2 LITERATURE REVIEW

2.1 INTRODUCTION

Computerized Tomography (CT) scan is a less-invasive medical test that helps clinicians diagnose and treat various medical conditions. It combines special x-ray equipment with sophisticated computers to produce multiple images for the inside of body. Since its introduction in the early 1970’s, it has become an important tool in the medical imaging to supplement x-rays and ultrasonography. The number and variety of CT examinations have increased steadily over the years because it has many advantages to offer radiology investigations and its uses and applications are significantly increasing and is expected to raise in the future. This increase in use and application of CT has the unwanted outcome of a significant increase in population effective dose (Brenner DJ et al 2007). The development of CT technology in terms of its power, utility, flexibility, ease of use and image quality has resulted in an exponential increase in its application in virtually all fields of clinical practice. With increase in CT utilization, concern of radiation hazards from CT also increases (Moifo B et al, 2017). Sensible use of CT modality is required, ensuring that individuals are protected when undergoing medical exposures by strict adherence to radiation protection principle of justification, optimization and minimization. (ICRP, 2007). An essential part of ensuring medical exposures are optimized is the establishment, use and regular review of diagnostic reference levels (DRLs) for medical radiological procedures. DRLs were first proposed by International Commission on Radiation Protection (ICRP). This concept of DRLs was adopted by IAEA in ,of which Botswana is a member state. DRLs help to ensure that the radiation dose received by patients for a specific type of medical radiological procedure is optimized. Currently in Botswana there are no published CT DRLs despite being an IAEA member state since 2002. There is therefore an urgent need of establishment of DRLs in Botswana

**2.2MEDICAL IMAGING BRIEF OVERVIEW**

Medical imaging is the technique and processes of creating visual representation of areas inside the human body for clinical purposes such as seeking to reveal, diagnose or examine injury, dysfunction or pathology. In 1895 William Roentgen discovered x-rays, determining that they can pass through human tissue leaving bones and metal visible. X-rays were then soon used clinically to assess bone fracture and gun wounds. Since this time medical imaging has evolved to include a range of techniques and modalities, each with their own advantages and disadvantages. Each of these techniques sends a signal into the body to see how the body reacts with the signal and how that reaction affects the original signal or a return signal. The most common modalities are X-ray radiography, Computed tomography, mammography, fluoroscopy, magnetic resonance imaging, ultrasound and nuclear medicine.

In x-ray radiography x-ray signals are used to produce a 2D image. Ultrasound imaging uses high frequency sound waves to produce dynamic visual images of organs tissues or blood flow inside the body. It does not require the use of ionizing radiation nor the injection of nephrotoxic contrast agents. Magnetic resonance imaging uses a powerful magnetic field and radiofrequency pulses to produce detailed images of the body’s internal structure, as cross sectional images or slices. MRI does not emit any ionizing radiation. Fluoroscopy uses x-rays to produce real time moving images (e.g. heart pumping or food swallowing) using contrast media such as barium or iodine. Mammography uses low energy x-rays to produce detailed images of breast to screen for breast cancer, locate suspicious tissue prior to biopsy or lumpectomy. In CT high x-rays dose is used to produce images where the x-ray source and detector are both rotating around the body during examination so that multiple images can be acquired resulting in 3D visualization. Nuclear medicine uses targeted radiopharmaceuticals, small amounts of radioactive material to image pathological or physiological processes.

**2.21 MEDICAL USE OF IONIZING RADIATION AND POPULATION RISK**

Medical use of ionizing radiation is amongst the longest established applications of ionizing radiation. According to United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the estimated worldwide annual number of diagnostic and interventional radiological procedures (including dental) was 3.6 billion, the estimated number of nuclear medicine procedures was over 30 million and the estimated number of radiation therapy was over 5 million (UNSCEAR, 2008). The number of such procedures has continued to increase since then. These medical uses bring considerable public health benefits. Medical uses of ionizing radiation take place in a variety of settings, including hospitals, medical centers, health clinics, specialist clinics, and dental practices. Medical uses of ionizing radiation involve all three categories of exposure: occupational exposure for those involved in the performance of radiological procedures; medical exposure, primarily for the patients undergoing the radiological procedures, but also for careers and comforters and for volunteers’ subject to exposure as part of a programme of medical research; and public exposure for members of the public, such as in waiting rooms. The requirements for radiation protection and safety differ according to the category of exposure, so it is important that the exposure of persons is categorized correctly.

**SUMMARY OF RADIATION PROTECTION PRINCIPLES AS APPLIED TO OCCUPATIONAL EXPOSURE AND PUBLIC EXPOSURE IN COMPARISON WITH MEDICAL EXPOSURE**

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| **Occupational exposure and Public exposure** | **Medical exposure** |
| **Justification of practices:** Adopting a practice that entails exposure to radiation only if it yields sufficient benefit to the exposed individuals or to society to outweigh the radiation detriment. | **Justification of practices:** The diagnostic or therapeutic benefits of exposure are weighed against the radiation detriment they might cause, with account taken of the benefits and risks of available alternative techniques that do not involve medical exposure. |
| **Optimization of protection and safety:** Providing the best available protection and safety measures under the prevailing circumstances, so that the magnitudes and likelihood of exposures and the numbers of individuals exposed are as low as reasonably achievable, economic and social factors being taken into account | **Optimization of protection and safety:** In diagnostic and interventional medical exposure, keeping the exposure of patients to the minimum necessary to achieve the required diagnostic or interventional objective. In therapeutic medical exposure, keeping the exposure of normal tissue as low as reasonably achievable consistent with delivering the required dose to the planning target volume |
| **Limitation of doses:** Doses to individuals are limited (for occupational exposure and public exposure). | **Limitation of doses:** Does not apply to medical exposure |

