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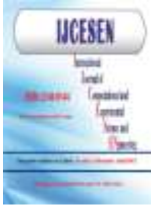

Determining the Radiation Dose Levels the Kidney is Exposed to in Kidney Stone Fragmentation Procedures

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Abstract:

This study examines the radiation dose levels to which the kidney is exposed during kidney stone fragmentation procedures that utilize scopy imaging. The assessment was conducted using the Alderson Rando phantom and Thermoluminescent Dosimeter (TLD). The study examined various exposure parameters and measured the radiation dose to the kidney over time. The results suggest a direct correlation between exposure duration and radiation dose, emphasizing the need to monitor radiation levels during scopy interventions, especially due to the kidneys' sensitivity to radiation. Future research should concentrate on optimizing scopy settings to minimize radiation exposure while ensuring diagnostic accuracy and patient safety.

1. Introduction

Radiation is primarily divided into ionizing and non-ionizing categories based on its effects on matter. Ionizing radiation induces energy deposition and ionization in living organisms and materials. It is further categorized into natural and artificial forms, depending on its source of generation. The distinction between artificial and natural ionizing radiation holds significant importance for human health, thus prompting extensive academic exploration in this domain. These investigations have utilized diverse methodologies [1-16].

Artificially generated radiation finds extensive applications in diverse sectors, including nuclear technology and healthcare. Ionizing radiation, a key component, is utilized for both medical treatment and diagnosis. Within the healthcare domain, X-rays, discovered by Wilhelm Conrad Roentgen in 1895, stand out as the most commonly employed ionizing radiation for disease diagnosis. Despite the swift integration of X-rays into medical science, their potential harmful effects were not initially comprehended fully. Subsequent studies brought to light the detrimental effects associated with prolonged exposure to X-rays.

In the field of radiology, devices utilizing ionizing radiation, including traditional X-rays, computed tomography (CT), and scopy, are frequently employed. Scopy enables the real-time acquisition of images for dynamic systems. Continuous or instantaneous imaging of dynamic events, such as organ movements or blood flow, can be achieved by amalgamating sequential images. Comparable to X-ray apparatus, scopy systems comprise an X-ray tube and detection systems. Contemporary camera systems are widely utilized in scopy imaging for image detection.

In scopy imaging systems, the duration of operation of the X-ray tube is regulated by the physician. During surgeries, physicians initiate scopy as required, and X-rays are continuously emitted for a specific duration. As a result, the patient experiences continuous exposure to ionizing radiation. Following a certain period, scopy operation ceases, and the same procedures are reiterated. The length of time the X-ray tube remains active during surgery varies based on the type of operation and several factors, spanning from seconds to minutes.

Presently, scopy devices play a pivotal role in orthopedic implant surgeries, offering surgeons improved assessments of anatomical structures and synthetic materials. Despite the benefits of utilizing scopy devices in medical settings, the potential risks associated with X-ray exposure cannot be overlooked. Despite the implementation of various protective measures, such as lead aprons, thyroid protectors, and lead goggles, cumulative adverse effects persist. Scopy devices can emit varying levels of radiation, potentially resulting in irreversible harm in healthcare settings.

Ionizing X-rays employed in scopy present deleterious implications for human health, potentially affecting fetal development if relevant. The ramifications of ionizing radiation exposure on humans are classified into somatic and genetic repercussions. Somatic effects encapsulate impacts beyond those on reproductive cells and are subdivided into deterministic and stochastic consequences. Deterministic effects necessitate exposure to a substantial radiation dose, surpassing a defined threshold, to materialize in humans. In contrast, stochastic effects, comprising thyroid cancer, lung cancer, and leukaemia, can arise from prolonged exposure to low radiation doses, devoid of a precise threshold level.

Reducing radiation exposure in all radiological imaging systems is crucial for ensuring radiation safety. The biological consequences of radiation exposure hinge on multiple factors, including the type, energy, penetrative capacity, and ionization potential of the radiation. Additionally, the physical, biological, and effective half-lives of radioactive materials, along with the distance between the biological system and the radiation source, play significant roles in determining radiation effects.

