

## Original Article

# Utility of Transtelephonic Electrocardiographic Transmission System for Detection of Ischemic ST-Segment during Exercise Stress Test

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**ABSTRACT**

**Objective:** To confirm or deny the hypothesis that the transtelephonic electrocardiographic (ECG) transmission system is useful for the detection of ischemic ST-segment during exercise in patients with typical chest pain.

**Design:** Prospective clinical study.

**Setting:** Non-invasive Cardiac Unit, Department of Medicine, Farwania Hospital, Kuwait.

**Methods:** One hundred patients with chest pain were included in the study but only 60 were patients with angiography documented coronary artery disease. All the patients underwent treadmill exercise ECG test. Transtelephonic ECG transmission system was provided for all the patients during their exercise ECG test.

**Results:** Simultaneous transtelephonic recording yielded 15 out of the 35 patients with a ST segment depression at peak exercise (sensitivity = 42%). Out of 60 patients with a negative ST segment response to exercise test, only five patients (false positive) had a 1 mm ST segment depression detected on transtelephonic system (specificity = 92%). There were 20 false negative transmissions on transtelephonic recorder when the ST segment response to exercise test was positive. But in the patient group that underwent coronary angiography,

there was an increase in sensitivity (60%) and specificity (100%) of transtelephonic recorder in detecting the ischemic ST segment, as there were no false positive results. With regard to detection of ventricular arrhythmias, the transtelephonic system had 100% sensitivity and specificity.

Stepwise logistic analysis showed no significant relation to age, gender, body mass index, history of myocardial infarction, diabetes mellitus status and hypertension as independent variables ( $p = \text{NS}$ ). Transtelephonic system tended to underestimate the peak amplitude of the ST segment depression as compared to the maximal ST segment depression observed during exercise test ( $1.22 \pm 0.21$  versus  $1.81 \pm 0.43$  mm,  $p < 0.05$ ). There was no significant correlation between ST segment depression observed by exercise test and transtelephonic system ( $r = 0.582$ ,  $p = \text{NS}$ ).

**Conclusions:** Despite the limitations and the confounders of our approach, this study suggests a limited value of this small monitor for the outpatients awaiting episodes of chest pain. Further studies are needed to clarify the validity and reliability of this diagnostic tool in these clinical settings.

**KEY WORDS:** coronary artery disease, exercise ECG test, transtelephonic system

**INTRODUCTION**

The importance of the ischemic ST-segment response in the detection of coronary artery disease is well documented<sup>[1]</sup>. Many investigators have described the predictive value of ST-segment depression in the diagnosis of coronary artery disease in asymptomatic patients<sup>[2]</sup>. Prospective studies document the importance of the ischemic ST-segment response in predicting cardiac events including sudden death and myocardial infarction<sup>[3]</sup>. Additionally, detection of the ST-segment response to submaximal exercise in patients after myocardial infarction identifies patients at risk for subsequent cardiac death or myocardial infarction within the next year<sup>[4]</sup>.

In many patients, the 24-hour Holter recording is incapable of documenting the cause of the patients' symptoms. Still, long term monitoring is necessary in these cases, which are common. This could be effected by simply repeating many 24-hour Holter recordings until symptoms occur but this is costly and inefficient<sup>[5]</sup>.

Transtelephonic event recorders are small ECG recording devices used for various time periods. The patient can save the recording by manually triggering the device, which stores the rhythm for later playback. Some devices allow capture of both retrospective and prospective recordings<sup>[6]</sup>. It has a memory loop that can store the previous one to four minutes of cardiac rhythm when activated by the symptomatic patient<sup>[7]</sup>.

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Fig. 1: Illustration of transtelephonic ECG transmission system

Transtelephonic electrocardiographic (ECG) transmission is a relatively new diagnostic technique, which has been shown to be useful in the detection of sporadic symptomatic arrhythmias as well as in the adjustment of antiarrhythmic drug regimens<sup>[8]</sup>. Less information is available regarding the ability of this transtelephonic ECG system to reliably record the ischemic ST-segment response. However, transtelephonic ECG transmission has detected ST-segment elevation during chest pain in patients with Prinzmetal's angina, both in individual case reports and series<sup>[9]</sup>.

The aim of this study was to evaluate the utility and usefulness of the transtelephonic electrocardiographic transmission system for detection of ischemic ST-segment during exercise in patients with stable angina.

