A Robust No-Reference Quality Assessment Method for PET Imaging Based on Dynamic Thresholding, Poisson-Aware Noise Modeling, and Multi-Dimensional Block-Level Feature Fusion

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1) Background and Purpose

No-reference image quality assessment for Positron Emission Tomography (PET) remains difficult because PET images are governed by Poisson-distributed counting noise, large foreground-background intensity differences, and scan-parameter-dependent signal dynamics. Conventional NR-IQA methods such as PIQE and NIQE were designed for natural images and may misclassify normal PET patterns as poor quality. This work proposes a PET-specific, adaptive quality assessment framework that aligns with PET imaging physics and provides a reliable multi-dimensional quality score for variable acquisition conditions and clinical applications.

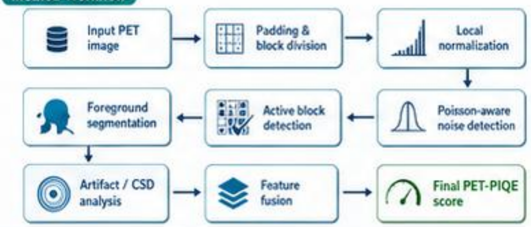
2) Innovation / Impact

- PET-specific NR-IQA rather than natural-image assumptions
- Dynamic thresholds adapt to scan condition and count level
- Poisson-aware noise modeling improves robustness
- Foreground-aware analysis reduces background bias
- Joint assessment of activity, artifacts, and structure

3) Methods

The PET image is padded if needed and divided into equal blocks. Each block undergoes local normalization before feature extraction. Foreground segmentation is performed on the whole image to estimate the foreground ratio in each block. Blocks are classified as active when cumulative activity and foreground ratio exceed adaptive thresholds. A Poisson-aware noise model identifies blocks with excessive noise relative to expected count statistics. Artifact detection is performed using block-based cues and a center-surround deviation (CSD) measure that tests whether local metabolic structure is preserved or distorted. For each block, a quality score is computed by combining noise and artifact evidence, and all active block scores are fused into a final PET-PIQE value.

Method Workflow



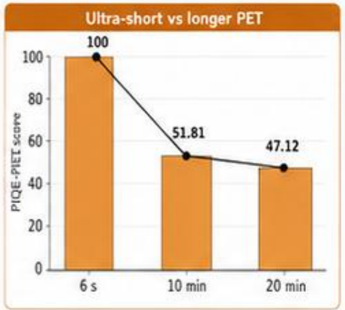
4) Core Scoring Principle

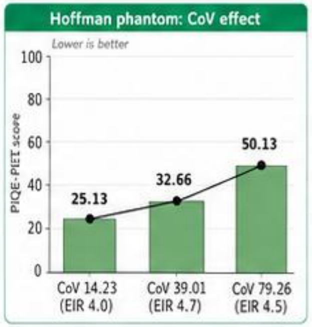
$$\text{PET-PIQE} = \left(\frac{(\sum DS_{block} + C)}{(N_{HSA} + C)} \right) \times 100$$

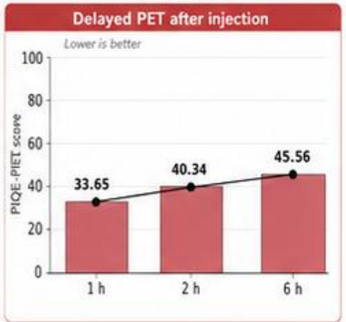
Lower PET-PIQE indicates better image quality; N_{HSA} is the number of active blocks and C is a stabilizing constant.

5) Key Results

Representative PET-PIQE results extracted from the patent examples.







PET-PIQE showed behavior consistent with expected image quality trends. For real patient scans acquired at the same time point, longer scan duration reduced the score from 40.88 (10 min) to 39.97 (20 min) and 37.36 (30 min), indicating better quality. In ultra-short versus longer acquisitions, the score improved from 100 (6 s) to 51.81 (10 min) and 47.12 (20 min). For Hoffman phantom images, PET-PIQE increased with poorer image quality: 25.13 at EIR 4.0 / CoV 14.23, 32.66 at EIR 4.7 / CoV 39.01, and 50.13 at EIR 4.5 / CoV 79.26. For delayed PET after injection, scores were 33.65 at 1 h, 40.34 at 2 h, and 45.56 at 6 h.

Key Takeaways

- *Lower score = better image quality*
- *Consistent with phantom CoV/EIR changes*
- *Sensitive to acquisition duration*
- *Captures quality degradation in delayed imaging*

6) Representative PET Examples

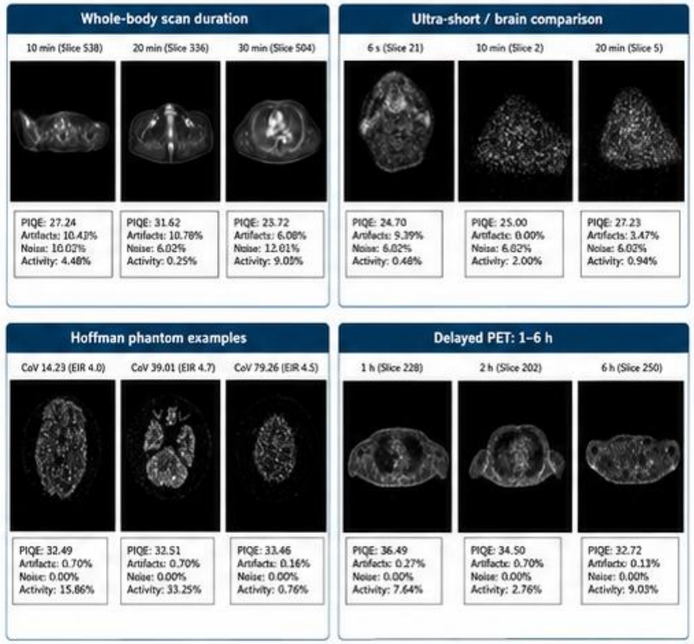


Fig. 1. *Representative PET-PIQE examples from whole-body duration comparison, ultra-short/brain comparison, Hoffman phantom scans, and delayed PET imaging.*

7) Conclusion and Applications

This study introduces a dedicated PET NR-IQA framework that adapts to varying imaging conditions, accounts for Poisson noise, and combines multiple image-quality dimensions into a single interpretable score. PET-PIQE is suitable for reconstruction quality control, comparison of dynamic and delayed PET studies, protocol optimization, and data screening for artificial intelligence or kinetic modeling workflows.

- Reconstruction QC
- Dynamic PET
- Protocol Optimization
- AI Data Screening
- Kinetic Modeling Support

Abbreviations: PET = Positron Emission Tomography; NR-IQA = No-Reference Image Quality Assessment; PIQE = Perception-based Image Quality Evaluator; NIQE = Natural Image Quality Evaluator; CoV = Coefficient of Variation; EIR = Edge Insertion Ratio; CSD = Center-Surround Deviation.

Note: All results are computed from images extracted from the patent examples and are used for illustration of metric behavior. Lower PET-PIQE indicates better image quality.