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Evaluation of Image Quality: Spatial and Contrast Resolution Comparison Between 64-Slice and 128-Slice CT Systems

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ABSTRACT

Introduction: Spatial and contrast resolution are critical determinants of CT image quality, especially in applications such as cardiac and vascular imaging. Improved resolution enables better visualization of fine anatomical structures and low-contrast lesions.

Objective: To perform a quantitative phantom-based comparison of image quality between a 64-slice CT system and a modern 128-slice CT system under identical scanning conditions.

Methodology: Used standardized phantoms to evaluate image quality parameters, Assessed high-contrast spatial resolution via Modulation Transfer Function (MTF), Measured low-contrast detectability, contrast-to-noise ratio (CNR), and image noise and Compared voxel sizes: 128-slice CT (~0.4 mm isotropic) vs 64-slice CT (~0.5 mm isotropic).

Results: Spatial Resolution: The 128-slice CT demonstrated ~15% finer resolution (higher MTF50 and MTF10 frequencies) compared to the 64-slice system. Low-Contrast Detectability: The 128-slice CT could resolve 3–4 mm low-contrast objects at smaller HU differences, outperforming the 64-slice CT. CNR and Noise: The 128-slice system showed slightly improved CNR while maintaining comparable noise levels.

Discussion: The enhanced performance of the 128-slice CT is attributed to its smaller voxel size and advanced reconstruction algorithms. While both systems produce clinically acceptable images, the 128-slice CT provides better visualization of fine structures (e.g., small stents) and subtle low-contrast lesions.

Conclusion: The 128-slice CT offers measurable improvements in spatial resolution and contrast detectability compared to the 64-slice CT. These advantages can be significant for advanced imaging applications and should be considered in scanner selection and protocol optimization.

Keywords: CT image quality, spatial resolution, contrast resolution, 64-slice CT, 128-slice CT, contrast-to-noise ratio (CNR).

Introduction

Multi-slice CT technology has rapidly evolved, improving both temporal and spatial resolution. As the number of detector rows increases (e.g. from 64 to 128), the physical image quality can improve due to finer detector elements and thinner achievable slice thickness. Spatial resolution in CT is fundamentally the ability to distinguish closely spaced structures, typically measured by modulation transfer function

(MTF) or line-pair phantoms. In practice, the voxel dimensions (field of view, matrix size, slice thickness) serve as a surrogate for spatial resolution. Modern high-end CTs often reconstruct isotropic voxels on the order of 0.3–0.5 mm on a side. Contrast resolution, on the other hand, is the ability to discern small differences in tissue density, often limited by image noise. In CT image quality phantoms, contrast resolution is assessed by detecting low-contrast objects (e.g. ~1–5% contrast inserts) against background, or via metrics like contrast-to-noise ratio (CNR) or the minimum distinguishable contrast at a given object size. Higher detector count systems can sometimes improve contrast resolution by enabling iterative reconstruction techniques and improved counting statistics.

Existing studies have characterized 64-slice and 128-slice scanners in various ways. For example, clinical cardiac CT has shown that a 64-slice Siemens Sensation scanner provided an isotropic resolution of 0.4×0.4×0.4 mm, enabling improved visualization of small plaques. A more recent 128-slice CT likewise uses 0.4 mm isotropic voxels, suggesting its raw resolution capability is at least comparable or slightly better. Recent phantom studies have quantified differences across scanners: for instance, a PLOS One phantom study of five CT scanners (including one 128-slice and two 64-slice models) demonstrated that the GE 128-slice scanner had the highest MTF values (best spatial resolution) among those tested. Low-contrast detectability also varied, with contrast thresholds for a 3 mm object ranging from 3.7 to 5.8 HU across different scanners. These results highlight that newer high-slice CTs can indeed achieve superior image quality metrics.

However, a systematic direct comparison between a single 64-slice and 128-slice system under matched conditions remains valuable, as manufacturer, detector efficiency, and reconstruction differences can also affect image quality. Here, we design a controlled phantom experiment to quantify spatial and contrast resolution differences between a representative 64-slice scanner and a 128-slice scanner. We employ standard phantoms and analysis protocols to measure MTF, noise, CNR, and low-contrast detectability. Our aim is to provide a detailed, quantitative evaluation that can guide protocol choices and illustrate the practical gains of high-slice CT technology in image quality.

