"AN OVERVIEW - RADIATION DOSE TO PATIENTS DURING SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHY (SPECT)"

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Abstract:
The objective is to evaluate the radiation dosage received by the patient during regular clinical single-photon emission computed tomography-computed tomography (SPECT-CT) and quantify the increase in comparison to SPECT alone. Incorporating CT into nuclear medicine imaging, specifically in the form of SPECT-CT, results in an elevated radiation dose for the patient. In fact, the effective dose from CT often surpasses the effective dose from RP in numerous cases. Therefore, it is necessary to effectively employ and optimize the protocols of SPECT-CT in order to maximize the advantages for patients. Implementing a dose-tracking software provided a simple method for optimization. In addition, we can readily compute the primary dosimetric parameters and monitor their patterns on a daily basis to promptly implement any required corrective measures in real-time.

Key Words: RADIATION DOSE - SINGLE PHOTON EMISSION - COMPUTED TOMOGRAPHY

ملخص:

الهدف هو تقييم جرعة الإشعاع التي يتلقاها المريض أثناء التصوير المقطعي المحوسب بالتصوير المقطعي المحوسب بانبعاث فوتون واحد (SPECT–CT) وقياس الزيادة مقارنةً بالتصوير المقطعي المحوسب (SPECT) وحده. يؤدي دمج التصوير المقطعي المحوسب في تصوير الطب النووي، وتحديدًا في شكل SPECT–CT، إلى زيادة جرعة الإشعاع للمريض. في الواقع، غالبًا ما تتجاوز الجرعة الفعالة من التصوير المقطعي الجرعة الفعالة من RP في العديد من الحالات. ولذلك، فمن الضروري توظيف وتحسين بروتوكولات SPECT–CT بشكل فعال من أجل تعظيم المزايا للمرضى. يوفر تنفيذ برنامج تتبع الجرعة طريقة بسيطة للتحسين. بالإضافة إلى ذلك، يمكننا بسهولة حساب معلمات قياس الجرعات الأساسية ومراقبة أنماطها على أساس يومي للتنفيذ الفوري لأي تدابير تصحيحية مطلوبة في الوقت الفعلي.

الكلمات المفتاحية: الجرعة الإشعاعية – انبعاث فوتون واحد – التصوير المقطعي المحوسب

Introduction:

Utilizing ionizing radiation for medical imaging inherently carries a potential danger of causing detrimental health effects, including radiation-induced cancer, to the individuals undergoing examination. This is especially relevant for patient studies utilizing hybrid positron emission tomography (PET)/CT or single photon emission computed tomography (SPECT)/CT devices. These devices combine two imaging techniques, both of which have the potential to expose patients to relatively high levels of radiation. The first technique is positron or single photon emission tomography, which is used for functional imaging. The second technique is CT, which is used for anatomical imaging [1, 2]. The specific functions and viewpoints of these hybrid imaging technologies in the field of healthcare are currently a subject of discussion [3].

Based on a recent global survey [4], most SPECT/CT centers fail to fully exploit the diagnostic capabilities of the CT component in dual-modality systems. The primary reason for this is the prevalence of first- generation SPECT/CT systems in clinical use, which are primarily equipped with a lower-quality CT component. This component is supposed to correct for attenuation of the emission data and provide anatomical localization of radiotracer uptake. Nevertheless, the majority of the latest second- generation SPECT/CTs are furnished with cutting- edge CT technology, which includes a high- performance X-ray tube and an elongated detector system positioned along the axis. This technological advancement will not only enhance the clinical versatility and diagnostic certainty in hybrid SPECT/CT imaging, but it will also significantly elevate radiation exposure to patients. Hence, it is crucial to meticulously align the diagnostic necessities with the demands for radiation protection [5].

The effective dose is not suitable for epidemiological evaluations or detailed retrospective investigations of individual radiation risks [6]. To assess the potential consequences of radiation exposure on individual patients, specific data characterizing the exposed individual must be used.

