Internal Medicine
The Japanese Society of Internal Medicine

doi: 10.2169/internalmedicine.3348-19
Intern Med 59: 23-28, 2020
http://internmed.jp

【 ORIGINAL ARTICLE 】

Effects of Myocardial Perfusion Defect on the Frontal QRS-T Angle in Anterior Versus Inferior Myocardial Infarction

Satoshi Kurisu, Kazuhiro Nitta, Yoji Sumimoto, Hiroki Ikenaga, Ken Ishibashi, Yukihiro Fukuda and Yasuki Kihara

Abstract:

Objective The frontal QRS-T angle on a 12-lead electrocardiogram (ECG) has recently become accepted as a variable of ventricular repolarization. We compared the effects of myocardial perfusion defect (MPD) on the frontal QRS-T angle between anterior and inferior myocardial infarction (MI) using single-photon emission computed tomography.

Methods The frontal QRS-T angle was defined as the absolute value of the difference between the frontal plane QRS axis and T-wave axis. A QRS-T angle more than 90° was considered abnormal.

Patients Forty-two patients with anterior MI and 42 age- and sex-matched patients with inferior MI were enrolled. For controls, 42 age- and sex-matched patients with no MPD were selected.

Results The mean frontal QRS-T angles in anterior MI, inferior MI and control subjects were 94.7±46.2°, 26.7±22.1° and 27.0±23.2°, respectively. Compared with controls, the frontal QRS-T angle was larger in anterior MI subjects ($p<0.001$), and similar in value to that in inferior MI subjects ($p=0.69$). An abnormal QRS-T angle was frequent in the anterior MI subjects than the inferior MI subjects (55% vs. 2%, $p<0.001$). In anterior MI subjects, MPD was significantly associated with the T-wave axis ($\rho=0.46$, $p=0.002$) and QRS-T angle ($\rho=0.47$, $p=0.002$), but was not with the QRS axis ($\rho=0.07$, $p=0.66$). In inferior MI subjects, there were no associations between MPD and the ECG variables.

Conclusion Our data suggest that the frontal QRS-T angle in inferior MI subjects is not increased as evidently as that in anterior MI subjects.

Key words: electrocardiogram, ventricular function, ventricular remodeling, myocardial perfusion

(Intern Med 59: 23-28, 2020)
(DOI: 10.2169/internalmedicine.3348-19)

Introduction

The frontal QRS-T angle, which is the absolute value of the difference between QRS axis and T-wave axis on a 12-lead electrocardiogram (ECG), has recently become accepted as a variable of ventricular repolarization (1-6). The QRS-T angle has been shown to be useful in predicting total mortality (1-3) and ventricular arrhythmias (4).

In patients with prior anterior myocardial infarction (MI), we recently reported that the extent of myocardial perfusion defect (MPD), a quantitative variable of MI size, is a determinant of the frontal QRS-T angle (6). However, whether or not the association can also be applied to patients with prior inferior MI remains unclear.

ECG-gated myocardial perfusion single photon emission computed tomography (SPECT) enables us to evaluate the MI size and left ventricular function simultaneously (7, 8). In the present study, we sought to compare the effects of MPD on the frontal QRS-T angle between anterior and inferior MI using myocardial perfusion SPECT.

Department of Cardiovascular Medicine, Hiroshima University Graduate School of Biomedical and Health Sciences, Japan
Received: May 21, 2019; Accepted: July 21, 2019; Advance Publication by J-STAGE: September 11, 2019
Correspondence to Dr. Satoshi Kurisu, skurisu@nifty.com

Materials and Methods

Patients

Between April 2015 and October 2016, 714 patients underwent an ECG and myocardial perfusion SPECT for the evaluation of myocardial ischemia. Of these, 68 patients with anterior MI and 52 with inferior MI with at least more than 12 months since the onset were retrospectively selected. Patients with bundle branch block, significant valvular disease, cardiomyopathy and those undergoing hemodialysis or cardiac surgery were excluded. Ultimately, 42 patients with anterior MI and 42 age- and sex-matched patients with inferior MI were enrolled in this study. For controls, 42 age- and sex-matched patients with no MPD were selected. The study protocol was approved by the Ethical Committee for Epidemiology of Hiroshima University.

