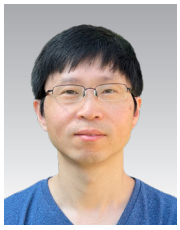
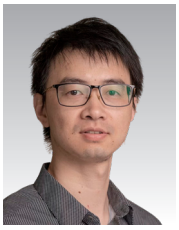
CT / White paper

CLEAR Motion Cardiac: Deep Learning Raw Data-based Motion Correction

powered by Altivity



Jian Zhou, PhD
Senior Principal Scientist
Canon Medical Research USA



Liang Cai, PhD
Manager, CT Physics and Reconstruction
Canon Medical Research USA



Zhou Yu, PhD
Director, CT R&D
Canon Medical Research USA

Introduction

Cardiovascular disease (CVD) remains the leading cause of death worldwide[1]. Early diagnosis of CVD is crucial for improving life expectancy and effective treatment planning. Cardiac CT Angiography (CCTA) serves as a non-invasive test to diagnose coronary artery disease (CAD). A multi-center international study demonstrated that CCTA accurately identifies the presence and severity of obstructive CAD and aids in determining subsequent revascularization in symptomatic patients[2].

Recent updates to the diagnostic guidelines in the US and Europe have elevated the role of CCTA in managing patients with chest pain. European guidelines recommend CCTA to exclude acute coronary disease in patients with low to intermediate likelihood of CAD[3]. Similarly, in the US, CCTA is recommended as a frontline test for evaluating patients with stable and acute chest pain without prior history of CAD[4]. Both guidelines assign CCTA a Class 1 Level A designation, the highest recommendation level, underscoring its proven benefits and safety[3,4].

With these updated guidelines, CCTA has become a routine part of clinical practice for many sites worldwide, with the number of CCTA exams rapidly increasing. To support an efficient workflow, the quality of these exams must be sufficiently high to enable rapid and confident diagnosis. Despite significant advances in CT gantry rotation speeds over the past decade, the 30 ms temporal resolution achieved by invasive coronary angiography remains unmatched[5].

Harnessing Deep Learning for Motion Correction

In recent years, Deep Learning methods for motion estimation and compensation have shown promising results[6-8]. These methods typically involve generating multiple images at different time points and utilizing a trained deep neural network to predict the motion between them. This motion estimation is subsequently incorporated into the image reconstruction process, resulting in motion-compensated images.
Building on this technology and our expertise in Deep Learning Reconstruction, we developed CLEAR Motion Cardiac—a novel algorithm using a Deep Convolutional Neural Network (DCNN) to compensate for coronary artery motion. CLEAR Motion Cardiac effectively reduces motion blurring, improving CCTA image clarity to improve diagnostic confidence. Canon Medical's new cardiac motion correction technology takes one-beat cardiac imaging to a new level of confidence.

How CLEAR Motion Cardiac Works

CLEAR Motion Cardiac employs a Deep Learning-based raw data motion correction method, significantly reducing motion artifacts in ECG-gated cardiac CTA scans. Figure 1 illustrates the workflow of CLEAR Motion Cardiac. The core principle involves estimating cardiac motion to create a continuous four-dimensional (4D) motion vector map.

Reconstruction of a cardiac scan begins with a minimum of half-rotation data targeted to a specific phase of the cardiac cycle. This half-scan data is divided into segments, each with 14 millisecond temporal resolution. These segments undergo partial angle reconstruction (PAR) to create images which are subsequently analyzed to detect motion differences, resulting in the generation of a 4D motion vector map.

The 4D motion vector map is then applied during the reconstruction process resulting in motion-compensated cardiac images. By applying motion correction at the raw data level, CLEAR Motion Cardiac uniquely facilitates the combined use of Deep Learning Reconstruction algorithms (Advanced intelligent Clear-IQ Engine (AiCE) and Precise IQ Engine (PIQE)), enabling effective motion correction, noise reduction, and Super Resolution concurrently.

Unlike image-based correction methods, CLEAR Motion Cardiac performs motion correction directly within the raw data, eliminating the need for additional "padding" and the associated increase in radiation dose.

