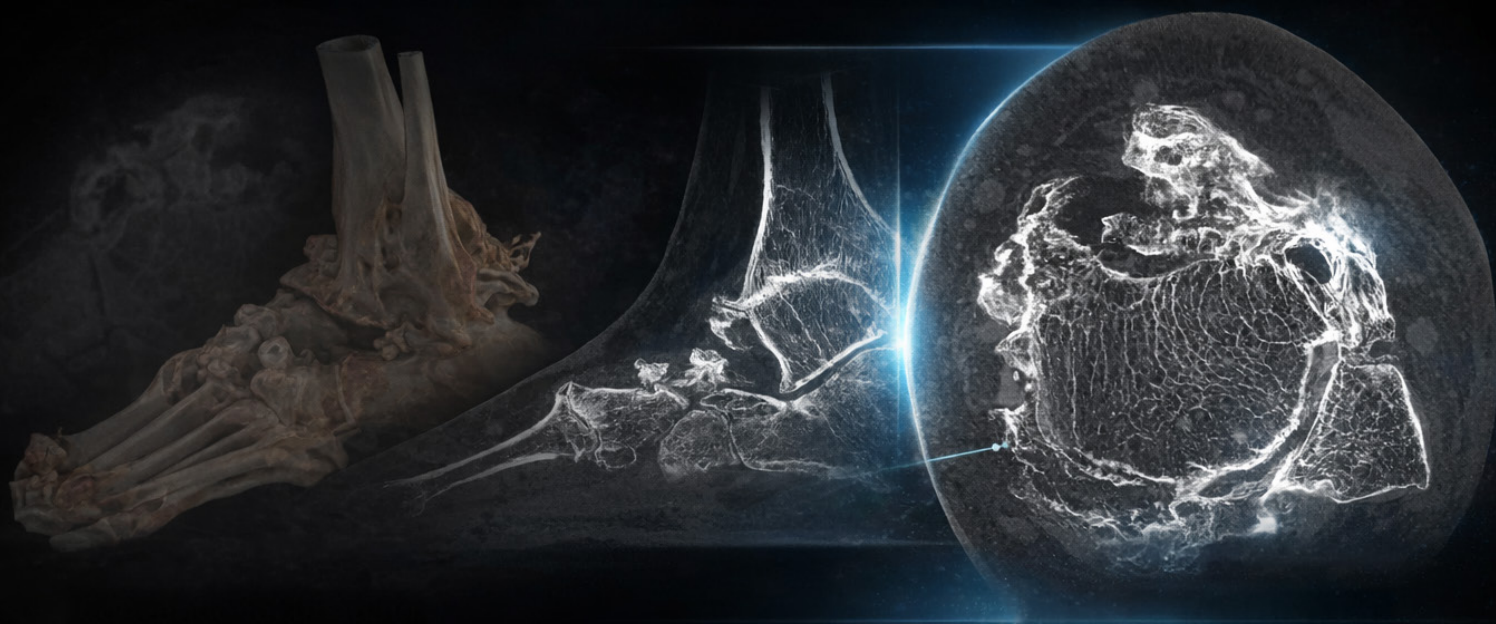




GE HealthCare



True Definition DL

Technical white paper

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Introduction

Computed tomography (CT) has become an indispensable diagnostic tool across a wide range of clinical applications, from routine screening and emergency imaging to advanced cardiovascular, oncology, and musculoskeletal assessments. As clinical questions become increasingly complex, radiologists are being asked to detect smaller lesions, characterize subtle anatomical structures, and make more confident diagnoses from every examination.

To meet these demands, radiologists consistently seek greater image definition—higher spatial resolution, improved anatomical clarity, and enhanced visualization of fine details. Clearer images enable clinicians to identify subtle findings with greater confidence, reduce diagnostic uncertainty, and support more informed clinical decision-making.

However, achieving superior image quality remains challenging in everyday clinical practice. Image clarity is often compromised by multiple factors, including patient size, motion, low-dose imaging protocols, acquisition speed requirements, metal and beam-hardening artifacts, and other real-world scanning constraints. At the same time, healthcare providers face increasing pressure to minimize radiation dose while maintaining diagnostic performance across diverse patient populations.