ECG

A standard 12-lead ECG was recorded at a paper speed of 25 mm/sec and an amplification of 10 mm/mV (FCP-7541; Fukuda Denshi, Tokyo, Japan) at the time of myocardial perfusion SPECT. The QRS axis and T-wave axis were automatically measured. In accordance with previous reports (1-6), the frontal QRS-T angle was defined as the absolute value of the difference between the frontal plane QRS axis and T-wave axis. When the QRS-T angle was more than 180°, it was adjusted to the minimal angle using “360° - angle”. A QRS-T angle of more than 90° was considered abnormal, as previously reported (4).

Myocardial perfusion SPECT

All patients fasted overnight, and underwent myocardial perfusion SPECT synchronized with an ECG (7, 8). Adenosine was infused over 6 minutes (120 μg/kg/min), and Tl-201 [111 MBq (3.0 mCi)] was injected 3 minutes after the initiation of adenosine infusion. The stress Tl-201 SPECT acquisition was started 5 minutes after the stress test. Four hours later, redistribution Tl-201 SPECT images were obtained. SPECT images were acquired with a dual-detector 90°γ-camera (Brightview X; Philips Healthcare, Milpitas, USA). Images were acquired with the following parameters: 36 total projections; 180° from right anterior oblique to left posterior oblique and a noncircular orbit; 64×64 matrix; 6.4 mm pixel size; 16 frames per cardiac cycle with retrospective electrocardiogram gating; low-energy, high-resolution collimation; and 40 seconds per stop. Images were reconstructed using ordered-subset expectation maximization (iteration, 2 ; subset, 9) with a Butterworth filter (order, 8; cutoff frequency, 0.50 cycles/pixel for stress images and 0.45 cycles/pixel for redistribution images).

The analysis of myocardial perfusion SPECT

The semiquantitative visual interpretation of SPECT images was performed with the short and vertical long axes divided into 17 segments. Each segment was scored using a 5-point scoring system (0, normal uptake; 1, mildly reduced uptake; 2, moderately reduced uptake; 3, severely reduced uptake; and 4, absence of detectable radiotracer in a segment) (9). The summed stress score (SSS) and the summed redistribution score (SRS) were determined, and the summed difference score (SDS) was obtained by subtracting the SRS from the SSS. As a quantitative variable of the MI size, MPD was obtained by using the following formula: MPD (%) = SRS ×100 / 68. The left ventricular end-diastolic volume (LVEDV), end-systolic volume (LVESV) and ejection fraction (LVEF) were obtained from stress images using quantitative gated SPECT (QGS) (Cedars-Sinai Medical Center, Los Angeles, USA) (10).

Statistical analyses

Continuous variables are shown as the mean ± standard deviation (SD), and categorical variables are shown as frequencies and percentages. Continuous variables were compared by Wilcoxon’s test. Categorical variables were compared by the chi-square test or Fisher’s exact test. Correlations between SPECT and ECG variables in anterior and inferior MIs were assessed by Spearman’s rank correlation coefficient (ρ). Differences were considered significant if the p value was <0.05. Statistical analysis was conducted using JMP 11 software program (SAS Institute, Tokyo, Japan).

Results

Patient characteristics

The patient characteristics are shown in Table 1. The body mass index and serum creatinine were similar among the three groups. Patients with anterior or inferior MI had hypertension more frequently than control patients. Compared to patients with inferior MI, those with anterior MI had larger MPD (24.3±14.8% vs. 17.0±8.2%, p<0.001), larger LVEDV (116±66 mL vs. 78±29 mL, p<0.001) and lower LVEF (41±13% vs 53±10%, p<0.001).

The QRS axis, T-wave axis and frontal QRS-T angle in anterior versus inferior MI

The mean time from the onset of MI to the ECG was 5.1 ±3.7 years. Four patients with anterior MI and one with inferior MI had atrial fibrillation. The QRS and T-wave axes of each group are shown in Fig. 1. The mean QRS axes in anterior MI, inferior MI and control subjects were 10.2± 50.7°, 1.1±36.2° and 38.2±32.1°, whereas the mean T-wave axes were 95.8±53.5°, 13.0±35.3° and 52.4±22.2°, respectively. The mean frontal QRS-T angles in anterior MI, inferior MI and control subjects were 94.7±46.2°, 26.7±22.1° and 27.0±23.2°, respectively (Fig. 2). Compared with control subjects, the frontal QRS-T angle was larger in anterior MI subjects (p<0.001), and similar in value to that in inferior MI subjects (p=0.69). An abnormal QRS-T angle was more frequent in anterior MI subjects than inferior MI sub-

Table 1. Patient Characteristics.

