



(RESEARCH ARTICLE)



## Computed Tomography Dose Index in Computed Tomography (CT), Positron Emission Tomography (PET) and Single Photon Emission Computed Tomography (SPECT)

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### Abstract

More deaths occurred without proper diagnosis and medication in the early days. Thus, proper diagnosis is necessary to overcome the issues faced in the early days. The identification of the nature of an illness or other problem by symptom examination is diagnosis. Significant advancements were made in the 20th century in combating disease by uncovering its causes and understanding how it spreads. This process of identification is performed through advanced technologies in the medical field. (i) Computed Tomography (CT), (ii) Positron Emission Tomography (PET), along with (iii) Single-Photon Emission Computed Tomography (SPECT), are some of the advanced technologies. The combination of CT with PET and SPECT has revolutionized the imaging capabilities in clinical diagnostics, providing detailed anatomical and functional information. Concerns about radiation exposure, especially the Radiation Dose (RD) linked to CT scanning, are raised by the use of CT in these hybrid imaging modalities. Thus, by utilizing the aforementioned advanced technologies, this study focuses on the crucial field of analysis of the Computed Tomography Dose Index (CTDI). An indicator of the RD is the CTDI, which is primarily used to measure the radiation dosage absorbed during a CT scan. Thus, the overview of CT, the importance of CT-PET and SPECT, and the significance of CTDI and their Dose Indexes (DI) are explored in this review.

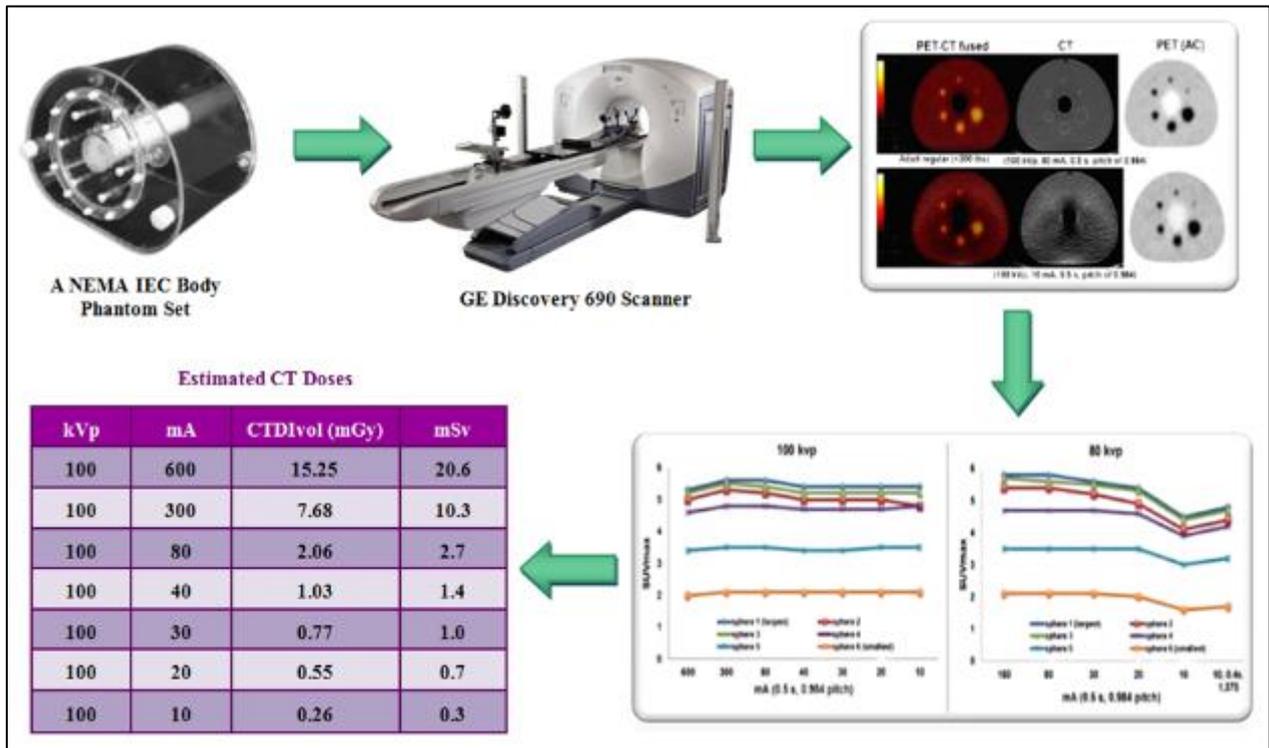
**Keywords** Computed Tomography; Positron Emission Tomography; Single-Photon Emission Computed Tomography; Computed Tomography Dose Index; Scanning; Diagnosis and Disease

