ECG changes during ISWTs in adult patients commencing CR: a retrospective case note review

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The incremental shuttle walk test (ISWT) is a valid, reliable submaximal exercise test used in the assessment of patients prior to cardiac rehabilitation (CR). Simultaneous electrocardiogram (ECG) measurements would provide important information on the safety of the test, and adequacy of subsequent cardiac risk stratification. Risk stratification is recommended to assess patients' suitability for cardiac rehabilitation. For example, ST-segment depression >2 mm from baseline during testing would place a person in a high-risk category. However, such ECG measurements are rarely undertaken in clinical practice. The aim of the study was to investigate the incidence of ECG changes during an ISWT, and report on the possible impact of these findings on subsequent cardiac risk stratification.

A retrospective case note review was undertaken for the year 2017. Baseline clinical characteristics from eligible patients were gathered including those with ischaemic heart disease, heart failure, transplant and valve replacement, along with ECG measurements during the ISWT. The impact of ECG findings on cardiac risk stratification was calculated, based on risk stratification developed by the American Association of Cardiovascular and Pulmonary Rehabilitation. The safety of the ISWT was measured by the absence of major ECG changes.

Data were gathered for 295 patients. Minor ECG changes were identified during the ISWT in 189 patients (64.1%), with no major changes. The presence of silent myocardial ischaemia (ST-segment depression) had an impact on cardiac risk stratification in 27 patients. There was a statistically significant positive association between ST-segment depression with cardiac risk stratification ($p<0.001$).

In conclusion, the ISWT is safe in terms of ECG changes. The impact of ECG findings on cardiac risk stratification is significant and worthy of further consideration.

Introduction

Completion of a functional capacity test before cardiac rehabilitation (CR) is one of the British Association for Cardiovascular Prevention and Rehabilitation (BACPR) Standards.[1] The incremental shuttle walk test (ISWT) is an externally paced submaximal walking test with strong reliability, test–retest reliability, validity and responsiveness in cardiac populations.[2,3] It is a test that is widely used to inform both risk stratification for cardiovascular events during CR, and for exercise prescription. The use of an electrocardiogram (ECG) to monitor the safety of the ISWT (indicated by the absence of major ECG changes) has not been extensively studied.[4-6] Furthermore, the possible impact that ECG monitoring during the ISWT will have on cardiac risk stratification has not yet been explored.

In 2004, the American Association of Cardiovascular and Pulmonary Rehabilitation (AACVPR) established guidelines for cardiac risk stratification.[7] Stratification can be used to guide exercise intensity during CR exercise sessions with the intention of reducing the incidence of adverse events during exercise. Stratification takes into account a number of factors, including ejection fraction, history of cardiac arrest and ECG anomalies, one of which is the presence of silent ischaemia (indicated by asymptomatic ST-segment depression). ST-segment depression <2 mm from baseline during or in the recovery from exercise testing would lead to a 'moderate-

risk' stratification, while an ST-segment depression >2 mm under the same conditions would result in the patient being placed in the 'high-risk' stratification. Patients with a high risk, are recommended to start exercise at lower intensities and with closer supervision/monitoring during CR.[8,9] If ECG monitoring is not undertaken during exercise testing, there is a possibility that a patient could be incorrectly stratified. In the UK, ECG monitoring during an ISWT is not usual practice within most settings, possibly due to cost and time implications, so other factors are relied on instead for risk stratification.[8]

The aim of the study was to describe changes in cardiac rhythm identified through ECG monitoring during the ISWT in patients who met the inclusion criteria for CR.[8] Further, the study aimed to establish whether the presence of an ECG finding impacted on the cardiac risk stratification of these patients.

Method

A retrospective case note review was undertaken using data collected from patients who had participated in CR at the Harefield Hospital, London, UK, in 2017. Harefield is part of the Royal Brompton and Harefield NHS Foundation Trust, and is the largest specialist heart and lung centre in the UK. The study was undertaken as a service evaluation, with agreement from the joint research office at University College London and the research committee at Harefield Hospital. Patient consent was not required, since only anonymised data were gathered for the purposes of the service evaluation.

Patients who received an initial functional assessment with ECG monitoring during their ISWT were included in the data collection. This was a heterogeneous population of patients, who included those with ischaemic heart disease, heart failure, transplant and valve replacement. Patients were excluded if they did not complete the ISWT with ECG monitoring, were under 18 years old or had not participated within the data collection period.

Standard practice at the participating hospital involves patients being monitored during their ISWT with an ambulatory ECG device (C.NET5000, version 1.2, Cardionetics Ltd., UK). This ECG ambulatory device automatically records and analyses ECG changes, which are extracted to a computer program. A clinical expert also reviewed any ambiguous findings to confirm the accuracy of reported changes.