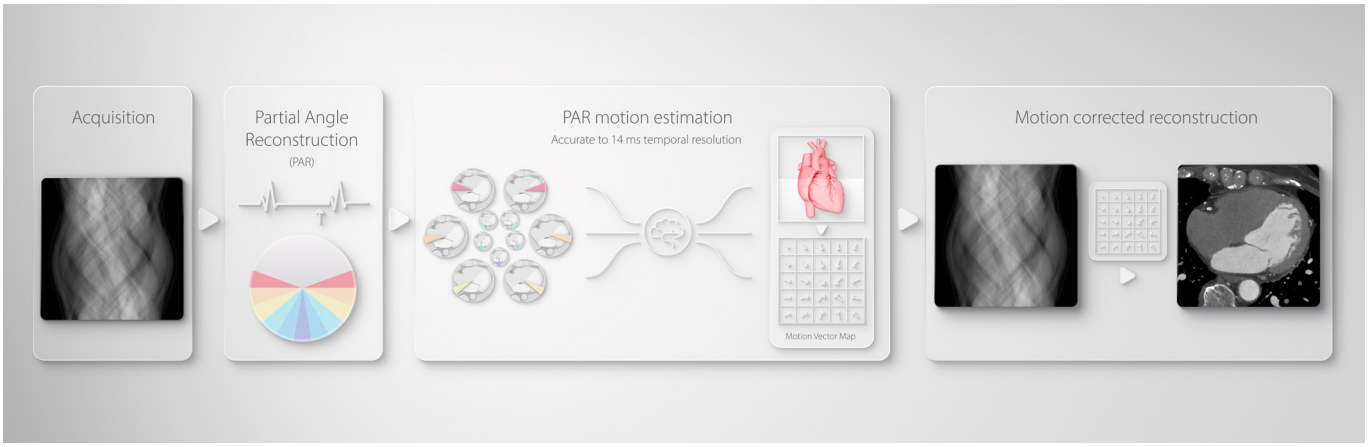


Figure 1: How CLEAR Motion Cardiac works.

"Even in cases where the image was deemed unevaluable due to motion artifacts, applying CLEAR Motion improved the quality to a readable level. The improvement in motion artifacts enables evaluation of mixed plaques and detection of positive remodeling, which is clinically invaluable."

Dr. Seitaro Oda, Kumamoto University

"Even at heart rates around 80 bpm, the correction is remarkable, enhancing visibility of small plaques that were otherwise obscured."

Dr. Fuminari Tatsugami, Hiroshima University

As demonstrated in Figure 2, CLEAR Motion Cardiac shows robust motion correction over a wide range of the cardiac cycle independent to the degree of motion in the vessel.

These images are reconstructed automatically as part of the scan protocol ensuring excellent clinical workflow with consistent results regardless of the operator's experience.