### 1. Introduction

Currently, several diseases are spreading worldwide. Widespread illness, often leading to lasting medical complications and even death, is largely driven by disease. There are enormous affected individuals; hence, enhancements in early diagnosis are needed. Human health is hugely impacted by the potentially curable stage.<sup>1</sup> When analogized to other sorts of problems associated with medications along with surgical procedures, diagnostic errors commonly occur in the early days. Patients with multiple comorbidities often require complex diagnoses, which can increase their risk of misdiagnosis. Misdiagnosis poses a serious risk to the health of older patients while also burdening healthcare systems with unnecessary clinical interventions and the management of iatrogenic conditions.<sup>2</sup> This occurs due to the unavailability of advanced equipment models. Throughout the 20th century, the dominant models shaping medicine, along with Human health, have undergone significant changes in contemporary Western society.<sup>3</sup> These models facilitate accurate diagnosis in healthcare. The proper diagnosis of equipment promotes health care through the curing of (i) disease, (ii) illness, (iii) injury, and (iv) physical and mental impairments in people. To investigate the advantages of this technology, several systems have been constructed. This advancing technology has made significant strides in recent decades.<sup>4</sup> One of the advanced technologies is used to offer suitable therapies to patients. The introduction of CT

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scanning has transformed radiology, initially using scanners dedicated solely to the head.<sup>5</sup> CT is a technique for computerized X-ray imaging where a narrow X-ray beam quickly rotates around the patient's body, focusing on them and sending signals that the computer decodes to create slice or cross-sectional pictures. Compared to standard X-rays, the slices, known as tomographic images, can give a physician more precise information.<sup>6</sup> The slices display particular CT images that are derived from CT-PET and Single-Photon Emission Computed Tomography (SPECT). Combining the benefits of PET and CT scans, the CT-PET scan serves as a comprehensive diagnostic tool. PET/CT imaging has been widely used in neurology to evaluate medication therapy and diagnose disorders, oncology, and cardiology.<sup>7</sup> Figure 1 illustrates the process of defining the minimum ultra-low-dose CT level necessary for the accurate attenuation correction of 18F-FDG PET/CT.



**Figure 1** Determining the minimal required ultra-low-dose CT dose level for reliable attenuation correction of 18F-FDG PET/CT

SPECT is another scan technology. The purpose of SPECT in this analysis is to show how the internal organs work. SPECT is an advanced imaging technique that is essential for both monitoring and diagnosing a variety of conditions. SPECT generates a 3-dimensional (3D) map of gamma ray emissions from radionuclides. Images offer functional information about organs and tissues, making it possible to identify functional anomalies prior to physical alterations.<sup>8</sup> Thus, the study concentrates on the DI in CT-PET and SPECT. Utilizing CTDI maximizes Images quality for precise diagnosis and treatment planning, while assisting in maintaining radiation dose within acceptable bounds.<sup>9</sup> A dosimetry parameter utilized in CT imaging is referred to as CTDI. A homogenous cylindrical Polymethyl Methacrylate (PMMA) is used to quantify CTDI. The "2" diameter sizes of a typical PMMA phantom are 32 cm for adult bodies and 16 cm for adult heads and paediatric bodies.<sup>10</sup> Screening the level of RD delivered to patients in CT-PET and SPECT imaging procedures is the purpose of using the CTDI in CT-PET scans and SPECT. Thus, healthcare providers can balance the significance of precise diagnostic dosing evaluation with the need to reduce radiation exposure for the benefit of patient safety and care. Figure 2 explains the review's architecture.



Figure 2 Architecture of the review

## 2. Development of Research Questions and Article Selection Strategy

Research Questions (RQs) are a preliminary methodological stage in conducting research. The following categories are used in this article to explain the RQs:

- In this article, the RQs guided the review article in an efficient way.
- In this article, RQs are framed based on the review objective.
- RQs provided an efficient direction for collecting the related articles and also helped in the analyses of the relevant data based on the objective.

### 2.1. Developed RQs

The RQs are framed in this review based on the title provided and the parts of the objectives that are of particular interest. The following sections demonstrate the five categories into which the RQs are divided. Based on this, the classification of the RQs is explained in Figure 3.

