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Research Article

Determination of radiation dose levels to which parotis and spinal cord (C1-C2) regions exposed in computed tomography brain imaging

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Abstract: The adverse effects of ionizing radiation are well known among researchers today. However, ionizing radiation is commonly used for diagnostic purposes in many medical imaging techniques. One of the most important devices used for diagnostic purposes is computed tomography (CT). It is vital to determine radiation doses, ensure patient safety, and minimize potential health risks.This study aims to determine the doses of radiation to the parotid glands and the spinal cord (C1-C2) region during computed tomography (CT) brain imaging. To achieve this goal, the exposure of these areas to different radiation levels was simulated and measured. This study contributes to the improvement of CT brain imaging procedures and the reduction of patients' radiation exposure risks. The Alderson Rando phantom was used for assessing radiation exposure. TLD-100 dosimeters were strategically placed in the spinal cord (C1/C2) region of the phantom's 6th section. The study was conducted at Istanbul University Cerrahpaşa Nuclear Medicine, and the Alderson Rando phantom was provided by the Department of Radiation Oncology. The evaluation of research findings was performed at the Çekmece Nuclear Research Center. The study revealed average doses of 4.585 mSv for the spinal cord (C1/C2) region, 5.425 mSv for the left parotid, and 5.29 mSv for the right parotid during CT imaging.

1. Introduction

Radioactive atoms are atomic nuclei with unbalanced numbers of protons and neutrons. These atoms tend to emit radiation by releasing their excess energy to reach a stable structure. This energy makes the nuclei more stable [1]. Although X-rays are an important tool in medical imaging, exposure to high

doses can lead to serious problems such as cancer, radiation burns and hereditary disorders. Therefore, determining and controlling the radiation dose of patients is extremely important. The annual dose limits currently recommended by International Radiation Protection (ICRP) are 20 mSv for workers exposed to radiation and 5 mSv for patient relatives [2]. Computed tomography (CT) brain imaging is one of the most widely used medical methods today. This method allows comprehensive examination of important systems such as the spinal cord and brain, which is an important tool in diagnosis and surgical interventions. However, patients may be exposed to X-rays during this imaging procedure. During CT brain imaging, the spinal cord (C1-C2) region and parotid glands are of particular importance. The parotid glands, which are salivary glands, may be sensitive to radiation [3]. The spinal cord is an important part of the body's central nervous system and radiation can be dangerous because it can damage this area [4]. Researchers who are aware of the harmful effects of radiation on human health use phantoms that represent the human body to conduct their research. The Alderson Rando phantom is one such phantom that is often preferred to simulate radiation exposure due to its similar properties to the human body [5]. ART (Alderson Radiation Therapy) phantoms are designed to determine radiation doses and evaluate the performance of medical imaging devices. These phantoms are made of a special acrylic material that mimics the anatomy of human tissue. They aimed to mimic the radiation exposure levels of various parts of the body. ART phantoms are widely used to verify the safe and effective functioning of medical devices and play an important role in the development of healthcare technologies. Radiation dosimeters measure and record levels of radiation exposure to humans or the environment. Thermoluminescence dosimetry (TLD) is used to determine radiation doses. The thermoluminescent materials it contains enable TLD dosimeters to absorb radiation. Safety and control of radiation exposure are important thanks to these dosimeters [6].
In this study, the radiation exposure doses of the spinal cord (C1-C2) region and parotid glands during CT brain imaging were determined, and the exposure of these areas to radiation levels was simulated and measured. It is very important to determine the radiation dose to ensure the safety of patients and to minimize health risks.

