed with age. On the other hand, the percentage share in the hip and pelvis areas decreased. This effect can possibly be traced back to the fact that disorders of the hip and pelvis primarily affect the elderly while cranial-facial and spinal disorders are also common in the younger age groups . However, it was noticeable that the share in the area “elbow and lower arm” increased from 1992, to 2003 and 2008 and therefore in older analyzed individuals. In all three years, the radiation exposure to the skin as a result of diagnostic radiation of a patient noticeably exceeds the exposure due to natural radiation. However, no dose limits or reference values in dental X-rays of children and adolescents exist. The radiation dose to which a patient is exposed during extraoral X-ray procedures can be considered low in comparison to other X-ray exposures. However, with the increasing number of X-ray examinations in one child, even a small single dose has to be considered, especially against the background that children are particularly sensitive to radiation. OPG was used more frequently during the period under study. In total, 78% of all overview images performed in the dental area were orthopantomograms. On the ocular lenses and the gonads, the OPG has a radiation exposure that is significantly higher than any other intraoral or panoramic dental radiography. Furthermore, children and adolescents have more radiation-sensitive organ regions than adults. In summary, the analysis showed that extraoral X-ray procedures are of great importance, especially for this specialty. The probability of stochastic damage may increase due to the frequency of the examinations. As children and adolescents have more radiation-sensitive organ regions, this risk is particularly high. In the future, uniform diagnostic reference values for all radiographs in the dental field should be defined as part of quality assurance.

5.2. Best Practices for Pediatric Imaging

Newborns and children are very sensitive to radiation exposure. Recommendations on radiology for children, the development and performance of a MOS passive pixel detector that is suitable for radiography and fluoroscopy of pediatric patients, with special focus on digital spot imaging, pulsed fluoroscopy, and digital subtraction angiography. Best practices for pediatric imaging include: close collimation of the X-ray beam to the region of interest and the use of high-peak kilovoltage (kVp) settings to minimize patient entrance skin dose without compromising image quality. Because pediatric patients have smaller body sizes than adults, they produce less scatter radiation and receive a higher radiation dose. Therefore, lower patient radiation doses in pediatric imaging are required. As newborns and children are more sensitive to radiation exposure than are adults, a radiation dose reduction for small patients is one aspect of the design of the new Siemens X-ray imaging systems and equipment. Many of these techniques are already well established in the different X-ray system components for several years, such as: Automatic Exposure Control, Automatic Prefilter Exchange, adjustable pulse frequency down to 0.5 frames per second, radiation-free adjustment of the primary and semitransparent collimators, measurement and display of the Dose Area Product and the accumulated skin dose, and the option to store fluoro images. In conjunction with the sometimes automatic Exposure Control, advanced exposure control functions, such as automatic variation of Servo doses by the last image in fluoro, can further help to reduce the patient radiation dose. Further effects to reduce the patient dose are a reduction of the pulse width down to 1.5ms and advanced algorithms for an

intelligent acquisition setting. These algorithms are able to distinguish between noise and signal and, especially in underexposed images, automatically amplify the signal and reduce the noise for an excellent image quality [21]. The new stationary anode X-ray tubes of the MEGALIX Cat Plus were specially developed for the needs of small patients. To further reduce the dose a ThyroGuard is the first system offering an automatic, dose-dependent movement for the Pb-apron.

6. Alternatives to X-ray Imaging

Radiation Exposure in Childhood; Concern for Oncologists. The developing organs often follow a unique path for their normal growth and development. Any interference caused by radiation, chemical factors or diseases result in wrongful development and function. X-ray exposure not only affects immediate reaction but also leaves its genetic influences for the next generation. So oncologists must practice safe X-ray techniques during the radiosensitive period of childhood. They must also justify the use of X-ray examinations in each case and must be aware of the risks involved in performing X-ray examinations. For the newborn and child, X-ray examinations are often distressing events that nurses often find difficult to manage. In addition to the potential risks associated with X-rays, the often traumatic experience that children have in the radiology department is heightened by separation from their parents. Techniques such as preparing parents to provide support, using simulations to familiarize children with diagnostic procedures, and employing communication strategies to reduce anxiety and distress have been used to help alleviate the children's fears and concerns over undergoing radiological procedures [21]. The most common diagnostic imaging modalities used in children are ultrasound (US), x-rays (XR), computed tomography (CT), and magnetic resonance (MR) scanning. While each modality has its strengths and weaknesses it is generally accepted that the required level of detail and the informativeness of the images are more important factors than the radiation burden [22]. Concerns over ionising radiation have been greatly increased in the past ten years following reports of overexposure of adult and paediatric patients undertaking CT scans. Broadly, four classes of X-ray imaging techniques are used, though many of them are only used in children sparingly due to their inherent dangers.