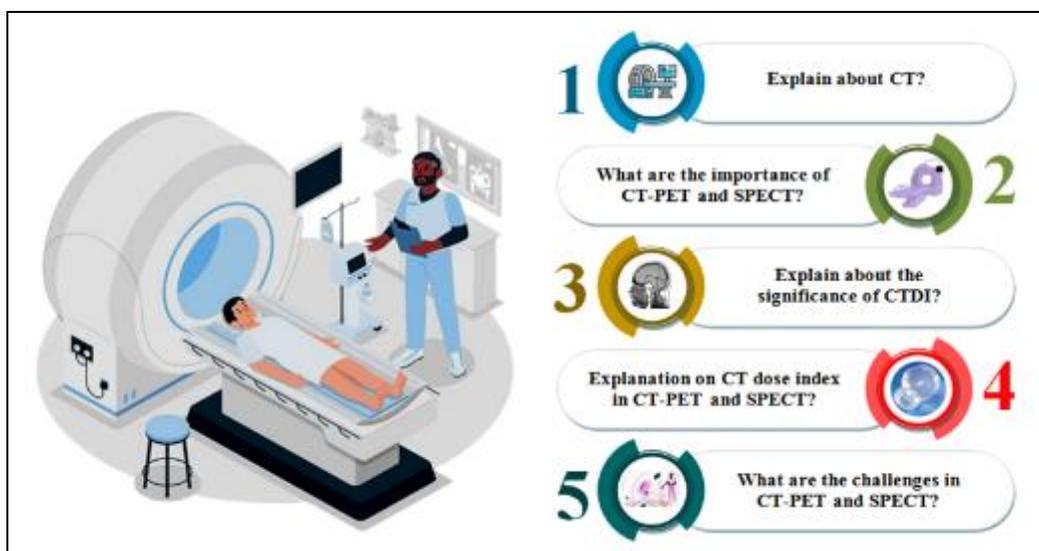


Figure 3 Developed RQs

## 2.2. Article selection strategy

Article selection refers to the procedure for selecting the proper kind for evaluation. The final result and calibre of the job are greatly impacted by this procedure. Each sort of article selection used in this study has its own distinct personality.

## 2.3. Eligibility Criteria

In the eligibility criteria, essentially, there are two kinds of processes at play. The procedures are criteria for admission and exclusion. This method effectively determines the kinds of research that are included and withdrawn.

The included parts of this review were,

- The related articles that stated the CT were included.
- Articles reporting on the CT-PET scans and SPECT were included.
- Articles published between 2015 and 2024 were included.

The excluded parts of this review were,

- The articles that reported on magnetic resonance imaging scans and X-rays were excluded.
- The article, other than CTDI, was excluded from this study.
- The articles published before 2015 were excluded.

## 2.4. Resources of Search

The areas of the search and the selection of appropriate, pertinent content are the main focus of search resources. The primary goal of the resource search is to select the appropriate search and locate the crucial evidence for the study being presented. This section provides an explanation of the search resources, including databases, sources, database insights, and paper selection.

- Sources: Academic search engines, including ScienceDirect, Elsevier, Springer, IEEE Xplore, Google Scholar, Taylor & Francis, and others, were utilized to locate relevant papers. Thus, a correlation was found between the data and the research goal. The search focused on research publications from 2015 to 2024 that addressed the CTDI in CT, PET, and SPECT.
- Databases: Important databases were utilized to find the publications, including Scopus, Science Citation Index Expanded (SCIE), and Web of Science (WOS).
- Database Insights: Dove Medical Press Ltd, Health for All Nations, and Lippincott Williams and Wilkins Ltd. were shown to be different from other significant datasets. Journals of science and proceedings of conferences were available in Dove Medical Press Ltd, Health for All Nations, and Lippincott Williams and Wilkins Ltd; so, they were the best resource for researchers.
- Paper selection: A total of 60 papers were chosen for this evaluation. The papers were identified and chosen based on the specified criteria.

There is a systematic approach available for selecting the article for the research. The articles are selected for this review based on the PRISMA methodology. The PRISMA approach, which is a collection of rules and checklists intended to assist scientific writers in publishing systematic reviews and meta-analyses. It stands for Preferred Reporting Items for Systematic Reviews and Meta-Analyses. PRISMA principles enable researchers to thoroughly uncover, assess, and synthesize previous research, thereby reducing bias and enhancing the validity of the findings. This structured approach also facilitates comprehensive coverage of relevant literature, ensuring that all pertinent studies are considered. Therefore, in Figure 4, the PRISMA is shown.