2. Materials and Methods

TLD dosimeters, Alderson Rando Phantom (Figure 1), TLD-100 dosimeters (Figure 2) and 128-section CT (Figure 3) devices were used to make optical measurements. TLD-100 dosimeters (Figure 2) are used to analyze the effect of radiation doses on specific areas and to understand how radiation is distributed in the body. These dosimeters are placed in appropriate places on the TLDs Alderson Rando Phantom, which are used to learn the radiation dose. Alderson Rando Phantom is manufactured in accordance with ICRU-44 standards, is 155 cm tall and weighs 50 kg [7]. Produced from acrylic material, this model contains detailed anatomical structures and is designed to represent the human body [8]. This device, which has a density similar to natural human tissue, aims to simulate the effects of radiation on the human body. There are special needle holders in the sections inside the phantom, and these sections determine the areas where the TLD dosimeters will be placed. This phantom is used to simulate areas exposed to radiation emitted by medical imaging devices. The TLD Dosimeters used are 0.89 mm thick, 3.2 mm wide and 3.2 mm in size and contain components such as LiF (Lithium fluoride), Mg (Magnesium) and Ti (Titanium) [9]. These dosimeters have thermoluminescence properties that release the accumulated radiation dose when exposed to radiation. It is processed in special calibration ovens to increase their sensitivity. These materials are placed in a specific area and used to measure and record radiation exposure. It is also used to measure and analyze how radiation is distributed in the body and the doses of the areas it affects by placing TLD-100 dosimeters in certain anatomical areas. Figure 4 shows sections of the phantom. A TLD-100 dosimeter is placed in a separate area for background measurement. This is an area where radiation exposure is minimal and natural radiation will be measured. Other TLD-100 dosimeters are placed in the relevant areas in section 6 on the Phantom. (Figure 5) Spinal cords were used for C1 and C2, 2 for the right parotid and 2 for the left parotid. Siemens brand 128-slice Computed Tomography device located at Istanbul University Cerrahpaşa Medical Faculty Hospital was used for scanning in automatic mode. Cross-sectional images were obtained with high-resolution radiation scanning, and structural details in different anatomical regions were visualized in detail during the imaging process. The data set included data recorded by TLD-100 dosimeters placed on specific areas of the Alderson Rando Phantom during the CT scanning process. These data sets include data from TLD-100 dosimeters that measure radiation doses and cross-sectional

Figure 1. *Alderson Rando Female Phantom (ART)*

Figure 2. *Thermoluminescent Dosimeters*

Figure 3. *CT*

CT data obtained during the medical imaging process. TLDs are scanned with the optical reading device at TENMAK. Obtained data, measurements, dose values and other relevant information are reported.A calibration process was performed to ensure correct operation of TLD dosimeters. In this process, magnesium and titanium alloy lithium fluoride MTS-100 TLDs were calibrated using the Cesium-137 radioactive source [10]. 40 TLDs were irradiated at a dose of 5 mSv in the plate phantom in a special TLD cassette holder and then stored for at least 24 hours. Next, TLDs were read one by one using the Harshaw 4500 TLD reader system and Elemental Correction Coefficient (ECC) values were found. ECC values were examined at a 1% sensitivity level and used to determine poor dosimetry. After the calibration process, 6 dosimeters became ready to be used at critical points. It was also emphasized that all dosimeters were annealed according to the manufacturer's instructions and that this process was important to increase sensitivity and eliminate instability. The location of the Parotid and Spinal Cord (C1-C2) regions in the 6th section of the phantom was determined. Numbered TLDs were placed in designated regions. Brain imaging was performed using the CT part of the PET CT device at Istanbul University Cerrahpaşa Nuclear Medicine Unit. (Figure 5) Brain images were taken in CT automatic mode and TLDs placed in the Parotid and Spinal Cord (C1-C2) regions were exposed to radiation. TLDs are placed in the TLD reading device and the recorded data is read (Figure 6).

Figure 4. *Sections of the phantom*

Figure 5. *Placing the phantom into the device*

Figure 6. *Reading TLDs*

3. Results and Discussions

In this study, we examined the measurement of radiation dose in the brain region in the spinal cord (C1-C2), left and right parotid glands. The results obtained show dose differences between different tissues in the brain. In particular, the low radiation dose measured in the spinal cord region reflects the effectiveness of protective measures and treatment methods in this area. The spinal cord is a critical part of the body's central nervous system and is extremely sensitive to radiation. Therefore, low radiation doses in this area should be considered an important indicator in assessing the adequacy of protective measures. The intensity graph at the TLD reading level can be seen in Figure 7 and Figure 8. High radiation doses to the left and right parotid glands are also notable. These glands are located in the head and neck region and play an important role in saliva production. High radiation doses in these areas may have potential effects on salivation, which in turn may have effects on oral hygiene. Therefore, evaluation of the radiation dose to the parotid glands should be taken into account during the planning and implementation of radiation therapy. In the experiments, minimum and maximum values were determined for both spinal cord (C1/C2), left parotid and right parotid. According to the results of the experiments, results were obtained by region. Min, max and average values are given in Table 1. Radiation dose level is as in Figure 9.