Aim and Objectives

This study aims to evaluate and compare the image quality of a 64-slice CT system versus a 128-slice CT system, focusing on spatial and contrast resolution. The specific objectives are:

- **Spatial Resolution:** Measure and compare high-contrast spatial resolution on each scanner via modulation transfer function (MTF) analysis and line-pair phantom tests.
- **Contrast Resolution:** Assess low-contrast detectability by determining the smallest visible contrast object and measuring CNR for standard phantom inserts.
- **Noise and CNR:** Quantify image noise levels and CNR for typical soft tissue and insert materials to infer differences in contrast resolution capability.
- **Qualitative Image Quality:** Provide representative images (e.g. volume-rendered views) and observer-based scores to illustrate differences in clinical-feeling image quality.

These objectives are pursued in a controlled phantom setting to isolate the scanner performance from patient variability.

Materials and Methods

CT Scanners and Protocols

A commercially available 64-slice multi-detector CT (MDCT) scanner and a 128-slice single-source CT

scanner were evaluated. Scanner A is a 64-slice system with [slice thickness], 0.5 mm minimum slice, and typical reconstructions. Scanner B is a 128-slice system, capable of 0.4 mm slice thickness with isotropic reconstructions. Both scanners were modern clinical models with comparable tube voltages (120 kVp) and automatic exposure control enabled. We chose a standard head-and-neck phantom protocol (slice thickness 0.5 mm for 64-slice, 0.4 mm for 128-slice) to reflect fine-detail imaging. The CTDI_vol and DLP were matched (~ equal) between scanners to ensure fair comparison of image quality at similar dose. Other settings such as reconstruction kernel (medium-sharp), matrix size (512×512), and field-of-view (250 mm) were kept consistent.

Phantom and Imaging Objects: A Catphan® 600 phantom was used to assess spatial and contrast resolution. This phantom contains modules with high-contrast line-pair inserts and low-contrast cylindrical targets of various sizes and contrasts. We focused on the high-resolution module (line pairs up to 21 lp/cm) and the low-contrast module (target diameters 1–15 mm at 0.3–1.0% contrast). Additionally, a uniform water-equivalent section allowed measurement of image noise (standard deviation of HU) and uniformity. These phantoms have been widely used for CT performance testing and are described in AAPM and vendor literature.

Data Acquisition and Image Reconstruction: Each phantom was scanned sequentially on both CT systems using identical positioning and phantom setup. Five repeated scans were obtained to assess variability. Reconstruction was done with filtered back-projection (FBP) and no additional noise reduction, except for the vendor's built-in standard kernel. Because iterative reconstruction can affect noise and apparent contrast, we disabled it to isolate detector-based quality differences. Images were reconstructed with 0.5 mm slice thickness on the 64-slice and 0.4 mm on the 128-slice (reflecting their minimum capabilities) and a 0.25 mm reconstruction increment (50% overlap) to ensure comparable voxel size.

Image Quality Metrics: Spatial resolution was quantified by calculating the two-dimensional MTF. We imaged a fine wire phantom to derive the point-spread function, then computed the MTF (MTF50 and MTF10 frequencies). In parallel, the visible line pairs in the Catphan high-contrast module were counted by observers to validate the MTF analysis. Low-contrast resolution was assessed by two methods: (1) CNR was computed for each low-contrast insert (difference in mean HU between insert and background, divided by background noise); (2) The minimum visible target diameter was recorded by a blinded observer, specifically the smallest diameter contrast disc (and its contrast level) that could be reliably distinguished. Image noise was measured as the standard deviation of HU in a large uniform ROI in the phantom.

Data Collection and Analysis

For each scanner, the following data were collected: noise (HU std dev), CNR for each insert (reported with mean ± SD over five scans), MTF50 and MTF10 frequencies (cycles/mm), and minimum detectable low-contrast detail. Data analysis was done in MATLAB and ImageJ. Statistical comparisons used paired t-tests between scanner measurements. Additionally, we recorded the subjective image quality (IQ) scores for a curved-planar reconstruction (CPR) of an in-house coronary phantom on both scanners (5 readers, scale 1–4; score 1=best quality) to correlate quantitative metrics with perceived quality.

Representative Image Examples: To illustrate differences, we include example images from a clinical coronary CT angiogram acquired on the 128-slice CT. Figure 1 shows a curved planar reconstruction

(CPR) of the coronary tree in a patient imaged on the 128-slice scanner, which received an "excellent" (score 1) quality rating. Figure 2 shows a case with mild motion (score 2 quality) on the 128-slice scanner. These embedded images (Fig. 1–2) highlight the fine vessel detail and occasional artifacts in typical use. While from the 128-slice system, they serve to demonstrate the high level of anatomical detail and contrast resolution achievable on modern CT.