## PATIENTS AND METHODS

### Study patients:

The study included 100 patients with chest pain due to stable angina (85 male and 15 female). Only sixty patients had an angiography documented coronary artery disease. All patients were referred by their physicians to the Non-Invasive Cardiac Unit, Department of Medicine, Farwania Hospital with chest pain between January 2000 and December 2003. All patients were evaluated clinically by looking at history, physical examination, 12-leads ECG, routine laboratory investigations and echocardiography and Doppler study.

Exclusion criteria included patients with significant valvular disease, irritability, anxiety, and history of heart failure. Exclusion was based on medical history, physical examination, routine biochemical tests, and echocardiography to avoid confounding factors.

### Treadmill exercise ECG test protocol:

All patients underwent the exercise ECG test using standard or modified Bruce models at the

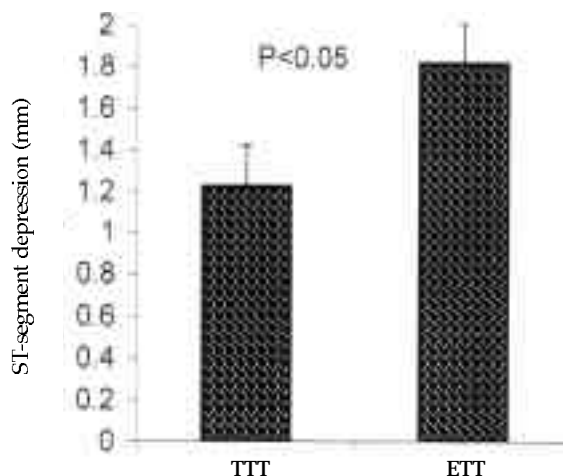


Fig. 2: Comparison of ST segment depression detected during exercise test and by transtelephonic system

baseline of the study. Resting blood pressure (measured manually by arm-cuff sphygmomanometer) was measured in supine and standing positions before the test. Patients with orthostatic hypotension (defined as a decrease of  $> 20$  mmHg of systolic blood pressure after standing) were excluded. Resting ECG was done for all patients to exclude patients with significant ST-segment changes, left bundle branch block or tachyarrhythmias.

The stress ECG test was terminated, if there was a decrease in blood pressure ( $>20$  mmHg), significant arrhythmias (non-sustained or sustained ventricular tachycardia), typical chest pain (test limiting angina) or  $> 2$  mm ST-segment depression from baseline. Peak heart rate [HR: achieved percentage of age-related peak heart rate = (peak HR / 220 - age) x 100] and the heart rate reserve percent were computed for each patient.

### Transtelephonic Electrocardiographic Transmission System

This new monitoring device evolved from real time event recorders called "King of Hearts Express" from Spacelabs. It has a maximal capacity of storing five minutes of rhythm (15 x 20 seconds memory segments). This device has digital memory (freeing the patient from the necessity of immediate access to a telephone) as well as a "leading edge" memory loop that continuously stores several minutes of ECG in digital form. The monitor is activated by the patient pushing a record button during the prodrome of an event or upon arousal. The device then stores the previous 1 to 4 minutes of cardiac rhythm in memory as well as the subsequent 30 to 60 seconds of rhythm. The "King of Heart Express" is 5.5 x 3.0 inches and weighs 150 gm. It uses 2 AA batteries. The transtelephonic event recorder requires the use of two standard Holter monitoring electrodes.

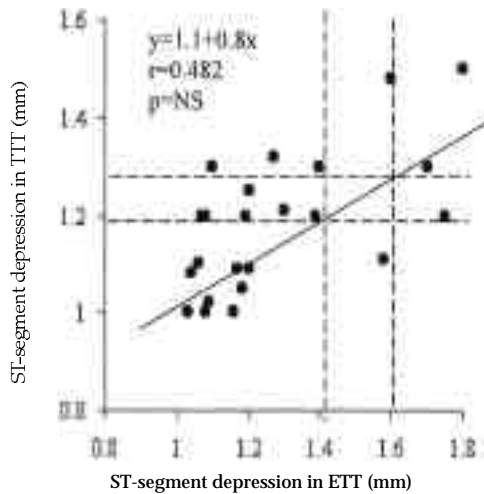


Fig. 3: Correlation between ST segment depression detected by exercise test and transtelephonic system

### Study design:

All the patients were provided with a loop event ECG recorder during treadmill exercise ECG test. A test ECG strip was transmitted by the patient before starting exercise ECG test at the non-invasive cardiac laboratory to ascertain his ability to use the device correctly.