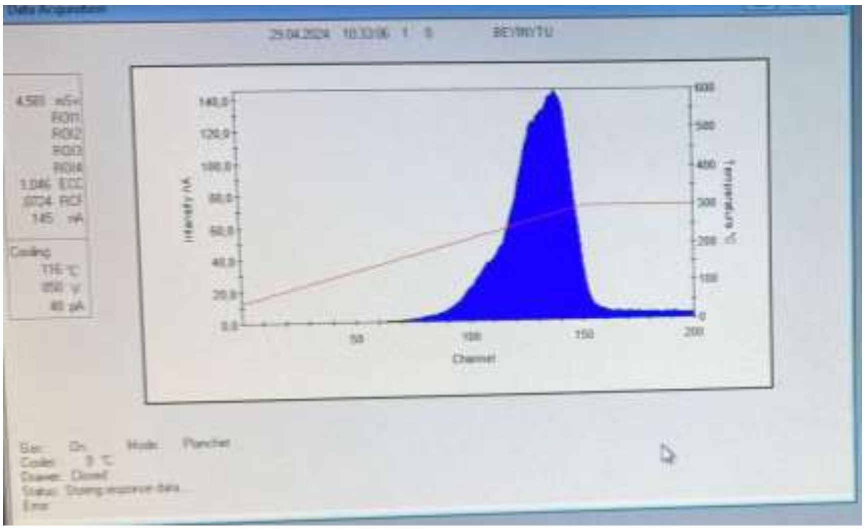

Figure 7. *Result of TLD placed in the spinal cord region*

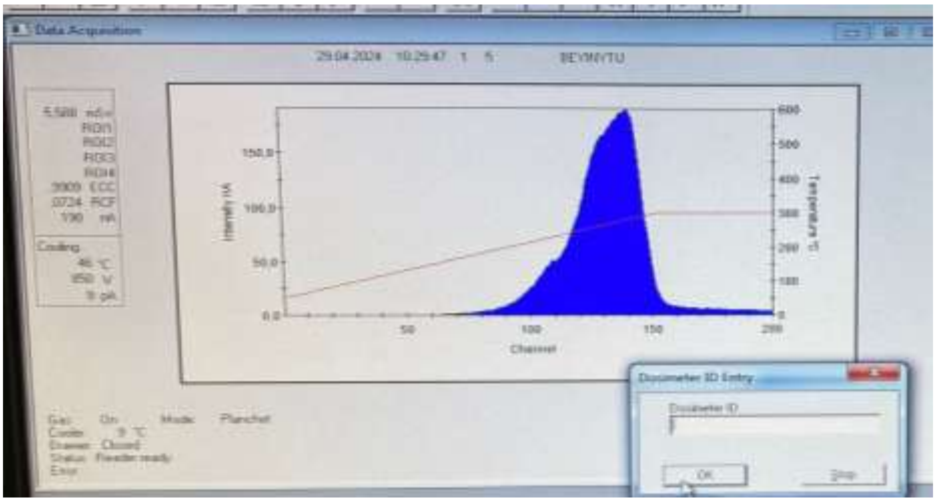

Figure 8. *Result of TLD placed in the left parotis region*

Table 1. *Values of the radiation dose that affects the area.*

Area	Average Value (mSv)	Minimum Value (mSv)	Maximum Value (mSv)
Spinal Cord (C1/C2)	4.585	4.58	4.59
Left Parotis	5.425	5.16	5.69
Right Parotis	5.185	4.79	5.58

