

[ORIGINAL ARTICLE]

Effects of Newly Developed Right Versus Left Bundle Branch Block on the QRS Axis, T-wave Axis and Frontal QRS-T Angle in Patients with a Narrow QRS

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Abstract:

Objective The QRS-T angle has been established as a repolarization marker. In the present study, we determined whether or not newly developed bundle branch block (BBB) affected the QRS-T angle in patients with a narrow QRS.

Methods Twenty-four patients with newly developed BBB and no adverse cardiac events were retrospectively included. The frontal QRS-T angle was defined as the absolute value of the difference between the frontal plane QRS axis and the T-wave axis. These electrocardiogram parameters were serially measured in the settings of narrow QRS and BBB.

Results Twelve patients had newly developed right BBB (RBBB), and 12 had newly developed left BBB (LBBB). The development of RBBB did not affect the QRS axis, T-wave axis of QRS-T angle ($41^\circ \pm 42^\circ$ to $53^\circ \pm 65^\circ$, $p = 0.63$). In contrast, the development of LBBB shifted the QRS axis to the left ($25^\circ \pm 29^\circ$ to $-18^\circ \pm 31^\circ$, $p = 0.003$), resulting in an increased QRS-T angle ($72^\circ \pm 50^\circ$ to $123^\circ \pm 39^\circ$, $p = 0.001$). Regarding RBBB, an excellent correlation and agreement were found between the QRS-T angles in the setting of narrow QRS and RBBB ($r = 0.88$; $p < 0.001$; bias, $2.9^\circ \pm 20.9^\circ$). However, there was a significant bias between the QRS-T angles in the setting of narrow QRS and LBBB ($51.9^\circ \pm 40.4^\circ$; $p = 0.001$).

Conclusion Our data suggested that the QRS-T angle in the setting of RBBB reflected the original QRS-T angle in the setting of narrow QRS well, whereas the QRS-T angle in the setting of LBBB did not.

Key words: electrocardiogram, bundle branch block, repolarization

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Introduction

The QRS-T angle has been established as a repolarization marker (1). Previous studies have shown that an increased QRS-T angle is predictive of mortality or ventricular arrhythmia, mainly in patients with a narrow QRS without bundle branch block (BBB) (2, 3).

The frontal QRS-T angle is an alternative to the spatial QRS-T angle as a parameter easily calculated from the frontal QRS axis and T-wave axis on a 12-lead electrocardiogram (ECG) (1). Repolarization abnormalities in the setting of right BBB (RBBB) or left BBB (LBBB) are traditionally

considered secondary to depolarization changes and of little diagnostic or prognostic utility. At least in part because of this, few reports have evaluated the implications of the QRS-T angle in patients with BBB (4, 5). Whether or not the QRS-T angle in the setting of BBB represents the original QRS-T angle in the setting of narrow QRS well therefore remains unclear.

In the present study, we determined whether or not newly developed BBB affected the QRS-T angle in patients with a narrow QRS.

Materials and Methods

Patients

Between January 2013 and June 2019, a total of 2,631 patients underwent an ECG before myocardial perfusion single-photon emission computed tomography (SPECT) for evaluating myocardial perfusion. Of these, 152 patients had BBB. A diagnosis of RBBB required all of the following: QRS duration \geq 120 ms; R-wave or RSR' complex in lead V1; and an R-complex with a prolonged, shallow S-wave in leads V5, V6, aVL or I (6). A diagnosis of LBBB required all of the following: QRS duration \geq 120 ms; QS- or RS-complex in lead V1; broad or notched R-waves in leads V5 and V6, or an RS pattern; and the absence of Q wave in leads V5, V6 or I (6). Patients with prior myocardial infarction confirmed by SPECT or medical records were excluded. Patients with previous cardiac surgery and atrial fibrillation were also excluded. Based on serial ECGs and medical records, 24 patients were documented to have newly developed BBB with no adverse cardiac events within 1 year before SPECT. These 24 patients were retrospectively included in this study.

The study protocol was approved by the Ethics Committee for Epidemiology of Hiroshima University.

