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ORIGINAL RESEARCH ARTICLE

Assessing the role of supine and prone positioning on left ventricular volumes, ejection fraction, and heart rate using ECG-gated [^{99m}Tc]Tc-MIBI myocardial perfusion scan

Maryam Tajik Rostami[1], Seyed Ali Mirshahvalad[2], Shirin Familrashtian[3], Hosein Ghanbari[3], Sadegh Dehghani[3]

[1]*Department of Nuclear Medicine, Tehran Heart Center, Tehran University of Medical Sciences, Tehran, Iran*

[2]*Research Center for Nuclear Medicine, Shariati Hospital, Tehran University of Medical Sciences, Tehran, Iran*

[3]*Radiation Sciences Department, School of Allied Medical Sciences, Tehran University of Medical Sciences, Tehran, Iran*

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*Corresponding Author:
Dr. Sadegh Dehghani
Address: Radiation Sciences Department, School of Allied Medical Sciences, Tehran University of Medical Sciences, Tehran, Iran
Email: dehghani_s@sina.tums.ac.ir

ABSTRACT

Introduction: Gated myocardial perfusion SPECT (GMPS) using [^{99m}Tc]Tc-MIBI allows the cardiac function assessment in addition to the myocardial perfusion. Although the prone position has been suggested as a complementary protocol in GMPS, there is no firm recommendation on its effect on function and physiologic conditions of cardiac. We aimed to evaluate the impact of supine and prone positions on left ventricular end-systolic volume (ESV), end-diastolic volume (EDV), ejection fraction (LVEF), and heart rate (HR).

Methods: Ninety-six patients with no history of ischemic heart disease or cardiomyopathy participated in this study. Using GMPS at both supine and prone positions, volume-based cardiac function was evaluated. ESV, EDV, LVEF, and HR were obtained and compared between supine and prone positions. A two-tailed p-value of < 0.05 was considered significant.

Results: Using GMPS, no significant difference in ESV, EDV, LVEF, and HR was demonstrated between the two positions (p-value>0.05). The mean LVEF results derived from the supine versus prone position were 67.22% (42–93%) vs. 64.22% (41–89%) (p-value=0.71). ESV results were 23.28 vs. 27.23 (p-value=0.39). EDV results were 65.78 vs. 70.33 (p-value=0.27). Furthermore, HR results were close to each other in supine 72.22 (45-106) and prone 74.99 (47-110) positions (p-value=0.68).

Conclusion: It seems that prone positioning causes no considerable change in cardiac volumes. As a result, the prone position can be an acceptable alternative to the supine position when volume-based assessments are considered.

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INTRODUCTION

As an effective clinical tool for diagnosing coronary artery disease (CAD), myocardial perfusion imaging (MPI) using single-photon emission computed tomography (SPECT) has grown to be used in risk stratifying of patients after infarction, recognizing myocardial viability, and planning therapy [1, 2]. Performing electrocardiography (ECG)-Gated MPI SPECT (GMPS) in both prone and supine positions has been suggested as a poor man's attenuation compensation [3, 4]. In particular, an additional prone position can be considered a simple and efficient method field to reduce the diaphragmatic attenuation in the inferior wall [5-7]. Although direct approaches have also been commercially introduced for attenuation correction, they are not readily available to all departments and are sometimes not cost-effective [5, 6].

GMPS can visualize systolic function disorders by decreased left ventricular ejection fraction (LVEF) and abnormal LV volumes [7]. By subsequent regional wall motion analysis and total function quantification, GMPS using [^{99m}Tc]Tc-MIBI provides the measurement of left ventricular end-systolic volume (ESV), end-diastolic volume (EDV), stroke volume (SV), heart rate (HR), and LVEF [8, 9]. So far, data acquisition in various studies has been made mainly based on the information obtained from the supine position as the standard protocol. This is because the hypotheses, such as prone positioning, may increase the intra-abdominal pressure and sympathetic nerve activity [10] and affect the arterial stuffing [11]. However, the impact of these physiologic changes on ESV, EDV, LVEF, and HR remained unclear. Hayes et al. reported that despite an equal prognostic value between a normal finding on combined prone and supine acquisitions and supine-only acquisitions, supine-only acquisitions have different values in obscure or pathologic findings [12]. Berman et al. reported a good correlation between LVEF, ESV, and EDV between prone and supine acquisitions of GMPS after stress [13]. However, HR was not reported in their study. Due to their post-stress study, often-seen time-dependent ischemic was significant after exercise [14-16]. Schaefer et al. indicated that EDV, ESV, and HR values between prone and supine acquisitions of [^{99m}Tc]Tc-MIBI GMPS could differ significantly. However, ESV and LVEF did not show any considerable differences. Therefore, they concluded that the values generated from supine GMPS should not be compared with those derived from the prone position. As a limitation, they investigated a small sample size, and random positioning was not done for all patients [17].