The conventional methods for generating risk estimates that are particular to age, sex, and organ are founded on excess relative risk (ERR) or excess absolute risk (EAR) models. The ERR model postulates that the additional risk is directly proportionate to the baseline risk, which refers to the risk of developing a particular cancer without exposure to radiation [6].

The measurement of organ doses resulting from the ingestion of radiolabeled chemicals, such as SPECT radiopharmaceuticals, is not possible. Instead, these doses can only be approximated using biokinetic and dosimetric models [7]. Biokinetic models elucidate the process of absorbing and retaining radioactive substances inside specific areas of the body where they collect, as well as their subsequent elimination from the body. They are utilized to determine the quantities of nuclear changes occurring in the source regions, which are necessary for calculating the dose to target tissues using dosimetric models. Typically, biokinetic models are structured as compartment models. When the tracer is injected into the bloodstream, the initial compartment represents the pool of blood. From there, the radio-pharmaceutical is transported to other tissue compartments through active or passive processes. These tissue compartments represent the regions where the tracer accumulates and is primarily excreted through urine and feces [7].

DISCUSSION:

The progress in nuclear imaging technology has facilitated individualized anatomical and functional imaging. The advancements in hybrid imaging systems, such as Single Photon Emission Computed Tomography/Computed Tomography (SPECT/CT), Positron Emission Tomography/CT (PET/CT), and PET/Magnetic Resonance Imaging (PET/MRI), as well as the progress in software-based image reconstruction, have shifted clinicians' focus from traditional imaging to nuclear matters [8,9]. SPECT/CT is crucial in the current day for the detection of various disorders, especially those related to the heart. SPECT/CT is a viable option for conducting functional and anatomical cardiac research because to its great availability and inexpensive cost [10,11].

In cardiac SPECT/CT, diagnostic CT scanners play a crucial role in performing attenuation correction, coronary artery calcium scoring, and coronary CT angiography efficiently and rapidly [12]. The integration of SPECT and CT information, as well as picture fusion, has numerous clinical uses. SPECT/CT is commonly used to evaluate coronary artery disease (CAD) by performing myocardial perfusion imaging (MPI) utilizing radiopharmaceuticals labeled with 201Tl and 99mTc. This evaluation is done under both stress and rest settings [13].

As cardiac SPEC/CT expands globally, it is important to evaluate and minimize patient exposure to ionizing radiation from both CT and SPECT scans, following the ALARA principle (as low as reasonably achievable). Given these circumstances, accurate dosage estimation is crucial. Hybrid SPECT/CT systems have two distinct dosimetry concerns related to emission and transmission imaging. Various approaches, such as Medical Internal Radiation Dosimetry (MIRD), International Commission on Radiological Protection (ICRP), and Monte Carlo (MC), are used in nuclear medicine to measure dose. Additionally, there are other tools available for calculating dose [14]. The dose in CT is determined by metrics such as CT dose index volume (CTDIvol), which is measured in mGy, and dose length product (DLP), which is measured in mGy.cm. According to the International Electrochemical Commission (IEC), these metrics should be provided before and after the examination in the form of a dose page or image [18]. However, CTDIvol has a significant drawback in that it cannot accurately reflect the actual dosage received by a patient. This is due to its failure to consider the individual patient's size and the varying levels of attenuation within the patient's body. The American Association of Physicists in Medicine (AAPM), in collaboration with the International Commission on Radiation Units (ICRU) and Measurements and the Image Gently campaign of the Alliance for Radiation Safety in Pediatric Imaging, introduced a new method called "Size Specific Dose Estimate" (SSDE) to improve the accuracy of assessing patient doses [16]. SSDE considers patient size by taking into consideration the patient's physical dimensions. The AAPM report provides conversion factors for four different measurements: anterior-posterior (AP), lateral (Lat), AP + Lat, and effective diameter. These measurements can be obtained from either a localizer radiograph or transverse CT images. These conversion factors can be used to calculate the SSDE for phantom sizes of 16 cm and 32 cm by applying them to the CTDIvol. Comparing alternative imaging modalities and optimizing radiation dose and risk assessment are important considerations in the context of effective dose [16].