BBB and the frontal QRS-T angle

A standard 12-lead ECG was obtained at a paper speed of 25 mm/sec and an amplification of 10 mm/mV using commercially available machines. The QRS duration, QT interval, QRS axis and T-wave axis were automatically measured (7, 8). 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 " $360^\circ - \text{angle}$ " (1-5, 7, 8). A QRS-T $>90^\circ$ was considered abnormal, as shown in previous reports (9). These ECG parameters were serially measured in the settings of narrow QRS and BBB.

Myocardial perfusion SPECT

All patients fasted overnight, and underwent ECG-gated SPECT (10, 11). Adenosine was infused over 6 minutes (120 $\mu\text{g}/\text{kg}/\text{min}$), 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).

Analyses of myocardial perfusion SPECT findings

Semi-quantitative 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) (10). 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. The left ventricular (LV) end-diastolic volume (LVEDV), LV end-systolic volume (LVESV) and LV ejection fraction (LVEF) were obtained on stress images using the widely adopted algorithm [Quantitative gated SPECT (QGS); Cedars-Sinai Medical Center, Los Angeles, USA] (10-12).

Statistical analyses

Continuous variables are shown as mean \pm SD, and categorical variables are shown as frequencies and percentages. Continuous variables between groups were compared by the Mann-Whitney U test. Categorical variables were compared by the chi-square test. The correlation between the QRS-T angle in the settings of narrow QRS and BBB was assessed using Pearson's correlation coefficient. The accuracy of the QRS-T angle in the setting of BBB was tested using a Bland-Altman analysis with comparison to the QRS-T angle in the setting of narrow QRS.

Differences were considered significant if the p value was <0.05 . Statistical analyses were conducted using the JMP 11 software program (SAS Institute, Tokyo, Japan).

Results

Patient characteristics

The patient characteristics are shown in Table 1. Twelve patients had newly developed RBBB, and 12 had newly developed LBBB. The age and ratios of women, hypertension and diabetes mellitus were similar between the two groups. Although two patients with RBBB and three with LBBB had prior coronary intervention, none had adverse cardiac events, such as myocardial infarction or repeated coronary intervention, during the period between the serial ECG recordings. Medications, including beta blockers and calcium channel blockers, were similar between the two groups. None of the patients were treated with anti-arrhythmic drugs. The SRS (1 ± 2 vs. 2 ± 2 , $p = 0.56$), a parameter of myocardial damage, and the SDS (3 ± 3 vs. 3 ± 3 , $p = 0.97$), a parameter of myocardial ischemia, were similar between the two groups. Compared to patients with RBBB, patients with LBBB had larger LVEDV (58 ± 26 mL vs. 83 ± 32 mL, $p = 0.01$), larger LVESV (21 ± 17 mL vs. 45 ± 32 mL, $p = 0.02$) and lower LVEF ($67\% \pm 11\%$ vs. $51\% \pm 18\%$, $p = 0.04$).

Effects of the development of RBBB and LBBB

The effects of the development of RBBB and LBBB on ECG variables are shown in Table 2. Representative cases of RBBB and LBBB are shown in Fig. 1. The time intervals between the serial ECG recordings were similar between the

Table 1. Patient Characteristics.

Variable	Patients with RBBB (n=12)	Patients with LBBB (n=12)	p value
Age (years)	76±8	74±10	0.64
Female	5 (42%)	4 (33%)	0.67
Body mass index (kg/m ²)	22±2	24±3	0.01
Hypertension	10 (83%)	10 (83%)	1.00
Diabetes mellitus	4 (33%)	1 (8%)	0.13
Prior coronary intervention	2 (17%)	3 (25%)	0.62
Prior myocardial infarction	0 (%)	0 (0%)	1.00
Medications			
ACE inhibitors or ARBs	4 (33%)	6 (50%)	0.41
Beta blockers	6 (50%)	4 (33%)	0.41
Calcium channel blockers	4 (33%)	5 (42%)	0.67
Diuretics	2 (17%)	5 (42%)	0.18
Statins	9 (75%)	6 (50%)	0.21
Anti-arrhythmic drugs	0 (0%)	0 (0%)	1.00
Myocardial perfusion SPECT			
Summed stress score	4±5	4±2	0.79
Summed redistribution score	1±2	2±2	0.56
Summed difference score	3±3	3±3	0.97
LV end-diastolic volume (mL)	58±26	83±32	0.01
LV end-systolic volume (mL)	21±17	45±32	0.02
LV ejection fraction (%)	67±11	51±18	0.04

RBBB: right bundle branch block, LBBB: left bundle branch block, ACE: angiotensin-converting enzyme, ARB: angiotensin II receptor blocker, SPECT: single photon emission computed tomography, LV: left ventricle

Table 2. Effects of the Developments of RBBB and LBBB on ECG Variables.