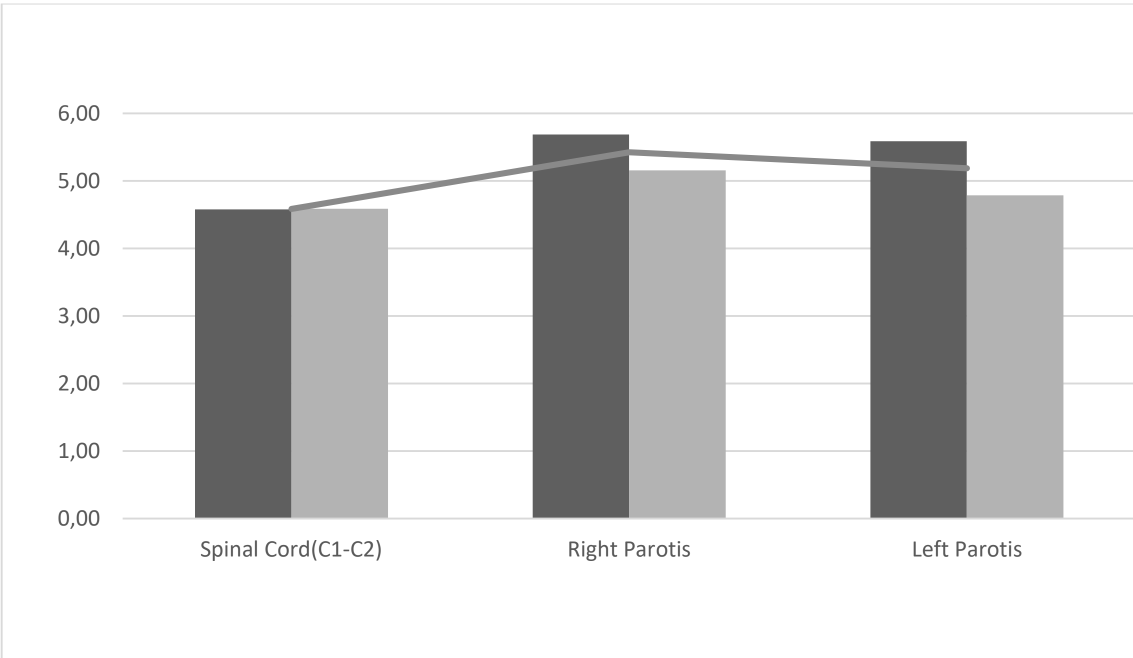

Figure 9. *Average values schema*

This study provided important information for determining radiation exposure levels during CT scans. This information helps both patients and healthcare professionals exposed to radiation understand the importance of safety in medical imaging processes to reduce potential health risks. However, the limitations of this study and its contributions to future research should also be evaluated.

The energy emitted by radioactive nuclei to become stable is called radiation. (11) We are exposed to radiation in almost every area of our daily life. Computed tomography (CT) is a common imaging

modality. In CT scans, the radiation dose to which the patient is exposed may vary depending on factors such as tissue thickness, X-ray beam properties, location of the organ, voltage and current applied to the X-ray tube, scanning time, scanned area size, scanning mode and section thickness. These factors can usually be adjusted by the operator in the IT control room. However, typically these parameters are kept constant in patients of normal height and weight [11-13]. Depending on the CT imaging parameters, there may be changes in the radiation dose in the patient's immediate environment due to the radiation dose to which the patient is exposed and the radiation emitted from the patient.
Radiation protection refers to the measures taken to protect people and the environment from the effects of harmful radiation. These precautions include reducing exposure to ionizing radiation as much as possible. This includes unnecessary avoidance of radiation sources and activities that involve ionizing radiation. It also includes measures such as the use of personal protective equipment, regular measurement and monitoring of radiation levels, taking appropriate measures to prevent radiation leaks, and providing regular training to workers and the public. These precautions may vary depending on the type and source of radiation. The radiation dose limit amounts recommended by TAEK for the public and radiation authorities are as in the table 2.

Tablo 2. *Radiation dose limits proposed by TAEK [14]*

		Radiation Officers	**Society**
Effective Dose	Annual Average	20 mSv/year	1 mSv/year
Equivalent Dose	Annual	50 mSv/year	5 mSv/year
	Eye	150 mSv/year	15 mSv/year
	Skin	500 mSv/year	50 mSv/year
	Hand-Feet	500 mSv/year	50 mSv/year

One of the important contributions of this study is the improvements made in calculating the amount of radiation to which patients are exposed during computed tomography (CT) scans. In this way, the level of radiation exposure of patients during CT scans was better understood and the possible effects of this exposure on human health were more clearly emphasized.
However, it is noteworthy that there is not enough research in the literature for important anatomical regions such as parotid and spinal cord. More studies are needed on radiation exposure during CT scans of these areas. This study may be a starting point for determining radiation exposure levels during CT scans of these critical anatomical regions.
For the safety of patients, radiation exposure levels of important anatomical structures such as the parotid and spinal cord during CT scans need to be evaluated and determined in more detail. This will help make medical imaging procedures safer and minimize risks to patients. We believe that future research will allow us to better understand and improve the risks associated with radiation dose in these specific areas.

4. Conclusions

In this study, we focused on measuring the radiation dose in the brain region in the left and right parotid glands along with the spinal cord (C1-C2). The results obtained show significant dose differences between different tissues in the brain region. In particular, the low radiation dose measured in the spinal cord region reflects the effectiveness of protective measures and treatment methods in this area. The spinal cord is a critical part of the body's central nervous system and is therefore extremely sensitive to radiation. Therefore, low radiation doses in this area should be considered an important indicator in assessing the adequacy of protective measures.
High radiation doses to the left and right parotid glands are also notable. These glands are located in the head and neck region and play an important role in saliva production. High radiation doses in these areas may have potential effects on salivation, which in turn may have effects on oral hygiene. Therefore,

evaluation of the radiation dose to the parotid glands should be taken into account during the planning and implementation of radiation therapy.

The findings from this study provided significant progress in determining and evaluating radiation dose to the brain region. However, the limitations of this study and its contributions to future research should also be considered. In particular, it is thought that studies with larger samples will allow a more comprehensive evaluation of the radiation dose in the brain region. Additionally, it is thought that studies comparing and improving the effectiveness of different radiation treatment methods may provide further guidance to clinical practices. The findings obtained may contribute to future research further increasing knowledge in this field and developing strategies to control radiation exposure and improve treatment outcomes. Radiation is interesting field and it has been studied and reported in literatüre [15-24].

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
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