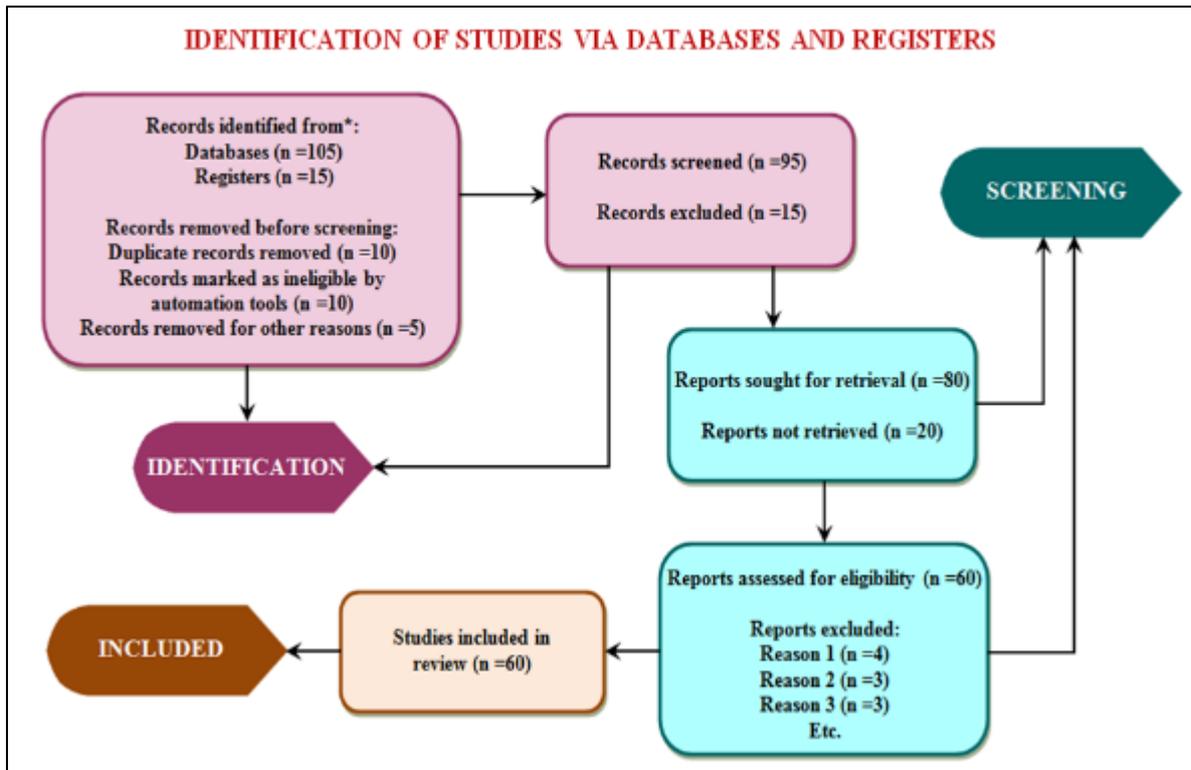


Figure 4 PRISMA Framework

The results of this literature survey's search are summarized in Figure 5 after an analysis of the search's specifics.

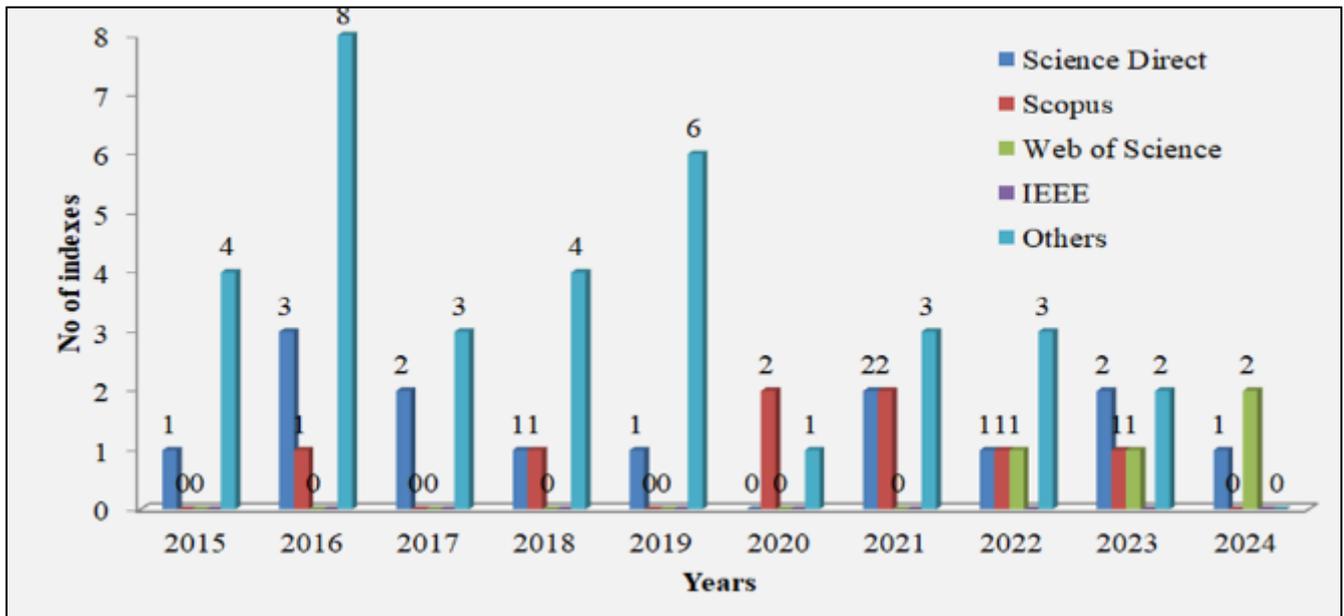


Figure 5 Search Outcomes

### 3. Literature Review

A method of medical imaging that produces a CT scan is a type of fine-grained imaging of the interior of the body. CTDI is a standardized metric for assessing a CT scanner's RD output, enabling users to appraise radiation output across diverse CT scanners. Here, 2 types of scans, namely CT-PET and SPECT scans, are analyzed. CT-PET is an imaging test that can aid in revealing the metabolic or biochemical activity of tissues and organs. SPECT is a nuclear medicine test

that shows brain function (what the brain is doing), whereas CT and MRI scans show brain structure (what the brain looks like). Thus, this review explains the perspective of CT along with the significance of CT-PET and SPECT. Next, a detailed examination of the importance of CTDI is analyzed to examine the radiation. It also investigates how radiation exposure is kept within safe limits. Moreover, CT DI in CT-PET is used to analyze key body functions, such as metabolism. It also assists doctors in assessing the functionality of organs and tissues. Likewise, to examine how the internal organs look like, the CT DI in SPECT is analyzed. A SPECT scan could show how well the organs work. Lastly, the challenges related to CT-PET and SPECT are analyzed.