Variable	Patients with RBBB (n=12)		p value	Patients with LBBB (n=12)		p value
	Narrow QRS	RBBB		Narrow QRS	LBBB	
Heart rate (bpm)	71±11	74±12	0.14	69±10	73±10	0.16
QRS duration (ms)	92±7	131±9	<0.001	93±14	146±12	<0.001
QT interval (ms)	395±32	419±27	0.01	396±33	448±24	<0.001
Corrected QT interval (ms)	429±30	467±22	<0.001	421±17	493±26	<0.001
QRS axis (degree)	44±33	51±39	0.28	25±29	-18±31	0.003
T-wave axis (degree)	43±47	47±64	0.69	71±80	105±36	0.13
Frontal QRS-T angle (degree)	41±42	53±65	0.63	72±50	123±39	0.001
Abnormal QRS-T angle	2 (17%)	2 (17%)	1.00	5 (42%)	10 (83%)	0.04

RBBB: right bundle branch block, LBBB: left bundle branch block

two groups (179±101 days vs. 173±112 days, $p = 0.90$).

The development of RBBB increased the QRS duration (92±7 to 131±9 ms, $p < 0.001$), which was accompanied by significant prolongation of the corrected QT interval (429±30 to 467±22 ms, $p < 0.001$). However, the development of RBBB did not affect the QRS axis, T-wave axis, QRS-T angle (41° ±42° to 53° ±65°, $p = 0.63$) or prevalence of an abnormal QRS-T angle (Fig. 2). No marked association was found between the QRS-T angle in the setting of RBBB and LVEF.

The development of LBBB increased the QRS duration (93±14 to 146±12 ms, $p < 0.001$), which was accompanied by the significant prolongation of the corrected QT interval

(421±17 to 493±26 ms, $p < 0.001$). The development of LBBB shifted the QRS axis to the left (25° ±29° to -18° ±31°, $p = 0.003$), resulting in an increased QRS-T angle (72° ±50° to 123° ±39°, $p = 0.001$) and increased prevalence of an abnormal QRS-T angle (Fig. 2). No marked association was found between the QRS-T angle in the setting of LBBB and LVEF.

Agreement of QRS-T angles in the settings of narrow QRS and BBB

Regarding RBBB, an excellent correlation and agreement were found between the QRS-T angles in the setting of narrow QRS and RBBB ($r = 0.88$; $p < 0.001$; bias, 2.9° ±20.9°)

