

Tumor Detection with PET and CT: A Comparative Physical Review

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ABSTRACT: Positron emission tomography (PET) is an important molecular imaging modality in oncology because it provides functional and metabolic information that complements the anatomical information obtained from computed tomography (CT). However, the ability of PET to detect tumors is fundamentally determined by several physical characteristics of the imaging system, including spatial resolution, sensitivity, image contrast, noise, photon attenuation, scatter, random coincidences, and partial-volume effects. This review aims to examine the physical basis of PET for tumor detection and to compare its principal imaging characteristics with those of CT. A comparative narrative review was conducted using relevant literature on PET physics, detector instrumentation, image formation, image-quality determinants, tumor detectability, and the physical principles of CT. The reviewed evidence indicates that PET provides high sensitivity to radiotracer distribution and functional abnormalities, making it particularly valuable for detecting metabolically active tumors. However, its relatively limited spatial resolution and susceptibility to attenuation, scatter, noise, and partial-volume effects can restrict the detection and accurate characterization of small or low-contrast lesions. In contrast, CT provides superior anatomical detail and spatial resolution through X-ray attenuation measurements but offers substantially less direct functional information. The evidence therefore indicates that PET and CT possess complementary physical capabilities: PET is primarily advantageous for functional and metabolic tumor characterization, whereas CT is superior for anatomical localization and structural delineation. Understanding these physical differences is essential for interpreting the respective strengths and limitations of PET and CT in tumor detection and for optimizing their complementary use in hybrid PET/CT imaging.

KEYWORDS: PET, CT, tumor detection, PET physics, spatial resolution, molecular imaging

1. INTRODUCTION Cancer imaging plays a fundamental role in the detection, characterization, staging, and follow-up of malignant disease. Conventional anatomical imaging techniques, particularly CT, provide detailed information regarding lesion location, size, morphology, and relationships with surrounding structures. However, anatomical alterations do not always directly reflect the biological activity of a tumor. Molecular and functional imaging techniques have therefore become increasingly important because they can provide information about physiological and metabolic processes that may complement structural findings. In oncology, the integration of functional and anatomical imaging has improved the ability to characterize lesions and localize biologically active abnormalities within their anatomical context. (Histed et al., 2012)

Positron emission tomography PET is a nuclear molecular imaging technique that enables the noninvasive visualization and measurement of radiotracer distribution in vivo. In oncological imaging, PET is particularly valuable because radiolabeled tracers can reflect specific biological processes associated with tumor metabolism and cellular function. The widespread use of 2-deoxy-2-[¹⁸F]fluoro-D-glucose (FDG) has established PET as an important modality for evaluating metabolic abnormalities in many malignancies. Unlike purely anatomical imaging, PET can demonstrate differences in tracer accumulation that are related to tissue function, thereby providing information that may precede or complement morphological changes. (Kubota, 2001)

The ability of PET to generate molecular images is fundamentally determined by the physics of positron emission, electron-positron annihilation, and coincidence detection of the resulting 511-keV photons. Following positron emission, the positron loses energy in surrounding tissue before annihilating with an electron, producing two approximately 511-keV photons emitted in nearly opposite directions. PET detectors record coincident photon events to estimate the lines of response from which the spatial distribution of the radiotracer can be reconstructed. Consequently, detector performance, coincidence detection, photon

attenuation, scatter, system sensitivity, spatial resolution, and image-reconstruction methods directly influence PET image quality and lesion detectability.(Basu et al., 2011; Torres Espallardo, 2017)

Despite its high sensitivity to radiotracer distribution, PET has several physical limitations that influence the detectability and characterization of lesions. Spatial resolution is generally lower than that of high-resolution anatomical imaging, while attenuation, scattered photons, random coincidences, statistical noise, and partial-volume effects can reduce lesion contrast and affect the measured tracer concentration. These limitations become particularly relevant for small lesions, lesions with low tumor-to-background ratios, and tumors located in regions affected by substantial photon attenuation or physiological tracer uptake. Therefore, tumor detectability in PET is not determined solely by tracer uptake but results from the interaction between lesion characteristics, background activity, count statistics, detector performance, and image reconstruction.(Aide et al., 2022; Erdi, 2012)

