

The Feasibility of Ultrafast Gated Myocardial Perfusion Imaging Using a Dedicated Solid-state Cardiac Camera

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Abstract

Purpose

To explore the feasibility of ultrafast gated myocardial perfusion imaging (GMPI) using a dedicated solid-state cardiac camera.

Methods

Seventy-six consecutive patients who were suspected with coronary artery disease referred for gated-MPI scan on the Discovery NM 530c (DNM) were retrospectively included. Thirty patients were selected as the test group to determine the minimum scan time and was validated in all the included patients. The original 6-min list-mode raw data from the test group were reframed into 1–5 min datasets, while the rest patients were reframed to generate the minimum scan time dataset. Subgroup analysis of stress and rest scan, male and female patients, different body mass index (BMI), perfusion defect severity were performed. All datasets were quantified using automated method including perfusion and functional parameters, additional visual score was performed by three clinicians. Quantitative parameters between different scan times were compared using Wilcoxon test or paired t test. The agreement of quantitative parameters between reframed scan and original 6-min scan was analyzed using intraclass correlation coefficient.

Results

The minimum scan time was determined as 3 min in the test group. No difference was observed between 3-min and 6-min scan ($P > 0.05$ for all parameters). For subgroup analysis, EDV ($p = 0.04$) and ESV ($P < 0.001$) in male patients, ESV ($p = 0.001$) and EF ($P = 0.008$) in patients with big BMI were found with significant differences, while other subgroups showed no significant differences ($P > 0.05$).

Conclusion

The DNM camera allows for a minimum of 3-min scan for GMPI without compromising quantitative accuracy of perfusion and function analysis.

Key Points

- Ultrafast 3-min GMPI scan preserves quantitative accuracy both for perfusion and function parameters when compared with standard 6-min scan in Chinese cohort with relatively small cardiac volumes.

- Subgroup analysis showed no significant differences of perfusion and functional parameters between different scan type (stress and rest) and perfusion defect severity ($SSS < 4$ and $SSS \geq 4$), while sex and BMI specific vulnerabilities in functional quantification was observed.

Introduction

Gated myocardial perfusion imaging (GMPI) encompasses measurement of myocardial perfusion and left ventricular (LV) function, which is essential for the diagnosis risk stratification and prognosis of ischemic cardiac diseases [1]. However, the time-consuming protocol (typically 10–20 min) of single-photon emission computed tomography (SPECT) MPI can impact patient comfort, increase motion artifacts, and limit clinical throughput. The introduction of the novel dedicated cardiac camera (Discovery NM 530c, DNM; GE Healthcare) equipped with cadmium-zinc-telluride (CZT) detectors offers the potential for ultrafast or ultra-low dose protocols without compromising image quality and diagnostic accuracy [2–4].

Since the initial reports of rapid CZT-SPECT imaging emerged around 2010 [5, 6], several studies have confirmed the general feasibility of reducing scan time 3–5 minutes for perfusion analysis (3–5 min) and LV function analysis (5–10 min) in Western populations [7–12]. However, these early investigations primarily validated correlation with conventional cameras or MRI, rather than determining the intrinsic minimum scan time within the CZT platform itself. Furthermore, they predominantly focused on perfusion parameters, while the minimum acquisition time required for reliable LV functional quantification has been less systematically evaluated. More importantly, no study has specifically evaluated the minimum scan duration in Asian populations, who typically have smaller cardiac volumes than Western cohorts—a factor that may significantly influence count statistics and the reliability of ultrafast acquisition.

To address these gaps, this study was designed to determine the minimum scan time in a Chinese population for simultaneous perfusion and functional assessment on the DNM camera using 6-min list-mode data as the internal reference and further evaluating the robustness of ultrafast GMPI across clinically relevant subgroups defined by sex, BMI.

Methods

Patient population

Patients with suspected coronary artery disease referred for GMPI scan on DNM at Chinese PLA general hospital from May 2023 to May 2024 were consecutively included for retrospective analysis. Among the included 76 patients with 100 scans (52 underwent stress-only protocol, 24 underwent 2-d adenosine stress-rest protocol), 15 male and 15 female patients randomly selected from the stress-only group constituted the test group to determine the minimum scan time for GMPI.