Recent technological innovations, particularly photon-counting CT (PCCT), have demonstrated the potential to deliver exceptional levels of image detail and spatial resolution. However, widespread adoption of these next-generation technologies remains limited by factors such as capital investment requirements, infrastructure considerations, and accessibility across existing installed fleets.

As a result, healthcare providers are faced with a critical challenge: how to deliver greater image definition, improved diagnostic confidence, and more consistent image quality across a broad range of clinical scenarios—without compromising dose efficiency, workflow, or access to advanced imaging capabilities.

Addressing this challenge requires innovations that enhance image clarity and resolution in everyday CT, enabling more confident diagnoses while avoiding the cost and complexity of major hardware upgrades. Accordingly, there is continued interest in technologies that can improve image quality and image definition using existing CT system platforms, providing broader access to advanced imaging capabilities without requiring major hardware transitions.

GE HealthCare as AI Leader in Deep Learning Image Reconstruction

GE HealthCare has a long-standing history of applying artificial intelligence and deep learning technologies to address some of the most fundamental challenges in CT imaging. Rather than focusing on a single aspect of image quality, GE HealthCare has developed a portfolio of deep learning innovations designed to enhance multiple dimensions of diagnostic image performance.

With TrueFidelity™ DL, Deep Learning Image Reconstruction, GE HealthCare introduced a new approach to noise reduction and image clarity, enabling clinicians to achieve excellent image quality while supporting dose-efficient imaging practices. Building upon this foundation, True Enhance™ DL was developed using deep learning technology to improve low-contrast detectability and lesion conspicuity. By leveraging Spectral Imaging (GSI) spectral behavior during training, it enables clinicians to visualize subtle tissue attenuation differences with greater confidence.

GE HealthCare as AI Leader in Deep Learning Image Reconstruction *(cont.)*

Today, True Definition™ DL extends this innovation journey by addressing another critical dimension of image quality: spatial resolution and fine-detail visualization. By enhancing the visibility of small anatomical structures and improving image sharpness, True Definition helps clinicians see more detail and gain greater diagnostic confidence across a wide range of clinical applications.

Together, these technologies represent a comprehensive AI-powered imaging strategy—one that advances clarity, contrast, and resolution to help clinicians overcome traditional imaging limitations and extract more diagnostic value from every CT examination. As healthcare providers seek pathways toward higher image definition without the complexity of major hardware transitions, deep learning innovations offer an increasingly accessible means of elevating image quality across existing CT fleets.

