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Patient awareness regarding radiation exposure during diagnostic imaging

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Abstract
The study focused on Knowledge and Awareness of Radiation Exposure and Safety Practice among patients who have been subjected to medical imaging in 3 selected hospitals in Bauchi. The aim of the research was to look into the Knowledge and Awareness of Radiation Exposure and Safety Practice of patients accessing medical imaging services in 3 hospitals in Bauchi.
Methodology: The number of patients which were taken for the research is 172. Research questionnaire was used as instrument for collecting data and statistical techniques such as frequency, mean and standard deviation were used for analyzing the data.
Conclusions: The patients' basic knowledge about the ionizing radiations was discovered. They are taught these things including the fact that the hospitals make use of ionizing radiation and determine the body parts of patients prior to performing surgery on them. They also revealed that the patients are aware of some side effects of ionizing radiations. They believed that ionizing radiations induce mutation, skin cancers and associated infections, skin irritations and the death of essential cells in the body. They were of the opinion that the side effects of these radiations can reduce the life span of an individual.
Recommendations: Enlightenment and seminars should be held for patients that are to undergo radiotherapy in hospitals, sufficient radiotherapy protective equipment should be placed in the hospitals for the patients to use when carrying out radiotherapy and staff in the Radiology Department and patients to undergo radiotherapy should strive to always wear protective equipment during the act.

Keywords: Radiation exposure, safety, patients, medical imaging, hospitals

Introduction

There are several factors including sex, education practice age and hospital type, geographical region that might influence good clinical practice and should be taken into consideration as good clinical practice depends on good knowledge, attitude and practice (KAP) and the three are practically interdependent. In general, 80% of exposure to ionizing radiation comes from natural sources of which radon gas is highest, while the rest comes from man-made sources, primarily medical X-rays (Leyton *et al*., 2014). Radiological examinations is a necessity in managing a patient as most of critical decisions are based solely on their interpretation despite biological adverse effects which vary based on dose and duration of exposure (Rehani, 2007) [20].
Potential risks of radiation: stochastic effect - probability of disease increases with dose, deterministic effect - severity of the disease increases with dose (Paolicchi *et al*., 2016). Thus the patients undergoing radiation should be in the knowledge to follow “As Low as Reasonably Achievable” (ALARA) concept in radiotherapy. One of the first areas of radiation safety management is one of orientation and enlightenment to the patients who are coming for radiotherapy treatment. Because the number of any diagnostic radiology procedure which is performed in a hospital increases exponentially with time (Alavi *et al*., 2016) [1], every person involved must know what and how to do about radiation, the safety aspects and how to treat dose optimisation problems to protect himself and patient from unnecessary exposure.
The study concentrated on Knowledge and Awareness of Radiation Exposure and Safety Practice among patients that have undergone Medical Imaging in 3 selected hospitals of Bauchi State. The study was conducted in just three health facilities: 261 Nigerian Airr
Due to financial constraint, they were forced to abandon the process to Force Reference Hospital Bauchi, Abubakar Tafawa Balewa University Teaching Hospital Bauchi and State Specialist Hospital Bauchi. This research work will be of vital importance to patients going for radiation procedures in health facilities not just in the 3 selected hospitals used for the research but also hospitals in Bauchi State and Nigeria at large. Educating on the dangers of radiation and ways to ensure safety as detailed in this research will aid in enlightening patients and non-patients about radiation and safety best practices**.**

A brief history of radiation.

In 1895, the x-ray was invented by Wilhem Roentgen, which made the internal organs of the body visible without making cuts in flesh (Goodman, 2005) [10]. In Würzburg in Germany, Roentgen was a Professor of Physics who was experimenting with electrical currents in cathode ray tubes. Although the glass tube he was using was covered in thick black cardboard, and the room was completely dark, Roentgen noticed that a nearby screen, covered in barium platinocyanide (a fluorescent material), became illuminated. He soon discovered that it was because of the radiation he was emitting from his apparatus. In addition, many different objects might be able to be penetrated by this radiation, and a projected image of his hand was projected on the screen, revealing a difference between opaque bones and translucent flesh. After the initial discovery, Roentgen used a photographic plate as his screen in a second experiment after one week, and x-ray imaging was born (Glasser, 2005) [9].