### 3.1. Overview of CT

CT is an imaging methodology that involves irradiating an object using statistical methods and Cross-sectional images can be produced using gamma or X-rays.<sup>11,12</sup> For recording density patterns and generating an image of a tissue "slice" or "cut," ionizing radiation, or X-rays, combined with an array of electronic detectors, was deployed by CT.<sup>13,14</sup> For instance, CT is a valuable broadcast tool to detect possible tumors or else lesions in the abdomen. CT systems with fast gantry rotation (i.e., equal to or less than 350 ms) can be utilized.<sup>15</sup>

Raymond, et al.<sup>16</sup> defined the early development of medical CT. To examine the developmental changes that occurred in CT, the X-ray dosimetry method was used in this study. According to the findings, CT was widely adopted as a remarkable technology that helps numerous patients every day. Using radiography had the drawback of superimposing images of a location on images of the tissues under and above the structures.

Anton, et al.<sup>17</sup> defined the evaluation of medical imaging along with X-ray CT in industry for non-destructive testing. To scan the test objects, medical and mini CT scanners were used. The results showed that CT systems were an improved choice for applications like rapid scout scans, higher throughput applications, together with large objects. Yet, the study's sample size was constrained.

Joseph, et al.<sup>18</sup> described the outcomes of automated CT in idiopathic pulmonary fibrosis. For detecting pulmonary function measures, as well as visual, along with Pathology Evaluation and Rating Using Computer-Aided Lung Informatics (CALLIPER), St. Antonius Hospital in Utrecht was examined. The utilization of cohort enrichment CALIPER software showed a score greater than that of the lung (4.4%), which could minimize the necessary sample size. The vessel-related structures limited the prohibitive trial costs.

Paras, et al.<sup>19</sup> elucidated diverse additive manufacturing techniques employing CT. The study offered an optimized analysis by employing CT, incorporating internal channels, tolerancing characteristics, and representational geometric dimensioning. According to the analysis, CT operational parameters were 190–200kV and 35–50 $\mu$ A at a magnification of 2.0. A voxle size of 95.3 $\mu$ m was caused. The potential for the implemented testing was limited for some processes owing to the feature sizes varying between 2 and 8 mm.

Susilo, et al.<sup>20</sup> elucidated modified micro-CT system development for non-destructive testing. The study presented the development of a micro-CT imaging system centered on digital radiography. The sample was exposed to the next X-ray beam, producing a 2D radiograph. Nevertheless, micro-CT was a higher-cost equipment; hence, research institutions, together with medical clinics with minor funds, couldn't afford it.

### 3.2. Significance of CT- PET and SPECT

Scanning technologies that are used for the analysis are CT-PET and SPECT. PET scans can help assess organs and tissues for disease or other medical conditions.<sup>21</sup> PET could be wielded for appraising organ function. A SPECT scan is a non-invasive nuclear imaging test.<sup>22</sup> In the oncology setting, the CT-PET combination is wielded. It is also a crucial part of several cancer patients' treatment pathways.<sup>23</sup> The other scanning technology is SPECT, which emerges as a promising quantitative nuclear imaging tool.<sup>24</sup> In Table I, the articles linked to the CT-PET and SPECT scans are explained.

**Table 1** The articles related to the CT-PET and SPECT scans

Authors' Name	Aims	Types of scan	Outcomes	Limitations
Tore et al. <sup>25</sup>	To define a multisite experience of PET/ CT agent fluciclovine's	CT-PET	Detection rate 67.7%	CT-PET was inadequate for bone metastase detection.

	efficacy along with safety (18F) after biochemical recurrence.				
Samira et al. <sup>26</sup>	Detecting CT-PET's clinical utility to find unknown primary as well as metastatic was the goal.	CT-PET	Lesion detected rate 65.2%	Anatomic imaging nor In-pentetreotide 40%	The study did not consider any histopathologic proof meant for each lesion noticed; therefore, false positive outcomes were possible.
Erik et al. <sup>27</sup>	To appraise SPECT sensitivity in patients with chronic lower back pain (Group I) when analogized to patients devoid of chronic lower back pain (Group II).	SPECT	The control group's chance of locating a normal picture was 2.05 times higher than Group I's, and Group I's sensitivity score was 2.37.		While interpreting the samples, the SPECT images were limited.
Hayan et al. <sup>28</sup>	To identify the prevalence of abnormal stress in SPECT myocardial perfusion images amongst patients devoid of Coronary Artery Disease (CAD) history.	SPECT	The risk summed stress score was lower for almost all tests (80%) in 2012 compared to 29% in 1991 (P<0.001).		A key limitation was the inability to appraise SPECT tests' appropriateness.
Knut, et al. <sup>29</sup>	The objective was to assess CT-PET's diagnostic value in patients receiving treatment in a neurological ICU or stroke unit.	CT-PET	As per the results, the indications were identified for performing the CT-PET scan.		The retrospective design along with fewer patients per subgroup limited the interpretation of this study's results.