Computed tomography is fundamentally based on the measurement of the attenuation of X-rays as they pass through the body from multiple projection angles. Reconstruction of these measurements produces cross-sectional anatomical images in which differences in X-ray attenuation can be represented quantitatively using CT numbers. The high spatial resolution and detailed anatomical representation provided by CT make it particularly useful for defining lesion location, size, morphology, and relationships with adjacent anatomical structures. However, conventional CT primarily depicts structural and attenuation differences and therefore provides less direct information about tissue metabolism and molecular activity than PET. (Erdi, 2012; Histed et al., 2012)

The complementary physical characteristics of PET and CT provide the fundamental rationale for hybrid PET/CT imaging. PET contributes functional and metabolic information derived from radiotracer distribution, whereas CT provides high-resolution anatomical information and can also be used for attenuation correction of PET data. The co-registration of these two datasets allows metabolically abnormal regions to be localized within detailed anatomical structures, thereby reducing some of the limitations associated with either modality when used independently. The development of integrated PET/CT has consequently established a framework in which functional and anatomical information can be evaluated within a single imaging examination.(Miles, 2008)

Although numerous reviews have described PET/CT instrumentation, molecular imaging applications, and the clinical role of hybrid imaging, the physical determinants of tumor detectability are often discussed separately across different technical and clinical contexts. A focused synthesis that connects the fundamental physics of PET—particularly spatial resolution, sensitivity, contrast, attenuation, scatter, statistical noise, and partial-volume effects—with the practical problem of tumor detection, while directly comparing these characteristics with the physical capabilities of CT, can provide a more integrated perspective. Such a comparison is important for understanding not only the respective strengths of PET and CT but also the physical basis of their complementary roles in oncological imaging.(Torres Espallardo, 2017)

Accordingly, this review aims to critically examine the physical basis of PET for tumor detection and to compare its principal imaging characteristics with those of CT. Specifically, the review evaluates the physical principles underlying PET image formation; examines the effects of spatial resolution, sensitivity, contrast, noise, attenuation, scatter, random coincidences, and partial-volume effects on tumor detectability; considers the physical basis of CT relevant to anatomical tumor detection; and synthesizes the complementary strengths and limitations of PET and CT for oncological imaging.

2) MATERIALS AND METHODS

2.1. Study Design

This study was designed as a comparative narrative review focusing on the physical basis of PET for tumor detection and its comparison with CT. The review was structured to synthesize evidence concerning the physical principles of PET image formation, detector characteristics, spatial resolution, sensitivity, image contrast, noise, attenuation, scatter, random coincidences, partial-volume effects, and their implications for tumor detectability. The physical basis and tumor-detection characteristics of CT were subsequently reviewed to provide a direct comparison between the two imaging modalities.

The review was conducted using a structured literature-search and evidence-synthesis approach. The methodological framework was informed by the principles of the Scale for the Assessment of Narrative Review Articles (SANRA), particularly with respect

to clearly defining the review objective, describing the literature search, supporting key statements with appropriate references, and applying scientific reasoning in the synthesis of evidence. (Baethge et al., 2019)

2.2. REVIEW OBJECTIVES AND SCOPE

The primary objective of this review was to critically examine the physical characteristics of PET that determine its capability for tumor detection and to compare these characteristics with those of CT. The review specifically addressed five areas: (1) the fundamental physical principles of PET image formation; (2) physical determinants of PET image quality and tumor detectability; (3) the relationship between PET physical characteristics and detection of small or low-contrast lesions; (4) the physical basis of CT relevant to anatomical tumor detection; and (5) the comparative and complementary capabilities of PET and CT in oncological imaging.