The 20-seconds memory segments were utilized in obtaining the ECG at rest, peak exercise, and 2 minutes after exercise. Simultaneous ECG tracings were taken from Event Recorder as well as the standard 12-lead ECG at rest, peak exercise and two minutes after exercise during recovery phase and were printed out in real time for analysis.

Patients were contacted by the study data cardiologist to discuss any difficulties with the machine. The primary outcome measure of the study was the number of patients for whom a clear recording of ST segment depression was obtained during exercise test.

### Statistical analysis:

Continuous variables are summarized as a mean  $\pm$  standard deviation (SD). Comparison between two groups was performed with t-test for continuous variables and chi-square test for categorical variables. A p-value  $< 0.05$  was considered statistically significant and a p-value  $< 0.01$  was considered statistically highly significant. A stepwise multivariate regression model was used to identify possible independent variables associated with decreased utility of transtelephonic ECG transmission system to detect ischemic ST-segment. The strength of the association with decreased TTT detection of ST-segment was presented as 95% confidence intervals. Potential confounding of clinical variables was entered as independent variables.

Table 1 : Agreement of the exercise treadmill test and transtelephonic transmission with regard to detection of ST segment depression

	Positive ETT	Negative ETT	Total
Depressed ST- TTT	15	5	20
Normal ST- TTT	20	60	80
Total	35	65	100

Kappa coefficient value (k) = 0.752

ETT = exercise treadmill test, TTT = transtelephonic transmission

The validity of the transtelephonic ECG transmission system for detection of ischemic ST-segment was assessed by estimating the predictive indices and Kappa coefficient to determine the overall agreement with the data obtained from the Holter 24-hour ECG monitoring.

Kappa coefficient value (k) = (Observed frequency of agreement - Expected frequency of agreement) / (Total observed - Expected frequency of agreement).  
Predictive Indices:

True positive (TP), true negative (TN), false positive (FP) and false negative (FN) were calculated. Sensitivity = TP / (TP + FN), specificity = TN / (TN + FP), positive predictive value = TP / (TP + FP), negative predictive value = TN / (TN + FN) and accuracy = (TP + TN) / (TP + TN + FP + FN).

### RESULTS

A total of 100 patients with the presenting complaint of chest pain and a mean age of  $55.3 \pm 6.4$  years underwent maximal Bruce exercise ECG testing. The mean percentage of maximal heart rate achieved for the entire group was 83% and the mean duration of exercise test time was  $7.52 \pm 2.4$  minutes. During exercise test, 16 patients developed infrequent unifocal ventricular ectopics and only two patients developed short run of ventricular bigeminy. No patients developed R on T phenomenon, ventricular couplets, non-sustained or sustained ventricular tachycardia.

Tables 1, 2 and 3 showed that in the group of 100 patients, 35 had  $> 1$  mm of flat ST segment depression on maximal Bruce treadmill exercise ECG test. In this group, with ST segment depression during exercise test, simultaneous transtelephonic ECG transmission recording yielded 15 of the 35 patients with a concomitant ST segment depression at peak exercise (sensitivity = 42.8%). Of the 15 patients (true positive) found on transtelephonic recorder, the maximal ST depression found on 12-lead ECG during Bruce exercise testing was located inferiorly (II, III, aVF) in five patients and anterolateral leads (V4, V5, V6) in ten patients. Out of 60 patients with a negative ST segment response to maximal treadmill exercise test, only five patients (false positive) had a 1 mm ST segment

**Table 2 :** Agreement of the results of coronary angiography and transtelephonic transmission with regard to detection ST-segment depression

	Angio +ve	Angio -ve	Total
Depressed ST- TTT	15	0	15
Normal ST- TTT	10	35	45
Total	25	35	60

Kappa coefficient value (k) = 0.841

Angio = coronary angiography, TTT = transtelephonic transmission

depression detected on transtelephonic event recorder (specificity = 92%). There were 20 (false negative) transmissions on transtelephonic event recorder when the ST segment response to maximal Bruce exercise was positive. But, in those patients who had undergone coronary angiography, there was increased sensitivity (60%) and specificity (100%) of transtelephonic event recorder to detect ischemic ST segment and there was no false positive.