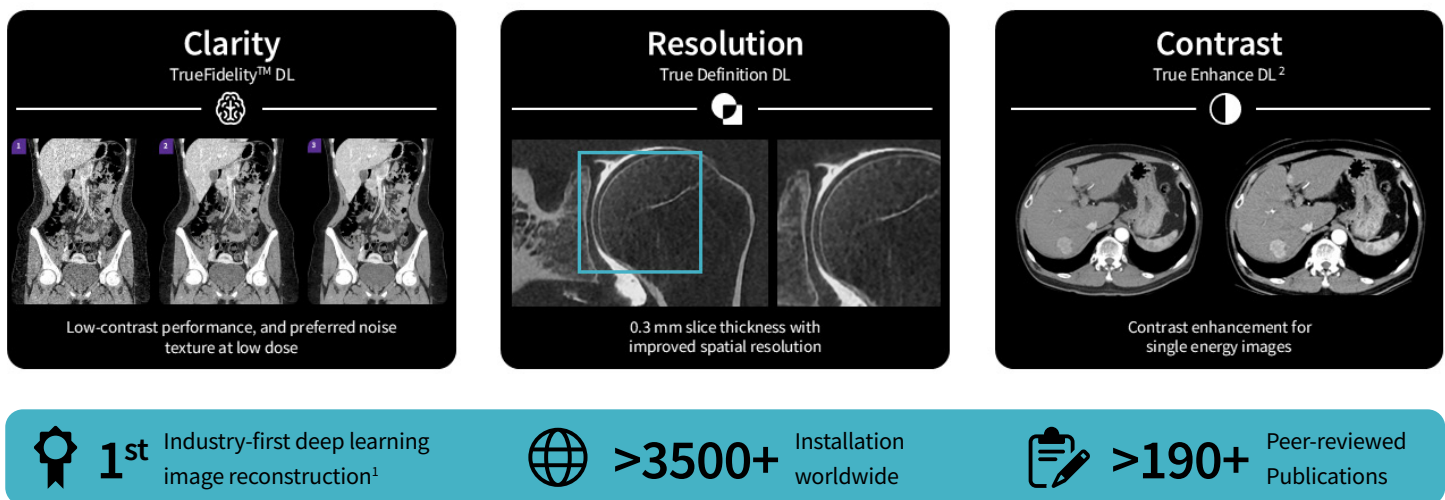


Figure 1: GE HealthCare's innovation in deep learning image reconstruction

True Definition DL Unlocks Greater Image Detail

Spatial resolution in CT imaging is primarily determined by the system geometry, including the system magnification, focal spot dimensions, and detector pixel dimensions.

When traditional reconstruction algorithms, such as filtered back projection, are used there is a direct link between the spatial resolution and image noise. In order to enhance spatial resolution while better managing the associated increase in image noise, advanced algorithms have been developed, including iterative reconstruction and deep learning algorithms.

The True Definition DL algorithm is designed to improve image clarity and spatial resolution for both in-plane and cross-plane directions through deep learning techniques. By improving the balance among spatial resolution, image noise, and radiation dose, the algorithm aims to enhance visualization of fine anatomical structures while maintaining overall image quality. For target clinical regions such as the lungs and bones, the aim of the algorithm is to improve high-contrast spatial resolution, which is critical for visualizing fine anatomical structures like small airways, nodules, and trabecular bone patterns as illustrated in Figure 2.

¹ TrueFidelity DL/deep learning image reconstruction receives the first FDA 510(k) clearance in April 2019 <https://gehealthcare.ent.box.com/file/1815918747694>

² True Enhance DL is currently available on Revolution Ascend platform.