The scope of the review was restricted to the physical and imaging characteristics of PET and CT. Studies primarily concerned with artificial intelligence, automated tumor segmentation, deep-learning architectures, segmentation accuracy, geometric segmentation errors, or uncertainty quantification were outside the scope of this review.

2.3. LITERATURE SOURCES

Relevant scientific literature was identified through searches of major biomedical and multidisciplinary scientific databases, including PubMed/MEDLINE, Web of Science, and ScienceDirect. Google Scholar was used as a supplementary source for identifying additional relevant publications and tracing potentially important references cited in key review articles.

The literature search focused on peer-reviewed publications addressing PET physics, PET/CT instrumentation, detector technology, image formation, spatial resolution, sensitivity, image contrast, attenuation, scatter, random coincidences, partial-volume effects, tumor detectability, CT imaging physics, and comparative PET/CT applications in oncology.

2.4. SEARCH STRATEGY

A structured search strategy was developed using combinations of keywords related to PET, CT, imaging physics, and tumor detection. The principal search terms included “positron emission tomography,” “PET,” “PET physics,” “PET/CT,” “tumor detection,” “cancer imaging,” “spatial resolution,” “sensitivity,” “image contrast,” “attenuation,” “scatter,” “random coincidences,” “partial-volume effect,” “CT physics,” and “computed tomography.”

Boolean operators AND and OR were used to combine related concepts. Representative search combinations included:

(“positron emission tomography” OR PET) AND (“tumor detection” OR “cancer imaging”)

(“PET” OR “PET/CT”) AND (“physical basis” OR physics OR instrumentation)

(“PET” OR “positron emission tomography”) AND (“spatial resolution” OR sensitivity OR contrast)

(“PET” OR “PET/CT”) AND (attenuation OR scatter OR “random coincidences” OR “partial-volume effect”)

(“PET” OR “positron emission tomography”) AND (“computed tomography” OR CT) AND (“tumor detection” OR oncology)

The search strategy was designed to identify literature addressing both the fundamental physical mechanisms of image formation and their consequences for tumor detectability. The search process and search terms were documented to facilitate transparency and reproducibility, consistent with recommendations for reporting literature searches. (Rethlefsen et al., 2021)

Studies were considered eligible when they met one or more of the following criteria:

2.5. Eligibility Criteria

Inclusion Criteria

1. Discussed the fundamental physical principles of PET imaging.
2. Addressed PET detector systems, coincidence detection, or PET image formation.
3. Examined PET spatial resolution, sensitivity, contrast, noise, or related image-quality characteristics.
4. Investigated physical factors such as attenuation, scatter, random coincidences, or partial-volume effects.
5. Examined the physical basis or limitations of PET for tumor or lesion detection.
6. Discussed CT image formation, X-ray attenuation, spatial resolution, or anatomical tumor detection.
7. Directly compared PET and CT imaging characteristics or their complementary roles in oncology.
8. Were peer-reviewed scientific articles, authoritative reviews, or relevant methodological/technical publications.
9. Were published in English

Exclusion Criteria

Studies were excluded when they:

1. Focused exclusively on diseases or applications unrelated to tumor imaging without providing relevant physical information.
2. Addressed PET or CT only from a clinical perspective without information relevant to the physical basis or imaging characteristics.
3. Focused primarily on automated segmentation, deep learning, nnU-Net, artificial intelligence, or segmentation performance.
4. Focused primarily on geometric segmentation error or uncertainty quantification.
5. Were editorials, letters, conference abstracts, commercial materials, or non-peer-reviewed sources unless considered essential for a specific technical fact.
6. Did not provide sufficient information relevant to the objectives of the review.

2.6. STUDY SELECTION

Retrieved records were screened according to their titles and abstracts for relevance to the predefined objectives. Potentially relevant articles were subsequently assessed through full-text evaluation. Publications that satisfied the eligibility criteria and provided substantive information related to PET physics, CT physics, tumor detectability, or PET–CT comparison were retained for qualitative synthesis.