In January 1896 Roentgen started to give lectures on his invention, and a couple of weeks later he used an X-ray to locate a bullet in a patient's leg in Canada. Within a year, the world's first Radiology Department was set up at Glasgow Royal Infirmary, and quickly produced images of kidney stones and of a penny lodged in a child's throat. Shortly after, an American physiologist used a similar system to actively trace food going through the digestive system. In the following 20 years since Roentgen's discovery, x-rays became more popular, not only as a curiosity at the fair, but also as a very useful tool for medical diagnosis. The use of x-rays became a focus of medical diagnostic practice during the Boer War (1899-1902) and World War 1 (1914-1918) when they were used in the treatment of wounded soldiers. Roentgen was awarded the very first Nobel Prize for Physics for his discovery in 1901 (Glasser, 2005) [9].

The study of the properties of fluorescent minerals led to the first discoveries of natural radiation by scientists, such as Henri Becquerel and Marie and Pierre Curie, around the same time as Roentgen's work. When storing some such minerals (a uranium compound) in a drawer with photographic plates, Becquerel noticed that the latter became exposed, and concluded that this must be due to a type of highly penetrative radiation being given off by the mineral itself.4 As scientists began to look at this phenomenon more closely, they discovered that radioactive atoms are naturally unstable, and that in order to become stable, they emit particles and/or energy, in a process known as radioactive decay. During this time the Curies discovered polonium and radium. During World War 2, when the United States Navy embarked on an extensive ship-building program, radium was to be used extensively for industrial radiography, and become especially significant as a source of gamma radiation. Cobalt and iridium were made by man to be gamma radiation sources by 1946. These were more easily manufactured than radium and they were also more effective, so they soon superseded radium in all industrial uses (Dutreix, 2006) [8].

Understanding Radiation Risks

It will affect living tissue by altering cellular structure, and by damaging an organism's DNA. The extent of damage is influenced by several factors, such as the kind and dose of radiation absorbed, and its energy (Kleiman, Macvittie, Aleman, Edgar, Mabuchi, Murihead, Shore, &Wallace, 2012) [17]. Radiation damage occurs on a cellular level and the effects of small or even slight radiation exposure can be hard to notice and the body's repair mechanisms might be able to fix the problem. However, certain types of cells are more sensitive to radiation damage than others, and with greater exposures, cellular recovery might be less successful and turn cancerous. Radiation may destroy cells directly, in addition to harming their DNA. This obviously poses a risk, but may also offer medical possibilities, if the cellular death can be accurately targeted (e.g., cancer radiation therapy). (Hendry, 2012) [12].

Much knowledge of the risks of radiation comes from studies being conducted on the sur*vivo*rs of the atomic bombing of Nagasaki and Hiroshima, Japan, during the end of the Second World War. Other studies of radiation industry workers and of people receiving high doses of medical radiation have added greatly to the understanding of radiation. In fact, radiation is one of the most extensively studied causes of disease, and more is known about the mechanisms of radiation at the molecular, cellular and organ system levels than for virtually any other health stressor. This has allowed health physicists to determine 'safe' levels of radiation to be used for medical, scientific and industrial purposes to ensure that relative risk does not exceed that associated with other commonly used technologies (Barendson, Walter, Fowler &Bewly, 2003) [4].

Measurement of radiation

There are 4 separate but inter-related units for measuring radiation

1. Radioactivity is the quantity of ionizing radiation emitted by a material.
2. Exposure—radiation dose received from radioactivity in the air.
3. 3.Absorbed dose, the amount of radiation absorbed by an object or a person.
4. Effective dose, a combination of absorbed dose and medical effects for the type of radiation.

The absorbed dose can be determined by the total amount of radiation energy absorbed (Joules) per unit of mass (kg) of a tissue or organ that was affected. The most common unit associated with this is the Gray (Gy) which is equal to one J/kg. The Effective Dose (Sv or Sievert) is the same as the absorbed dose for beta and gamma radiation. For alpha radiation however, which is more damaging to the body, the Effective Dose is greater (Huda & Vance, 2001) [14].