This study aimed to evaluate the differences in ESV, EDV, LVEF, and HR between prone and supine acquisitions using GMPS.

METHODS

Ninety-six consecutive patients were enrolled in this prospective study between 2021 and 2022. The written approval of the local ethics committee was obtained (ID number, IR.TUMS.SPH.REC.1400.213) and formal informed consent was waived. The inclusion criteria were having no perfusion defect at rest phase imaging with a summed rest score of less than 3. Patients with irregular R-R distance, atrial fibrillation, and inability to lie in a prone position were excluded.

SPECT imaging

All patients fasted for four hours prior to GMPS. There was a prohibition of coffee and caffeine-containing medication, nitrates, aminophylline, or beta-blockers for at least 12 hours. Based on the patients' weight, 740-925 MBq (20-25 mCi) [^{99m}Tc]Tc-MIBI was injected intravenously. To avoid the considerable influence of background activity, the scan was initiated 45-60 minutes after the injection of the radiotracer. Furthermore, full-fat milk was consumed to enhance hepatobiliary ^{99m}Tc-MIBI clearance and avoid liver-dominant SPECT images.

First, the ECG-gated SPECT acquisition was performed in the supine position. Right after the supine position imaging was completed, patients were repositioned to initiate the prone position acquisition. The Bright View SPECT gamma camera (Philips Healthcare, Cleveland, OH) was utilized. The acquisition parameters were: 20% energy window symmetrically set over 140 keV; low-energy high-resolution parallel-hole collimators; and acquisition of 32 projections over a 180° arc with 25 seconds per stop, beginning from 45 right anterior oblique to 135 left posterior oblique. Step-and-shoot acquisition was performed on a 64 x 64 x 16 matrix and 38.5 cm detector mask (1.22 zoom) using a gated mode with a prefixed R–R interval and beat acceptance window of 40%. The cardiac cycle was divided into eight equal distances. The filtered back projection was used for all datasets. The raw data from stress acquisition were prefiltered by ramp and subsequently by Butterworth filters with a frequency cut-off of 0.45 and order of 9 for each of the eight gated frames and then a frequency cut-off of 0.40 and order of 9 for summed gated frames (composite images) without attenuation correction. Then, filtered back-projected data were reconstructed into short-axis, vertical long-axis, and horizontal long-axis slices.

Image analysis

Auto Quant 7.2 software was used to quantitatively analyze reconstructed tomographic slices. To define the myocardium border, automatic contour detection was used during post-processing. Quantitative image data were generated with a fully automated approach, including ESV, EDV, LVEF, and HR. To be robust, no manual modification was applied.

Statistical analysis

All analyses were done using Origin 6.1 G (Origin Lab Corp.) and SPSS 25 (SPSS Inc.) software. The Wilcoxon matched-pairs signed-rank test was used to evaluate the mean differences of ESV, EDV, LVEF, and HR between the two positions. Data were presented as mean ± SD, and a two-tailed p-value of <0.05 was considered significant.

RESULTS

A total of 96 patients (age = 54.16 ± 8.71) were recruited for myocardial perfusion scans, of which 54 (56.3%) were female. As shown in Table 1, of these 96 patients, 63 (65.62%) were referred for assessment of chest pain, 56 (58.33%) for dyspnea, and 26 (27.08%) for palpitation. None of these patients had a prior history of percutaneous coronary intervention, ischemic heart disease, myocardial infarction, or coronary artery bypass grafting. The most prevalent risk factors of the patients were high blood pressure (49%), diabetes (31.25%), dyslipidemia (46.87%), smoking (21.87%), and positive family history (29.16%).

All patients underwent SPECT imaging in supine and then prone positions. As shown in Table 2, there were no significant differences in ESV, EDV, LVEF, and HR between supine and prone positioning (p-values>0.05). The mean LVEF results derived from the supine versus prone position were 67.22% (42–93%) vs. 64.22% (41–89%) (p-value=0.71). ESV results were 23.28 vs. 27.23 (p-value=0.39). EDV results were 65.78 vs. 70.33 (p-value=0.27). Furthermore, HR results were close to each other in supine 72.22 (45-106) and prone 74.99 (47-110) positions (p-value=0.68).

Figure 1 shows quantitative GMPS analyses of a patient in supine and prone positions with no significant changes in LVEF, EDV, and ESV after repositioning. A typical [^{99m}Tc]Tc-MIBI image of the patient in supine and prone positions shows reduced radiotracer uptake can be observed in the inferior wall. At the same time, no significant perfusion defect is noted in the prone position, suggesting diaphragmatic attenuation (Figure 2). The supine and prone GMPS-derived LVEF demonstrated a correlation r-value of 0.78 (R2= 0.69, Figure 3a), while the correlation of HR in both groups had an r-value of 0.97 (R2= 0.94, Figure 3b). The correlation of r = 0.88 (R2= 0.84, Figure 3c) was achieved for EDV, and r = 0.86 (R2= 0.77, Figure 3d) for ESV.