Particular attention was given to authoritative review articles and technically focused studies that provided detailed evidence concerning the physical determinants of PET image quality and lesion detectability. Reference lists of highly relevant publications were also examined to identify additional eligible studies that might not have been retrieved through the primary database searches.

2.7. Data Extraction

Relevant information was extracted from the selected publications using a structured evidence framework. For each publication, the following information was recorded where applicable:

- Author(s) and publication year
- Study or review type
- PET physical principle addressed
- Detector or instrumentation characteristics
- Spatial resolution
- Sensitivity
- Image contrast and noise
- Attenuation
- Scatter
- Random coincidences
- Partial-volume effects
- Lesion or tumor detectability
- CT physical characteristics
- PET–CT comparison
- Principal findings relevant to the objectives of the review

The extracted information was organized according to the major thematic domains of the review rather than according to individual studies. This approach allowed evidence from different publications to be integrated around common physical concepts and their implications for tumor detection.

2.8. EVIDENCE SYNTHESIS AND COMPARATIVE ANALYSIS

The selected evidence was synthesized qualitatively and organized into four principal domains: (1) fundamental PET physics and image formation, (2) physical determinants of PET tumor detectability, (3) physical basis of CT for anatomical tumor detection,

and (4) comparative physical characteristics of PET and CT. PET and CT were compared according to their underlying imaging mechanisms, spatial resolution, sensitivity, image contrast, type of information provided, and principal physical limitations. Particular emphasis was placed on identifying how the physical characteristics of each modality influence the detection and characterization of tumors, especially small or low-contrast lesions. Because the present study was designed as a narrative review rather than a systematic review with quantitative meta-analysis, no pooled effect estimates or statistical meta-analysis were performed. The evidence was instead critically synthesized according to the relevance, consistency, and technical significance of the findings reported in the literature.

2.9. QUALITY AND REPORTING CONSIDERATIONS

The methodological quality and reporting transparency of the review were supported by principles from SANRA, which emphasizes a clearly stated rationale and objective, an adequately described literature search, appropriate referencing, scientific reasoning, and presentation of relevant evidence in narrative reviews. (Baethge et al., 2019)

The reporting of the literature-search procedure was additionally informed by the PRISMA-S recommendations concerning transparent documentation of information sources and search strategies. PRISMA-S is specifically intended to improve the reproducibility and completeness of literature-search reporting. (Rethlefsen et al., 2021)

PRISMA 2020 was not presented as the primary reporting framework because this study was designed as a narrative review rather than a systematic review or meta-analysis.

2.10. SOFTWARE AND REFERENCE MANAGEMENT

Zotero reference management software was used to organize and manage the bibliographic records identified during the literature search. Retrieved references were imported into Zotero and organized according to the major thematic domains of the review, including PET physics, PET instrumentation, image quality, tumor detectability, CT imaging physics, and PET–CT comparison. Bibliographic information, including authors, publication year, article title, journal, DOI, and source details, was reviewed and standardized within the reference library. Duplicate records were identified and removed before the final selection of eligible publications. Zotero was also used to manage in-text citations and generate the reference list in accordance with the citation style required by the journal.

3. RESULTS

3.1. Fundamental Physical Characteristics of PET

The reviewed literature consistently identifies positron emission, electron–positron annihilation, and coincidence detection of annihilation photons as the fundamental physical processes underlying PET imaging. Following positron emission, the positron loses kinetic energy within tissue before annihilating with an electron, producing two approximately 511-keV photons that propagate in nearly opposite directions. Coincident detection of these photons establishes a line of response between detector elements and provides the fundamental measurement used for PET image reconstruction. The physical performance of the detector system, including photon detection efficiency, detector geometry, energy resolution, timing characteristics, and spatial localization, directly influences the quality of the reconstructed image. (Torres Espallardo, 2017) (Peng & Levin, 2010)