With regard to detection of ventricular arrhythmias by transtelephonic event recorder system, there was no false positive and no false negative (sensitivity = 100% and specificity = 100%) result (Table 4).

Table 5 and 6 shows that there was a significant increase in observed ST segment than expected ST segment depression by transtelephonic system in patients with flat ST segment during treadmill exercise ECG test [25 (71.4%) versus 10 (28.6%) respectively,  $p < 0.05$ ]. There was a significant decrease in observed ST segment than expected ST segment depression by transtelephonic system in patients with upsloping ST segment during exercise test [4 (28.5%) versus 10 (71.5%) respectively,  $p < 0.05$ ].

Stepwise multivariate logistic analysis of patients with ST segment depression versus those without ST segment depression by transtelephonic ECG transmission system showed no significant relation with regard to age, gender, body mass index, history of myocardial infarction, diabetes mellitus status and hypertension as independent variables ( $p = \text{NS}$ , Table 7).

Fig. 1 shows illustration of transtelephonic ECG transmission system.

Fig. 2 showed that the transtelephonic transmission system tended to underestimate the peak amplitude of the ST segment depression compared to the maximal ST segment depression observed during treadmill Bruce exercise ECG test ( $1.22 \pm 0.21$  versus  $1.81 \pm 0.43$  mm,  $p < 0.05$ ).

Fig. 3 showed that no significant correlation between ST segment depression observed by treadmill exercise test and transtelephonic transmission system ( $r = 0.582$ ,  $p = \text{NS}$ ).

**Table 3 :** Agreement of the exercise treadmill test and transtelephonic transmission with regard to detection of ventricular arrhythmias

	PVC'S -ETT	No PVC'S-ETT	Total
PVC'S- TTT	18	0	18
No PVC'S-TTT	0	82	82
Total	18	82	100

Kappa Coefficient value (k) = 1.00

ETT= exercise tolerance test, TTT= transtelephonic transmission, PVC'S= premature ventricular contractions

## DISCUSSION

The importance of the ischemic ST segment response to exercise as a sensitive predictor of coronary artery disease as well as a prognostic indicator of coronary events emphasizes the need for a reliable system to detect these ST segment changes in ambulatory patients outside of the hospital setting. Presently, continuous ambulatory ECG monitoring has been extensively studied to analyze ST changes with normal activity in ambulatory patients. However, the utility of these devices in detecting ST segment changes predictive of coronary artery disease is questionable. Guidelines for the use of ambulatory ECG continue to evolve with advances in technology of the monitoring devices as well as other medical devices and clinical research<sup>[10]</sup>. An ACC/AHA task force issued updated guidelines for the use of this technology in 1997<sup>[11]</sup>, a decade after its first guidelines in 1989<sup>[12]</sup>. Particularly, important progress was made during this period including solid-state digital technology that facilitates transtelephonic transmission of ECG data, technical advances in long-term event recorders and improved signal quality and interpretation.

The present study demonstrates the utility of the transtelephonic electrocardiographic transmission system in detecting ST segment depression documented during maximal Bruce exercise ECG testing with sensitivity of 42% and specificity of 92%, accuracy of 75%, positive predictive value of 75% and negative predictive value of 75%. The sensitivity of the transtelephonic ECG transmission system was not affected by peak heart rate achieved. Also, it is not surprising that sensitivity of the transtelephonic system was reduced compared to Bruce exercise ECG test since the comparison is between one-lead and 12- lead systems.

In the subset of the patients with angiography documented coronary artery disease and positive ST segment shifts during maximal Bruce exercise, transtelephonic ECG transmission was concomitantly positive in 15 patients. Thus, although the goal of our study was to verify the reliability of transtelephonic ECG systems in reproducing ST segment depression detected during exercise

**Table 4 :** Indices for prediction of ischemic ST-segment by TTT in all patient groups and in angiographic group and PVCs detections

	TP	TN	FP	FN	Sens %	Spec %	Acc %	PPV %	NPV %
TTT in all group	15	60	5	20	42	92	75	75	75
TTT in angio- group	15	35	0	10	60	100	83	100	77
TTT (detect PVCs)	18	82	0	0	100	100	100	100	100

TP=true positive, TN=true negative, FN=false negative, FP=false positive, Sens = sensitivity, Spec=specificity, Acc=accuracy, PPV=positive predictive value, NPV=negative predictive value

**Table 6 :** Morphology of equivocal exercise ECG test - Agreement of the exercise treadmill test and transtelephonic transmission with regard to detection of the upsloping ST segment

Upsloping ST- segment	Transtelephonic ECG Transmission	
	n	%
Observed	4	28.5
Expected	10	71.5
Total	14	100
p-value	<0.05	

testing, it was very reliable in those patients in whom cardiac diagnosis was confirmed by angiography.