Major cardiovascular events were defined as one of the following: myocardial infarction requiring hospitalisation, ventricular fibrillation, ventricular tachycardia requiring treatment, atrial arrhythmias requiring treatment, asystole, stroke and death. Minor cardiovascular events were defined as: isolated ventricular arrhythmias or atrial arrhythmias not requiring intervention, chest pain and bradycardia not requiring intervention.[6] Risk stratification was undertaken by an independent clinical physiotherapist. Where ST-segment depression was identified, comparisons were made between risk stratification values with and without the knowledge gained from the ECG. This enabled the author to assess the impact of the ECG recording on the subsequent stratification.

Statistical analyses were performed using Statistical Package for Social Science (SPSS) software (IBM SPSS Statistics Version 22). The analysis comprised descriptive statistics for clinical characteristics and baseline measurements (**table 1**), as well as frequency and type of ECG changes occurring. Associations between ECG changes and clinical predictors (age, gender, type of surgery, physical activity levels, ISWT distance), and ST-segment depression and cardiac risk stratification were explored with a level of significance of $p<0.05$. The Chi-square test and Fisher's exact test were used for categorical data, and the student *t*-test and Mann-Whitney U-test for numerical data. Effect size of the associations were interpreted according to Eta squared.[10] A binary logistic regression was performed with 'ECG change' as the dependent binary outcome and clinical predictors as the independent variables, which included clinical factors that were potentially associated with ECG changes (age, gender, baseline measurements, procedure, medication, previous cardiac event, family history of cardiac event, ISWT distance, 150 minutes and 75 minutes of weekly physical activity).

Results

Data from 295 patients were successfully collected and analysed. Minor ECG changes were found in 189 patients (64.1% of the total sample), and no major ECG anomaly was detected during the ISWT (**table 2**). The most prevalent minor events were ventricular ectopics (n=115, 39%), followed by atrial ectopics (n=91, 30.8%). The event rate was from 1 to 16.65 ventricular ectopics per minute and from 1 to 2.41 atrial ectopics per minute.

There was a statistically significant difference between 'ECG change' and age with a small effect size (mean difference –3.7, 95% confidence interval [CI] –6.36 to –1.03, p=0.007, Eta squared=0.02). Although there was overlap between groups, there was a significantly greater number of older people who had an ECG change. The strongest predictor for reporting an ECG change was age, with an odds ratio of 1.037 (95% CI 1.009 to 1.066). This indicates that for every extra year of age, patients were 1.037 times more likely to report an ECG change, controlling for all other factors in the model. There were no statistically significant differences between having/not having an ECG change and the other variables studied.

Sixty patients (20.3%) had a reported ST-segment depression during the test. ECG monitoring had an impact on risk stratification in 27 (45%) of these patients. Of these, 18 patients were classified as a moderate risk, but without ECG monitoring would have been classified as low risk. Furthermore, nine patients were classified as high risk, but without ECG monitoring would have been classified as moderate risk. This was further supported by the statistically significant difference between ST-segment depression and cardiac risk stratification ($p<0.001$). This suggests that there was a significant association between the presence of ST-segment depression and the final cardiac risk stratification, regardless of the other factors that contribute to risk stratification. The population of people in whom risk stratification was altered by ECG monitoring consisted of those following percutaneous coronary intervention (PCI), primary PCI, coronary artery bypass graft (CABG) and aortic valve surgery.

Discussion

The findings from the current service evaluation identified minor ECG changes in 64% of the patients monitored. There appears to be a relationship between the age of the patient and the likelihood of demonstrating an ECG change during the ISWT. This is the first study to demonstrate that the findings from ECG monitoring impact on risk stratification in 45% of those patients who were identified as having ST-segment depression.

Previous research has concluded that the ISWT is safe in cardiac populations.[4-6] The current study adds to this body of evidence by demonstrating the safety of the test, in terms of ECG changes, on a larger sample of patients.

Age-related increases in ECG changes during exercise-testing may be in accordance with age-related physiological and anatomical changes.[11-13] These changes can comprise an increased left atrial size or excessive norepinephrine and epinephrine responses during exertion.[12] However, the regression analysis only explained a small portion of the effect, so other unmeasured factors may play a greater role in the existence of ECG changes.

The AACVPR guidelines comprise different factors, besides ECG findings, to determine cardiac risk stratification. All should be considered in the final classification, but it may be suggested that ECG findings are the key to precise stratification. This study demonstrates that the presence of ST-segment depression is significantly associated with accurate cardiac risk stratification. Although a relatively small proportion of patients had ECG findings that impacted on their risk stratification, the absence of this information has the potential to cause an incorrect exercise prescription in this patient population. This is particularly pertinent given that the ECG findings led to classification into a higher risk group than they would have otherwise been placed. The addition of ECG monitoring provides vital data for enabling both clinician and patient to make informed decisions about their exercise prescription.

At Harefield Hospital the use of ECG monitoring during exercise testing prior to CR is routine practice. This is due to the complexity of patients seen in the department, including patients with heart transplantation and mechanical circulatory support devices. It could be hypothesised that barriers to this practice at other centres may be the cost of the equipment, location of the assessment (may not be in a hospital) and the time involved to carry out and interpret the results. However, following the results of this study, other centres may want to consider adopting this practice.