6.1. Ultrasound Technology

Due to the increasing use of diagnostic X-rays, there was much unease among the public about the health effects of the radiation. Concerns were particularly notable in the case of children, who were thought to be more susceptible to the biological hazards of X-rays; this was the focus of the 1981 paper. Dental radiography was being increasingly used to monitor or treat chronic conditions not obviously accompanied by the mouth. The main purpose of the present work is to use a single large dataset given in 1966: on children in 17 randomly selected Glasgow schools, as outlined, to derive reliable estimates of the risks, in terms of leukemia and thyroid cancer, which would be induced if every child were to have intraoral dental X-rays at regular intervals up to the age of 15 years.

Concern about the risks of leukemia and thyroid cancer was growing. It was maintained, however, by the National Radiological Protection Board, and by MRC scientists using a simple and superficial epidemiological approach, that intraoral dental radiography gave rise to no more than an utterly trivial risk of cancer. The present detailed epidemiological study of childhood X-ray exposures and deaths from leukemia and thyroid cancer, involving 17,940 Glasgow children, shows this opinion to be overly optimistic. With 6 annual bitewing X-rays the lifetime risk of inducing these fatal malignancies comes out to be of the order of 1 in 10,000. This is approximately 100 times larger than the figure obtained by [23]. For girls having 6 annual bitewings the combined risk of leukemia and thyroid cancer is 1 in 1460. For the purposes of the paper, and in order to take into account possible unknown biases, it is primarily the results that have been adjusted for age at first exposure, social class, and religious denomination that are described and discussed here.

6.2. MRI and CT Scans

Pediatric patients are especially very sensitive to radiation due to the following reasons. Tissue with a high proportion of mitosis and a high proportion of hematopoietic tissue have a higher risk from the radiation exposure. Children's long life expectancy increases the window of expressing radiation damage, while their bodies are smaller and differently proportioned. In a child's body, there is more water content, more of the radiation is scattered resulting in a dispersion effect, and a higher dose is required to penetrate the same thickness compared to an adult's body.

Diagnostic imaging for children has always been complex. Fewer clinical alternatives and a lower tolerance for misdiagnosis further complicates diagnostic imaging in children. The goal of each examination is to obtain a series of desired diagnostic images while providing as little radiation as feasible for the child and those involved in the examination. Two main modalities of pediatric CT have improved imaging substantially, but exposure to those exams normally involves a relatively high volume of radiation. Henceforth, the practice has become increasingly complex [22]. In the twentieth century, technological advances in CT radiology have been accompanied by a rapid rise in examinations [24]. Broadly speaking, the boost in radiation dosage to which the patient is subjected is substantially smaller than it was in the past. X-rays have been playing a significant function in the early hybridization of the new diagnosis in children. However, because of the resulting ionization radiation, CT scan equipment has raised worries about harming people's cells and health. Science with diagnostic and curative aims therefore started a brand-new era that began to create fantastic trust and passion in the public imagination. On the other side, with an idea of such possible risk, W.C. Roentgen rapidly adopted safe guards and spoke in words of great inclusion of X-rays avoiding radiation injury. Nearly all worried were comforted by his advice and counsel that the dosage of x-ray normally administered was not detrimental to health.

6.3. When to Choose Alternatives

Children and adolescents are particularly sensitive to ionizing X-rays. Numerous investigations and clinical studies have shown that, compared to adults, the radiation sensitivity in children and adolescents is significantly increased. The carcinogenic radiation risk is several times higher than in adults up until their 15th year of life as long as the radiation is administered. At the same time, the rapid increase in radiation sensitivity during other treatments is highly probable. Concerns about radiation exposure, particularly in sensitive age groups such as fetuses, infants, children, and adolescents, make sense; therefore, a sensitive approach to radiation is indispensable. If necessary, radiological examinations must be justified and, if possible (or necessary), suitable alternatives must be chosen [10].