Variable	Anterior MI (n=42)	Inferior MI (n=42)	Control (n=42)	p value
Age (years)	70±9	70±9	70±8	0.96
Female	7 (17%)	7 (17%)	7 (17%)	1.00
BMI (kg/m^2)	24±4	24±4	24±3	0.82
Systolic blood pressure (mmHg)	123±18	121±17	131±16	0.02
Diastolic blood pressure (mmHg)	70±11	72±9	73±12	0.55
Pulse rate (bpm)	66±12	64±9	67±13	0.80
Hypertension	39 (93%)	35 (83%)	25 (60%)	<0.001
Diabetes	20 (48%)	18 (43%)	12 (29%)	0.17
Atrial fibrillation	0 (0%)	1 (2%)	4 (10%)	0.23
Medications				
Angiotensin-converting enzyme inhibitors	7 (17%)	9 (21%)	1 (2%)	0.07
Angiotensin II receptor blockers	15 (36%)	18 (43%)	12 (29%)	0.39
Beta blockers	32 (76%)	25 (60%)	9 (21%)	<0.001
Calcium channel blockers	11 (26%)	17 (40%)	15 (36%)	0.37
Statins	31 (74%)	29 (69%)	20 (48%)	0.03
SPECT				
SSS	20.4±9.8	14.8±6.6	1.0±1.7	<0.001
SRS	16.5±10.1	11.6±5.6	0	<0.001
MPD (%)	24.3±14.8	17.0±8.2	0	<0.001
SDS	3.8±3.9	3.3±3.2	1.0±1.7	<0.001
LVEDV (mL)	116±66	78±29	61±15	<0.001
LVESV (mL)	73±58	38±21	23±10	<0.001
LVEF (%)	41±13	53±10	65±10	<0.001

MI: myocardial infarction, BMI: body mass index, SPECT: single photon emission computed tomography, SSS: summed stress score, SRS: summed rest score, MPD: myocardial perfusion defect, SDS: summed difference score, LVEDV: left ventricular end-diastolic volume, LVESV: left ventricular end-systolic volume, LVEF: left ventricular ejection fraction

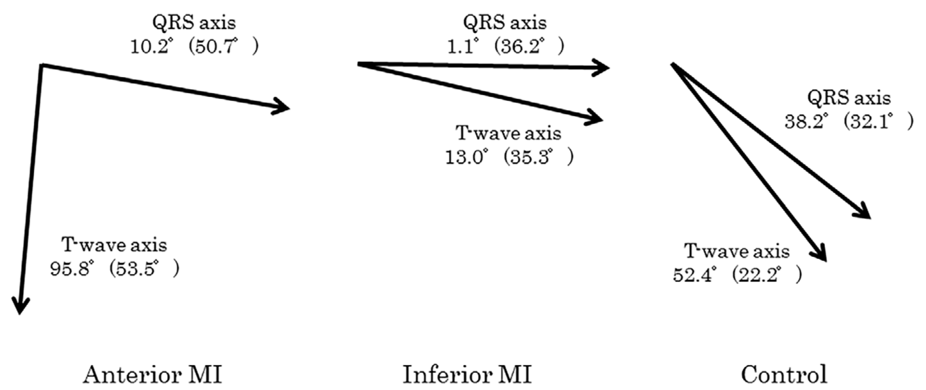

Figure 1. The QRS and T-wave axes in anterior myocardial infarction, inferior myocardial infarction and control subjects.

jects (55% vs. 2%, p<0.001).

Correlations between SPECT and ECG variables in anterior vs. inferior MI subjects (Table 2)

In anterior MI subjects, MPD was significantly associated with the T-wave axis (ρ=0.46, p=0.002) and QRS-T angle (ρ=0.47, p=0.002) (Fig. 3, left panel), but was not with the QRS axis (ρ=0.07, p=0.66). In inferior MI subjects, there were no associations between MPD and ECG variables (Fig. 3, right panel).