Delphine et al.<sup>30</sup> defined the CT-PET angiography meant for giant cell arteritis diagnosis. The subject of the investigation was giant cell arteritis in all consecutive patients suspected. Likewise, '24' patients who were suspected of GCA were comprised. As per the results, the specificity attained about 100% and 84.6%. Yet, the monocentric study was only conducted; therefore, a small number of patients were included.

Mohamed, et al.<sup>31</sup> elucidated PET/CT's role in breast cancer. It was utilized to assess therapeutic response, detect recurrent disease, along identify distal metastases. It detected breast lesions with 100% sensitivity. However, accelerated activity sites were rarely detected in unexpected locations, despite using PET/CT more frequently, which may not be related to the patient's medical history.

Stephanie et al.<sup>32</sup> elucidated the SPECT/CT for early post-myocardial Infarction Remodelling (IR) evaluation. For appraising left ventricular function, dual isotope imaging was done with Tc-RP805 for '3' days post-ischemia reperfusion. In the saline group, the Tc-RP805 ischemic-to-nonischemic ratio augmented following IR, whereas rTIMP-3 treatment significantly reduced this ratio. Yet, in myocardial blood flow evaluation, the apical segments weren't included.

### 3.3. Importance of CTDI

The CTDI is a commonly used radiation exposure index in X-ray CT. Dose optimization is necessary for an accurate diagnosis that aligns with radiation protection.<sup>33</sup> During a CT scan, the radiation could be appraised by deploying the CT DI. CTDI is displayed on most CT scanners. Across patients, RDs differ for CT.<sup>34</sup> For quality control, the CTDI is used. It is wielded to appraise the radiation output amongst diverse protocols along with scanners. Yet, patient RD depends on acquisitions together with the patient's morphology.<sup>35,36</sup>

Yusuke et al.<sup>37</sup> recognised the RD indices' relation with body size indices in adult body CT. The study examined 3,200 CT scans of the (i) thoracic, (ii) abdominal, (iii) abdominopelvic, or (iv) thoraco-abdominopelvic regions, conducted

employing '1' of '4' CT scanners. Physical measurement-centric indices (e.g., weight/height) exhibited the sturdiest associations, with weight following closely behind. This study utilized data collected solely from routine clinical practice, with imaging protocols deemed acceptable regarding RD and image quality.

Colin et al.<sup>38</sup> elucidated the CT DI estimation for cone-beam CT on radiotherapy equipment. It was exhibited on Varian CT imaging equipment for the On-Board Imager (OBI). The disparities stemmed from differences in phantom height, leading to proportionally longer sections of abdominal organs in females. Radiotherapists, along with radiographers, had limited knowledge of organ doses regarding CT imaging.

Alexander et al.<sup>39</sup> elucidated the application of the CT DI in dosage control in relation to the noise index and third-generation iterative reconstruction. The dose modulation data were collected in this study for the analysis. According to the results, the accuracy of the CTDI forecasts was 15% higher than that of the phantom results. There weren't enough degrees of freedom in the quadratic function to account for the limited range of the data.

Supawitoo et al.<sup>40</sup> defined the comparison of nylon dosimetry phantoms and CTDI in polymethyl methacrylate. The evaluation made as of nylon was wielded instead of the PMMA. The CTDI values obtained from the phantoms made of nylon were somewhat larger than those made of PMMA. The region of interest was less than  $\pm 5$  HU, which was within the recommendation limit.

Timothy et al.<sup>41</sup> elucidated the comparison of cancer-specific CT Protocols with CT dose studies from two cancer centres served as the basis for the American College of Radiology DI registry. Variance's N-way analysis was employed to appraise dose levels betwixt two protocols at site 1 as well as '3' protocols at site 2. Both Sites are stratified independently of their doses based on cancer indications similarly. The use of higher doses in non-contrast scans had limited due to a lack of intravenous contrast.

Kamezawa et al.<sup>42</sup> defined practical patient DI's investigation for patient organ dose assessment as of cone-beam CT in radiation therapy. For DI investigation in patients, the MONTE CARLO SIMULATION was used. Among the eight dose indices,  $f(0)_{Pat}$  had the lowest error rate of 5% concerning the ODprost reference dose of 19.3 mGy. The CBCT scan was limited by its long computation time.

Anam et al.<sup>43</sup> elucidated the (CTDIvol) as well as the Size-Specific Dose Estimate (SSDE) meant for Tube Current Modulation (TCM). 57 individuals who had undergone abdomen, as well as thorax, multi-detector CT examinations, were retrospectively given the software. The discrepancies betwixt the estimated CTDIvol along with the CT scanner reported CTDIvol values of  $4.4 \pm 1.2\%$  and  $6.0 \pm 2.0\%$ , respectively. The study was restricted to two anatomical regions: the abdomen and thorax.