3.2. PET Spatial Resolution and Sensitivity

Spatial resolution and sensitivity emerged as two fundamental and interdependent performance characteristics of PET systems. The reviewed evidence indicates that PET spatial resolution is influenced by detector-element dimensions, positron range, annihilation-photon acollinearity, detector geometry, depth-of-interaction effects, and image-reconstruction methods. Improvements in detector design and reconstruction can enhance spatial resolution and lesion visualization, although increasing spatial resolution may impose requirements for sufficient counting statistics to maintain acceptable signal-to-noise performance. PET sensitivity, in contrast, is determined by factors including geometric efficiency, detector stopping power, detector thickness, system configuration, and coincidence detection efficiency. Higher sensitivity increases the number of detected events available for image reconstruction and can therefore improve statistical image quality and lesion detectability. (Gonzalez-Montoro et al., 2022; Moses, 2011; Peng & Levin, 2010)

3.3. Physical Factors Affecting PET Image Quality

The literature identifies several physical processes that degrade PET image quality or introduce uncertainty into measured activity distributions. Scatter events occur when one or both annihilation photons undergo interactions before detection, causing the recorded line of response to differ from the true photon trajectory. Random coincidences arise when photons originating from separate annihilation events are detected within the same coincidence time window. Both effects introduce background events and can reduce image contrast and quantitative accuracy. The relative contribution of true, scatter, and random coincidences is therefore an important determinant of PET counting performance and signal-to-noise characteristics. (Peng & Levin, 2010; Tong et al., 2010)

3.4. Partial-Volume Effect and Small-Lesion Detection

The reviewed studies indicate that the partial-volume effect is a major physical limitation when PET is used to characterize small lesions. Because the spatial resolution of clinical PET systems is finite, activity originating from a small lesion is distributed over a larger reconstructed volume. Consequently, the measured activity concentration of small tumors may be underestimated, while lesion contrast may be reduced. The magnitude of this effect depends on lesion size, system spatial resolution, lesion-to-background activity distribution, and the characteristics of the reconstructed image. The partial-volume effect is therefore particularly important when interpreting PET measurements from small tumors and when attempting quantitative characterization of lesion uptake. (Erlandsson et al., 2012; Soret et al., 2007)

3.5. Physical Determinants of Tumor Detectability

The reviewed evidence demonstrates that PET tumor detectability is determined by the interaction of lesion-to-background contrast, lesion size, count statistics, spatial resolution, and the physical characteristics of the imaging system rather than by tracer uptake alone. Experimental investigations have shown that increasing tumor-to-background ratios improves lesion visibility, whereas increased background activity and reduced lesion size make detection progressively more difficult. PET has a substantially improved ability to detect small objects compared with conventional nuclear medicine imaging because of its superior sensitivity and spatial-resolution characteristics. However, the practical limit of lesion detection remains dependent on the combination of lesion size, contrast, background activity, and image noise. (Erdi, 2012a)

3.6. Advances Affecting PET Lesion Detectability

The reviewed literature indicates that technological developments in PET have progressively improved image quality and the detection of small lesions. Important developments include time-of-flight (TOF) information, point-spread-function modelling, improved detector materials, digital photodetectors, wider axial fields of view, and advanced iterative or penalized reconstruction methods. These developments improve the utilization of detected photon events and can increase image contrast, reduce noise, improve spatial resolution, or increase sensitivity. Evidence from reviews of contemporary PET/CT technology indicates that such developments have contributed to improved small-lesion detectability and more accurate quantitative assessment of radiotracer uptake. (Aide et al., 2022; Slomka et al., 2016; van der Vos et al., 2017)

3.7. PHYSICAL CHARACTERISTICS OF CT RELEVANT TO TUMOR DETECTION

The reviewed literature indicates that CT provides high-resolution anatomical information through measurements of X-ray attenuation across multiple projection angles. This physical principle enables the reconstruction of detailed cross-sectional representations of tissue structures and provides information about lesion size, morphology, location, and anatomical relationships. In comparison with PET, CT generally provides substantially greater anatomical detail and spatial resolution, although its contrast mechanism is based primarily on differences in X-ray attenuation rather than direct measurement of radiotracer distribution or tissue metabolism. (Erdi, 2012; Griffeth, 2005)