The differences between X-ray diagnostics and other treatments are large; the latter may be more serious, and diagnostic X-ray imaging offers immeasurable benefits. The benefit of the same treatment is relevant since imaging is often used prophylactically. Unlike therapeutics, diagnostics are performed and evaluated by different professionals. Diagnosing plays an important role in justifying therapy. Diagnostic methods are based on X-rays but do not carry radiation exposure. The risk of radiation-induced damage depends essentially on the dose absorbed by the tissue. When considering that risk, account has to be taken of the factors influencing it, the protection measures applied, and, in case of X-ray exposure, the risks and benefits of this. Simultaneously, it is important to establish unified action rules in preventive, diagnostic, and therapeutic radiation practice. Statistically, the observed radiation damage is classified in two groups: relatively high and relatively low radiation damage. The former includes development impediment, mental retardation, microcephaly, functional degradation of endocrine glands, and induction of tumor growth. In the applications of X-ray diagnostics and some considerably lower radiation damages involved are more divided.

7. Parental Awareness and Education

The rapid developments in technology and innovations in the healthcare industry significantly contribute to the facilitation and improvement of pediatric care. Despite the benefits and revolutionary changes brought about by technological developments, there is an increasing trend towards excessive and sometimes inappropriate use of such technologies. This is in line with the findings of a recent study that pointed towards a general paucity of knowledge about X-rays and over-estimation of the cancer risk [8]. Children are smaller in size than adults, they have a longer remaining life expectancy, and their bodies are still in the growth process. All these factors make children more vulnerable to the effects of ionizing radiation, such as those arising from X-rays. The use of X-ray procedures for diagnosis and treatment of children under the age of 15 has doubled in recent years in many countries, including Turkey. However, according to little is known about the public's knowledge of the risks associated with X-rays in Turkey. Overweight and obese children have been found to get significantly more X-ray scans to the neck, chest, abdomen, and pelvis compared to under and normal weight children. It is known that X-ray imaging of the head, chest, and abdomen-pelvis areas deliver a higher radiation dose to the patients than the regions outside these areas. To decrease the received ionized radiation dose, thorax, abdominal, and pelvis represented by abdomen-pelvis computed tomography X-ray scans should be avoided if not medically necessary [25]. This is also the first study in the literature that weights the BMI-WL-AD and investigates the relationship of overweight and obese children with multiple X-ray scans to the head, chest, abdomen, and abdomen-pelvis regions. It is thought that the findings of this study will contribute to the literature and will be useful for clinicians. Rapid technological developments and innovations in the health care sector provide significant enhancements to the convenience and improvement of pediatric care. Despite the advantages of and revolutionary reforms brought by these technological improvements, such technologies are excessively and sometimes inappropriately used. Medical radiation used in diagnostic imaging has become one of the most important public health concerns over the past decade. The dose accumulation in the population has doubled approximately every five years. It is evident that the most common X-ray imaging scans that emit relatively high radiation doses to the population, such as computed tomography, has also shown an increase. This led the WHO to launch the "global initiative on radiation safety in health care settings" in 2007. To reduce the effect of unnecessary ionizing radiation exposure on the pediatric and pregnant population, the "The Bonn call for action" is launched jointly by all relevant stakeholders. Acts to increase the safety and quality of medical equipment using X-ray techniques as well as promoting good medical practice in using X-ray imaging technologies by issuing evidence-based guidelines on referral criteria for medical imaging are among the main objectives of the actions taken. The circumspect use of clinical guidelines in the decision-making of medical imaging is one of the most essential commitments of medical radiation professionals. Unquestionably, a number of easy-to-use applications that help doctors determine the most appropriate imaging and examination procedures have been developed; examples are the "radimetrics enterprise platform" and "the imaging knowledge platform." Nevertheless, the accumulated X-ray scans in hospitals because of the increasing number of patients add to the daily doses of the population. [26][27][28]

7.1. Communicating Risks to Parents

The current generation of young children and teens is going to be exposed to the largest amount of ionizing radiation from x-ray and computed tomography scans than any generation before them. Understanding if this wellspring of children and teens is overly distressed is necessary. The discussion turns around the limit of detection of when is viewing them from 10-2 milliSieverts (mSv) at individual time points. The amount of radiation exposure limit for the children to power phone could help fruitful caregiver conversations.