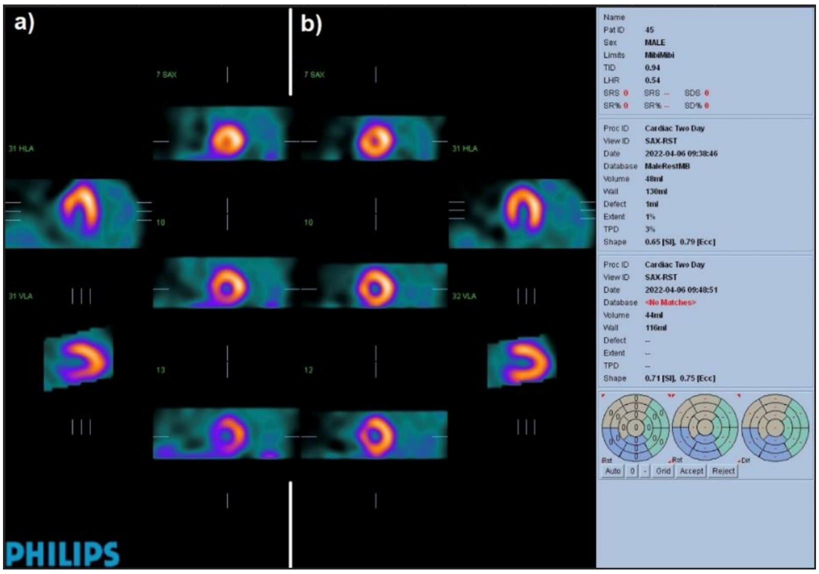

Fig 1. Rest images are displayed in a) supine and b) prone positions. In the supine images, reduced uptake of the radiotracer in the inferior wall is shown, but no significant perfusion defect is noted in the prone images suggesting diaphragmatic attenuation

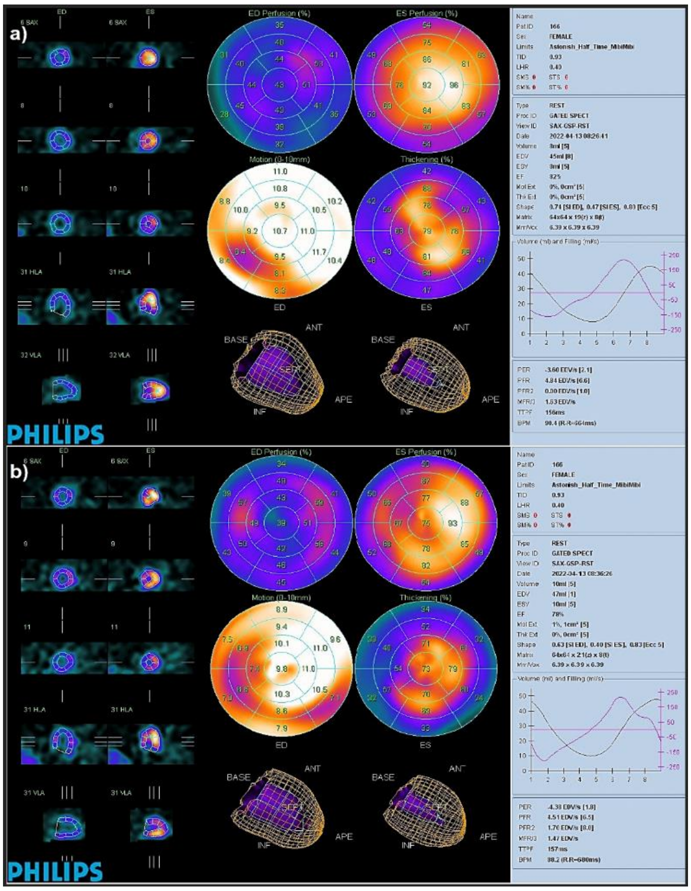

Fig 2. Quantitative Gated myocardial perfusion SPECT (GMPS), analysis of a patient in a) supine and b) prone position. Notice that there are no significant changes in LVEF, EDV, and ESV by changing position