True Definition DL Unlocks Greater Image Detail *(cont.)*

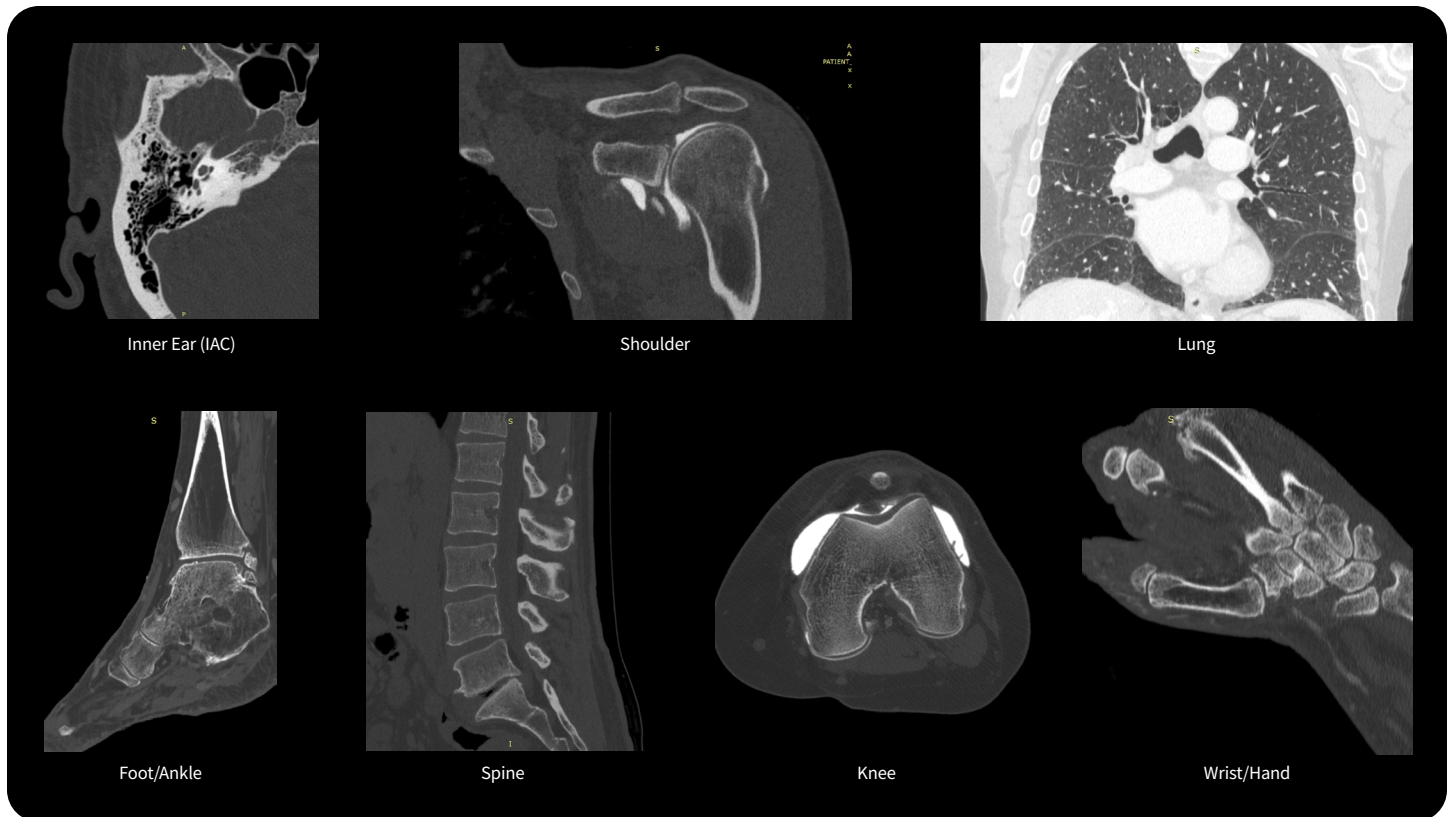


Figure 2: Example of clinical target regions

Spatial Resolution in CT Imaging

The spatial resolution of a given imaging system determines how sharply edges are defined in the resulting images. Typically, spatial resolution is pushed to the highest levels for high-contrast imaging tasks (e.g., bone and lung imaging). In X-ray computed tomography (CT), spatial resolution is primarily determined by the projection geometry of each beamlet used to form individual projection measurements. This is governed by the focal spot dimensions and the detector pixel dimensions, as these parameters define the effective geometric footprint of each CT measurement¹.

A straightforward approach to enhancing spatial resolution is through hardware-based modifications, such as reducing the X-ray tube

focal spot size, decreasing detector pixel size, and increasing the number of view samples. While these hardware changes often add system complexity and cost. In addition, reducing detector element dimensions in energy-integrating detector (EID) systems may decrease photon collection efficiency, potentially increasing image noise unless compensated by additional photon statistics. A key challenge in this approach is that higher spatial resolution requires a higher CT dose to ensure sufficient photon statistics. At the same time, a smaller focal spot size limits the available tube current (mA), and increasing CT dose is generally not acceptable^{2,3}. Additionally, from the customer's perspective, such improvements may require the purchase of new equipment.

Spatial Resolution in CT Imaging *(cont.)*

Another approach to improving spatial resolution is through reconstruction algorithms within the imaging chain. Reconstruction techniques, including frequency-domain filter kernel design, are well established. Users can select reconstruction settings such as “Standard” for conventional soft-tissue imaging, “Bone/Bone Plus” for high-resolution imaging, and “Lung” for intermediate-resolution imaging, which enhances contrast and edges by boosting middle-frequency components⁴. However, as dictated by the Nyquist sampling theorem, this approach to spatial resolution enhancement has inherent limitations, and current CT systems have already largely exploited its potential.

Image Noise Enhancements

Improving spatial resolution using high-frequency reconstruction kernels is generally accompanied by increased image noise. Although the exact relationship depends on acquisition parameters, reconstruction methodology, and radiation dose, the fundamental tradeoff remains unchanged: enhancement of fine image detail typically increases image noise unless compensated by additional photon statistics or advanced reconstruction approaches¹⁻⁴.

Although this relationship does not necessarily hold with modern nonlinear image reconstruction techniques, noise levels increase significantly under these conditions.

From the perspective of image clarity, spatial resolution is a primary factor; however, the contribution of image noise is equally significant. Therefore, it is essential to properly manage image noise.

