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Clinical and electrocardiographic covariates of deceleration capacity in patients with ST-segment elevation myocardial infarction

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Abstract

Background: *Deceleration capacity (DC) is a novel electrocardiography (ECG) parameter characterizing the overall capacity of slowing down the heart rate. The aim of this study was to evaluate clinical and ECG covariates of DC in patients with the first episode of ST-segment elevation myocardial infarction (STEMI) treated with primary angioplasty.*

Methods: *Deceleration capacity, heart rate variability (HRV) and heart rate turbulence (HRT) were assessed from 24-hour ECG Holter recordings in 70 patients (66 male, mean age 57 years) with STEMI. Deceleration capacity was evaluated as continuous or dichotomized (≤ 4.5* vs. *> 4.5 ms) variable.*

Results: *The median value of DC was 5.12 ms. Thirty patients (43%) had abnormal DC (≤ 4.5 ms). The abnormal DC was more common in female, older and hypertensive patients. Although DC was not associated with either STEMI localization or left ventricular ejection fraction, it was significantly correlated with mean heart rate, standard HRV indices and HRT slope. Multivariate logistic regression showed that hypertension (OR = 3.23, 95% CI = 1.1–9.9, p = 0.039) and mean heart rate > 70 beats/minute (OR = 6.05, 95% CI = 2.0–18.4, p = 0.001) were independently associated with abnormal DC.*

Conclusions: *Deceleration capacity in patients with the first STEMI treated with primary angioplasty is influenced by age, gender, hypertension and heart rate, but not the location of myocardial infarction or left ventricular ejection fraction. Correlation between DC and HRV indices suggests that DC is related to autonomic modulation of heart rate.* (Cardiol J 2009; 16, 6: 528–534)

Key words: deceleration capacity, heart rate variability, ST-elevation myocardial infarction

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Introduction

For many years, ambulatory electrocardiography (ECG) monitoring has been used in risk stratification of post-infarction patients. Assessment of various Holter-based indices gives insight into the autonomic modulation of the cardiovascular system and it has been proven useful in risk stratification in post-infarction and heart failure patients [1–5].

Risk predictors based on heart rate dynamicity such as heart rate variability (HRV) or heart rate turbulence (HRT) have been extensively studied over recent decades [6–9]. Deceleration capacity (DC) is a new risk stratifier, characterizing heart rate dynamics in the neighborhood of a deceleration. Decreased DC was proven to be a better risk predictor of mortality in post-infarction patients than left ventricular ejection fraction (LVEF) and standard deviation of normal-to-normal NN intervals (SDNN) [10]. Although different studies documented that HRV and HRT are influenced by clinical and ECG covariates, and suggested that these associations should be taken into account while using them for risk stratification purposes [7, 8, 11, 12] the relation of DC to similar variables has not been studied so far.

The aim of this study is to evaluate the relationship between DC and various clinical and ECG-derived parameters in patients with the first ST-segment elevation myocardial infarction (STEMI) treated with the primary angioplasty.

Methods

Study population

The study population consisted of 70 consecutive patients with the first STEMI and sinus rhythm who were admitted to the hospital for percutaneous coronary intervention. Diagnosis of STEMI required the following criteria: rise of cardiac biomarkers with at least one of the following: symptoms of ischemia, elevation of at least 0.2 mV in men or 0.15 mV in women in two neighboring limb leads or V2–V3 chest leads and/or ST elevation of at least 0.1 mV in other leads, and/or new left bundle branch block, development of pathological Q waves in the ECG and/or imaging evidence of new loss of viable myocardium or new regional wall motion abnormality [13]. Exclusion criteria were: non-sinus rhythm, previous myocardial infarction and coexisting severe valvular heart disease. Data on clinical characteristics and before-hospital medication was acquired at enrollment.

Holter recordings

The 24-hour Holter ECG recordings were performed between the third and fifth day after admission to evaluate mean heart rate, ventricular arrhythmia, HRV, HRT, and DC. Holter recordings were performed using Oxford Medilog System (Oxford, UK). The RR intervals were exported and used in further analysis of HRV, HRT and DC.