3.8. COMPARATIVE PHYSICAL CHARACTERISTICS OF PET AND CT

The comparative evidence demonstrates distinct physical strengths for PET and CT in tumor imaging. PET provides high sensitivity to the spatial distribution of radiotracers and can identify functional or metabolic abnormalities, whereas CT provides detailed anatomical information with superior spatial resolution. PET is therefore particularly advantageous when biological activity differs between tumor and surrounding tissue, while CT is particularly advantageous for defining anatomical boundaries, lesion morphology, and spatial relationships with adjacent structures. The combination of the two modalities allows functional

abnormalities identified by PET to be localized within the anatomical framework provided by CT. (Czernin et al., 2013; Lee et al., 2016; Miles, 2008)

3.9. SUMMARY OF COMPARATIVE FINDINGS

Overall, the reviewed evidence shows that PET and CT differ fundamentally in the physical information they measure. PET is characterized by high molecular sensitivity but is constrained by factors such as finite spatial resolution, photon attenuation, scatter, random coincidences, statistical noise, and partial-volume effects. CT provides substantially greater anatomical detail and spatial resolution but primarily represents differences in X-ray attenuation and therefore does not directly measure radiotracer distribution. The evidence consequently supports a complementary rather than substitutive relationship between the two modalities, with PET providing functional information and CT providing anatomical localization and structural characterization.(Histed et al., 2012; Miles, 2008)

Table I. Major Physical Determinants of PET Tumor Detectability

Physical factor	Effect on PET imaging	Relevance to tumor detection
Spatial resolution	Determines ability to separate small structures	Critical for small lesions
Sensitivity	Determines detected photon statistics	Affects image quality and detectability
Tumor-to-background ratio	Determines lesion contrast	Higher ratio improves visibility
Noise	Reduces image contrast	Can obscure low-contrast lesions
Attenuation	Reduces detected photon counts	Particularly important for deep lesions
Scatter	Introduces background events	Reduces quantitative accuracy and contrast
Random coincidences	Adds false coincidence events	Increases background/noise
Partial-volume effect	Underestimates activity in small lesions	Important for quantitative tumor assessment

Table II. Physial Comparison of PET and CT

Characteristic	PET	CT
Physical basis	Positron annihilation and coincidence detection	X-ray attenuation
Primary information	Functional/molecular	Anatomical/structural
Spatial resolution	Relatively lower	Generally higher
Sensitivity to molecular activity	High	Indirect
Lesion contrast mechanism	Radiotracer distribution	X-ray attenuation differences
Small-lesion limitation	Resolution/PVE/noise	Contrast and anatomical complexity
Major physical limitations	Attenuation, scatter, randoms, PVE, noise	Radiation dose, low soft-tissue contrast in some applications
Main complementary role	Functional characterization	Anatomical localization

4. DISCUSSION

4.1. Physical Basis of PET and Its Importance for Tumor Detection

The findings of this review indicate that the tumor-detection capability of PET is fundamentally determined by the physical chain extending from positron emission and annihilation to photon detection and image reconstruction. PET therefore does not simply represent tracer uptake; the observed image is the result of multiple physical processes, including positron range, photon attenuation, scatter, coincidence detection, detector response, counting statistics, and image reconstruction. This explains why two lesions with similar biological tracer uptake may not necessarily exhibit identical visual or quantitative characteristics when their size, location, surrounding activity, or imaging conditions differ. The literature on PET/CT physics similarly emphasizes that improvements in detector technology, reconstruction algorithms, time-of-flight information, and point-spread-function modelling can influence lesion detection and image quality. (Aide et al., 2022; Torres Espallardo, 2017)

