ST Changes Observed in Short Spaced Bipolar Leads Suitable for Patch Based Monitoring

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Abstract

This article investigates the selection of optimal ECG leads for the detection of ST changes more likely to appear in patch systems with closely spaced leads. Method: We analysed body surface potential maps (BSPMs) from 44 subjects undergoing PTCA. BSPMs were recorded at 120 sites and these were expanded to 352 nodes (Dalhousie torso) using Laplacian interpolation. A total of 88 BSPMs were investigated. This included the 44 subjects at baseline and the 44 subjects at peak balloon inflation (PBI). At PBI the subjects had various coronary arteries occluded (14 LAD, 15 LCX, 15 RCA). All possible bipolar leads were calculated for each subject. Leads were ranked based on the maximum ST-segment change between baseline and PBI for each subject. Leads with electrode spacing of more than 100 mm were excluded. The highest ranked lead was chosen as the short spaced lead (SSL) on the anterior torso. Result: The median ST-segment change for the chosen SSL for each vessel was LAD = 134 μV, LCX = 65 μV, RCA = 166 μV. The maximum ST segment change observed for the same lead was LAD = 277 μV, LCX = 166 μV, RCA = 257 μV . For comparison, the highest median observed on the 12-lead ECG for each vessel was LAD = 137 μV (V3), LCX = 130 μV (III), RCA = 196 μV (III).

1. Introduction

The 12-lead ECG is still the most important tool for detecting acute coronary syndromes, with consideration of at least two contiguous leads required for diagnosis [1]. However, the development of new patch-based short spaced lead (SSL) ECG systems to detect cardiac defects has increased dramatically, with a lack of academic literature investigating their performance [2]. Novel techniques of ambulatory monitoring are capable of storing and transmitting ECG data for diagnostic purposes [3]. Patch devices have shown accurate cardiac arrhythmia detection, however, a single lead is limited in the localisation of diagnoses compared to a 12-lead ECG [4]. Deviation from 12-lead ECG configurations has been shown to reduce the diagnostic accuracy of algorithms relying on current ST amplitude criteria [5]. The Zio® XT is an example of an existing SSL patch-based ECG monitor designed to challenge existing diagnostic methods, particularly with longer recording duration and automated arrhythmia detection [6]. Many patch-based ECG devices are designed to detect specific arrhythmias based on torso placement with a lack of specificity to ST-segment changes [6]. Further studies have discussed novel vessel-specific leads (VSLs) to detect ST-elevation myocardial infarction (STEMI) [7]. We aim to investigate a new short-spaced lead (SSL) as a means to detect ST-elevation (STE) constrained to 100 mm between electrodes.

2. Method

The proposed method uses body surface potential maps (BSPM) to investigate lead placement in the detection of STE for short spaced leads (SSL).

2.1. Data

The data are previously described in [8, 9] and include recordings from 44 subjects undergoing elective percutaneous transluminal coronary angioplasty (PTCA). Data were recorded, with respect to the Wilson central terminal, at 120 leads. After recording, these 120 leads were further expanded to potentials at the locations of 352 nodes through Laplacian interpolation. All subjects had single-vessel coronary heart disease and had positive ECG changes upon balloon inflation in one-of-three coronary arteries: left anterior descending (LAD, n=14), left circumflex (LCX, n=15) and the right coronary artery (RCA, n=15). Data were available at baseline (absence of ST-elevation) and during PBI. ECGs during PBI were assumed to represent changes compatible with those observed in patients suffering ischaemic episodes.

2.2. Algorithm

MATLAB was used to calculate all possible lead combinations (n=123904) from all possible pairs of the 352 nodes. The signal amplitude was extracted from 40 ms after the J-point (J + 40 ms) to give a representative measure of ST-segment value. The difference at J + 40 ms between baseline and PBI was calculated. This process was repeated for all leads created previously. Each lead was ranked in descending order of absolute ST-segment change (ΔST). This process was repeated for each subject (n=44), where the rank given to a lead for the previous subject is added to the rank of the next subject. The lowest ranked value denotes the lead with the highest ΔST across all subjects. A 3D torso described in a previous study [9] was used to calculate the distance between electrodes for each lead. Leads spaced greater than 100 mm apart were excluded based on the Dalhousie torso [9]. The SSL was selected as the lowest ranked lead from remaining leads (n=9760). Figure 1 shows this process.