The HRV analysis was performed in time and frequency domain according to ESC/NASPE guidelines [6]. The following time domain parameters were calculated: SDNN, rMMSD, the square root of the mean of the sum of the square of differences between adjacent NN intervals, and pNN50–NN50 count divided by the total number of all NN intervals. Spectral analysis included total power (TP), low frequency power (LF for 0.04–0.15 Hz) and high frequency power (HF for 0.15–0.4 Hz).

HRT was analyzed with the use of the original HRTView (accessible for non-commercial purposes from www.h-r-t.org). ECG recordings with at least 1 ventricular premature beat during the 24-hour ECG recording were eligible for HRT analysis. In HRT analysis two numerical descriptors: turbulence onset (TO), and turbulence slope (TS) were defined and calculated according to original method by Schmidt et al. [14]. TO and TS were defined as abnormal according to the definition proposed by Schmidt et al. [14]: TS ≤ 2.5 ms/RR and TO ≥ 0%.

We used a signal processing technique of phase rectified signal averaging (PRSA) to process sequences of RR intervals obtained from Holter recordings (PRSA algorithm is accessible for non-commercial use from www.prsa.eu). The technique provides separate characterizations of deceleration-related modulations, quantified by DC. For computation of DC, heartbeat intervals longer than the preceding interval are identified as anchors. Subsequently segments neighboring with anchor points are aligned around anchor points and the signal is averaged. A detailed method of DC calculation has been described [10, 15]. Deceleration capacity was categorized into low (> 4.5 ms), medium (4.5–2.5 ms) and high (≤ 2.5 ms) risk categories according to the original publication [10]. Abnormal DC was defined as ≤ 4.5 ms.

The study was approved by the local bioethical committee and all patients gave their informed consent.

Statistical analysis

Data are expressed as mean ± SD (median) for continuous variables and as a number (percentage)

for categorical variables. Univariate comparison of DC values according to clinical variables was performed using U-Mann-Whitney or χ^2 test/Fisher exact test, where appropriate. Spearman correlations were performed to evaluate the relationship between DC and ECG parameters. Uni- and multivariate logistic regression analyses were used to determine the association between clinical and ECG variables and abnormal DC values. P value < 0.05 was considered statistically significant. Analysis was performed with SPSS version 15 (Chicago, IL).

Results

Clinical characteristics of studied patients

The study population consisted of 70 patients (55 male and 15 female) aged 36–79 years (mean 58 ± 11 years). There were 18 (26%) diabetic and 39 (57%) hypertensive patients. Twenty per cent of patients were obese (body mass index > 30 kg/m^2) and 51% had a history of smoking. There were 39 (57%) patients with predominant ST elevation in anterolateral leads and 31 (43%) patients with ST elevation in inferior leads on the ECG recorded at admission. Angioplasty was performed in all cases, in 64 patients with stent implantation. Left ventricular ejection fraction, assessed by echocardiography on the second or third day after revascularization, varied from 22% to 73% (mean 53 ± 11%). Only 6% of patients presented with LVEF ≤ 35%. During Holter recordings patients were treated with beta-blockers (94%), angiotensin converting enzyme (ACE) inhibitors and/or angiotensin II receptor blockers (ARB; 73%), statins/fibrates (100%), nitrates (76%) and antiplatelet therapy (100%). Detailed characteristics of the studied population can be seen in Table 1.

Holter recordings

During Holter recording all the patients remained in the sinus rhythm. Ventricular premature beats were present in 68 patients; in 7% of them frequent ventricular premature beats > 10/h were observed; nonsustained ventricular tachycardia was found in five recordings (7%).

Results of HRV analysis are displayed in Table 1. Eleven patients (16%) presented with SDNN < 70 ms. HRT parameters were calculated in 60 patients (86%). In the remaining 14%, no ventricular premature beats were found or they did not fulfil the criteria for HRT quantification. There were 17 (28%) patients with abnormal TO, and eight (13%) with abnormal TS. When categorizing

Table 1. Clinical and electrocardiography characteristics of studied patients.