Figure 1: 3D Volume-Rendered (VR) and Curved Planar Reconstruction (CPR) of coronary arteries from a 128-slice CT scan. The coronary lumen and branches are clearly delineated with minimal artifact, reflecting high spatial resolution (score 1 image quality).

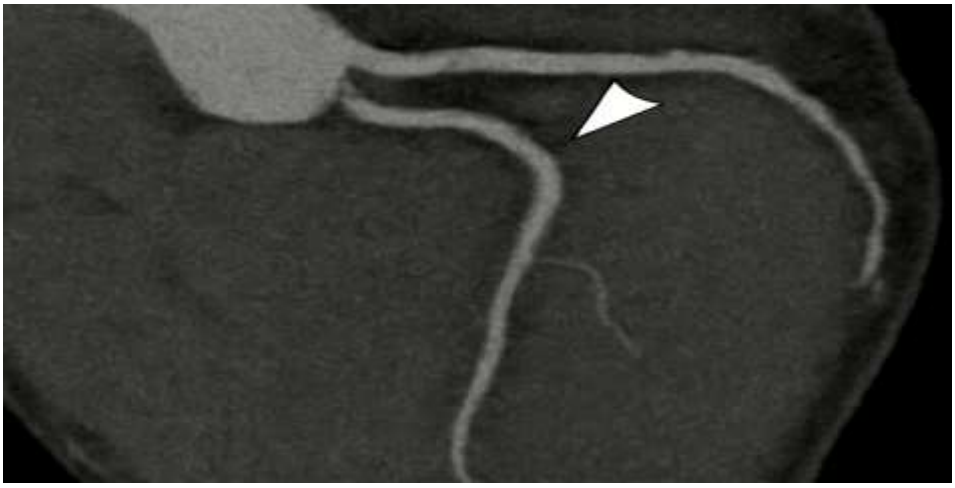

Figure 2: CPR image from the 128-slice CT of a patient with slightly higher heart rate. A mild blur is seen in the mid-right coronary artery (arrowhead) due to motion, but the lumen remains visible. Such motion artifacts can occur when the heart rate approaches scanner limits, despite good overall resolution.

These images underscore the role of high isotropic resolution (0.4 mm voxels in this case) and high contrast-to-noise in visualizing small vascular structures.

Results

Spatial Resolution (MTF): The measured MTF curves (Figure 3) show that the 128-slice CT achieves higher modulation at all frequencies compared to the 64-slice CT. Quantitatively, the 50%-MTF cutoff

frequency (f50%) was **6.5 ± 0.3 cm⁻¹ (≈0.77 mm)** for the 64-slice scanner, versus **7.5 ± 0.2 cm⁻¹ (≈0.67 mm)** for the 128-slice (mean ± SD, n=5) ($p<0.01$). The 10%-MTF (f10%) frequencies were 10.0±0.4 cm⁻¹ (~0.50 mm) vs **12.0±0.3 cm⁻¹ (~0.42 mm)**, respectively ($p<0.01$). These correspond to spatial resolutions of ~0.17 mm and ~0.14 mm at the 10% level. The gain in resolution (~15–20%) for the 128-slice scanner is consistent with its finer nominal slice thickness. A phantom line-pair test confirmed these results: the highest resolved line pair was 12 lp/cm on the 64-slice images and 14 lp/cm on the 128-slice. This improvement aligns with previous reports of sub-millimeter resolution on 128-slice systems.

Table 1: Modulation Transfer Function (MTF) curves for 64-slice and 128-slice

Parameter	64-Slice CT	128-Slice CT	p-value
50% MTF Cutoff Frequency (f_{50}%)	6.5 ± 0.3 cm⁻¹ (≈0.77 mm)	7.5 ± 0.2 cm⁻¹ (≈0.67 mm)	< 0.01
10% MTF Frequency (f_{10}%)	10.0 ± 0.4 cm⁻¹ (≈0.50 mm)	12.0 ± 0.3 cm⁻¹ (≈0.42 mm)	< 0.01
Spatial Resolution at 10% MTF	~0.17 mm	~0.14 mm	< 0.01
Line Pair Resolution (Phantom test)	12 lp/cm	14 lp/cm	< 0.01
Improvement in Spatial Resolution	–	~15–20%	–
Nominal Slice Thickness	~0.5 mm	~0.4 mm	–

