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ROLE OF AI IN ACQUISITION IN MEDICAL IMAGE ANALYSIS

Artificial intelligence (AI) transforms medical image acquisition by optimizing scanning workflows, reducing radiation doses, accelerating scan times, and enhancing raw data reconstruction. Unlike post-processing analysis, AI in acquisition operates directly at the hardware and raw data level (k-space in MRI or sinograms in CT) to ensure the highest possible initial image quality.

1. Architectural Workflow of AI in Image Acquisition

The integration of AI into the acquisition pipeline follows a three-stage sequential architecture:

- **Pre-Scanning:** AI automates patient positioning using 3D optical cameras and selects optimal protocols.
- **During Scanning:** Machine learning monitors patient motion and dynamically adjusts beam geometry or pulse sequences.
- **Post-Scanning:** Deep learning models reconstruct high-quality matrices from sparse, noisy, or undersampled raw data.

2. Advanced Image Reconstruction (The Core Engine)

AI replaces traditional mathematical reconstruction methods like Filtered Back Projection (FBP) and Iterative Reconstruction (IR) with Deep Learning Reconstruction (DLR).

- **Convolutional Neural Networks (CNNs):** Networks map noisy, undersampled raw data directly to artifact-free, high-resolution target images.

- **Generative Adversarial Networks (GANs):** A generator creates realistic high-resolution images from low-dose inputs, while a discriminator ensures anatomical accuracy.
- **K-Space Manipulation in MRI:** AI predicts missing lines in the MRI k-space matrix, allowing scanners to skip data points during acquisition and speed up scans by 50–75%.
- **Commercial Examples:** GE Healthcare's *TrueFidelity* (CT) and Canon's *AiCE* (Advanced Intelligent Clear-IQ Engine) utilize deep learning to separate true anatomical signals from background noise.

3. Scan Time Acceleration (Fast Imaging)

Prolonged scan times lead to patient discomfort and involuntary motion artifacts. AI mitigates this across modalities:

- **Undersampled Acquisition:** Scanners capture only a fraction of the required data points, drastically shortening the time a patient spends inside MRI or CT bores.
- **Physics-Informed Neural Networks (PINNs):** AI integrates known physical laws of magnetic resonance and X-ray attenuation to fill in missing scan data accurately.
- **Compressed Sensing Acceleration:** Deep learning models accelerate traditional compressed sensing algorithms, reducing MRI cardiac and abdominal scan times from minutes to seconds.

4. Radiation Dose Optimization and Patient Safety

Minimizing ionizing radiation while maintaining diagnostic image quality is a fundamental challenge in CT and X-ray imaging (the ALARA principle: As Low As Reasonably Achievable).

- **Low-Dose CT (LDCT) Enhancement:** AI models are trained on pairs of low-dose and standard-dose images. The trained network can take an ultra-low-dose scan (with up to an 80% radiation reduction) and upgrade its quality to match a standard full-dose scan.
- **Denoising Sinograms:** AI cleans up noise directly within the raw sinogram projection data before final image reconstruction takes place.
- **Pediatric Protocols:** Algorithms automatically adjust tube current and voltage based on a child's specific body mass index (BMI) to prevent over-radiation.

5. Real-Time Quality Control and Artifact Mitigation

Patient motion, metal implants, and physiological processes (breathing, heartbeats) introduce severe artifacts that degrade diagnostic utility.

- **Motion Tracking and Correction:** AI monitors the patient using external sensors or internal navigator signals, dynamically adjusting the scanner's focus to track movement in real time.
- **Metal Artifact Reduction (MAR):** Deep learning identifies the severe streaks caused by orthopedic implants or dental fillings in CT scans and mathematically replaces corrupted pixels with predicted anatomical data.
- **Instant Re-scan Alerts:** The system evaluates image sharpness immediately after acquisition. If the quality falls below a diagnostic threshold, it alerts the technician to re-scan before the patient leaves the table.

6. Smart Workflow Automation and Protocoling

AI acts as an intelligent assistant to standardise imaging procedures across different operators and hospital branches.

- **3D Camera Patient Positioning:** Ceiling-mounted AI cameras detect the patient's anatomical landmarks to automatically align the scan region with the machine's isocenter, preventing positioning errors.
- **Automated Scout View Analysis:** The system analyzes the initial low-dose "scout" or "localizer" image to automatically prescribe the exact start and end points for the high-resolution diagnostic scan.
- **Anatomical Auto-Gating:** AI tracks respiratory and cardiac cycles via non-invasive visual monitoring, triggering the scanner precisely during phases of minimal organ movement.