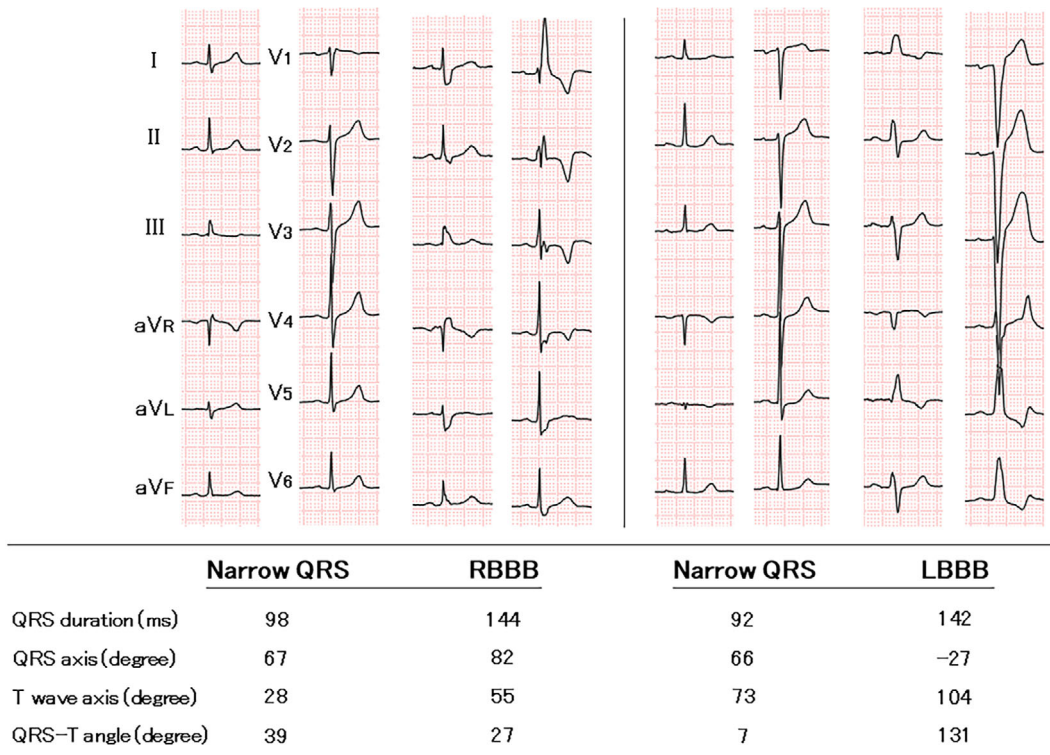


Figure 1. Representative cases showing developed right bundle branch block (left panel) and left bundle branch block (right panel).

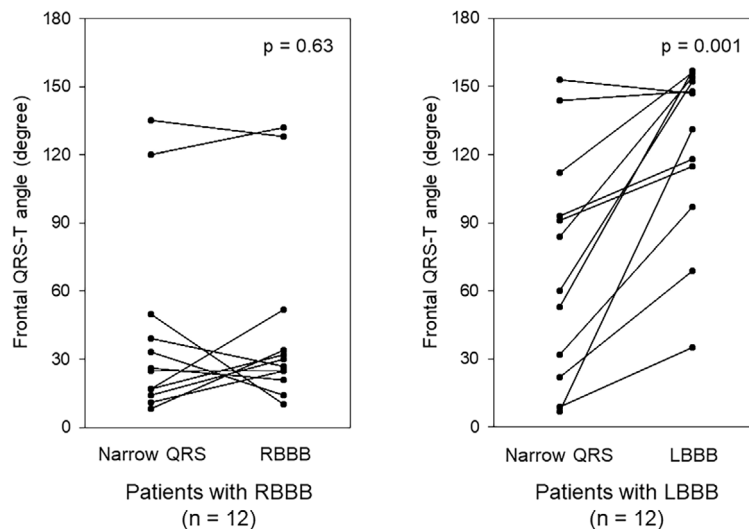


Figure 2. Effects of the developments of right bundle branch block (left panel) and left bundle branch block (right panel) on the frontal QRS-T angle.

(Fig. 3, left panel). However, there was a significant bias between the QRS-T angles in the setting of narrow QRS and LBBB ($51.9^\circ \pm 40.4^\circ$; $p = 0.001$) with 95% limits of agreement of -29.2° to 132.3° (Fig. 3, right panel).

Discussion

In the present study, we showed the following: 1) newly developed RBBB did not affect the QRS-T angle, and an excellent correlation and agreement were found between the

QRS-T angles in the setting of narrow QRS and RBBB; and 2) newly developed LBBB increased the QRS-T angle, and the original QRS-T angle with a narrow QRS was overestimated when measured in the setting of LBBB.

When there is an imbalance in the electrical activation and recovery of the ventricles, the QRS axis and T-wave axis are no longer aligned, and the QRS-T angle widens. The widening of the frontal QRS-T angle has been shown to be predictive of mortality (2) or ventricular arrhythmia (3), mainly in patients with a narrow QRS without BBB. There