Parameters	Studied population (n = 70)
Clinical variables	
Age (years)	58 (55) ± 11
Age > 65 years	20 (29%)
Gender (men)	55 (79%)
Hypertension	39 (57%)
Diabetes	18 (26%)
Smoking	36 (51%)
Hyperlipidemia	44 (63%)
Body mass index > 30 kg/m^2	14 (20%)
Location of myocardial infarction:	
Anterolateral	39 (57%)
Inferior	31 (43%)
LVEF (%)	53 (55) ± 11
LVEF ≤ 30%	2 (3%)
LVEF ≤ 45%	13 (19%)
Systolic blood pressure [mm Hg]	133 (125) ± 23
Diastolic blood pressure [mm Hg]	82 (80) ± 14
Medication	
Beta-blockers	66 (94%)
ACE inhibitors/ARB	51 (73%)
Nitrates	53 (76%)
Statins/fibrates	70 (100%)
Antiplatelets	70 (100%)
ECG variables	
Mean heart rate [bpm]	71 (70) ± 10
No. of VPB	68 (7) ± 243
VPB > 10/h	5 (7%)
Heart rate variability	
SDNN [ms]	99 (99) ± 30
rMSSD [ms]	38 (30) ± 24
pNN50 (%)	7.15 (3.0) ± 9.7
TPln [ms^2]	7.85 (7.79) ± 1.00
LFln [ms^2]	5.84 (5.89) ± 0.98
HFln [ms^2]	4.95 (4.85) ± 0.99
Heart rate turbulence	
TO (%)	–0.92 (–1.07) ± 3.47
Abnormal TO	17 (28%)
TS [ms/RR]	11.23 (7.43) ± 12.72
Abnormal TS	8 (13%)
HRT0	36 (60%)
HRT1	23 (38%)
HRT2	1 (2%)

LVEF — left ventricular ejection fraction; ACE — angiotensin converting enzyme; ARB — angiotensin II receptor blockers; VPB — ventricular premature beats; SDNN — standard deviation of all NN intervals; rMSSD — root mean square of successive differences; pNN50 — percentage of differences between adjacent NN intervals that are > 50 ms; TPln — natural logarithm of total power; LFln — natural logarithm of low frequency; HFln — natural logarithm of high frequency; TO — turbulence onset; TS — turbulence slope; HRT — heart rate turbulence; HRT0 — both TO and TS normal; HRT1 — TO or TS abnormal; HRT2 — both TO and TS abnormal

patients according to original HRT criteria [14], the HRT category 1 (TO or TS abnormal) was observed in 24 (40%) patients and HRT category 2 was found only in one patient (both TO and TS abnormal).

Deceleration capacity

Mean (median) value of DC was 4.94 (5.12) ± ± 2.96 ms (IQR: 3.53–6.63 ms) When categorizing patients according to the original criteria [10], 40 (57%) patients presented with 'low risk' (> 4.5 ms) DC, 23 (33%) with 'intermediate risk' DC and seven (10%) with 'high risk' values (≤ 2.5 ms). Therefore, 43% of studied patients had abnormal DC.

Clinical covariates of deceleration capacity

Deceleration capacity showed significant negative correlation with age (r = –0.31, p = 0.011; Fig. 1). Consequently, older patients (> 65 years) had lower values of DC (median 4.07 *vs*. 5.65 ms, p = 0.030; Table 2). Reduced DC was also observed in women (4.39 *vs*. 5.56 ms, p = 0.012) and patients with hypertension (4.39 *vs*. 5.94 ms, p = 0.019).

Female gender, advanced age (> 65 years) and coexisting hypertension were found to be related to abnormal values of DC (DC ≤ 4.5 ms) in univariate analysis. Multivariate analysis, including only clinical covariates, showed that female gender was independently associated with lower values of DC (OR = 4.2, 95% CI =1.3–4.1, p = 0.020; Table 3).