Image acquisition and analysis

A 2-d adenosine stress-first protocol was employed. Rest scan was waived following clinical evaluation. About 90–120 min post-injection of ^{99m}Tc -sestamibi (MIBI) (555 MBq), gated-MPI (8-frame) scans (stress or rest) were performed on the DNM camera for 6 min using list-mode. Data from the test group were reframed to create 1-min, 2-min, 3-min, 4-min, 5-min datasets, and the remaining patients were reframed according to the minimum scan time determined by the test group. All images were reconstructed using a new dedicated iterative algorithm (maximum penalized likelihood iterative reconstruction) [13] to generate perfusion images in standard axes.

Quantitative analysis was performed using a commercially available software solution (Cedars QPS/QGS, USA). Perfusion parameters were evaluated using a 17-segment LV model: tracer uptake (percentage of maximum uptake, perfusion%), stress score (SS) and rest score (RS) of each segment, SS and RS of the 3 main coronaries territories, summed stress score (SSS), global summed rest score (SRS). The following LV function parameters were recorded: end-diastolic volume (EDV), end-systolic volume (ESV) and ejection fraction (EF). An additional visual analysis of stress and rest score using the 17-segment LV model was conducted by three nuclear medical physicians. Diagnostic abnormalities were classified based on the following criteria: $\text{SSS} \geq 4$, $\text{LVEF} < 45$ for male and $\text{LVEF} < 55$ for female.

Statistical analysis

Continuous variables that follow a normal distribution are presented as mean $\pm$ standard deviation (SD), while those that do not follow a normal distribution are presented as median (interquartile range). Categorical variables were shown as number (n) and percentage (%). Inter-reader agreement was assessed using Cohen's kappa statistic. The agreement of quantitative parameters between reframed scans and original 6-min scan were assessed using intraclass correlation coefficient (ICC, two-way random effects model, absolute agreement). The minimum scan time was defined as the duration at which no further improvement was found in the ICC ($< 5\%$ increase) between the reframed scan and the 6-min scan. Differences in quantitative parameters between the minimum scan and 6-min scan was compared using Wilcoxon test or paired t test. Bland–Altman analysis was conducted to assess the limits of agreement and potential systematic bias between different scan durations. Sub-group analysis based on scan type (stress and rest), gender (male and female), body mass index ($\text{BMI} \leq 24$ and $\text{BMI} > 24$), perfusion defect severity ($\text{SSS} < 4$ and $\text{SSS} \geq 4$) were performed. SPSS software (version 29.0, SPSS Inc.) and Graphpad prism (version 10, GraphPad Software) were used for statistical analysis. P value less than 0.05 was considered statistically significant.

Results

Patient characteristics

The study included 76 patients with 100 scans, among which 52 underwent stress-only protocol, 24 underwent 2-d adenosine stress-rest protocol. Table 1 summarized the detailed patient characteristics.

Table 1
Patient information

Total	Test group	Included patients
	30	76
Age, mean ± SD (range)	63.2 ± 11.6 (40.0, 79.0)	62.3 ± 10.4 (40.0, 82.0)
Gender		
Male	15 (50%)	40 (52.6%)
Female	15 (50%)	36 (47.4%)
BMI, mean ± SD (range)	24.41 ± 3.07 (19.5, 30.9)	24.7 ± 2.9 (19.3, 35.0)
BMI ≤ 24	15 (50%, 7 female)	36 (47.4%, 13 female)
BMI > 24	15 (50%, 8 female)	40 (52.6%, 13 female)
Scan protocol		
stress-only	30 (100%)	52 (68.4%, 18 female)
stress-rest	-	24 (31.6%, 8 female)

SD: standard deviation; BMI: body mass index.

Determination of the minimum scan time

Perfusion parameters (segmental perfusion%, Segmental, territory and global SS) and stress function parameters (LVEDV, LVESV, LVEF) were compared between the reframed scans (1–5 min) and the original 6-min scan. The ICC values showed an increasing trend as scan time prolonged (Fig. 1). For all the analyzed parameters, no further improvement was found in ICCs at 3-min scan (Table 2). Considering all these results, the minimum scan time was determined to be 3 minutes.