Artifacts in High Resolution Imaging

In CT systems, spatial resolution performance is achieved through precise acquisition, sampling, and reconstruction processes. As spatial resolution increases, image features that may be less apparent under conventional imaging conditions become more visible. At the same time, artifacts associated with image acquisition, sampling, and reconstruction may also become more pronounced. As a result, although limited in magnitude, artifacts related to spatial frequency such as aliasing, may occur in high-resolution imaging.

In addition, in helical scanning, differences in sampling intervals depending on the helical pitch can introduce artifacts when imaging complex anatomical structures. These helical artifacts (also referred to as pinwheel artifacts) become more pronounced in high-resolution imaging. In image reconstruction, over-enhancing the reconstruction kernel function may result in undershoot and overshoot artifacts.

In particular, such frequency-induced artifacts increase significantly with enhanced spatial resolution; therefore, their proper management is essential.

True Definition DL Design Concept

To achieve higher spatial resolution with improved image clarity, it is necessary to overcome the traditional trade-off associated with significantly increased image noise and artifacts.

The True Definition DL algorithm is designed to consist of three key steps: a noise reduction step, an artifact reduction step, and a spatial resolution enhancement step.

In the first step, noise reduction, the TrueFidelity™ DL (Deep Learning Image Reconstruction, DLIR) technique is utilized. TrueFidelity™ DL has been widely adopted in GE HealthCare CT products since its initial commercialization with the Revolution CT in 2019⁵.

The second step, artifact reduction, is newly introduced. This step addresses high-frequency artifacts such as pinwheel (helical) artifacts,

aliasing artifacts, and streak artifacts. By leveraging extensive CT product development experience accumulated over several decades in multi-slice CT, we developed a method to effectively separate clinical anatomical structures from these artifacts while minimizing any adverse impact on spatial resolution. This innovation represents one of the key elements of True Definition DL.

The third component is the spatial resolution enhancement step, which forms the core of True Definition DL. One prior approach involved using both higher-resolution CT data and standard-resolution CT data; however, there have been no clinical CT products with significantly higher spatial resolution than currently available systems. After exploring numerous technical approaches, we ultimately converged on a feasible solution.

True Definition DL Design Concept *(cont.)*

This approach leverages the physically achievable spatial resolution determined by the system geometry, including the X-ray tube focal spot size, isocenter position, detector pixel size, and the distances among these components. At the same time, we incorporate the actual measured spatial resolution, such as the modulation transfer function (MTF), obtained using features such as ultra-fine wires or extremely thin foils/coins. By characterizing the difference between the theoretically achievable and measured system resolution as a system blur model, this information is incorporated into the True Definition DL algorithm.

In modern CT systems, spatial resolution characteristics are inherently three-dimensional; therefore, this algorithm enhances spatial resolution across the axial, sagittal, and coronal planes.

True Definition DL – AI Model Design

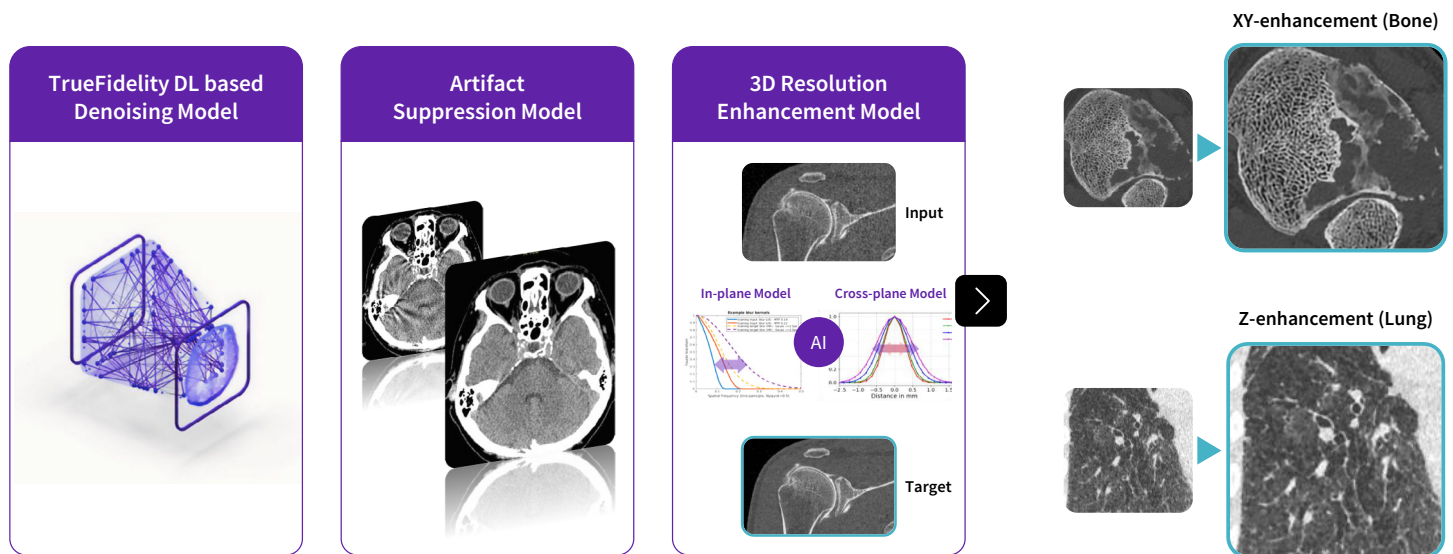
To train a deep learning-based Resolution Boost AI model, we selected a supervised learning approach in which paired datasets consisting of