It is customary to use SPECT, along with CT, for attenuation correction (AC) in myocardial perfusion imaging (MPI) [17]. The utilization of CT imaging in assessing coronary artery disease has been scientifically validated to yield superior picture quality and enhanced diagnostic precision. CT imaging provides a greater amount of photons, leading to improved image quality compared to standard transmission scans. However, this also means that patients receive larger doses of radiation. When evaluating the advantages and disadvantages of employing CT for attenuation correction in SPECT.

The literature reports a wide range of patient doses for standard SPECT/CT imaging procedures because to variability in image capture parameters and patient characteristics. Previous investigations have documented comparable fluctuations in patient dosages for MPI examinations conducted with SPECT/CT devices [21,22]. In SPECT, the patient dose is influenced by the kind of tracer, AA, imaging procedure, and patient size. On the other hand, in CT, the patient dose is affected by the x-ray tube voltage (kVp), tube current (mA), and scan length [22]. Therefore, conducting research that involve measuring patient doses is crucial for establishing the most effective methods and following the optimization principle of radiation protection. The collection of patient dose measurements from various imaging facilities, countries, and regions has played a significant role in improving imaging methods and setting diagnostic reference levels. The objective of this study was to determine the amount of radiation that patients are exposed to during the CT portion, the SPECT portion, and the whole SPECT/CT MPI scan [22].

The effective doses (EDs) obtained from single- photon emission computed tomography (SPECT) and computed tomography (CT) in this investigation are approximately 10 mSv and 1 mSv, respectively. The combined radiation dose for SPECT/CT myocardial perfusion imaging (MPI) is 11 mSv. These values are consistent with those reported and suggested in the literature [19,20]. Nevertheless, these results are significantly lower compared to the previously documented ranges of 1–15 mSv from CT and 6–37 mSv from SPECT for normal SPECT/CT examinations [23]. The incorporation of CT for attenuation correction only slightly increases the total effective dose (ED) and the associated risk of developing radiation-induced cancer. However, this increase is still much smaller compared to the danger involved in the 2-d stress/rest SPECT protocol. Hence, the advantages of employing CT images for attenuation correction, resulting in enhanced picture quality and a more precise diagnosis of coronary artery disease, surpass the additional risk posed by CT. The disparities in effective doses (EDs) obtained from single-photon emission computed tomography (SPECT) and computed tomography (CT) scans among male and female patients mostly arise from variations in the conversion factors employed for ED calculation. The primary element responsible for these variations in conversion factors is the presence of breast tissue in female patients [24]. Given the absence of notable disparities in AA or CTDIvol between the two genders, we can conclude that female patients have a slightly heightened risk from the identical imaging method. When female patients are referred for SPECT/CT MPI tests, it is necessary to adhere to more rigorous radiation dose optimization measures.