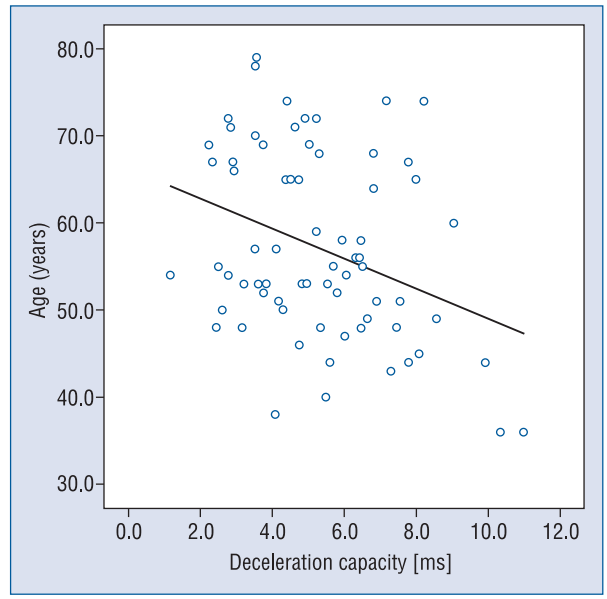

Figure 1. Correlation between deceleration capacity and age.

ECG covariates of deceleration capacity

Deceleration capacity was significantly correlated with mean heart rate, all HRV measures and turbulence slope (Table 4). Patients with faster heart rate and those with lower TS had lower DC values (Fig. 2, 3). The analysis of the relationship between DC and HRV parameters showed stronger

Table 2. Median values of deceleration capacity depending on clinical variables.

Clinical covariate	Group	Deceleration capacity	p
Age (years)	< 65	5.61 (5.56) ± 2.15	0.030
	> 65	4.49 (4.07) ± 1.81	
Gender	Males	5.14 (5.56) ± 3.24	0.012
	Females	4.21 (4.39) ± 1.39	
LVEF	≤ 45%	5.53 (5.09) ± 4.77	0.906
	> 45%	5.27 (5.21) ± 2.41	
Diabetes	Yes	3.54 (4.07) ± 4.55	0.096
	No	5.42 (5.27) ± 2.0	
Hypertension	Yes	4.17 (4.39) ± 3.46	0.019
	No	5.90 (5.94) ± 1.80	
Smoking	Yes	5.22 (5.18) ± 2.93	0.681
	No	5.08 (4.63) ± 2.99	
BMI	> 30 kg/m^2	4.40 (4.55) ± 3.26	0.490
	< 30 kg/m^2	5.07 (5.27) ± 2.9	
Location of MI	Anterolateral	4.42 (4.94) ± 3.39	0.255
	Inferior	5.53 (5.41) ± 2.22	

LVEF — left ventricular ejection fraction; BMI — body mass index; MI — myocardial infarction

Table 3. Correlations between deceleration capacity and clinical and electrocardiography covariates.

	R*	P
Age (years)	–0.35	0.011
LVEF (%)	0.17	0.333
Heart rate [bpm]	–0.55	< 0.001
Number of VPBs	–0.06	0.638
PAC	–0.13	0.268
SDNN [ms]	0.44	< 0.001
rMSSD [ms]	0.34	< 0.001
pNN50	0.49	< 0.001
TP [ms^2]	0.5	< 0.001
LF [ms^2]	0.66	< 0.001
HF [ms^2]	0.56	< 0.001
TO (%)	–0.19	0.132
TS [ms/RR]	0.37	0.003

*Spearman correlation; LVEF — left ventricular ejection fraction; VPB — ventricular premature beats; PAC — premature atrial contractions; SDNN — standard deviation of all NN intervals; rMSSD — root mean square of successive differences; pNN50 — percentage of differences between adjacent NN intervals that are > 50 ms; TP — total power; LF — low frequency; HF — high frequency; TO — turbulence onset; TS — turbulence slope