Table 2
ICCs of perfusion and function parameters in the test group

Perfusion parameters	1 min	2 min	3 min	4 min	5 min	Minimum scan time
	vs	vs	vs	vs	vs	
	6 min	6 min	6 min	6 min	6 min	
Perfusion%	0.890	0.915	0.959	0.970	0.972	3 min
per segment						
SS	0.770	0.870	0.896	0.868	0.933	3 min
per segment						
SS	0.727	0.92	0.936	0.949	0.978	3 min
per territory						
Global SS	0.881	0.962	0.981	0.976	0.986	2 min
LV function parameters	1 min	2 min	3 min	4 min	5 min	Minimum scan time
	vs	vs	vs	vs	vs	
	6 min	6 min	6 min	6 min	6 min	
EDV	0.983	0.990	0.989	0.995	0.991	1 min
ESV	0.974	0.992	0.993	0.994	0.990	1 min
EF	0.939	0.972	0.985	0.987	0.990	2 min

ICC: intra-class correlation; SS: stress score; LV: left ventricle; EDV: end-diastolic volume; ESV: end-systolic volume; EF: ejection fraction.

Validation of the minimum scan time

Segmental, territory SS and RS, global SSS and SRS, stress and rest EDV, ESV, EF were compared between 3-min and 6-min scans in all the included patients and showed no significant differences (Fig. 2). Bland-Altman plots demonstrated narrow limits of agreement between 3-min and 6-min scans for both perfusion and functional parameters (**Supplementary Fig. 1**). The agreement rates for abnormal SSS and EF classification were 93.4% (71/76) and 96.1% (73/76), respectively.

For visual scores, it showed high inter-observer agreement (kappa value = 0.88, $p < 0.001$), excellent agreement between 3-min and 6-min scans (SSS, SRS and SDS ICC = 0.984, 0.992 and 0.945, all $p < 0.001$), and no significant differences were found between 3-min and 6-min scans (SSS, SRS and SDS, all $P > 0.05$).

Subgroup analysis was performed (**Supplementary Fig. 2–5**). For stress and rest subgroups, no significant difference was observed between 3-min and 6-min scans ((**Supplementary Fig. 2**). For different gender subgroups, EDV and ESV of male patients were found with significant differences ($p = 0.04$ for EDV and $P < 0.001$ for ESV, respectively) (**Supplementary Fig. 3**). For different BMI subgroups, ESV and EF of patients with big BMI showed significant differences ($p = 0.001$ for ESV and $P = 0.008$ for EF, respectively) (**Supplementary Fig. 4**). For perfusion defect severity subgroups, no significant difference was found (**Supplementary Fig. 5**).

Discussion

This study investigated the feasibility of ultrafast GMPI on DNM. Our findings establish that a 3-minute gated acquisition maintains quantitative accuracy for both perfusion and LV function analysis, with important implications for clinical workflow optimization.

For perfusion parameters in the test group, the results were aligned with previous reported findings[5] that ICCs increase with prolonged scan time but no further improvement was seen with scan duration over 3 min. Unlike previous studies which validate the CZT camera against conventional dual-head SPECT (15-min acquisition) as the reference standard[5, 6], our study used 6-min CZT list-mode data as the internal reference to determine how much further this could be reduced without compromising the camera's intrinsic performance. By validating the quantitative parameters obtained on commercially available software and the visual scores between 3-min and 6-min scans, the results confirm that the ultrafast protocol preserves both quantitative precision and visual interpretability.

Previous studies demonstrated good correlation of LV volume and LVEF between gated-MPI on DNM (5–10 min scan) and cardiac magnetic resonance imaging [7–10]. However, the minimum scan time for functional parameters has not been evaluated. We systematically evaluated both perfusion and LV functional parameters (EDV, ESV, EF) within the same framework. Notably, we found that functional parameters achieved excellent agreement even at 1–2 minutes in the test group, yet a 3-minute minimum was chosen to ensure simultaneous robustness across all perfusion and functional indices.

In addition, previous studies were conducted in Western cohorts with relatively larger cardiac volumes (reported EDV and ESV: ~138 and 68 mL for male, 125 and 61 mL for female) [14]. In our Chinese cohort, median EDV and ESV were markedly smaller (89.5 and 39.0 mL for male, 69.0 and 23.0 mL for female), raising the question of whether prior conclusions would generalize to populations with smaller hearts. Our data confirm that a 3-min protocol remains feasible in this demographic.