Discussion

In the present study, we showed the following: 1) compared with control subjects, the frontal QRS-T angle was larger in anterior MI, and similar in value to that in inferior MI; and 2) the T-wave axis and frontal QRS-T angle increased with increasing MPD in anterior MI, whereas no

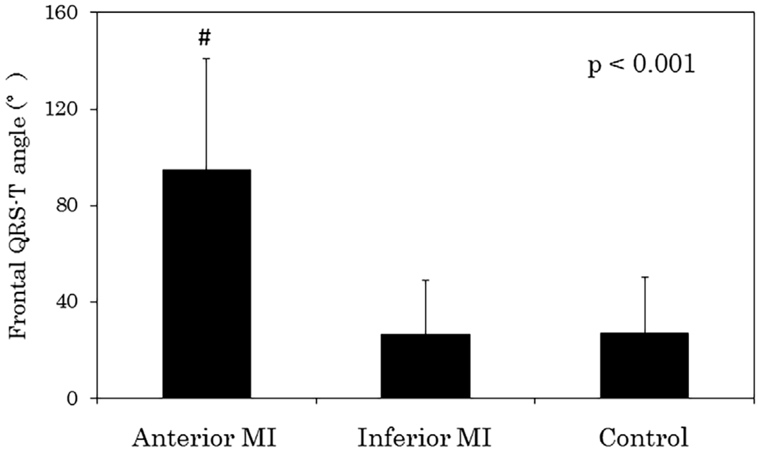

Figure 2. The frontal QRS-T angles in anterior myocardial infarction, inferior myocardial infarction and control subjects. # p<0.001 versus control.

Table 2. Correlations between SPECT and ECG Variables.

	Anterior MI					
	QRS axis		T-wave axis		QRS-T angle	
	ρ	p value	ρ	p value	ρ	p value
SSS	0.04	0.78	0.44	0.003	0.46	0.002
SRS or MPD	0.06	0.72	0.46	0.002	0.47	0.002
SDS	0.004	0.98	0.06	0.71	0.002	0.99

	Inferior MI					
	QRS axis		T-wave axis		QRS-T angle	
	ρ	p value	ρ	p value	ρ	p value
SSS	-0.07	0.58	-0.11	0.49	0.13	0.40
SRS or MPD	-0.14	0.37	-0.16	0.31	0.07	0.66
SDS	0.20	0.20	0.28	0.07	0.20	0.20

SPECT: single photon emission computed tomography, MI: myocardial infarction, SSS: summed stress score, SRS: summed rest score, MPD: myocardial perfusion defect, SDS: summed difference score

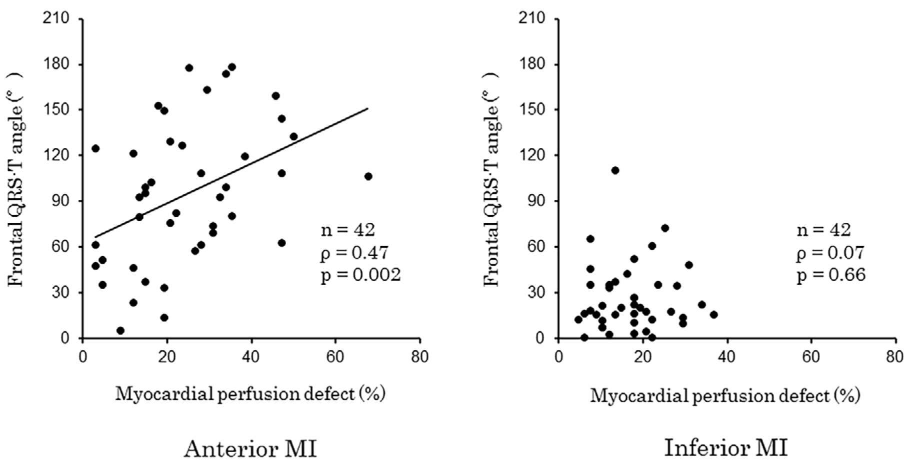

Figure 3. The correlations between the extent of myocardial perfusion defect and frontal QRS-T angle in anterior myocardial infarction (left panel) and inferior myocardial infarction (right panel).

correlations were found in inferior MI.