Yusuke et al.<sup>44</sup> elucidated CT components' RD modulation in CT-PET. For TCM, the Automatic Exposure Control (AEC) was wielded. A decrease in slice thickness reduced the available signals for slice reconstruction, leading to increased image noise. Clinical demands meant for image quality varied, mainly relying on the CT component. Nevertheless, the lesion localization was insufficient in the CT diagnosis.

### 3.4. CT Dose Index in CT-PET

Integrated PET/CT is extensively utilized for staging, along with monitoring human diseases during whole-body scans.<sup>45</sup> Specialized pediatric dosage regimens are required to minimize radiation exposure and lower radiation-induced carcinogenesis risk.<sup>46</sup>

Natalie et al.<sup>47</sup> clarified PET quantification, CT RD reduction in phantoms, and PET-CT validation of CARE kilovolts automated tube voltage selection. The observed activity concentrations intended for PET were calculated using the CARE kilovolts image quality standard at 120 kV/50 mAs. As per the results, the CARE kilovolts determined the optimal tube voltage on dose when analogized to the 120 kV reference. PET-CT examinations' dose reduction was restricted due to the lowest tube current.

Brian et al.<sup>48</sup> defined the radiation dosimetry of fluorine-18 Fluoro Deoxy Glucose (FDG) PET/CT, integrating exam-detailed parameters in dose estimates. In this investigation, '2' consecutive adult patients' Whole-body PET/CT scan sets were analyzed. Patients' mean effective mAs were  $39 \pm 11$  mAs for all benchmarks. The restrictions imposed by the ambiguities in the correlation between dosage and risk.

Michael et al.<sup>49</sup> established a nationwide DRL in the second phase of hybrid imaging studies for CT dosage audits in the population of Kuwait in 2019. The methodology for estimating radiation exposure in patients receiving 18F-FDG was analyzed and comprehended. The dosage results (CTDIvol) expected for "6" centres were lower in oncology inspections. Due to the paucity of previous research, data collection was restricted to adult cancer patients.

Hyun et al.<sup>50</sup> elucidated the RD as of whole-body F-18 Fluorodeoxyglucose in CT-PET in nationwide Korea. A nationwide questionnaire was conducted to gather information about each institution operating PET/CT scanners in Korea. According to the results, the average effective dose of fluorodeoxyglucose was  $5.89 \pm 1.46$  mSv. This study had a limitation in that the questionnaire survey was devoid of the RD's actual evaluation in every scanner.

### 3.5. CT Dose Index in SPECT

SPECT exhibits outstanding sensitivity in sensing mismatch perfusion defects. The volume CT DI (CTDIvol), along with Each patient's radiation exposure is evaluated using the dose-length Product (DLP), which is documented as a dose report, next, by multiplying DLP by 0.014 mSv. mGy-1cm-1 k factor, the estimated effective dose is estimated.<sup>51</sup> The dose differs with gantry rotation time. Reducing this time shortens radiation exposure, thereby lowering the dose while minimizing the risk of motion artifacts.<sup>52</sup>

Faisal et al.<sup>53</sup> defined RD estimation related to bone SPECT/CT, along with established size-specific dose estimations for local diagnostic reference values. It attained mean CTDIvol ( $8.76 \pm 3.25$  mGy), DLP ( $350 \pm 138$  mGy cm), SSDE ( $13 \pm 4$  mGy), and E values ( $4.90 \pm 1.94$  mSv) for the CT component. The patients' RDs fell within reasonable bounds.

Ajit<sup>54</sup> defined the effectual dose to patients as of SPECT along with CT in myocardial perfusion imaging. Statistical analyses were performed employing a t-test as well as a 1-way variance analysis, with  $p < 0.05$  implication level. In SPECT, 8.8 mSv mean ED value for males was considerably low ( $p=0.002$ ) when weighed to 10.4 mSv recorded for females. The study did not assess image quality variations across different scanners or imaging centers.

Shamim et al.<sup>55</sup> defined organs' average absorbed dose distribution comparison in SPECT-CT uses a Monte Carlo simulation. This study investigated a voxelized phantom of according to the International Commission on Radiological Protection (ICRP), the patient. As per the findings, the ratio was enhanced to 0.19 in the colon and intestine and 0.25 in the bladder. Yet, the simulation approach was a weakness of the study.

### 3.6. Challenges in CT-PET and SPECT

Unique insights are offered by CT-PET Imaging into tumor biology along with treatment response. Understanding the challenges and limitations in this field is essential for effectively integrating them into clinical practice.<sup>56</sup> Several challenges occur in CT-PET and SPECT. These include critical trade-offs betwixt resolution along noise, the precision of measurements, as well as the combination of magnetic resonance imaging and X-ray CT.<sup>57</sup>

Valentin et al.<sup>58</sup> elucidated the head along with the HECKTOR challenge with PET/CT neck tumour segmentation. Here, the automated method was used. According to the results, the automated methods effectively utilized the combined PET and CT modalities' rich metabolic and structural characteristics.