The agreement rates for abnormal SSS and EF classification were 93.4% (71/76) and 96.1% (73/76), respectively. The five patients with discordant SSS results were all patients with BMI over 24 (2 female and 3 male patients). The three patients with discordant EF classification were 2 patients (1 male and 1 female) with big BMI and one male patient with small BMI. These findings suggest the need of further validation in different patient subgroups. The subgroup analysis revealed sex and BMI specific vulnerabilities in functional quantification that were not previously characterized.

Limitations

The included patients in this retrospective study were mainly male patients and patients with relatively low BMI, which may limit the generalizability of the findings. With limited number of patients received rest scans, test group only included patients from the stress-only group which may introduce some bias, although rest parameters were analyzed in the validation group. Further prospective investigation in larger population and evaluation of overweight patients is under consideration.

Conclusions

Ultrafast 3-min scan is feasible for GMPI with standard injection dose using DNM without compromising quantitative accuracy. It could help improve the clinical efficiency and patient comfort without sacrificing diagnostic accuracy. However, slightly reduced diagnostic accuracy in obese patients was noted, which may require further investigation.

Declarations

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to patient privacy and data protection regulations, but are available from the corresponding author on reasonable request and subject to institutional approval.

Competing interests

The authors declare that they have no conflict of interest.

Compliance with Ethical Standards

The study has been approved by the Medical Ethics Committee of Chinese PLA General Hospital (S2025-062-01) and was conducted in accordance with the Helsinki Declaration and its later amendments or comparable ethical standards. As this was a single-center retrospective study in which all the data were collected as part of routine clinical care without patient intervention, written informed consent for the clinical gated myocardial perfusion imaging examination was obtained from patients. Patient data were handled in full compliance with applicable data security law of the People's Republic of China.

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No funding was received for conducting this study.

Authors' contributions

R Wang and J Liu designed the study, D Zhao and S Sun collected clinical and SPECT data, X Bi, T Ye and J Song helped with image processing, D Zhao analyzed the data and carried out the statistical analysis.

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Figures

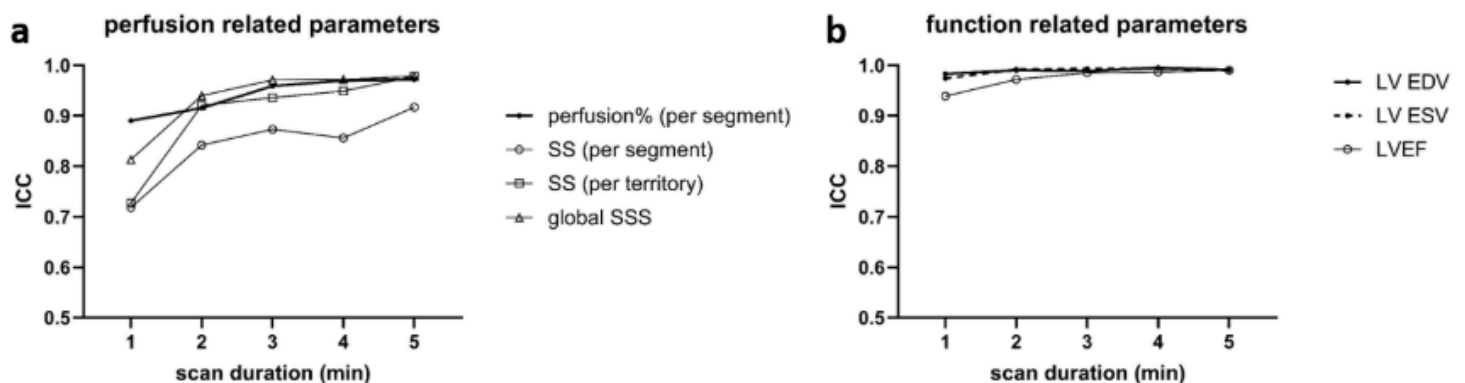


Figure 1

ICCs of stress scores (A) and left ventricular function parameters (B) between reframed scan time (1-5 min) and original scan time (6 min) in the test group. ICCs showed increasing trend with prolonged scan time. ICC: intra-class correlation; SS: stress score; LV: left ventricle; EDV: end-diastolic volume; ESV: end-systolic volume; EF: ejection fraction