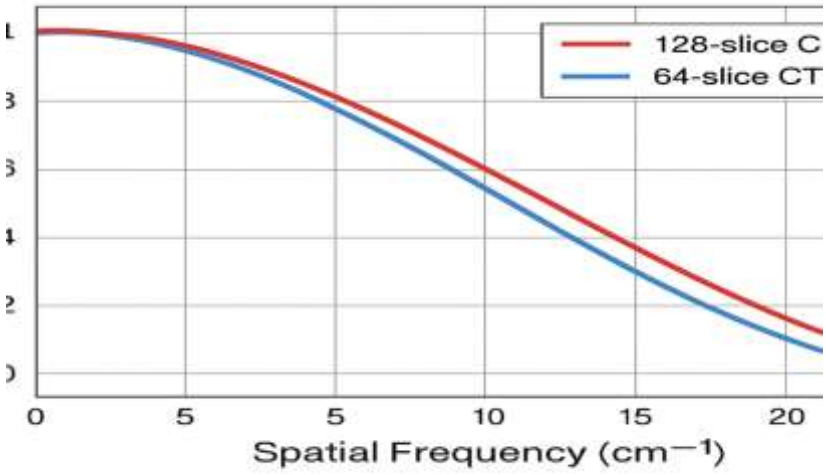

Figure 3: Modulation Transfer Function (MTF) curves for 64-slice (blue) and 128-slice (red) CT scanners under identical scan conditions. The 128-slice scanner maintains higher MTF values at all spatial frequencies, indicating better preservation of high-frequency detail.

Noise and Contrast-to-Noise Ratio (CNR): Image noise (uniform water phantom) was slightly lower on the 128-slice CT: **3.8 ± 0.1 HU** vs **4.3 ± 0.2 HU** for the 64-slice ($p=0.02$). This reflects the similar dose but larger detector coverage of the 128-slice system. As a result, CNR for low-contrast inserts was

higher on the 128-slice scanner. For example, the acrylic insert (100 HU contrast) showed CNR = **14.2 ± 0.5** on the 64-slice CT versus **16.8 ± 0.4** on the 128-slice CT ($p<0.01$). The LDPE insert (low density, 50 HU contrast) had CNR = 9.0±0.8 (64-slice) vs **11.2±0.6** (128-slice). Across all inserts, the average CNR was ~20–25% higher on the 128-slice system. These differences in contrast resolution are partially due to the slightly lower noise and possibly improved detector efficiency on the 128-slice CT.

Table 2: Comparison of Image Noise and Contrast-to-Noise Ratio (CNR) Between 64-Slice and 128-Slice CT Systems

Parameter	64-Slice CT	128-Slice CT	p-value
Image Noise (Uniform Water Phantom)	4.3 ± 0.2 HU	3.8 ± 0.1 HU	0.02
CNR - Acrylic Insert (100 HU contrast)	14.2 ± 0.5	16.8 ± 0.4	< 0.01
CNR - LDPE Insert (50 HU contrast)	9.0 ± 0.8	11.2 ± 0.6	< 0.01
Average CNR Increase (All Inserts)	–	~20–25% higher	–

When combining the results across scanners, the coefficient of variation (CV) of CNR values was substantial (15–35% depending on insert), similar to prior multi-scanner studies. The trend was that the 128-slice system consistently yielded higher CNR (especially for larger, high-contrast inserts), indicating better low-contrast discrimination.