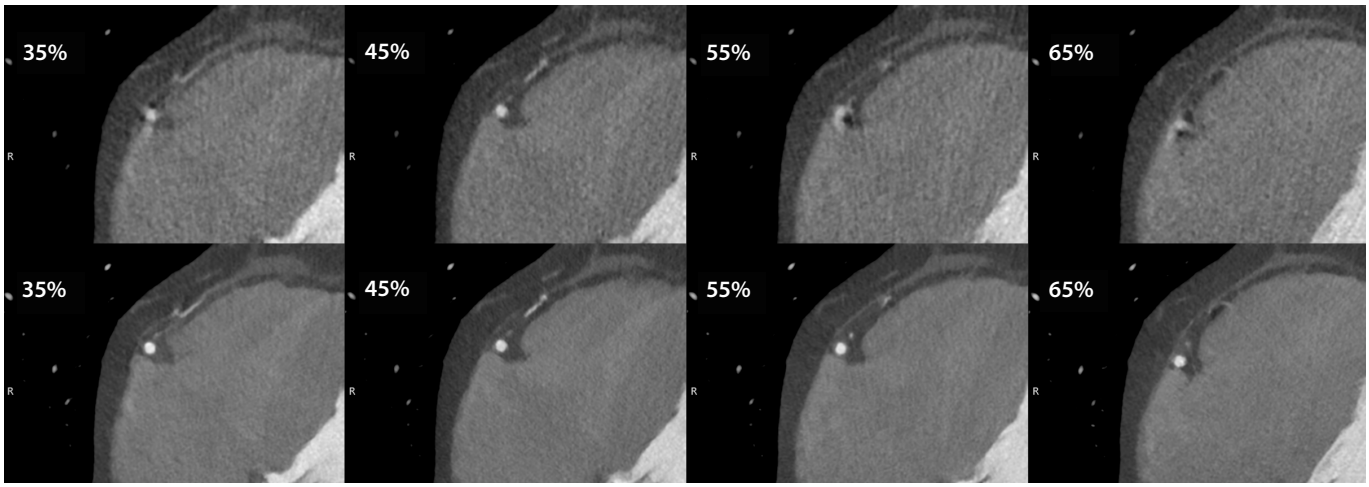


Figure 2: Reconstruction of multiple phases within the exposure window in this case with a heart rate of 83 bpm. Upper row, reconstructed with Adaptive Iterative Dose Reduction 3D (AIDR 3D), without motion correction. Bottom row, reconstructed with PIQE and CLEAR Motion. CLEAR Motion shows robust reduction in motion artifact over multiple cardiac phases.

Clinical Implementation and Results

Clinical results underscore CLEAR Motion Cardiac's efficacy in removing motion artifacts from CCTA exams. In Figure 3, the right coronary artery (RCA) shows severe motion artifacts in the proximal and mid segments, which make diagnosis challenging. CLEAR Motion removes these artifacts, allowing for confident diagnosis and revealing a vessel free of significant disease. Similarly, Figure 4 shows an RCA with significant motion artifacts obscuring stenosis, which CLEAR Motion successfully resolves, allowing for accurate stenosis evaluation.