Original-Resolution (i.e., lower-resolution, LR) and Ideal-Resolution (i.e., higher-resolution, HR) are used as the input and target data, respectively. These LR and HR datasets were generated using physics-based models, including the modulation transfer function (MTF) in the XY (in-plane) and axial planes, as well as the slice sensitivity profile (SSPz) in the Z-direction.

Together, these models characterize system blur effects that influence the visualization of fine anatomical structures.

Using these physics-based models, paired LR and HR datasets were generated for supervised learning, enabling the neural network to learn the relationship between system-limited data appearance and the corresponding higher-resolution target representation.

The quality and performance of the True Definition DL neural network were evaluated using a large and diverse collection of clinical CT images covering a broad range of bone and lung imaging applications.



AI True Definition DL Neural Network model incorporates the CT system resolution and blurring model in both the XY- and Z-planes during training, while also including a model to manage increased noise and artifacts.

Figure 3: True Definition DL Architecture advanced image reconstruction built on three core algorithms.



Figure 4: True Definition DL Process Flow

True Definition DL Performance – Clinical Image Quality

Validated by an independent reader study of 65 clinical cases across three anatomical regions, True Definition DL delivered consistently higher diagnostic image quality ratings than conventional high-resolution reconstruction, with statistically significant improvements in sharpness, noise performance, and overall image quality.

A total of 65 unique subjects' imaging data (Table 1) were used. A total of 8 readers were enrolled, all of whom were United States board-certified radiologists.

Anatomy	Sub-Group	Number of Cases
Bone / MSK	Lower/Upper extremities	15
	Shoulder	6
	Pelvis	6
Lung	Lung	20
Neuro	Inner Ear	8
	Spine	10
Total		65

Table 1: Case Categories and Clinical Anatomy Regions

Each case was independently evaluated by 3 readers for each anatomical section using a 5-point Likert scale, assessing the following

image quality attributes: Noise, Sharpness, and Artifacts. An Overall Diagnostic Quality score for each image type was also calculated by averaging the three attribute scores (Sharpness, Noise, and Artifacts) for each reader and each case.

The Diagnostic Image Quality scale was defined as follows:

- 5 = Excellent (Diagnostic Quality)
- 4 = Good (Diagnostic Quality)
- 3 = Moderate (Diagnostic Quality)
- 2 = Poor (Limited Diagnostic Quality – suitable in some scenarios)
- 1 = Uninterpretable (Non-Diagnostic Quality)

Table 2 summarizes reader ratings for image quality attributes—**Sharpness, Noise, Artifacts**, and the derived **Overall Image Quality (IQ)** for both Non-True Definition DL and True Definition DL reconstructions. Associated **p-values** from paired t-tests indicate whether the differences are statistically significant ($p < 0.05$).

Because 3 readers participated, the 27 bone/MSK cases yielded 81 total scores, the 20 lung cases yielded 60 total scores, and the 18 neuro cases yielded 54 total scores, for a combined total of 195 scores used in the calculation of mean $\pm$ standard deviation.