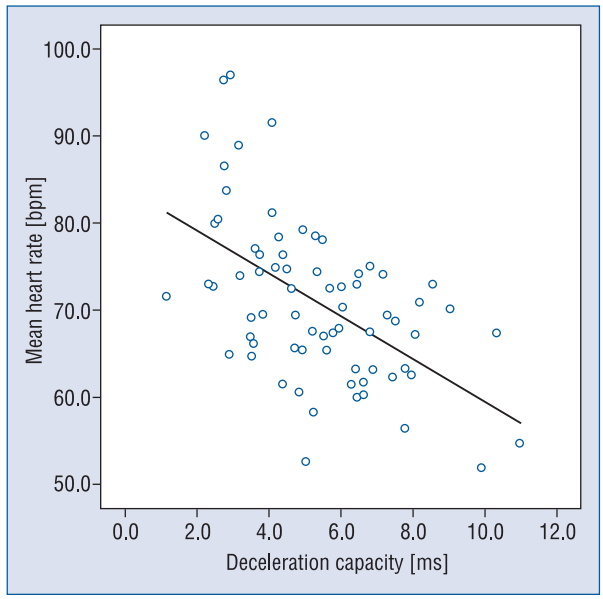

Figure 2. Correlation between deceleration capacity and mean heart rate.

Table 4. Clinical predictors of abnormal deceleration capacity in uni- and multivariate regression analyses.

	Univariate			Multivariate*		
	OR	95% CI	p	OR	95% CI	p
Age > 65 years	1.65	0.99–1.09	0.053	1.47	0.45–4.79	0.524
Gender (female)	4.22	1.26–14.12	0.020	4.22	1.26–14.12	0.020
Diabetes	1.16	0.40–3.39	0.781			
Hypertension	2.88	1.04–7.94	0.042	2.20	0.76–6.40	0.142
LVEF ≤ 45%	1.10	0.52–2.77	0.701			

*Only covariates with significance level < 0.10 in univariate analysis were used for multivariate model; OR — odds ratio; CI — confidence interval; LVEF — left ventricular ejection fraction

correlations with spectral than with time domain measures, with the highest correlation for LF ($r = 0.66$, $p < 0.001$; Fig. 4). The value of DC was unaffected by the number of premature ventricular or supraventricular beats.

As women have a significantly higher mean heart rate than men (79 ± 12 *vs*. 69 ± 8 bpm, $p < 0.001$), the mean heart rate > 70 bpm (equal to median value of mean heart rate for the entire studied population) was included into the multivariate logistic regression. This analysis showed that the abnormal DC was independently related to the presence of hypertension (OR = 3.2, 95% CI =1.1–9.9, $p = 0.039$) and the mean heart rate > 70 bpm (OR = 6.1, 95% CI = 2.0–18.4, $p = 0.001$) but not female gender ($p = 0.121$).

Discussion

This study shows that DC, the new risk predictor of mortality after myocardial infarction, is reduced in 43% of contemporarily treated STEMI patients and that it is significantly correlated with mean heart rate, several HRV indices and turbulence slope. Deceleration capacity decreases with increasing heart rate and age, it is lower in women and hypertensive patients. As DC is positively correlated with HRV indices, its value decreases along with HRV reduction.

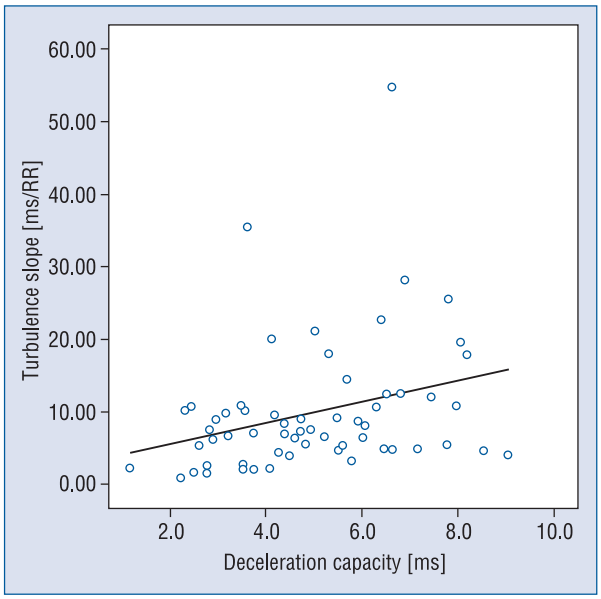

Figure 3. Correlation between deceleration capacity and turbulence slope.