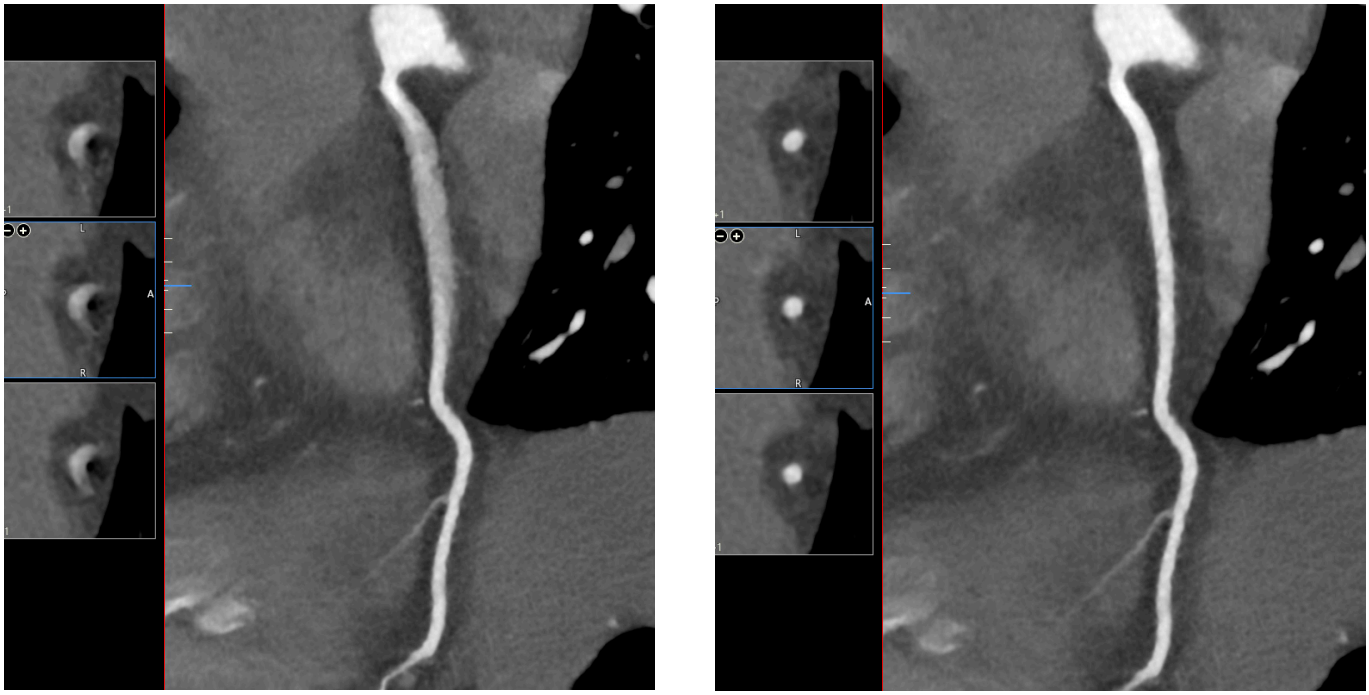
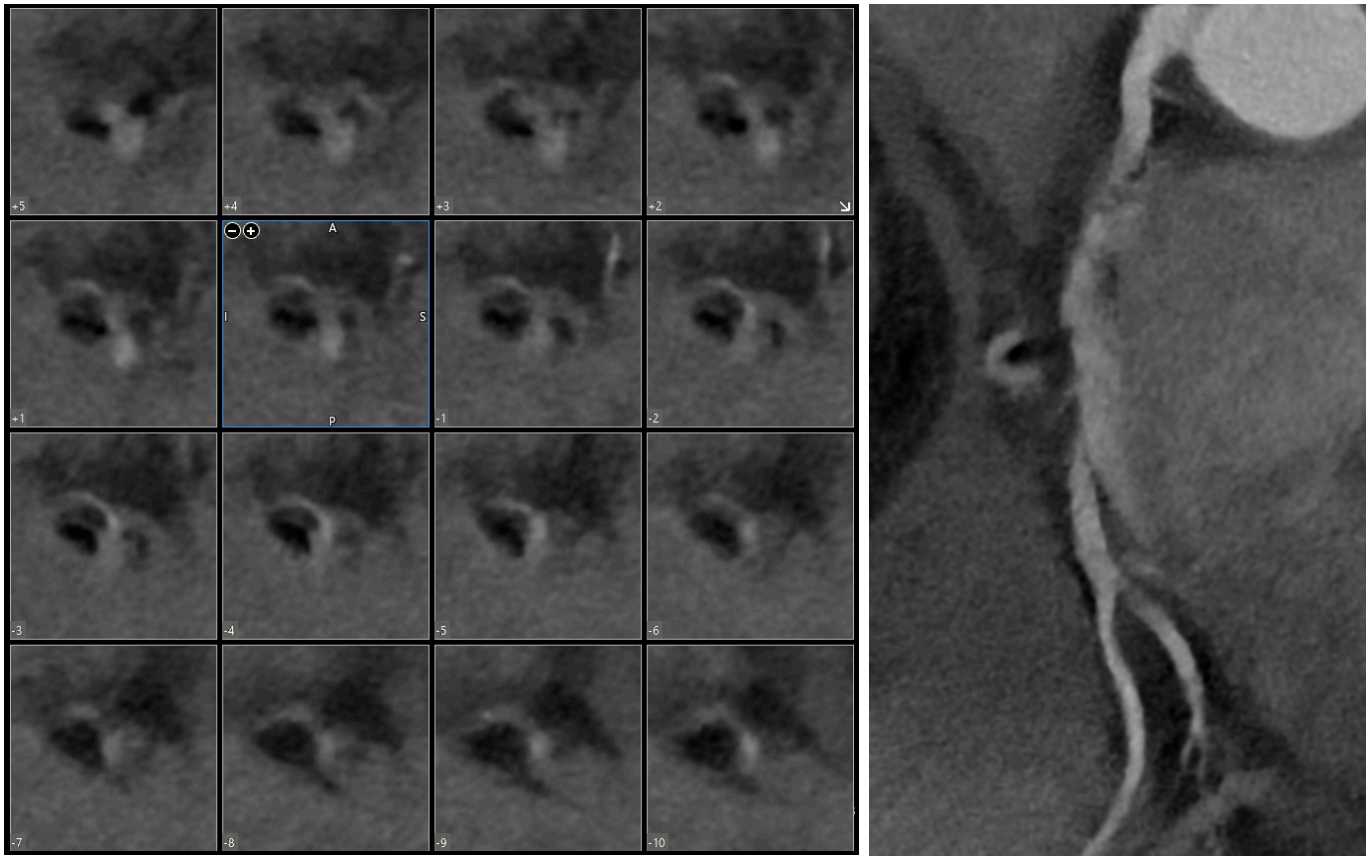


Figure 3: Patient with a HR 75 bpm. The RCA is seen without CLEAR Motion (left) and with CLEAR Motion (right). PIQE 1024 matrix reconstruction. (Courtesy Dr. Chen, National Institutes of Health, USA)