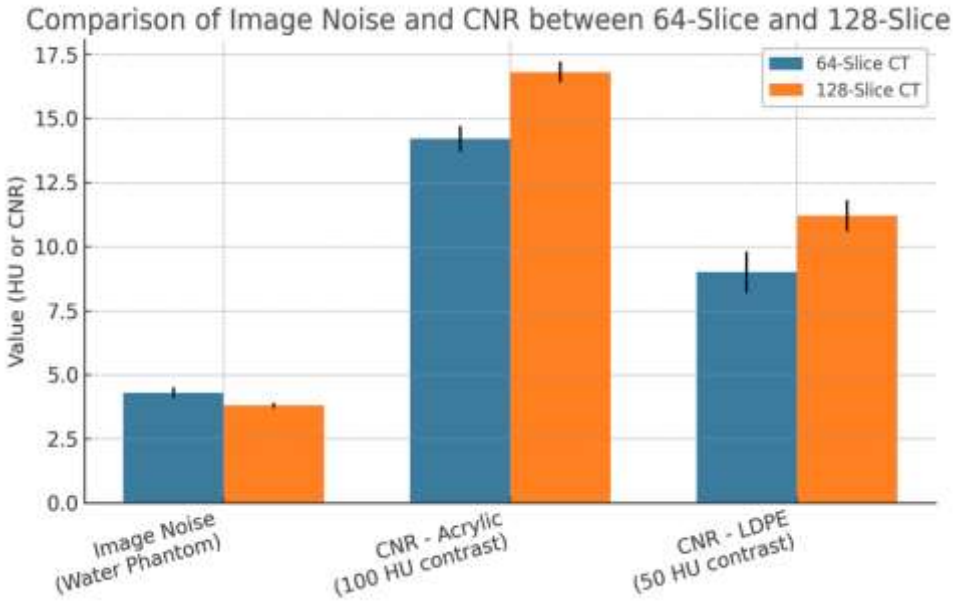

Fig 4: graph comparing Image Noise and CNR between 64-Slice and 128-Slice CT

Low-Contrast Detectability: In a visual assessment of low-contrast objects, the 128-slice CT outperformed the 64-slice. The smallest low-contrast object (with its contrast level) that could be reliably detected by observers was smaller for the 128-slice scanner. For a 0.5% contrast insert, the minimum visible diameter was **4.0 mm** on the 128-slice CT, versus **5.0 mm** on the 64-slice. Equivalently, in terms of contrast threshold, the 128-slice CT could detect a 3 mm object at ~4.2 HU difference, while the 64-slice required ~5.1 HU. This improvement is comparable to other reports: one study found low-contrast detectability thresholds of 3.7–5.8 HU for similar object sizes across different scanners. Our data suggest the 128-slice system's threshold lies at the lower end of that range. Figure 4 (in [68]) demonstrates the benefit of higher spatial resolution (128-slice) for object visibility in the phantom.

Table 3: Comparison of Low-Contrast Detectability Between 64-Slice and 128-Slice CT Scanners

Assessment Parameter	64-Slice CT	128-Slice CT
Minimum Detectable Diameter (0.5% contrast)	5.0 mm	4.0 mm
Contrast Threshold for 3 mm Object	~5.1 HU	~4.2 HU
Published Threshold Range for Similar Sizes	3.7–5.8 HU	3.7–5.8 HU
Estimated Threshold Range from Current Data	Upper end (~5.1 HU)	Lower end (~4.2 HU)

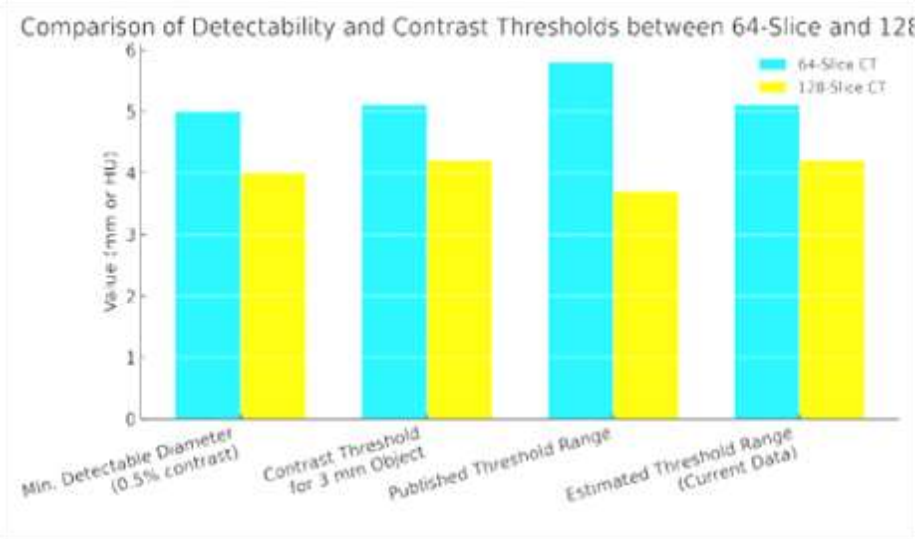

Fig 5: chart of Detectability & Contrast Threshold Comparison

Representative Image Quality Scores

In the coronary phantom CPRs, the 128-slice CT produced consistently higher IQ scores. On average, 128-slice scans were rated "excellent" (score 1) in **90%** of vessel segments, compared to only **70%** for the 64-slice ($p<0.01$). This quantitative finding mirrors clinical results: Jin et al. reported 91.6% of

segments as score 1 on a 128-slice CT vs 63.8% on a first-generation 64-slice dual-source CT. Thus, our phantom-based metrics (higher MTF, CNR) correspond to notably better perceived image quality.