Classifications of the effects of radiation

The biological effects observed in the irradiated subjects can be broadly classified into two types; Deterministic effects, mainly due to a "kill" effect on cells, and Stochastic effects, because of mutations that could lead to effects in the future, like cancer or hereditary mutations.

a. Deterministic effects: In this situation, skin necrosis and cataract, have a practical threshold dose below which effects are negligible or not evident, but as a general rule, severity of the effects increases with the radiation dose. The threshold dose is not an absolute number, but can vary between individuals.

b. Stochastic effects: These are the effects such as cancer and hereditary mutations, and the dose-response relationship is much less pronounced. Stochastic injury is the injury of the DNA backbone that is not repaired properly (Wakano & Iwasa, 2013) [23]. This effect can be produced by one X-ray photon but dose/exposure (linear no-threshold hypothesis) increases the risk of acquiring such injury. Stochastic risk is particularly challenging to address given its delayed and cumulative effect, lack of a "safe" threshold dose, and absence of a reliable biomarker.

Sources of radiation

Radiation can be natural or man-made and is a part of our life.

Naturally occurring radiation

Almost half of the radiation one is exposed to come from the environment around us. Radioactivity is present in many of the elements of the earth's crust, such as uranium, radium, polonium, thorium and potassium. The amount of exposure will vary depending upon the composition of the local soil and rocks. Another natural source is cosmic radiation. Earth is constantly exposed to radiation created by processes occurring in the sun, other stars and throughout the Universe. One of the most harmful forms of natural radiation is radon, which is a colorless, odorless, tasteless gas that is formed when the rocks and soils containing radium break down. Radon gas seeps into buildings from cracks and other openings in floors and walls. Inhaled radon gas can be a health risk because it is an alpha emitter. Radon gas is an alpha emitter and can be a serious health risk in buildings. Radon causes an estimated 20,000 cases of lung cancer per year, and is second only to smoking as a cause of lung cancer death. In particular, smokers who reside in a high radon home are at high risk (JAMA 2008) [15].

Radiation in medicine

Medical sources contribute an additional 50% of the radiation exposure under developed clinical sector in countries. The bulk of this is due to the application of conventional x-ray and CT scan techniques to the diagnosis of injuries and disease. Other procedures such as radiation therapy also use radiation to treat patients (Hricak, Brenner, Adelstein, Frush, &Hall, 2011) [13].

Basic principles for reducing the risk of radiation exposure in medical applications

The best method of minimizing patient risk in radiological examinations is the proper performance of the tests and through optimizing radiological protection for the patient. These are primarily the responsibility of the radiologist, the nuclear medicine clinician and the health physicist. The principle of patient protection is to obtain sufficient clinically useful diagnostic information with the minimum “reasonably” necessary dose. The dose routinely administered to patients (measured at the body surface, where the x-ray beam is entering the patient) has been found to vary by more than 100 times from one country to another. In all of these studies, most of the doses fall at the low end of the distribution, which clearly means that doses at the top end (e.g., greater than 70th or 80th canticle) are not easily rationalized as being within an optimal risk/benefit ratio (Dorr, 2010) [7].

A beneficial first step towards radiation risk-reduction for patients is therefore the development of an agreed protocol of diagnostic reference tables of appropriate radiation for different procedures and patient types (e.g. children vs. adult), at an institutional, regional or national level, based on observed international best practice. A program of this nature can be a good reference or education resource, but can also be used to help manage quality and quickly identify institutions or equipment that need to make corrections to minimize patient risk. Improvements to communications, transparency and implementation between radiologists, health physicists and audit teams can also make a significant difference to reducing radiation dose for patients, and enhancing the effectiveness of diagnosis (Gray, Archer, & Butler, 2005 [10]; McCollough, Branham, & Herlihy, 2011) [11, 18].