Anatomy	Assessment Question	Mean $\pm$ SD		
		True Definition DL	Non-True Definition DL	p-value
Bone / MSK	Image Sharpness	4.79 $\pm$ 0.44	4.19 $\pm$ 0.63	<0.001
	Image Noise	4.27 $\pm$ 0.61	3.85 $\pm$ 0.78	<0.001
	Image Artifact	4.65 $\pm$ 0.65	4.57 $\pm$ 0.77	0.034
	Overall Image Quality	4.57 $\pm$ 0.38	4.20 $\pm$ 0.48	<0.001
Lung	Image Sharpness	4.88 $\pm$ 0.32	3.92 $\pm$ 0.65	<0.001
	Image Noise	4.25 $\pm$ 0.51	3.25 $\pm$ 0.65	<0.001
	Image Artifact	4.55 $\pm$ 0.59	4.12 $\pm$ 1.03	<0.001
	Overall Image Quality	4.56 $\pm$ 0.38	3.76 $\pm$ 0.53	<0.001
Neuro	Image Sharpness	4.67 $\pm$ 0.58	4.15 $\pm$ 0.94	<0.001
	Image Noise	4.5 $\pm$ 0.61	3.96 $\pm$ 0.89	<0.001
	Image Artifact	4.28 $\pm$ 0.74	4.13 $\pm$ 0.80	0.019
	Overall Image Quality	4.48 $\pm$ 0.51	4.08 $\pm$ 0.68	<0.001

Table 2: Descriptive Statistics (Likert Scores) by Anatomy, Assessment Question, and Image Type

True Definition DL Performance – Clinical Image Quality *(cont.)*

Based on the results, Image Sharpness which is one of the primary objectives of image quality enhancement in True Definition DL showed significant improvement, ranging from a minimum increase of 0.52 points to a maximum of 0.96 points.

Another notable finding is that Image Noise scores were significantly improved with True Definition DL across all three anatomical categories. Regarding Image Artifacts, the results confirmed that performance with True Definition DL was not inferior.

Overall, this clinical image quality evaluation study demonstrates that True Definition DL provides significantly improved image clarity, primarily driven by enhancements in image sharpness and noise reduction.

True Definition DL: A Clinical Perspective

True Definition is an AI-powered CT image reconstruction technology that enhances spatial resolution and image clarity without requiring hardware changes. By improving detail visibility in both in-plane and cross-plane directions, it supports more confident diagnosis—especially for high-contrast imaging such as lung and bone—while maintaining dose efficiency and seamless integration into existing CT systems.



Dr. Stephanie Bitschnau
Radiologist, Radiomed

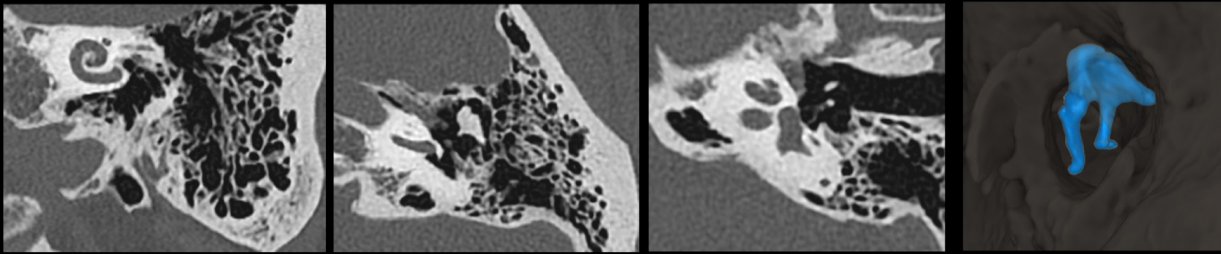
“True Definition DL enables a slice thickness of 0.3 mm, delivering exceptional spatial resolution for visualizing very small anatomical structures. In chest imaging, this level of detail is particularly valuable for assessing small airways and supports more confident evaluation of interstitial lung disease. The technology is also highly beneficial in applications such as inner ear imaging with PETRA, where it allows clear visualization of the auditory ossicles and detection of erosions. This enhanced definition also supports more confident fracture assessment.”