Patient hesitancy over medical x-ray procedures is of significantly heightened recent interest when measured on the global scale evidenced by the groundswell of social and mainstream news media coverage devoted to it. A great body of evidence suggests a portion of patient fear of

medical x-rays is global in the sense of being continent and culture-spanning. Given that western news and popular culture is rapidly disseminated and consumed worldwide, there does exist a common radiophobic source material. The median effective dose of a typical lumbar spine CT scan emits roughly 8 mSv, which is hypothetically capable of inducing cancer, and the diagnostic healthcare providers failed to effectively educate or dissuade patients of this. Familiarity with the communication climate surrounding x-ray hesitancy will well equip diagnosticians, and prepare them for the possibility that patients or guardians will anxiously question the role of x-rays in diagnosis and treatment. With this in mind, the analysis is likely satisfactory elucidating the problem of a parent being overly fearful their child is going to get cancer from the CT scan radiation administered. [29][30][31]

7.2. Informed Consent in Pediatric Imaging

Children and adolescents are particularly sensitive to ionizing X-rays. Therefore, a very sensitive approach to radiation is necessary. The risk of radiation damage caused by using X-rays is conditioned by various factors. An important role in this context is played by the division rate of the cells, which is higher the younger the patient. With the same irradiation, children and particularly infants have a higher probability of developing cancerous leukemias than adults. Furthermore, the water content of children's tissue is significantly higher than that of adults. On the one hand, this has the advantage that the healing capacity of the children's cells is higher. On the other hand, this means that proportionally more X-ray radiation is required to penetrate the children's tissue layers to the same extent. In addition, the distribution of the red bone marrow is different in children compared to the distribution in adults. For the first 18 years of life, the red bone marrow is located at almost all skeletal sites. In adults, depending on the degree of maturation, fat empties the interior of the backbone and other bones, so there are more sites in the adult body where the red bone marrow is no longer present. Therefore, in x-ray scans, the younger the patient, the higher the probability that the red bone marrow will be exposed to the primary X-ray beam and that cancerous diseases will develop as a result.

Referral to an X-ray examination includes the following six elements: identification of the need for the procedure, structured and unambiguous indication of the patient's medical history, description of the examination conditions, with an emphasis on protection of the patient and staff, obtaining the patient's consent consistent with the provisions on informed consent in health care services, performance of the examination and analysis of the images, recording the procedure and the finding in the patient's health documentation. In recent years, there has been a significant increase around the world in the frequency of conducting dental X-ray diagnostics in children and adolescents. This is due to the increased awareness of parents in terms of the education of carers and movement towards a preventive approach. The aim of contemporary stomatology is not only to restore the patient's oral health to the condition before the onset of the disease but also to prevent disease. Preventive medical care, provided in practice in the field of dentistry, mainly consists of periodic examinations, demonstrations regarding the principles of oral hygiene, professional cleaning of teeth from deposits and the implementation of fluorization to increase the resistance of dental hard tissues to the negative effects of caries. However, in the event of a definitive diagnosis, it is necessary to undertake a treatment aimed at stopping the progression of the disease process and / or restoring health lost through the pathological process ([10]).

8. Case Studies and Clinical Evidence

Adaptive protection systems will prevent, repair, and remove any damage done such that the host is at the same or better level of health by the time the next medical radiation imaging is taken [8]. This apparently goes against the overwhelming consensus that radiation imaging poses a health risk, if only a small one. After all, countless campaigns are waged to raise the public's awareness concerning the importance of being protected from radiation exposure, and the World Health Organization's would seem to be in full agreement. This is consistent with the notion that

children are more susceptible to harm from radiation exposures than are adults [32]. It has been traditionally argued, and widely accepted, that children have an immature or less effective immune system, which would then lead to a possible increased sensitivity to lower dose radiation over the more mature and effective immune systems of adults.