Challenges: Notable achievements in Brain Tumour Segmentation (BraTS) include Kidney Tumour Segmentation (KiTS), a form of medical image segmentation, alongside difficulties in visual concept extraction in radiology.

Carmen et al.<sup>59</sup> defined Machine Learning (ML) along with Deep Learning (DL) applications for both PET and SPECT imaging to overview the general challenges along with future prospects. The integration of PET and SPECT imaging methodologies with ML algorithms, with DL models, was used as a promising approach. Advancements in (1) image segmentation, (2) fusion, (3) classification, (4) synthesis, and (5) object detection in medical imaging stemmed from capturing complex relationships and dependencies.

Challenges: (i) Data standardization, (ii) limited data availability, (iii) evaluation, along with (iv) interpretability, could be highlighted amongst the difficulties tackled by ML in the fields of PET/SPECT imaging.

Milan & Pavel<sup>60</sup> explained the current state of SPECT/CT imaging in breast cancer and its difficulties. SPECT/CT's growing significance in bone metastase detection was used in this study. As per the results, SPECT/CT provided sentinel lymph nodes' accurate anatomical localization, aiding in surgical procedures.

Challenges: Unfortunately, CT scanning accuracy in recognizing metastatic disease in lymph nodes was inadequate.

#### 4. Summary of the Review

In CT, a usual radiation-dose parameter is CTDI. CTDI is unique, as it is calculated by dividing a single rotation scan's radiation-dose profile at a given table location by the nominal width of the radiation beam. CTDI is the main metric used in CT to quantify the radiation that a scanner emits. Yet, it is measured from one axial CT scan. This study analyzes 2 types of scans, namely CT-PET and SPECT. A dual-modality merging PET with X-ray CT is CT-PET. To examine diverse pathologies, a wide range of radiopharmaceuticals is used. Likewise, the other scan technology named SPECT is analyzed. SPECT examinations are regionally classified into (i) head, (ii) neck, (iii) myocardium, (iv) thorax, (v) abdomen, (vi) extremities, along (vii) whole-body scans. From the gender-specific conversion factors, the effective Dose as of the CT (EDCT) is estimated. SPECT/CT radiation dosimetry provides efficient information on the entire effective dose, as well as equivalent doses to the acute organs resulting from radiopharmaceutical administration, and the CT scan modality suitable for both adults and pediatric patients. In Section 4, some of the explanations of the RQs and the related contents are provided.

- Explanation based on CT (RQ1) - This question aimed to understand the studies associated with CT, which was illustrated in Section 3.1.
- Importance of CT-PET and SPECT (RQ2) - This question explained the importance of CT-PET and SPECT that were synthesized, which was described in Section 3.2.
- What is the significance of CTDI (RQ3) - This question helped in identifying the significance of CTDI, which was explained in Section 3.3.
- Explanation of CT dose index in CT-PET and SPECT (RQ4) - The studies associated with the CT DI in CT-PET and SPECT were mentioned in Sections 3.4 and 3.5.
- What are the challenges in CT-PET and SPECT (RQ5) - The studies associated with the challenges in CT-PET and SPECT were mentioned in Section 3.6.

Therefore, an overview of the CT and their DI is given in this review. The CT DI in CT-PET and SPECT is also analyzed along with the significance of CTDI. The analysis of this study shows how the internal organs work, and the tissue functions are identified in an effective way. SPECT and PET-CT are nuclear medicine imaging techniques that offer metabolic and functional insights, in contrast to CT and MRI. They are merged with CT and MRI for offering detailed anatomical along with metabolic information. Likewise, the ways to overcome the challenges are clearly mentioned in this review.

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#### 5. Conclusion

Here, the dose quantity is defined as the indication of the doses for the patient undergoing CT scans. The CT RD parameter was shown on the CT scanner console. To compute the dose, the American Association of Physics in Medicine (AAPM) formalism was used. The CT-PET allowed for the emission scan's CT-centric attenuation correction without the necessity for an external positron-emitting source meant for a transmission scan. Additionally, SPECT systems enhanced diagnostic accuracy by facilitating better localization, as well as the characterization of scintigraphic results. Nonetheless, patients may be exposed to significantly more radiation when functional and anatomical images are acquired simultaneously, especially if a hybrid system with diagnostic CT capabilities is used. Some of the limitations also occurred owing to these advantages. The typical protocol in SPECT was inefficient, often taking 3 to 5 hours to complete. Likewise, the limitation of CT-PET was that Nuclear medicine procedures could be time-consuming. This limitation will be noted by future researchers as they seek a solution to reduce time consumption. This technology will enable a deeper understanding of the future mechanisms behind sickness, as it allows for the real-time visualization of molecular processes, thereby paving the way for novel approaches toward personalized treatment.

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#### Compliance with ethical standards

##### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

##### *Use of Artificial Intelligence (AI)-Assisted Technology for Manuscript Preparation*

The authors confirm that there was no use of AI-assisted technology for assisting in the writing of the manuscript and no images were manipulated using AI.

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