CLEAR Motion OFF



CLEAR Motion ON

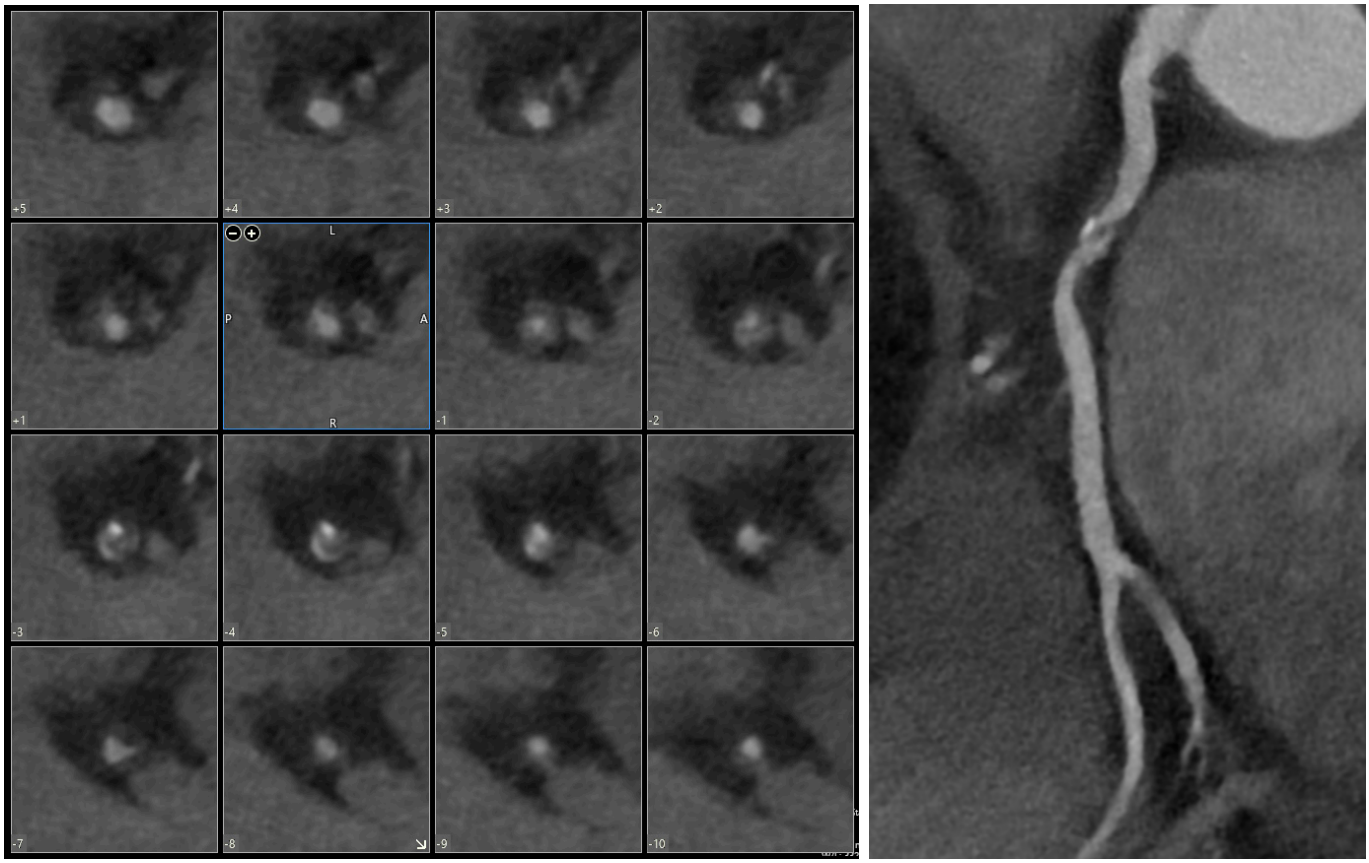


Figure 4: Patient with HR 70 bpm. CLEAR Motion OFF (top) and CLEAR Motion ON (Bottom). CLEAR Motion eliminated the significant motion in the RCA allowing evaluation of the stenosis in the mid vessel. (Courtesy Dr Chen, National Institutes of Health, USA)

Cardiac CT made easy

Clear Motion Cardiac joins and seamlessly integrates with our extensive suite of patient-centric technologies that ensure the highest quality cardiac CTA examinations for each individual patient.
INSTINX provides automatic patient positioning and in combination with a 3D Landmark Scan sets the scan range and Field of View (FOV) automatically. SUREExposure prescribes both kV and mA to produce the desired level of diagnostic image quality and includes dose reduction available with the preferred reconstruction technique. SURE Start bolus triggering automatically initiates the scan for optimal contrast enhancement of the heart.