Medical exposure differs from occupational and public exposure in that persons (primarily patients) are deliberately, directly and knowingly exposed to radiation for their benefit. In medical exposure, applying a dose limit is inappropriate, as it may limit the benefit for the patient; consequently, only two of the radiation protection principles apply — justification and optimization. Justification plays the role of gatekeeper, as it will determine whether or not the exposure will take place. If it is to take place, the radiological procedure should be performed in such a way that radiation protection and safety is optimized.

JUSTIFICATION

This aspect of justification is the process of determining whether the use of the given radiological procedure is expected to yield benefits to the individuals who undergo the procedure and to society that outweigh the harm (including radiation detriment) resulting from the procedure.

**Optimization of protection and safety**

The optimization of protection and safety, when applied to the exposure of workers and of members of the public, and of careers and comforters of patients undergoing radiological procedures, is a process for ensuring that the magnitude and likelihood of exposures and the number of individuals exposed are as low as reasonably achievable, with economic, societal and environmental factors taken into account. This means that the level of protection and safety would be the best possible under the prevailing circumstances. As is the case with justification, the application of the requirements for optimization to the medical exposure of patients and to the medical exposure of volunteers as part of a programme of biomedical research requires a special approach. Too low a radiation dose could be as bad as too high a radiation dose, in that the consequence could be that a cancer is not cured or the images taken are not of suitable diagnostic quality. The medical exposure should always lead to the required clinical outcome.

**Diagnostic reference levels**

IAEA defines DRLs as an important tool and should be used for optimization of protection and safety for diagnostic medical exposure

**Local facility DRLs**

Establishing local facility DRLs is the first step in the cyclical DRL process. All undertakings have a requirement under the regulations to establish local facility. Local facility DRLs should be established for procedures or clinical tasks quoted by national DRLs (when these procedures are undertaken locally). However, some procedures or clinical tasks may not be included in the national DRLs as they may be unique to a facility, hospital or medical specialty and expertise. Where this is the case, particularly when these procedures involve high patient doses, local facility DRLs for such procedures or clinical tasks should be established by the undertaking. A typical value should be used for setting an individual undertaking’s local DRLs. A typical value is defined as the median value of the distribution of DRL quantities for medical radiological procedures. Dose management systems, where available, can be used to contribute to the establishment and review of local facility DRLs. However, its application may not be practicable in all installations, for example, dental surgeries, due to cost. It should be noted that there is no regulatory requirement for undertakings to acquire or use such software however the availability and use of such systems demonstrates an example of proactive dose monitoring and prospective optimization. Retrospective analysis of radiology information systems (RIS) and hospital information systems (HIS) may allow access to dose data on large numbers of patients to facilitate the establishment of local facility DRLs. Manual recording of patient doses may also be used by undertakings to contribute to the establishment of local facility DRLs. Undertakings must consider the resources available and establish appropriate dose data collection methods to enable the establishment and review of local facility DRLs

**Using local facility DRLs**

The first step in using local facility DRLs is comparison with the national DRL value. If this does not exist for a particular procedure or clinical task, similar internationally established DRL values or peer reviewed literature can be consulted. If local facility DRLs exceed or are substantially lower than DRL values, an investigation must be conducted to ensure optimal practices and intended outcomes are delivered. Under the regulations, undertakings are required to retain records of DRL reviews and any corrective actions carried out for a period of five years and make these records available to HIQA on request. Failure to do so is an offence under the regulations. What value should be used when establishing facility DRLs? A median value should be used when setting an individual undertaking’s facility DRLs and should generally be used for all undertakings. (To find the median, the data should be arranged in order from least to greatest. If there is an even number of items in the distribution of the dose quantities collected, then the median is found by taking the mean (average) of the two middlemost quantities collected. If there are an odd number of items, the median is the middlemost quantity)

**Potential pitfalls in comparing your typical dose values (medians) with published DRLs?**

Published DRLs can prove useful in allowing comparison of median dose values in your facility, for a particular imaging system. There are several problems which can occur:

* Published DRLs values from other countries (with potentially different imaging practices and technology) may not be relevant to your particular circumstances;
* The types of examination or procedure specified for the published DRLs (as being with or without detailed clinical indications) may not be directly relevant to your particular practice;
* Published dose values may not have been obtained using the same methodology (e.g. total values or values per projection or per series) or in relation to the same standard condition like CT dosimetry phantom (diameter of 16 cm or 32 cm), or may be given in different dose quantity or unit;
* Published DRLs values may not be expressed in a different dose quantity or dose unit;
* The patient sample (number of patients and their body size) in the published survey may be different;
* Advances in technology, such as post-processing and iterative reconstruction in CT, will need to be taken into account when updating DRLs.