4.2. Spatial Resolution, Partial-Volume Effects, and Small Tumors

One of the most important implications of the reviewed evidence is that PET spatial resolution places a fundamental constraint on the detection and quantitative characterization of small tumors. When lesion dimensions approach the effective spatial resolution of the imaging system, activity originating from the lesion becomes distributed beyond its physical boundaries in the reconstructed image. This partial-volume effect can reduce apparent tracer concentration and lesion contrast and consequently produce an underestimation of quantitative uptake. The magnitude of this effect depends on lesion size, system resolution, and the distribution of activity within the lesion and surrounding tissue. Therefore, a high measured or low measured PET intensity should not be interpreted independently of lesion dimensions and system resolution, particularly when evaluating small lesions. (Erlandsson et al., 2012; Soret et al., 2007)

4.3. Sensitivity, Contrast, Noise, and Lesion Detectability

The reviewed evidence further indicates that PET tumor detectability represents a balance between lesion contrast and statistical image quality. High tracer accumulation within a tumor can increase lesion-to-background contrast, but this advantage may be reduced when background activity is high or when the number of detected counts is insufficient. Consequently, sensitivity and noise cannot be considered independently: increasing the number of detected events improves counting statistics, whereas insufficient counts can increase statistical noise and obscure low-contrast abnormalities. Modern PET technology has attempted to address this limitation through improved detector efficiency, time-of-flight information, advanced reconstruction, and increased system sensitivity. (Aide et al., 2022; S & Js, 2016)

4.4. Attenuation, Scatter, and Random Coincidences

Another important implication of the findings is that the detected PET signal cannot be regarded as a direct and undistorted representation of radiotracer distribution. Photon attenuation, scatter, and random coincidences modify the detected event population and can influence both image contrast and quantitative accuracy. Attenuation reduces the probability that annihilation photons reach the detectors, whereas scattered and random events introduce incorrect or background coincidence information. These effects explain why physical corrections and appropriate reconstruction procedures are essential for reliable PET imaging. The integration of CT with PET is particularly important in this context because CT provides an anatomical map that can be used for attenuation correction while simultaneously providing structural information. (Miles, 2008; Torres Espallardo, 2017)

4.5. PET and CT Provide Complementary Rather Than Identical Information

The comparison performed in this review supports the interpretation that PET and CT should not primarily be considered competing imaging techniques. Their physical measurement principles are fundamentally different. PET provides information related to the spatial distribution of radiotracer activity and therefore can reveal functional or metabolic abnormalities, whereas CT measures X-ray attenuation and provides high-resolution anatomical information. The complementary nature of these measurements is one of the principal physical reasons for the development and clinical adoption of integrated PET/CT. Previous reviews have emphasized that PET contributes information about tumor biology, while CT provides accurate anatomical localization and structural characterization. (Blodgett et al., 2007; Histed et al., 2012)

4.6. Implications for Tumor Detection

From a tumor-detection perspective, the findings suggest that the physical strengths of PET and CT address different components of the detection problem. PET can identify biologically active abnormalities that may not yet produce prominent morphological changes, whereas CT can provide precise anatomical localization and delineation of structural abnormalities. However, PET detectability may be compromised by small lesion size, low lesion-to-background contrast, physiological tracer uptake, noise, and partial-volume effects. Conversely, CT may provide excellent anatomical detail while offering limited direct information about tumor metabolism. The combination of both modalities therefore provides a more comprehensive representation of tumor characteristics than either physical measurement alone. (Histed et al., 2012; Miles, 2008)

4.7. Advances in PET Technology and Their Implications

The development of modern PET instrumentation demonstrates that some of the physical limitations identified in this review are not fixed technological constraints. Advances in scintillation crystals, detector systems, time-of-flight measurements, point-spread-function modelling, iterative and penalized reconstruction, and larger axial fields of view have improved the efficiency

with which detected photon information is used. Contemporary reviews report that these developments can improve lesion detection, image quality, quantitative accuracy, or acquisition efficiency. Nevertheless, technological improvements do not eliminate the fundamental physical relationship between lesion size, spatial resolution, contrast, and statistical noise. Thus, improved instrumentation should be regarded as reducing, rather than completely removing, the physical limitations of PET tumor detection.(Aide et al., 2022; S & Js, 2016; Torres Espallardo, 2017)

4.8. STRENGTHS OF THE REVIEW

A principal strength of this review is its focus on the physical basis of tumor detection, rather than treating PET and CT solely as clinical diagnostic technologies. By integrating the physical processes governing PET image formation with the factors that influence lesion visibility and quantitative interpretation, the review provides a direct framework for understanding why PET performance varies according to lesion size, contrast, background activity, and imaging-system characteristics. A second strength is the explicit comparison of PET with CT according to their underlying physical measurement principles, allowing their complementary roles in hybrid imaging to be considered within a common framework.