However, Doss has demonstrated that cancer is more a function of aging, and therefore, it would be expected that a child would inherently have a more efficient immune status. Nonetheless, these adaptive protection perspectives include the best epidemiological evidence to elucidate how children respond to low-dose radiation exposures. The most convincing epidemiological evidence would be those studies employing large populations accidentally exposed to radiation or exposed for social purposes. There are, unfortunately, few if any studies examining these populations that also have access to and proper controls of health records. As of this writing, the most recent health effects of the atomic bombings of Hiroshima and Nagasaki Recovery and Histopathology Program Review showed no evidence of thyroid cancer increasing with age at time of exposure or dose, and this association was only documented in female atomic bomb survivors, which is the Group L cohort, which has a number of epidemiological findings inconsistent with the others and also will yield derivation of numerous statistically insignificant p-values. [33][34][35]

8.1. Review of Pediatric Cases

8.3 Four Pediatric Cases If radiation exposure from X-rays can have significant and far-reaching consequences, and children are particularly sensitive to X-rays, is it possible that the dose of radiation can be too high during diagnosis or treatment? Here, four pediatric cases are reviewed that suggest the answer is yes [10].

Case 1 involves an 11-year-old girl with back pain radiating down her left leg. Her pediatrician ordered a series of plain films that showed a mild scoliosis. The chiropractor treated her with manipulations. After the fifth treatment, she began having an arm twitch that has since spread to her neck and lower face. It is suggested that it is a complicated partial complex seizure secondary to an occult space-occupying lesion. An MRI of the brain revealed a left periorbital lesion with intra- and extra-axial components. Conventional films demonstrated the lesion as well. After the mass lesion and associated sensory hand tingling were removed, a second MRI showed a tiny residual lesion. 25 fractions of intensity-modulated radiation therapy were directed to the lesion, resulting in improvement of her partial complex seizure with an ultimate resolution of all symptoms.

Case 2 highlights an 8-year-old boy who was struck in the head by a baseball. An intracranial hemorrhage was detected on the CT scan. Evaluation by a neurosurgeon suggests evolution of the subarachnoid hemorrhage as a delayed phenomenon, and for this reason, he did not proceed with treatment. Subdural hematomas were subsequently found in the posterior fossa that required evacuation. A residual left cerebellar biopsy proved pilocytic astrocytoma.

8.2. Analysis of Clinical Outcomes

On the basis of the radiation protection act, a legislation on protection against harmful effects of ionizing radiation is given since 7th July 2017, all people being exposed to ionizing radiation are subject to certain dose limits. There is an additional limitation for radiation exposure of minors. Especially for children and adolescents, this effective dose needs to be kept as low as possible, because organs and tissues are not fully developed yet, and due to living longer than adults, the probability for the recognition of radiation-induced late damage is higher [10]. Radiation exposure appears in various situations, like medical diagnostics. Analysis in this study showing how often extraoral and intraoral X-ray diagnostics were performed on children and adolescents between 2008 and 2017. Accordingly, diagnostic criteria of the ICD and the OPS codes were used.

This analysis showed that extraoral X-ray procedures have become almost indispensable on

children and adolescents between 2008 and 2017, which results in an effective dose for each patient. Especially high was the diagnostic effort for patients of ages 14 to 15. Radiographs of the dental area are mainly classified as OPG and DVT/CBCT. Nevertheless, for the evaluation of DXT, only OPG images were taken into account. Often, elective means are taken to improve image quality if their use is less harmful than either substituting irradiation or rejecting examinations. It turned out that OPG was used even more frequently during the period considered for the present study, whereby in a separate group, the mean effective dose for patients of complete jaw development (around the ages of 14 - 18) was evaluated. The main reason for taking radiographs was orthodontic issues, which accounted for the largest proportion of patient collective. The examination rate increased by more than 50 %. In addition to this specialty, extraoral X-ray diagnostics in the dental area are also performed by radiology and oral surgery practices. The result emphasized the increased importance of extraoral extraoral X-ray diagnostics with an effective mean dose of 0.069 mSv. [28][36][37]

9. Future Directions in Research

1. Many questions still remain concerning the effects of X-ray imaging on children, especially those that manifest later in life, which can make them difficult to determine. Research into the health and developmental impacts of pediatric X-ray imaging is still in its early stages, and the multi-factorial impacts of environmental and lifestyle influences add to the complexity in understanding these effects. The total prior studies of pediatric X-ray effects are largely various types of cancer. An integrative methodological approach is proposed that draws on large-scale and long-term, multi-disciplinary data sources to control for the wealth of other factors that can be confounded with X-ray imaging. Geographic information systems will be used to identify marginal locations of residential boundary shift for non-radiation control children and remote access to extensive data sources will be used to reevaluate the results of the very few studies that perform any age or dose stratifications. This same approach is then expanded upon to consider the educational and other developmental impacts of pediatric X-ray imaging.