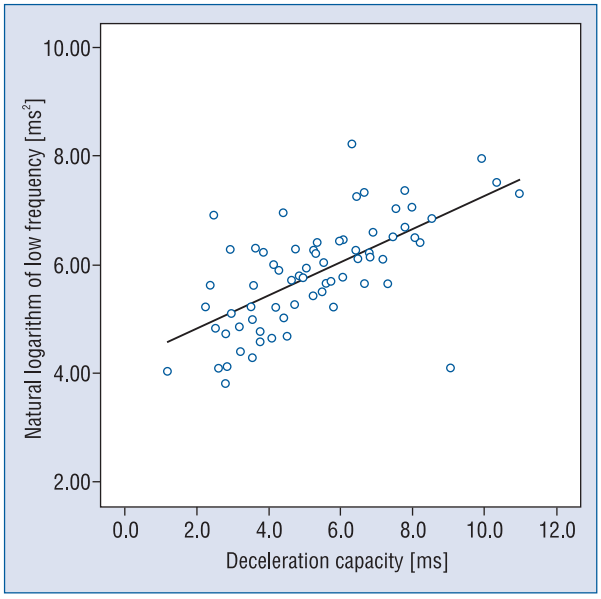

Figure 4. Correlation between deceleration capacity and low frequency power of heart rate variability.

The abnormal DC < 4.5 ms was found in 43% of patients but only 10% of them were characterized by severely reduced DC ≤ 2.5 ms/RR. These numbers are comparable to those presented by Bauer et al. [10] who analyzed data from three large post-infarction populations. However, there are many significant differences between patients in our group and those described by Bauer et al. [10] Severely compromised left ventricular function (LVEF ≤ 30%) was present in only 3% of our patients and in 10% of Bauer's group [10]. Median age of our patients was lower than the median age of patients in the study of Bauer et al. (55 *vs*. 57–64 years). The proportion of diabetic patients is higher in our study (26%) than in the Munich, London and Oulu groups. Women in our study appear to differ as well, comparing to the age of patients from Munich (14 and 22%, respectively). Patients with previous myocardial infarction were excluded from our study but not from the study of Bauer et al. [10]. Since some of the data used in the original study is historical, there are significant differences in the treatment strategies, such as different proportions of patients being on beta-blocker, ACE inhibitor/ARBs or statin therapy. Further, all of our patients underwent percutaneous coronary intervention, whereas this procedure was applied to 90% of patients from Munich, 24% from Oulu and was not performed on patients from London. Altogether, these comparisons show that some clinical characteristics are different between our patients and those presented by Bauer et al. [10].

Bauer et al. [10] in their original report, mainly focused on the presentation of a new variable (DC) with prognostic value, with no evaluation of the relationship between DC and clinical covariates. Our study aims to fill this gap. We have observed that lower DC values were present in older patients, women, and in those with hypertension. The presence of significant correlations between DC and standard HRV indices suggest that DC is a variant of HRV. Therefore, it is unsurprising that DC is reduced with advancing age similarly to other HRV parameters [16, 17]. Ageing is believed to be one of the major determinants of decrease in heart rate variability. Umetani et al. [17] reported that SDNN reaches 60% of baseline values by the age of 90 years. These changes are explained by the shift in sympathovagal balance with age with decline of parasympathetic tone at the age of 50 years. It is also known that women present higher resting and 24-hour mean heart rate and have lower HRV than men [18–20] and thus reduction in DC in female patients is not surprising either. However, in the multivariate analysis adjusted to mean heart rate > 70 bpm, female gender was no longer a significant contributor to abnormal DC. In the same analysis the presence of pre-hospital hypertension was an independent and significant determinant of abnormal DC. Patients with hypertension present with impaired autonomic control of the heart rate.

Sympathetic stimulation and/or parasympathetic inhibition have been considered as important contributors to the development of hypertension. Several studies [21–26] have documented decreased HRV in patients with hypertension. This is plausible evidence that the observed impairment of DC in hypertensive STEMI patients was another marker of co-existing autonomic dysfunction.

Conclusions

In conclusion, in STEMI patients treated with coronary angioplasty during the acute phase of the disease, the deceleration capacity is determined mainly by pre-existing hypertension and increased heart rate.

Acknowledgements

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