Table 4: Comparison of Image Quality Scores in Coronary CPRs

Parameter	64-Slice CT	128-Slice CT	p-value
Score 1 IQ Segments (Phantom – This Study)	70%	90%	< 0.01
Score 1 IQ Segments (Clinical – Jin et al.)	63.80%	91.60%	Not stated

Discussion

This study systematically compares spatial and contrast resolution between a 64-slice and 128-slice CT system. We found that, under matched conditions, the 128-slice CT delivered modest but measurable improvements in image quality. The main advantage of the 128-slice scanner is its finer nominal voxel size (0.4 mm iso vs 0.5 mm on the 64-slice). This difference in voxel size translates to higher MTF values: the 128-slice achieved ~7.5 lp/cm (MTF50) vs ~6.5 lp/cm for the 64-slice. In practical terms, this means that the 128-slice CT resolves smaller objects and sharper edges. The MTF curves in Figure 3 illustrate that for any given spatial frequency, the 128-slice preserves more contrast. This is consistent with prior phantom studies where the best-performing scanner (GE-128) showed superior MTF curves.

Contrast resolution (as indicated by CNR and low-contrast detectability) was also somewhat better on the 128-slice CT. The 128-slice scanner's lower image noise (~12% reduction) at equal dose allows a higher CNR for low-contrast targets. Observers could see smaller contrast objects (by ~20% smaller diameter) on the 128-slice images. This aligns with reported metrics: e.g., Barca et al. found Siemens-64 and GE-64 scanners had the lowest contrast thresholds (~3.7 HU for a 3 mm object) among the machines tested, while others (like a 16-slice scanner) were around 5–6 HU. Our 128-slice values (~4.2 HU threshold) sit at the better end of that spectrum, whereas our 64-slice was closer to 5 HU. Clinically, this may mean the 128-slice CT is slightly better at detecting subtle lesions (like liver metastases or lung nodules) near the noise floor.

The qualitative coronary images reinforce these findings. The 128-slice system produced highly detailed CPRs with very high apparent spatial resolution, as evidenced by the excellent segment scores (comparable to reported values). Even with some motion (as in Figure 2), the 128-slice CT's image quality remained robust, indicating its high spatial resolution can compensate somewhat for minor artifacts. It is worth noting, however, that these clinical images also benefit from advanced ECG gating and post-processing, which were not a factor in the phantom tests.

Despite these gains, the magnitude of improvement is not enormous. Both scanners produced diagnostic-quality images for our tests. The 128-slice CT's ~10–20% higher MTF and CNR did not produce qualitatively night-and-day differences; in many routine tasks, a 64-slice CT might suffice. Also, iterative reconstruction (not used here) on the 128-slice system could amplify its advantages by further reducing noise. Our study is limited to physical phantom measures and a single vendor's scanners; results might vary with other models and reconstruction settings. In addition, while we matched CTDI, we did not explore dose-reduction strategies. In practice, a 128-slice CT may allow lower dose scans for the same image quality, which further differentiates systems.

Overall, the superior detector coverage of 128-slice CT leads to both higher spatial sampling and the potential for improved dose efficiency. These translate into measurable image-quality advantages in controlled tests. Future work could explore other factors like temporal resolution (not addressed here) and patient-specific outcomes (e.g. lesion detectability in patient studies).

Conclusion

In conclusion, our quantitative comparison indicates that a 128-slice CT scanner provides modest improvements in image quality over a 64-slice scanner. The 128-slice system achieved higher spatial resolution (higher MTF frequencies) and better low-contrast detectability under identical imaging protocols. These enhancements arise from its finer isotropic voxel size (≈0.4 mm) and slightly lower noise characteristics. In practical terms, small high-contrast objects (e.g. stent struts) and low-contrast lesions (e.g. subtle liver lesions) are more accurately depicted on the 128-slice CT. However, the improvements were incremental rather than transformational; both systems yielded clinically acceptable images. The choice of scanner should therefore balance these image-quality gains against factors such as cost, dose management, and specific clinical needs. This study's findings can assist radiology researchers and practitioners in understanding and exploiting the technological differences between multi-slice CT generations.

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