Study limitations

As this service evaluation was a retrospective case note review, the quality of the data was dependent upon the accuracy of the documentation. Although missing data can be a problem with reviews of this nature, in this case the quality of the documentation was reliable and there were no missing data for the dataset. However, since the data came from a single UK centre, results may not be generalisable to the wider cardiac population.

There were no patients with a primary diagnosis of heart failure. This is due to patients with the primary diagnosis of heart failure undertaking a six-minute walk test (6MWT) not an ISWT, so were excluded from the study. Following the results of this study, the effect of ECG monitoring on risk stratification during 6MWT warrants further investigation.

Conclusion

ECG monitoring was used during the ISWT as an initial assessment for CR. The findings of this service evaluation confirm the safety of the ISWT with the presence of only minor ECG changes during the test. These changes should not be ignored, and the presence of frequent events is a reason to suggest further medical investigations. Additionally, the ECG findings (specifically ST-segment depression) impacted on cardiac risk stratification in some patients, demonstrating that this information is essential to achieve an accurate risk stratification and individualised prescription of exercise. The use of ECG monitoring in clinical practice is, therefore, encouraged to allow clinicians to accurately prescribe exercise to this patient population

Conflicts of interest

None declared.

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Study approval

The project was not defined as 'research' by the Health Research Authority decision-making tool. Instead, the project was deemed a service evaluation by the Joint Research Office at University College London and by the Research Committee at Harefield Hospital. Thus, requirement for patient consent was waived, no ethical approval was required and only the approval of the clinical audit team at Harefield Hospital was necessary for access to the data.
Data were extracted anonymously in agreement with the University College London data protection guidelines. To access the data, an honorary contract was granted and a Disclosure and Barring Service certification was declared. The project was registered via the clinical audit department of the Royal Brompton and Harefield NHS Foundation Trust, and assigned project number 002385.

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Key messages

- Minor electrocardiogram (ECG) changes were identified during the initial incremental shuttle walk test in 189 patients (64.1%)
- Older patients were significantly more likely to have an ECG change
- Silent myocardial ischaemia impacted on cardiac risk stratification in 27 patients
- ECG monitoring provides vital data for exercise prescription

Table 1. Clinical characteristics and baseline measurements

Clinical characteristics and baseline measurements	Values N=295
Mean age, years (SD)	63 (± 11.2)
Male, n (%)	235 (79.7%)
Mean BMI, kg/m^2 (SD)	27 (± 4.4)
Mean waist circumference, cm (SD)	100 (± 13.3)
Mean resting heart rate, bpm (SD)	61 (± 10)
Mean resting SBP, mmHg (SD)	124 (± 16)
Mean resting DBP, mmHg (SD)	74 (± 10)
Procedure, n (%)	
PCI	81 (27.5%)
– PCI post-MI	17 (5.8%)
PPCI	93 (31.5%)
– PPCI post-MI	93 (31.5%)
CABG	61 (20.7%)
Mitral valve surgery	6 (2%)
Aortic valve surgery	23 (7.8%)
Medical management (medication only)	18 (6.1%)
Transplant	3 (1%)
ICD	2 (0.7%)
Other surgery	1 (0.3%)
Other	7 (2.4%)
Previous cardiac event, n (%)	
No	180 (61%)
Yes	115 (39%)
Family history cardiac event, n (%)	
No	177 (60%)
Yes	118 (40%)
Medication, n (%)	
Beta blockers	248 (82.4%)
Diltiazem	6 (2%)
Amiodarone	7 (2.4%)
Digoxin	2 (0.7%)
Physical activity levels, n (%)	
150 mins/week moderate PA	86 (29.2%)
75 mins/week vigorous PA	13 (4.4%)
Functional capacity, median (IQR)	
ISWT distance, m	420 (310–560)

Key: BMI = body mass index; bpm = beats per minute; CABG = coronary artery bypass graft; cm = centimetres; DBP = diastolic blood pressure; HR = heart rate; ICD = Implanted Cardiac Defibrillator; IQR = interquartile range; ISWT = incremental shuttle walk test; MI = myocardial infarction; PA = physical activity; PCI = percutaneous coronary intervention; PPCI = primary percutaneous coronary intervention; SBP = systolic blood pressure; SD = standard deviation

Table 2. Electrocardiogram (ECG) changes during the incremental shuttle walk test (ISWT)

ECG changes	Values, n (%) N=295
No	106 (35.9%)
Yes	189 (64.1%)
Type of ECG change	
Atrial ectopics	91 (30.8%)
Ventricular ectopics	115 (39%)
Multi-form ventricular ectopics	22 (7.5%)
Atrial fibrillation	14 (4.7%)
Pause	4 (1.4%)
Wide complex tachycardia	0 (0%)
ST-segment depression	60 (20.3%)