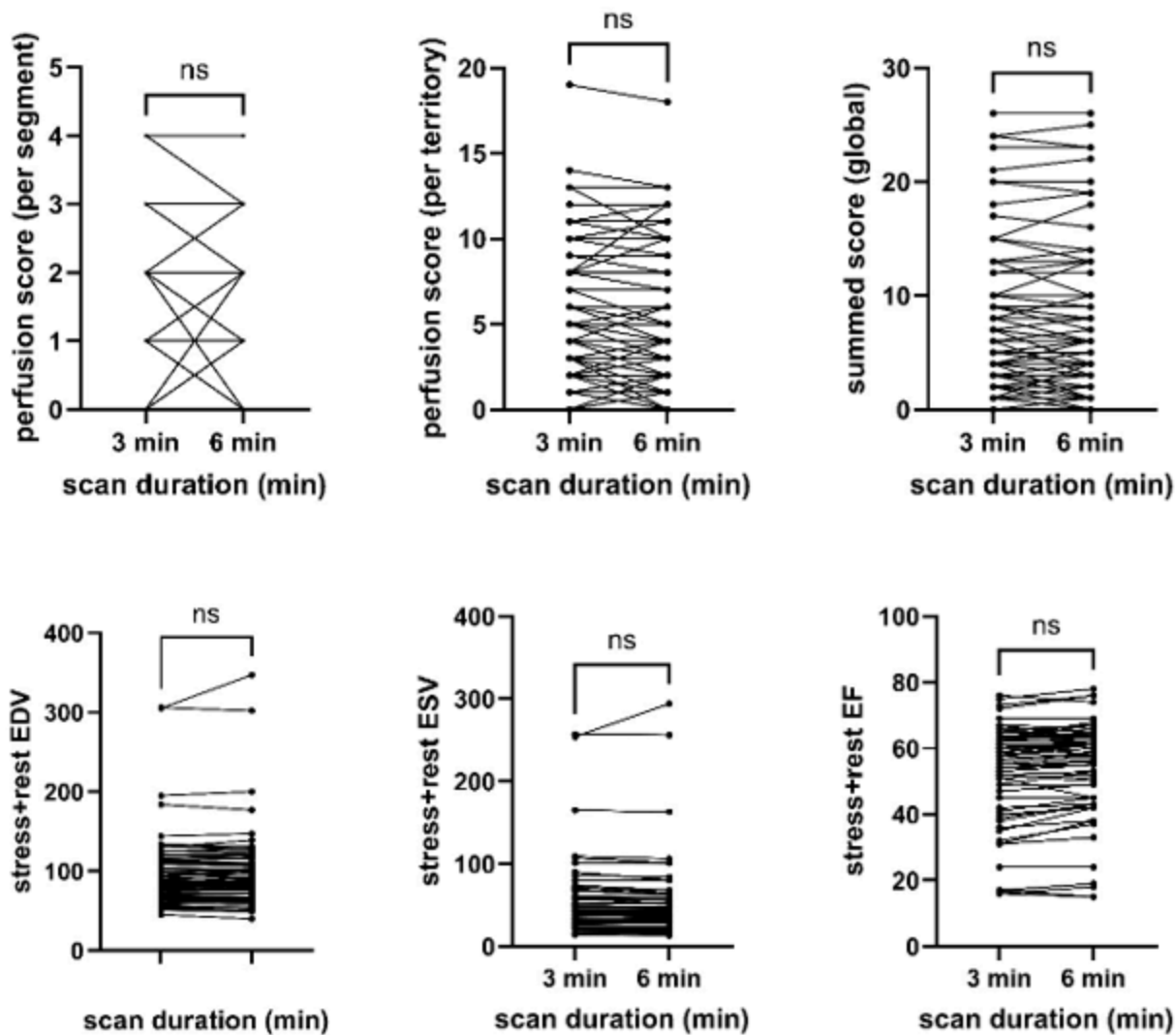


Figure 2

Inter-group analysis of perfusion (upper panel) and left function (lower panel) parameters between 3-min and 6-min scan. EDV: end-diastolic volume; ESV: end-systolic volume; EF: ejection fraction. (* $P < 0.05$, ns: no significant difference)

Supplementary Files

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