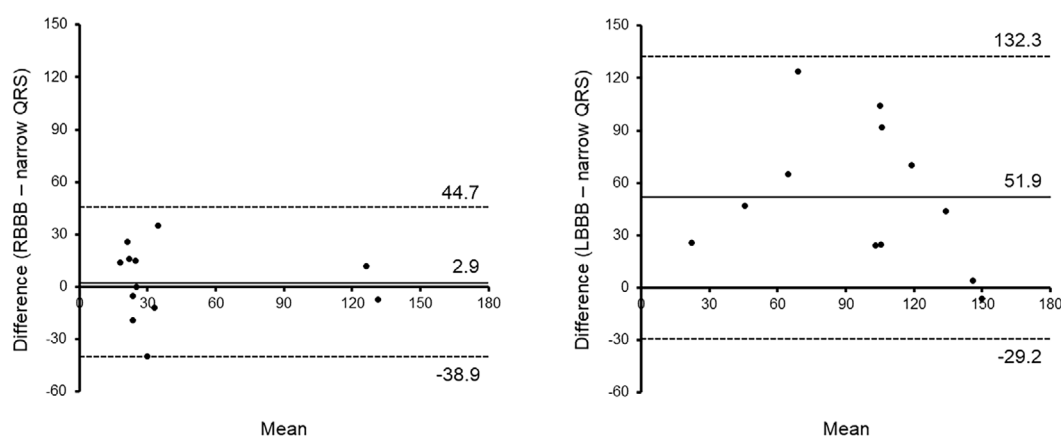


Figure 3. Bland-Altman plots with the mean bias and 95% limits of agreement of the QRS-T angles in the settings of narrow QRS and RBBB (left panel) or LBBB (right panel).

have been only a few reports assessing the frontal QRS-T angle in patients with BBB. Zhang et al. showed that both BBB and widening of the QRS-T angle were predictive of heart failure, and the concomitant presence of both carried a much higher risk than either predictor alone (4). However, regarding the QRS-T angle in the setting of BBB, whether the widening of the QRS-T angle was based purely on increased myocardial disease activity or was modified by the development of BBB itself has been unclear. To address this issue, we assessed the QRS axis, T-wave axis and frontal QRS-T angle before and after the development of RBBB or LBBB in patients with a narrow QRS.

In the present study, we showed that newly developed RBBB did not affect the QRS axis, T-wave axis or frontal QRS-T angle, whereas newly developed LBBB shifted the QRS axis to the left and increased the frontal QRS-T angle with the increased prevalence of an abnormal QRS-T angle. Regarding RBBB, the agreement between the QRS-T angles in the setting of narrow QRS and RBBB was acceptable, indicating that the QRS-T angle in the setting of RBBB reflected the original QRS-T angle in the setting of narrow QRS well. Our results suggest that when the measurement of the QRS-T angle is applied to patients with RBBB, it has a similar normal range and implications concerning the original myocardial disease activity to patients with a narrow QRS. In contrast, with regard to LBBB, a significant bias was noted between the QRS-T angles in the setting of narrow QRS and LBBB, indicating that the QRS-T angle in the setting of LBBB did not reflect the original QRS-T angle in the setting of narrow QRS. Our results suggest that, when the QRS-T angle is measured in patients with LBBB, it has a different normal range and implications concerning the original myocardial disease activity from patients with a narrow QRS or RBBB.

In the setting of RBBB, the LV, which makes up most of the QRS axis and T-wave axis, remains to be rapidly depolarized through the intact left bundle branch. In contrast, in the setting of LBBB, LV depolarization must propagate through the myocardium, and there is slow leftward activa-

tion of the LV free wall. The differences in the route of LV depolarization between RBBB and LBBB may be associated with their different effects on the frontal QRS-T angle. Indeed, we recently showed the association between the frontal QRS-T angle and LVEF in patients with a narrow QRS and a history of anterior myocardial infarction (8). However, the present study found no such association in patients with RBBB or LBBB, due at least in part to the small sample size. Further studies will be necessary to determine the normal range and clarify the implications of the QRS-T angle, especially in the setting of LBBB.

Several limitations associated with the present study warrant mention. First, there were some time intervals between the serial ECG recordings in both groups. However, it was noteworthy that none of the patients suffered adverse cardiac events during the time interval. RBBB and LBBB therefore probably developed spontaneously, independent of myocardial ischemia. Second, the development of LBBB is known to cause LV dyssynchrony (13). Hemodynamic adverse effects secondary to LV dyssynchrony may contribute to an increased frontal QRS-T angle to some extent. ECGs during the conversion from narrow QRS to LBBB are therefore considered to be useful for evaluating this possibility, although such ECGs are difficult to obtain in the clinical setting. Finally, the small sample size is a major limitation of this study.

In conclusion, our data suggested that the QRS-T angle in the setting of RBBB reflected the original QRS-T angle in the setting of narrow QRS well, whereas the QRS-T angle in the setting of LBBB did not.

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

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