The frontal QRS-T angle, which is easily obtained as the absolute value of the difference between the QRS axis and T-wave axis on a 12-lead ECG, has been described as a variable of ventricular repolarization. An abnormally wide frontal QRS-T angle has emerged as a prominent variable for predicting total mortality in patients with cardiomyopathy (2) or congestive heart failure (3), and for predicting ventricular arrhythmias in patients with coronary artery disease receiving implantable cardioverter-defibrillator (4).

Several groups, including ours, have shown the effects of previous MI on the frontal QRS-T angle (1, 6). May et al. recently showed that patients with an abnormal QRS-T angle, defined as more than 90°, had previous MI more frequently than those with a normal QRS-T angle in a diabetic population (1). We recently demonstrated the association between the extent of MPD and the frontal QRS-T angle in anterior MI subjects (6). In the present study, we further evaluated the frontal QRS-T angle in both anterior and inferior MI subjects, separately, and showed that the frontal QRS-T angle was increased in anterior MI, but not in inferior MI. Interestingly, approximately half of patients with anterior MI had an abnormal QRS-T angle, whereas most patients with inferior MI had a normal QRS-T angle. In anterior MI, the increase in the frontal QRS-T angle was mainly attributed to the rightward shift of the T-wave axis, which was dependent on the extent of MPD. In contrast, in inferior MI, there were no associations between the extent of MPD and ECG variables.

Previous studies have shown that infarct location as well as infarct size are important prognostic factors in MI, with an increased mortality associated with the involvement of the anterior wall (11-13). Our findings of a larger QRS-T angle in anterior MI subjects than in inferior MI subjects and the positive correlation between the extent of MPD and the QRS-T angle in anterior MI subjects may help explain the prognosis of patients with MI as is generally made in the clinical setting (11-13).

While previous studies have suggested that inferior MI subjects may be more prone to ventricular arrhythmias than anterior MI subjects (14, 15), we found that the frontal QRS-T angle in inferior MI subjects was not increased as evidently as that in anterior MI subjects. Although the reason for this inconsistency remains unclear, one possible reason is that the frontal QRS-T angle may not reflect the spatial QRS-T angle well, especially in inferior MI. The frontal QRS-T angle is produced based on the projection of the three-dimensional spatial QRS and T vectors onto the frontal plane. Whether or not the frontal QRS-T angle reflects the spatial QRS-T angle in both anterior and inferior MI separately should be confirmed. In addition, further studies are necessary to clarify the implications of the frontal QRS-T angle in predicting total mortality or ventricular arrhythmias in anterior and inferior MI separately.

There are several limitations associated with this study that should be considered. First, left ventricular hypertrophy may be associated with the frontal QRS-T angle (16). However, we were unable to evaluate the association of these items because the precise left ventricular mass in MI cases is difficult to calculate with echocardiography. Second, we did not assess the effects of the frontal QRS-T angle on total mortality or ventricular arrhythmias in each infarct location. Third, redistribution images were obtained four hours after the stress test. Assessing 24-hour late images can enhance the detection of myocardial viability after MI (17). Finally, the small sample size was a major limitation of this study.

In conclusion, our data suggest that the frontal QRS-T angle in inferior MI subjects is not increased as evidently as that in anterior MI subjects.

The authors state that they have no Conflict of Interest (COI).