2. Public Health Relevance: Even though a very small portion of childhood diagnostic medical X-ray usage of the first half of the 20th century, there is an identical and statistically significant relationship between the number of U.S. children X-rayed in the 6th-15th months of the first 7 years of the 20th century and subsequent childhood cancer. Pediatric X-ray imaging has become substantially more efficacious because of technological innovations and has become much more frequent as well. An estimated 70 million U.S. children were X-rayed in the second half of the 20th century, and contemporary children are now X-rayed about five times as frequently as their grandparents were during a comparable period of youth.

10. Conclusion

X-ray physicals of the hand, fingers, feet and toes are a legal requirement for many child workers in the USA. The Department of Labor and Industries mandates that field workers between the ages of 14 and 18 must have an annual x-ray examination of the bones most susceptible to injury. These kids are often employed in agriculture. The idea is that x-ray examination would be used as a baseline pre-employment examination. The soft tissues are compared with the x-ray to determine possible injuries. In many other developing countries, kids x-ray physicals are required to ensure prospective child workers do not have healed breaks or congenital malformations associated with valuable body parts. Supposedly, these x-rays could only be done digitally. The Department of Labor and Industries stipulating the x-ray physicals for child field workers does not specify digital. Hence these child fields workers are typically x-rayed. X-rays are also an issue with employee schools, i.e., schools which train kids to get jobs. Interviewers claimed to have witnessed repeated x-rays, up to fifty, of the same body part, taken to document injuries over time. There are persistent x-ray rumors concerning children’s hospitals. In the US, the increase in odds of getting cancer from radiation exposure drops to the same natural background rate 20 years after last exposure. So high school football on the weekends while 16,

for example, would result in increased DNA impairment which would eventually exhibit as some form of disease. There are an estimated 86,000 new cases of cancer annually in the 15 to 39-year age group. This represents 11% of cancers diagnosed annually, making the 15-39 year age group second only to the over 40 age group as a target for documented cancer. For kid football this would mean more cancer for the first 6 or so years after high school and then declining. France bans cell-phone use in school for children under 15. French hospitals have been prohibited from x-raying children in response, as people believe electromagnetic devices damage biological systems. France's opinion is for safety, they are against kids x-ray use. No hospitals in France take x-rays of children. X-ray skin tests of genes are effective up to one year post exposure. Japan conducted autopsies of atomic bomb victims. The mean age of the LD leukaemia victims was 17 years. The median time of LD leukaemia development was 13 years. From LD leukaemia was the most prevalent form of leukaemia with odds rate 18.6. Germany performed the ulcerations of NRI on artificial skin and is currently employed to measure the penetration of emollients in cellulite tissue. The modulated electron radiation therapies were admitted in many countries in the treatment of different chronic skin diseases in the control of Bowen's disease and the discretion of occupational diseases as chromate dermatitis. Alberta seduced a number of patients with the ongoing provision of ethnic youth, including UV radiation rouges which were the waste of plastic surgery. Tunisian advise the increased manipulation of devices containing mercury and Germany limited the standard salon for the therapy of skin diseases using UVB wavelengths in the narrow spectrum. Temporal limits exposures of kids were not valid: exposures in utero, children with CT scans with doses corresponding to nuclear bomb brain radiographies. NRI treated athlete's foot creams, club foot, gravidas, infants with "sinus flush" pneumonia, pilots with air sickness, pre-puberty phosphorus burns treated with facial radiation, tweens with Osgood-Slatters. Hormesis is not valid because atomic bomb victims did not have increased life spans like low resident natural background dose housewires. EFIT: effective dose from collective nuclear cardiology studies which would have resulted in additional predicted radiation-induced cancers and predicted radiation-induced myocardial infarctions have been noted, i.e., soon after studies are done, after time period clubs no longer insurable to stay within radiation using accepted risk levels. The reminder campaigns that resolve around effective dose from studies were published based on the conclusion of additional cases of breast cancer had it been exposed to dose are effective.

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