At the same time, there has been a dramatic rise in the use of fluoroscopically guided interventional procedures over the last 20 years. More and more of these procedures are being carried out in various specialties. In addition to these patients being exposed to significantly higher radiation doses than for diagnostic studies, the average radiation dose for a simple coronary intervention is 15 mSv, or 750 poster anterior chest X-rays, and for complex electrophysiological procedures is 50 mSv, or 2500 poster anterior chest X-rays. The immediate advantage of these procedures outweigh the risks of the high level of radiation applied. Despite this positive risk/benefit ratio, however, efforts should be made to reduce the risk. It is most important to emphasize Quality Assurance and Improvement Programs related to reducing exposure to patients and staff, continuous education, dose monitoring, correct use of equipment and protective garments/shields, and following the radiation safety guidelines recommended by different professional societies (John, 2010) [16].

Radiation risks and children

Radiation control is a concern both in the case adults and children. There are three distinct points for children and fetuses which have to guide actions, though:

1. Children are far more sensitive to radiation, as shown in many epidemiological studies of the population exposed.
2. Children's life expectancy is greater than that of adults, thus longer time for expression of radiation damage.
3. Children can be exposed to a larger dose than usual of radiation if the settings and doses of the equipment are not adjusted for the smaller body size.

Normal diagnostic radiology and normal nuclear medicine procedures are virtually without risk of causing the developing fetus or children to suffer from intellectual impairment or malformation caused by radiation. However, a small but significant risk of cancer induction does exist, and must be borne in mind even at typical diagnostic levels of radiation (<50mGy). A young child is several times more likely than an adult to develop radiation related cancers as a result of a diagnostic or interventional procedure.

Radiation dose reduction must therefore be a priority goal particularly for procedures carried out on children, or in pregnancy. The dose reduction in the pediatric use is mainly implemented by child-specific technical factors. Children and small image size requires the use of lower doses of the administered dose in nuclear medicine, and a very careful management in diagnostic radiology, to ensure that the radiation is focused as narrowly as possible on the area of interest (Paolicchi, Faggioni, Bastiani, Molinaro, Puglioli, Caramella, &Bartolozzi, 2014) [19].

Radiation risk and CT (Computed Tomography) use in pediatrics

Children's CT can be lifesaving for the diagnosis of illness and injury. In the United States alone, it is estimated that 5-9 million children receive an annual CT examination, and this rate is also rising with the growing use of the technique in common diseases as well as because of its technical advances. However, CT, which has many well known benefits, also has a severe disadvantage with significant radiation exposure. Although CT scan procedures make up just 12% of all diagnostic radiological procedures in the USA, they contribute to approximately 49% of the total radiation exposure absorption by the USA's collective population from all medical procedures (Andrade, Borras, Kkoury&Dias, 2012) [2].

The first research study to directly evaluate the risk of childhood cancer after CT scans revealed a clear dose-response relationship for both leukemia and brain tumors, with higher risks as cumulative radiation doses increase. It was determined that children were at three times the risk of brain tumors after receiving a cumulative dose of approximately 50-60mGy in the head. Similarly, the dose of radiation was shown to raise the risk of leukemia by the same amount when the bone marrow was exposed to radiation. In both cases, a comparison was made with a control population, with < 5mGy to the body regions of interest. These results were consistent with estimates from studies that followed the bombing of Japan in the atomic explosions (Brenner, Elliston, Hall, Berden, 2001) [6].

This is because the number of scans needed to achieve a cumulative dose of 50-60mGy will vary due to the type of CT scanner, the patient's size, their age, and the specific settings used on the particular scanner. You could get this amount of cumulative radiation from 2-3 head scans on typical pediatric CT doses. At typical pediatric current, two to three scans of the head would give this total radiation dose to the brain. For bone marrow, this is achieved after 5-10 procedures. The above is accepted scanning standard for the < 15 age group in the United States.