The importance of the morphology of ST segment depression has been demonstrated in a large group of patients who underwent exercise testing and concomitant coronary arteriograms, that flat or downsloping ST segment changes frequently identified multivessel disease<sup>[2]</sup>.

The ability of various ambulatory ECG recording devices to accurately reproduce artificially created ST segment shifts has been studied<sup>[11]</sup>. The only CardioBeeper studied (axillary 0.18 Hz) was found to have a poor low-frequency cutoff and a small, constant ST segment shift. However, unlike new ECG transmission system, the CardioBeeper had a flat frequency response in the pass band of the unit. Also, the old CardioBeeper system tended to change flat ST segment input signals to upsloping ST segment output signals. The significantly improved frequency response of the memory CardioBeeper, used in the most recent systems account for the more accurate morphology of ST segment reproduction by these units. In addition to these engineering characteristics, the electrode system used also plays a role in the reproduction of ST segment shifts<sup>[13]</sup>. The modified lead of new transtelephonic ECG transmission system tended to underestimate the magnitude of ST segment change and altered flat or downsloping morphology to upsloping<sup>[13]</sup>.

**Table 5 :** Morphology of positive exercise ECG test - Agreement of the exercise treadmill test and transtelephonic transmission with regard to detection of the flat ST segment

Flat ST- segment	Transtelephonic ECG Transmission	
	n	%
Observed	25	71.4
Expected	10	28.6
Total	35	100
p-value	< 0.05	

**Table 7 :** Stepwise logistic analysis of patients with versus those without depressed ST segment detected by transtelephonic system with regard to age, gender, maximal exercise heart rate, blood pressure and exercise duration

Variables	Regression Coefficient	Standard Error	p-value	95% Confidence
Age	0.4875	0.0536	NS	0.505 --- 0.925
Gender	0.1942	0.0481	NS	0.744 --- 1.032
MI	0.0875	0.0231	NS	0.675 --- 1.128
Maximal HR	0.2784	0.0733	NS	0.639 --- 0.989
Maximal BP	0.1645	0.0401	NS	0.541 --- 1.318
Exercise duration	0.4621	0.0601	NS	0.843 --- 1.433

BP= blood pressure, HR= heart rate, MI= myocardial infarction NS=not significant

The feature of fifteen 20-second memory segments allows a patient to store the ECG during exercise or during chest pain, allowing transmission at a later time when convenient. Most important, however, these systems demonstrate the ability to detect ST segment change with exercise while virtually producing only false positive ST segment response in five patients with a specificity of 92%.

In our study, with regard to the ability of transtelephonic ECG transmission system, there was no false positive or false negative result with sensitivity of 100% and specificity of 100% and this is in agreement with other studies that CardioBeeper transmissions accurately recorded ventricular arrhythmias<sup>[14,15]</sup>. Patient's activated recording system can reliably detect cardiac arrhythmias, either symptomatic or asymptomatic, during daily life activities, exercise or stress, during sleep and can identify cardiac patients at risk when it records non-sustained ventricular tachycardia or patients with syncopal attack<sup>[16,17]</sup>.

#### Practical implications:

The practical implications of this study include the potential of this device for monitoring high-risk patients during activity or prescribed exercise. This includes its possible utility in monitoring rehabilitation programs after myocardial infarction or coronary artery bypass surgery.

### Methodological consideration:

Thallium scanning would have been better to prove the presence of CAD in this study, but only 15 patients were known to have undergone stress thallium 201 scanning in the course of their clinical management. Only one cardiologist performed the interpretation of the results once. Therefore, it is difficult to assess the interobserver and intraobserver variability.

### Limitations of the study:

- 1 - Relatively small number of patients.
- 2 - Only one center experience.
- 3 - The study was done under ideal laboratory circumstances .

### CONCLUSIONS

Despite the limitations and the confounders in our approach, this study suggests a limited value of this small monitor for outpatients awaiting episodes of chest pain. Further studies are needed to clarify the validity and reliability of this diagnostic tool in these clinical settings.

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