References

1. May O, Graversen CB, Johansen MØ, Arildsen H. A large frontal QRS-T angle is a strong predictor of the long-term risk of myocardial infarction and all-cause mortality in the diabetic population. J Diabetes Complications **31**: 551-555, 2017.
2. Pavri BB, Hillis MB, Subacius H, et al.; Defibrillators in Non-ischemic Cardiomyopathy Treatment Evaluation (DEFINITE) Investigators. Prognostic value and temporal behavior of the planar QRS-T angle in patients with nonischemic cardiomyopathy. Circulation **117**: 3181-3186, 2008.
3. Gotsman I, Keren A, Hellman Y, Banker J, Lotan C, Zwas DR. Usefulness of electrocardiographic frontal QRS-T angle to predict increased morbidity and mortality in patients with chronic heart failure. Am J Cardiol **111**: 1452-1459, 2013.
4. Borleffs CJ, Scherptong RW, Man SC, et al. Predicting ventricular arrhythmias in patients with ischemic heart disease: clinical application of the ECG-derived QRS-T angle. Circ Arrhythm Electrophysiol **2**: 548-554, 2009.
5. Aro AL, Huikuri HV, Tikkanen JT, et al. QRS-T angle as a predictor of sudden cardiac death in a middle-aged general population. Europace **14**: 872-876, 2012.
6. Kurisu S, Nitta K, Sumimoto Y, et al. Myocardial perfusion defect assessed by single-photon emission computed tomography and frontal QRS-T angle in patients with prior anterior myocardial infarction. Heart Vessels **34**: 971-975, 2019.
7. Kurisu S, Shimonaga T, Ikenaga H, et al. Selvester QRS score and total perfusion deficit calculated by quantitative gated single-photon emission computed tomography in patients with prior anterior myocardial infarction in the coronary intervention era. Heart Vessels **32**: 369-375, 2017.
8. Kurisu S, Nitta K, Sumimoto Y, et al. Implications of electrocardiographic frontal QRS axis on left ventricular diastolic parameters derived from electrocardiogram-gated myocardial perfusion single photon emission computed tomography. Ann Nucl Med **32**: 404-409, 2018.
9. Padala SK, Ghatak A, Padala S, Katten DM, Polk DM, Heller GV. Cardiovascular risk stratification in diabetic patients following stress single-photon emission-computed tomography myocardial perfusion imaging: the impact of achieved exercise level. J Nucl Cardiol **21**: 1132-1143, 2014.
10. Germano G, Kavanagh PB, Slomka PJ, Van Kriekinge SD, Pollard G, Berman DS. Quantitation in gated perfusion SPECT imaging: the Cedars-Sinai approach. J Nucl Cardiol **14**: 433-454, 2007.
11. Behar S, Rabinowitz B, Zion M, et al. Immediate and long-term prognostic significance of a first anterior versus first inferior wall

Q-wave acute myocardial infarction. Secondary Prevention Reinfarction Israeli Nifedipine Trial (SPRINT) Study Group. Am J Cardiol **72**: 1366-1370, 1993.

12. Welty FK, Mittleman MA, Lewis SM, Healy RW, Shubrooks SJ Jr, Muller JE. Significance of location (anterior versus inferior) and type (Q-wave versus non-Q-wave) of acute myocardial infarction in patients undergoing percutaneous transluminal coronary angioplasty for postinfarction ischemia. Am J Cardiol **76**: 431-435, 1995.

13. Haim M, Hod H, Reisin L, et al. Comparison of short- and long-term prognosis in patients with anterior wall versus inferior or lateral wall non-Q-wave acute myocardial infarction. Secondary Prevention Reinfarction Israeli Nifedipine Trial (SPRINT) Study Group. Am J Cardiol **79**: 717-721, 1997.

14. Pascale P, Schlaepfer J, Oddo M, Schaller MD, Vogt P, Fromer M. Ventricular arrhythmia in coronary artery disease: limits of a risk stratification strategy based on the ejection fraction alone and impact of infarct localization. Europace **11**: 1639-1646, 2009.

15. Benchimol Barbosa PR, Sousa MO, Barbosa EC, Bomfim Ade S, Ginefra P, Nadal J. Analysis of the prevalence of ventricular late potentials in the late phase of myocardial infarction based on the site of infarction. Arq Bras Cardiol **78**: 352-363, 2002.

16. Cardoso CR, Leite NC, Salles GF. Factors associated with abnormal T-wave axis and increased QRS-T angle in type 2 diabetes. Acta Diabetol **50**: 919-925, 2013.

17. He YM, Yang XJ, Wu YW, Zhang B. Twenty-four-hour thallium-201 imaging enhances the detection of myocardial ischemia and viability after myocardial infarction: a comparison study with echocardiography follow-up. Clin Nucl Med **34**: 65-69, 2009.

Intern Med 59: 23-28, 2020