The radiation dose exposure levels of various organs in the body are typically assessed for computed tomography imaging systems. Some of these studies are conducted using Thermoluminescent Dosimeters (TLD), while others rely on simulation methods such as Monte Carlo simulations [17-23].

Kidney stones that reach a certain size can be fragmented into smaller pieces using various methods. During stone fragmentation, determining the precise location of the stone is achieved through scopy imaging. However, scopy imaging exposes the patient to radiation. This study aims to determine the radiation dose levels to which the kidney is exposed during scopy imaging. In the study, the radiation dose to the kidney was determined over time as scopy emitted radiation under physician control for different durations.

2. Material and Methods

In this study, the radiation dose level to which the kidney is exposed in scopy applications with various exposure parameters was determined.

The radiation dose level was assessed using the Alderson Rando phantom and Thermoluminescent Dosimeter (TLD). The Rando Phantom, a human-equivalent phantom primarily employed for dosimetric calculations in radiation oncology, was utilized. The organ densities and overall density (0.985 g/cm^3) of the phantom closely resemble those of human organs. For this study, the female version of the Rando phantom, comprising 32 individual sections and corresponding to a height of 155 cm and a weight of 50 kg, was utilized (Fig 1).

The TLD-100 dosimeters utilized in the study have dimensions of 3.2 mm in width, 3.2 mm in length, and 0.89 mm in thickness. These dosimeters are composed of LiF, Mg, and Ti.

Figure 1. *Alderson Rando phantom*

Both the calibration and post-CT imaging evaluation of the dosimeters were conducted at the Secondary Standard Dosimetry Laboratory (SSDL) located in the Çekmece Nuclear Research Center. The SSDL is equipped with a Harshaw 4500 model reader that connects to a computer and TLD card, capable of reading chips using the WinREMS software. The TLD reader heating process was carried out with liquid nitrogen gas.

The TLD chips, designed with lithium fluoride doped with magnesium and titanium (LiF:Mg,Ti) crystals by Harshaw, underwent calibration with a standard Cs-137 gamma source at the SSDL using the reader calibration factor (RCF) and element correction coefficients (ECCs) according to the WinREMS software guide. The calibrated TLDs were placed in the TLD transport apparatus.

Following the completion of calibration procedures and the setup preparation, TLDs were positioned on the kidney area. The X-ray tube remained open for 20 seconds, and irradiation was conducted (fig-2). Subsequently, the TLDs were replaced with new ones, and separate irradiations were carried out for 40, 60, 80, 100, 120, 140, and 160 seconds. Scopy imaging was performed using a Philips-brand scopy device available at Hisar Intercontinental Hospital. The irradiated TLDs were then removed from the phantom, and reading procedures were conducted at the SSDL laboratory.

Figure 2. *Scopy Imaging*

Scopy procedures are employed for differing durations across various surgical procedures. In this study, a simulation of a right kidney stone-breaking operation was conducted. Therefore, the scopy device was focused on the right kidney to emit X-ray shots.

3. Results and Discussions

In this study, the focus was on evaluating the radiation doses encountered by the kidneys during scopy imaging sessions. The comprehensive analysis presented in the table 1 below depicts the varying radiation doses concerning different durations of exposure: The obtained results were also plotted in Figure 3. The data reveals a consistent trend wherein longer exposure durations correlate with higher radiation doses inflicted upon the kidneys. Notably, both the minimum and maximum radiation doses show an upward trajectory as the time of exposure prolongs. The average radiation dose also follows this pattern, indicating a cumulative effect over the course of the fluoroscopic procedure.

A noteworthy metric is the normalized average radiation dose per minute, which elucidates the rate of radiation absorption by the kidneys over time. Although there are slight fluctuations in this parameter, the general range hovers between 7.3 and 8.6 mSv per minute across the various time intervals.