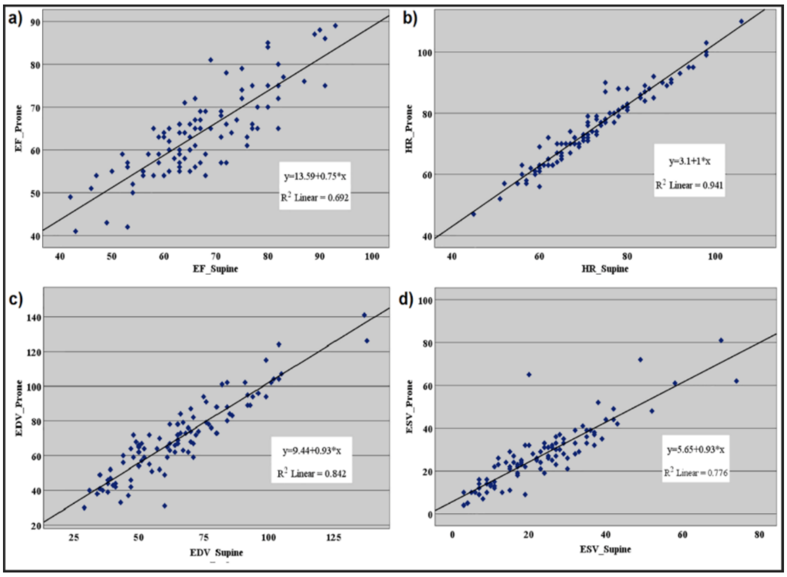

Fig 3. Linear correlation analysis of (a) LVEF, (b) EDV, (c) ESV, and (d) HR in the prone (Y axis) vs supine (X axis) positions obtained from Gated myocardial perfusion SPECT (GMPS). Left ventricular ejection fraction = LVEF, end diastolic volume = EDV, (c) end systolic volume = ESV, and heart rate = HR

Table 1. Baseline characteristics of patients

	Women	Men	Overall
Demographic data			
Chest pain	35 (64.81%)	28 (66.66%)	63 (65.62%)
Dyspnea	33 (61.11%)	23 (45.76%)	56 (58.33%)
Palpitation	13 (24.97%)	13 (30.95%)	26 (27.08%)
Baseline characteristic of patients			
Blood pressure	27 (50%)	22 (52.38%)	49 (51.94%)
Diabetes	19 (35.18%)	11 (26.19%)	30 (31.25%)
Dyslipidemia	26 (48.14%)	19 (45.23%)	45 (46.87%)
Smoking	4 (7.4%)	17 (40.47%)	21 (21.87%)
Family History	15 (27.77%)	13 (30.95%)	28 (29.16%)

Table 2. Prone and supine position variables

	Supine	Prone	P-Value
LVEF (%)	67.22	64.22	0.71
ESV (ml)	23.28	27.23	0.39
EDV (ml)	65.78	70.33	0.27
HR (bpm)	72.22	74.99	0.68

DISCUSSION

Our study explored how the supine and prone positions during GMPS may affect ESV, EDV, LVEF, and HR. Our results indicated that ESV, EDV, LVEF, and HR evaluated by gated GMPS were not considerably different whether measured in the supine or prone positions. The high correlations of LVEF (r = 0.78), ESV (r = 0.86), EDV (r = 0.88), and HR (r = 0.97) in supine and prone positions with high associated R2 values supported the reliability of these findings in both positions. This was similar to the previous results taken by Berman et al. [13] and Yap et al. [18], using [^{99m}Tc]Tc-MIBI perfusion tracers. Therefore, GMPS done only in prone positions seems to provide valid LVEF, EDV, ESV, and HR calculations.

However, our results were in contrast with those by Schaefer et al. [17] showed that EDV and ESV were considerably lower in prone than supine position (P <0.0004), despite using a protocol similar to our GMPS imaging. They reported no significant difference for ESV and LVEF between the two groups, whereas HR was significantly higher in a prone position (P < 0.0001). Other previous studies also showed an increase in HR in the prone position in comparison to the supine position [13, 17] that could be due to thoracic compression in the prone position, resulting in venous return reduction to the heart and causing a reflex increase in sympathetic activity because of the subsequent decrease in cardiac output.

A potential limitation of our study was that we evaluated changes in cardiac function in prone and supine positions using GMPS, which has a limited resolution in providing precise volumetrics. A cardiac MRI could be used as a gold standard for cardiac function estimation. However, we wanted to provide the literature with the potential of prone GMPS and how it can be presented as an independent alternative to supine imaging. Another limitation was that the patients were not classified according to their cardiac diseases and risk factors, as well as their GMPS summed scores in supine and prone positions. Moreover, our results are limited to the normal or low-likelihood population. Further studies with different risk-stratified subgroups and a wide range of perfusion defects are highly recommended.

CONCLUSION

When assessing LV volumes, the prone position imaging can be considered an acceptable alternative to the supine position, providing similar quantitative results. Therefore, the prone position may be a proper independent protocol, at least in patients who cannot undergo imaging in the supine position.

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