Vikram Rao Bollineni
M.D., PhD., EDiR
Radiologist,
Universitair Ziekenhuis Brussel

“The temporal bone is one of the most demanding regions in diagnostic imaging, packing some of the smallest and most intricate structures in the body into a confined space, where even subtle findings carry real diagnostic weight. In my experience, the finer anatomical detail from True Definition DL sharpens visualization of the ossicular chain, cochlea and semicircular canals, and translates directly into more confident interpretation of complex case.”

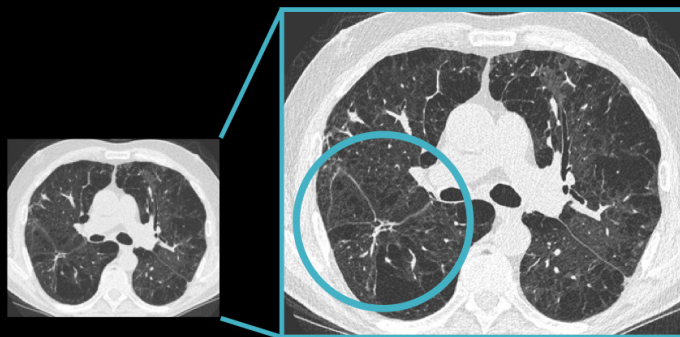
Enhanced Visualization of Fine Anatomical Structures



TDDL Bone

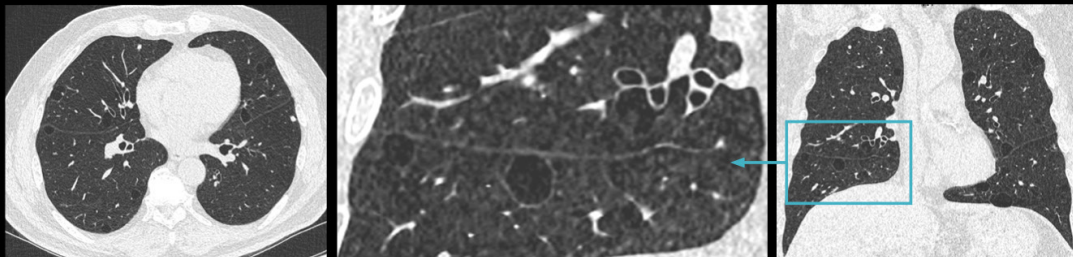
Parameters: Rot. 1 s | 120 kV | 255 mA | NI: 15 | 0.3 mm | CTDi: 78.70 mGy

Low-dose high-resolution chest CT for emphysema evaluation



Parameters: Rot. 0.28 s | 120 kV | 74/129 mA | NI: 30 | 0.3 mm | CTDi: 1.87 mGy

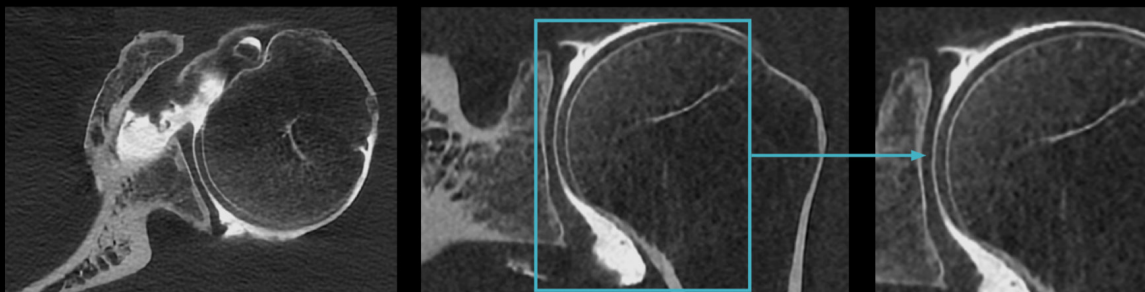
Low-dose high-resolution chest CT for emphysema evaluation



TDDL Bone

Parameters: Rot. 0.28 s | 120 kV | 74/114 mA | NI: 30 | 0.3 mm | CTDi: 1.62 mGy

High-resolution shoulder arthrography for detailed joint evaluation



TDDL Bone

Parameters: Rot. 0.8 s | 120 kV | 450 mA | 0.3 mm | CTDi: 45.57 mGy

References

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