These findings underscore the critical importance of closely monitoring radiation doses during fluoroscopic interventions, especially considering the kidneys' sensitivity to radiation exposure. It is imperative to implement robust strategies aimed at mitigating radiation exposure without compromising diagnostic accuracy or procedural efficacy. Future research endeavors could delve deeper into exploring specific techniques or technological advancements designed to optimize radiation doses during scopy procedures while prioritizing patient safety and well-being. Such initiatives hold promise in enhancing clinical outcomes and minimizing the potential risks associated with ionizing radiation exposure.

These findings underscore the imperative for stringent protocols aimed at minimizing radiation exposure without compromising diagnostic accuracy or procedural efficacy. Initiatives such as dose optimization strategies, real-time monitoring, and personnel training play pivotal roles in safeguarding patient and staff welfare during fluoroscopic interventions. Moving forward, continued research efforts are warranted to explore innovative technologies and procedural modifications that further mitigate radiation risks while ensuring optimal diagnostic outcomes. By fostering collaboration between clinicians, physicists, and technologists, we can advance the field towards safer, more effective fluoroscopic practices, ultimately enhancing patient care and safety in the clinical setting. The strong correlation observed (R^2=0.98) between the duration of X-ray tube exposure and the resultant radiation dose underscores the robustness of the scopy system. This consistency in radiation levels is pivotal for healthcare professionals, facilitating a more predictable assessment of radiation exposure during various phases of orthopedic procedures. The high correlation coefficient reaffirms the system's reliability in maintaining a proportional relationship between exposure duration and radiation dose, empowering clinicians to make informed decisions regarding the potential risks associated with prolonged scopy use.

Table 1. *Radiation Dose to the Kidney*

Time (second)	Min Dose (mSv)	Max Dose (mSv)	Avarage Dose (mSv)	Normalized Avarage Dose (mSv/min)
20	1.984	2.828	2.452	7.356
40	4.013	5.129	4.572	6.858
60	6.198	8.296	7.218	7.218
80	8.179	11.029	9.613	7.210
100	10.986	17.982	14.426	8.656
120	13.493	16.237	15.291	7.646
140	14.600	19.489	17.021	7.295
160	17.291	22.253	19.614	7.355
180	19.917	25.062	22.434	7.478

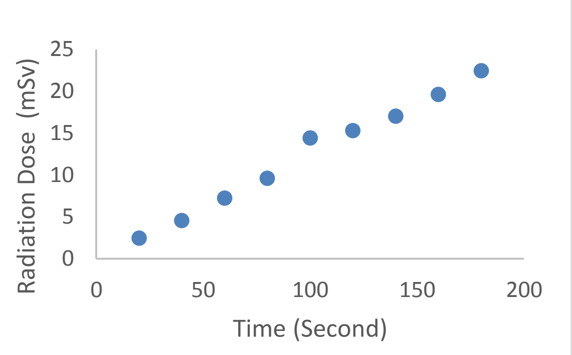

Figure 3. *Radiation Dose to the Kidney*

The visual representation of these correlations contributes to the broader discourse on radiation safety by offering a clear depiction of how radiation doses accumulate over time. Clinicians can leverage this information to enhance their awareness of the temporal dynamics of radiation exposure, guiding them in optimizing scopy settings and minimizing unnecessary radiation exposure to sensitive anatomical structures.

4. Conclusions

The findings of this study emphasize the critical need for stringent protocols to minimize radiation exposure during scopy procedures, especially concerning the kidneys' sensitivity to radiation. Strategies such as dose optimization, real-time monitoring, and personnel training are essential for ensuring patient and staff welfare. Continued research efforts should explore innovative technologies and procedural modifications aimed at further mitigating radiation risks while optimizing diagnostic outcomes. Collaboration between clinicians, physicists, and technologists is key to advancing fluoroscopic practices and enhancing patient care and safety in clinical settings.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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