4.9. LIMITATIONS

This review has several limitations. First, it was designed as a narrative review rather than a systematic review or meta-analysis; therefore, the literature was synthesized qualitatively and no pooled quantitative estimates were calculated. Second, the physical performance characteristics of PET systems vary according to scanner design, detector technology, acquisition protocol, reconstruction algorithm, and clinical application, which limits direct comparison of numerical performance values across studies. Third, tumor detectability is influenced not only by physical imaging parameters but also by biological tracer distribution, lesion heterogeneity, physiological background activity, and anatomical location. Finally, advances in PET instrumentation and reconstruction are occurring rapidly, meaning that reported performance characteristics may change as newer detector technologies and reconstruction approaches become available.(Aide et al., 2022; Torres Espallardo, 2017)

4.10. IMPLICATIONS AND FUTURE DIRECTIONS

Future development of PET tumor imaging is likely to depend on continued improvements in detector sensitivity, timing resolution, spatial resolution, reconstruction algorithms, and quantitative accuracy. Emerging long-axial-field-of-view and total-body PET systems offer substantially increased sensitivity and expanded anatomical coverage, while advances in reconstruction and detector technology may further improve lesion detectability and quantitative performance. Future research should therefore evaluate PET performance using standardized physical and quantitative metrics across different scanner platforms and acquisition conditions. Particular attention should also be given to the interaction between lesion size, tumor-to-background ratio, spatial resolution, noise, and partial-volume effects when assessing the ability of PET systems to detect and quantify small tumors.(Aide et al., 2022)

4.11. OVERALL INTERPRETATION

Taken together, the reviewed evidence indicates that the capability of PET for tumor detection is a product of both biological contrast and physical image quality. PET offers a unique ability to visualize radiotracer distribution and functional abnormalities, but its performance is constrained by finite spatial resolution, statistical noise, attenuation, scatter, random coincidences, and partial-volume effects. CT provides superior anatomical representation and spatial resolution but measures a fundamentally different physical property. The evidence therefore supports PET and CT as complementary components of oncological imaging, with their combined use providing functional information from PET together with anatomical localization from CT. (Histed et al., 2012)

5. CONCLUSION

This review demonstrates that the capability of positron emission tomography (PET) for tumor detection is fundamentally determined by the interaction between radiotracer distribution and the physical characteristics of the imaging system. Spatial resolution, sensitivity, image contrast, statistical noise, photon attenuation, scatter, random coincidences, and partial-volume effects collectively influence lesion visibility and the accuracy of PET measurements, particularly for small or low-contrast tumors.

Compared with PET, computed tomography (CT) provides substantially higher anatomical detail and spatial resolution through the measurement of X-ray attenuation, but it does not directly provide the same functional and metabolic information obtained from radiotracer distribution. The reviewed evidence therefore indicates that PET and CT have complementary physical capabilities rather than interchangeable roles. PET contributes functional and metabolic information, whereas CT provides anatomical localization and structural characterization. Their integration in PET/CT consequently combines these complementary forms of information and provides a more comprehensive physical basis for oncological tumor assessment.

Overall, understanding the physical determinants and limitations of PET is essential for accurate interpretation of tumor detectability and quantitative imaging findings. Continued advances in detector technology, sensitivity, timing resolution, image reconstruction, and quantitative methods may further improve PET performance, while careful consideration of lesion size, contrast, noise, and partial-volume effects remains essential for reliable tumor assessment.

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