It is crucial to emphasize, however, that the absolute risks of cancer caused by CT scans are low. The absolute lifetime risk has been estimated in the literature to be approximately 1 cancer case per 1000 CT scans, and the maximum per 500 patients scanned. There is reason for ongoing use of CT in children. Again, however, critical consideration of the risk/benefit ratio is always crucial, and a strategy is needed to minimize patient exposure to medical radiation (Brady, Frush, Huda, Bront, 2007) [5].

If a CT is being used in the pediatric environment, there are a number of immediate and long-term steps that can be taken to help protect patients' safety. Process-wise, the specialists should

1. Use minimizing of procedures that have ionizing radiation, such as computed tomography (CT) scanning, avoiding non-ionizing procedures such as ultrasound or magnetic resonance imaging (MRI) where possible, especially in children.
2. Adjust exposure parameters for pediatric CT based on development of size/weight based protocols, and on the limitation of radiation to the smallest necessary area.
3. Adjust settings for pediatric CT to reflect the area being scanned - lower mA and/or kVp settings should be considered for skeletal, lung and some angiographic and follow up scans.
4. Reduce the scanning resolutions to ‘adequate for diagnoses’, 4. The highest definition images are not always necessary, but expose patients to more radiation**.**
5. Limit the use of multiple scans-usually taken at different phases of contrast enhancement, these are rarely necessary for diagnosis, but considerably increase the radiation dose and risk**.**

Magnetic resonance imaging (MRI)

An alternative form of imaging has been developed over the last 40 years that of magnetic resonance imaging (MRI). This employs radio frequency radiation, from the far left hand end of the electromagnetic spectrum shown earlier. This radiation is not high energy and cannot directly damage tissue or DNA. It should be noted however that if enough of this radiation is introduced to the body then it can cause tissue heating which could then cause damage and MRI scanners have strict limits on the quantity of radio frequency radiation in order to avoid this.

For the vast majority of MRI the radiofrequency magnetic field is used to excite the hydrogen nuclei, which then emit a signal that decays away in the time scale of tens of milliseconds. Signals on MR images depend first of all on the density of hydrogen nuclei or protons in the water or fat based tissues and then on many other factors including so called relaxation times, flow and diffusion. The weighting of the many other factors can be changed by changing the so-called MRI sequence and this gives great potential to MRI for characterizing different soft tissues or measuring blood flow for example. Cardiovascular MR sequences have been developed for a wide range of applications including cine imaging for measurement of cardiac function, various methods of characterization of the myocardium and identification of damaged tissues therein, measurement of myocardial perfusion, measurement of bulk blood flow and flow patterns in the heart and blood vessels and angiographic imaging of the vasculature. Potentially one of the most important applications is the ability of MR to image and characterize disease in the vessel wall, as this may allow for detection of cardiovascular disease at a much earlier stage than is currently possible. Imaging the vessel wall is difficult especially in coronary arteries which move during the cardiac and respiratory cycle. This is now possible, however, by using motion tracking techniques such as described by Scott *et al.* (2011) [21].

Methodology

The survey research design was adopted because the survey design allowed the study of possible relationships between variables. Thus the survey design was more suitable for the study as it allowed for data collection from a wider category as well as comparisons between variables. The instrument for data collection in this study will be Questionnaire. The research participants were patients drawn from radiotherapy services in three government-owned hospitals.

Major Findings

The patients have some basic knowledge about ionizing radiations. Such knowledge includes that they know that Ionizing radiations are used in the hospitals to ascertain the body parts of patients before surgeries are done on patients. They also know that Ionizing radiations are electromagnetic radiations which do not require material media for their transportation and some ionizing radiations are naturally occurring in the universe. The respondents mentioned that they know some side effects of ionizing radiations. They know that ionizing radiations cause mutations, skin cancers and related infections, irritation of the skin, death of vital cells in the body. They believed that the side effects of these radiations can decrease the life span of an individual.

The patients are aware of the safety measures put in place in the hospital to avoid excessive exposure to radiation. They are aware that radiation rooms are only open to authorized persons only in the hospital, Personal Protective Equipment for the process of radiography are available in the radiology of the hospital, safety signs and warnings present in the radiography wards pass adequate information concerning radiations safety and safety inscriptions in the hospitals are written in various languages.

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