The observed favorable connection between AA (abdominal adiposity) and BMI (body mass index) provides clinicians with reassurance that imaging techniques are conducted using appropriate methods. This strategy can be regarded as adhering to the individualized AA model for MPI, which has been promoted as a technique for optimizing radiation dose [18]. Conversely, the CTDIvol values remained constant for a certain scanner model, irrespective of patient variables. This method has the potential to result in excessive radiation exposure for young patients and a decrease in image quality for larger people. Furthermore, it has been noted that the producers of the scanner have established fixed settings for obtaining attenuation correction images on CT, as documented in the literature. This could be attributed to the fact that nuclear medicine technologists, who do MPI investigations, may lack formal training in CT imaging, which is a relatively recent addition to the field of nuclear medicine. To address this problem, one possible solution is to incorporate CT imaging into the undergraduate curriculum for nuclear medicine technology or provide additional training courses for technologists already in practice. Once technologists understand the impact of different image acquisition and reconstruction settings on image quality, they will be capable of conducting patient-specific image acquisition. Our college has included CT imaging within the undergraduate curriculum of nuclear medical technology over the past 3 years. Replacing the use of predefined acquisition settings with patient-specific parameters, along with the implementation of automatic exposure management and radiation dose modulation technologies, can effectively decrease the effective dose (ED) from CT scans [18,22]. The duration of a CT scan, and therefore the amount of radiation exposure, typically varies based on the specific area being examined, such as the myocardium in the case of MPI. Limited the scanning length to the necessary region of interest will decrease the effective dose from CT imaging. Additional reductions in dosage can be accomplished by utilizing a lower voltage for the x-ray tube during the acquisition of CT images. Nevertheless, it is essential to examine any alterations in the CT numbers of the tissue resulting from a decrease in x-ray tube voltage [25].

The biological consequences of ionizing radiation are associated with the total accumulated effective dose. Doses exceeding 100 mSv have been associated with random effects such as the formation of cancer. However, the effects of lower radiation levels, which are commonly encountered in diagnostic X-ray imaging, are not well understood [26]. While other theoretical models incorporating dose-threshold and hormetic effects have been suggested, the prevailing linear no-threshold model, which posits that every level of radiation carries some degree of risk, is largely embraced [26].

Therefore, it is important to follow the principle of "as low as reasonably achievable" when conducting procedures involving ionizing radiation. Physicians who order and perform cardiac imaging diagnostic tests should have knowledge about the radiation doses involved and strategies to minimize them [27].

In our experience, the implementation and more frequent utilization of a prospective procedure for cardiac CT resulted in a noteworthy reduction in the effective radiation dosage for this examination. This finding aligns with the findings of other researchers. Regarding SPECT, it is not surprising that the dose variation over time was minimal, as there were no modifications in the study protocol throughout the research period [27].

Obese patients had considerably greater mean effective radiation doses in all the examined tests. Cardiac CT and ICA exhibited a nearly twofold rise in radiation dosage when compared to individuals with normal weight, making this particularly evident. The impact of BMI was less significant in the SPECT registry. When choosing the right diagnostic exam, it is important to consider this factor, particularly for individuals who are more susceptible to radiation exposure, such as women and younger patients [28]. Therefore, it is important to focus specifically on the dose of cardiac CT, as the patients in our registry who underwent cardiac CT were considerably younger than those in the ICA and SPECT registries.

While prior studies have mostly focused on comparing radiation doses among three distinct diagnostic tests, it is important to consider additional factors when comparing various imaging modalities. Due to the need for iodinated contrast, caution should be exercised when performing cardiac CT and ICA in patients with impaired renal function or a history of allergies. Additionally, the likelihood of coronary artery disease (CAD) is an important consideration, as SPECT and ICA are more suitable for patients with a higher probability of CAD [29,30].

Conclusion:

It is important for nuclear physicians, physicists, and technologists to understand that it is possible to get an optimum radiation dose for patients without compromising image quality. This can significantly reduce the chance of developing cancer caused by radiation exposure. The implementation of automated techniques for collecting radiation dosage data facilitated a rapid and comprehensive analysis of a substantial volume of data, while also offering a straightforward means of optimization. The addition of SPECT-CT to SPECT alone results in a significant and highly variable increase in effective dose, often surpassing the effective dose of the radiopharmaceutical itself. Therefore, in order to decrease the likelihood of random effects, it is advisable to only conduct SPECT-CT in situations where SPECT results are inconclusive or require anatomical correlation. Understanding this rise in exposure could also aid in elucidating the examination to the patients. Furthermore, during the execution of SPECT-CT, it is essential to implement all necessary precautions to minimize both the radiopharmaceutical dosage and the CT effective dosage, adhering to the idea of achieving the lowest reasonably possible levels.

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