ECG gating is overseen by SURECardio which offers intelligent automation that starts with a single breath hold practice. This enables the exposure window to be set automatically. During the scan. Real Time Beat Control monitors the patient's heart rate and adapts the exposure as necessary to ensure the prescribed phases are captured even reacting to an arrythmia.

PhaseXact detects the optimal cardiac phase with the least amount of motion for image reconstruction, either in systole, diastole or both. CLEAR Motion will compensate for any residual motion within the raw data allowing advanced 1024 matrix image reconstruction with PIQE.

The accumulated benefits of these patient centric technologies yield cardiac CTA exams that are sharp, clear and precise with consistent results for every patient regardless of operator experience. Quite simply, Cardiac CT made easy.

Conclusion

CLEAR Motion Cardiac represents a significant step forward in cardiac imaging by effectively reducing motion artifacts in CCTA exams. When paired with PIQE 1024 matrix, it yields sharp, motion-free images with excellent low-contrast detectability, all without additional radiation dose. With a full volume reconstruction time of two minutes, CLEAR Motion is seamlessly integrated into the clinical workflow of all cardiac examinations, setting new standards for CCTA image quality and efficiency.

Key Points

- Canon Medical's raw data cardiac motion correction enhances one-beat cardiac imaging for improved diagnostic confidence.
- CLEAR Motion Cardiac calculates differential motion in projection space with 14 ms temporal resolution, producing a precise motion vector map for correction prior to reconstruction.
- Deep Learning raw data correction applies to a single cardiac cycle phase, avoiding extra radiation exposure or padding typical of image-based correction.
- Motion correction in raw data space allows for simultaneous use of Deep Learning Reconstruction algorithms (AiCE and PIQE) for combined motion correction, noise reduction, and super-resolution.
- Produces high-quality 1024-matrix cardiac images, establishing new clinical practice standards globally.

References

1. IHME, Global Burden of Disease (2019).
2. Miller JM, Rochitte CE, Dewey M, et al. Diagnostic performance of coronary angiography by 64-row CT, N Engl J Med. 2008 Nov 27;359(22):2324-36.
3. Jean-Philippe Collet, Holger Thiele, Emanuele Barbato, et al. 2020 ESC Guidelines for the management of acute coronary syndromes, Eur Heart J. 2021 Apr 7;42(14):1289-1367.
4. Gulati M, Levy PD, Mukherjee D, et al. 2021 AHA/ACC/ASE/CHEST/SAEM/SCCT/SCMR Guideline for Evaluation and Diagnosis of Chest Pain, J Am Coll Cardiol. 2021 Nov 30;78(22).
5. Otero H, Steigner M, Rybicki F, The "Post- 64" Era of Coronary CT Angiography: Understanding New Technology from Physical Principles, Radiol Clin North Am. 2009 January ; 47(1): 79–90
6. Sokooti H, et al. "Nonrigid Image Registration Using Multi-scale 3D CNNs," MICCAI 2017, vol 10433.
7. Koen AJ, et al. "Deformable Image Registration Using CNNs," Proc. SPIE 2018, 105740S.
8. Lossau T, et al. "Motion Estimation and Correction in Cardiac CTA Images Using CNNs," Comput Med Imaging Graph, Vol 76, 2019.

Altivity is a new approach to AI innovation. It is a multimodality, overarching brand, for healthcare, which pulls together all the AI technology that Canon provides under one name.

CANON INC.

30-2, Shimomaruko 3-chome, Ohta-ku, Tokyo 146-8501, Japan
Telephone: (81)-3-3758-2111

©CANON INC. 2025-2026. All rights reserved.

Design and specifications are subject to change without notice.
MWPCT0015EA 2026-04 Published in Japan

The clinical results described in this paper are the experience of the author.
Results may vary due to clinical setting, patient presentation and other factors.

Development and manufacturing functions of Canon Medical Systems Corporation have been transferred to CANON INC.
This document was created prior to the name change and therefore the former company name may still be referred to within the document.

CANON MEDICAL GROUP

Made For life