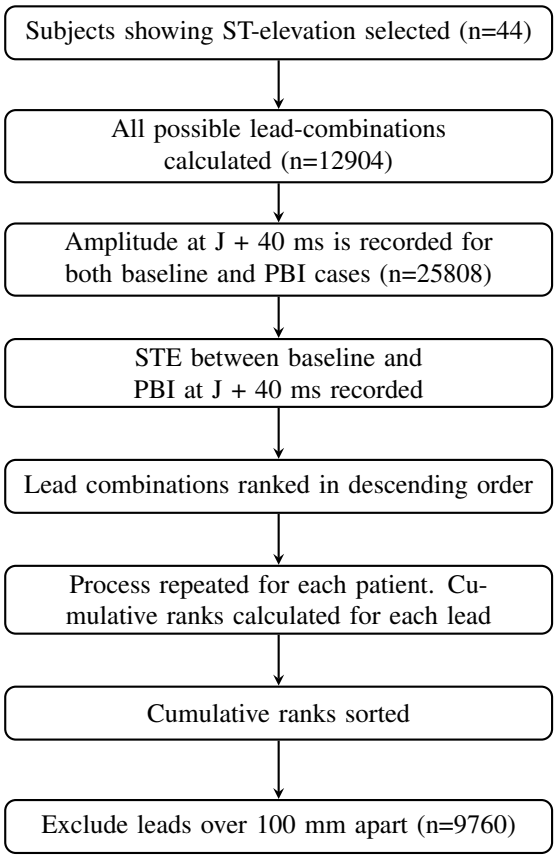

Figure 1. Flowchart of sorting algorithm

3. Results

3.1. Position of selected lead

The selected SSL which reflected the highest ST-segment change within the physical 100 mm constraint was identified as being on the anterior torso between a region in the left precordium and a more inferior abdominal region. Specifically, according to the node numbering on the Dalhousie torso [8,9], the SSL was positioned between an electrode superior to V3 (Dalhousie torso node 173) and an electrode left of the sagittal axis between the epigastric and umbilical abdominal regions (Dalhousie torso node 254). Figure 2 illustrates the position of the SSL with respect to the the six precordial leads of the 12-lead ECG. The BSPM shows the median observed signal amplitude during PBI at J + 40 ms for subjects undergoing LAD occlusion PTCA (n=14).

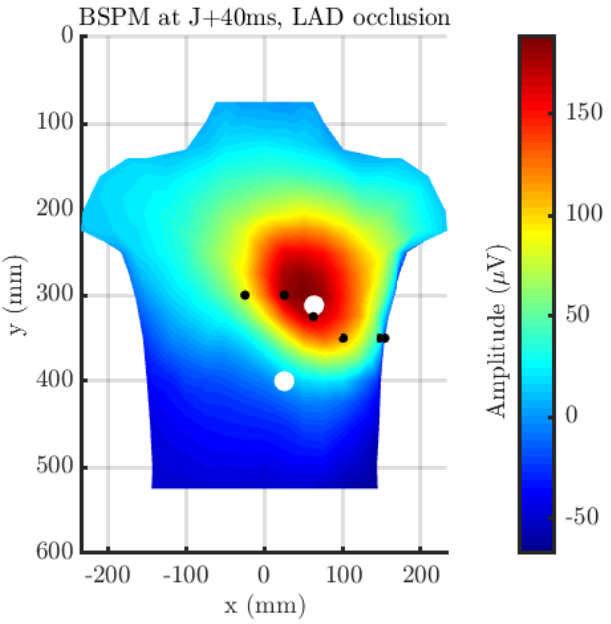

Figure 2. BSPM at J+40 ms during LAD occlusion. White = SSL, black = V-leads.

3.2. ST segment changes on selected lead

Figure 3 shows the absolute change in ST-elevation (ΔST) across all subjects as median, 25th and 75th percentiles. The SSL has a median ΔST of 125 μV with a maximum value of 277 μV. This performs comparatively with the precordial lead V2. VSLs from a previous study [7] are used in comparison with the SSL and 12-lead ECG for a critical analysis. The median ΔST for VSLs are as follows: LAD = 156 μV, LCX = 162 μV, RCA = 187 μV.

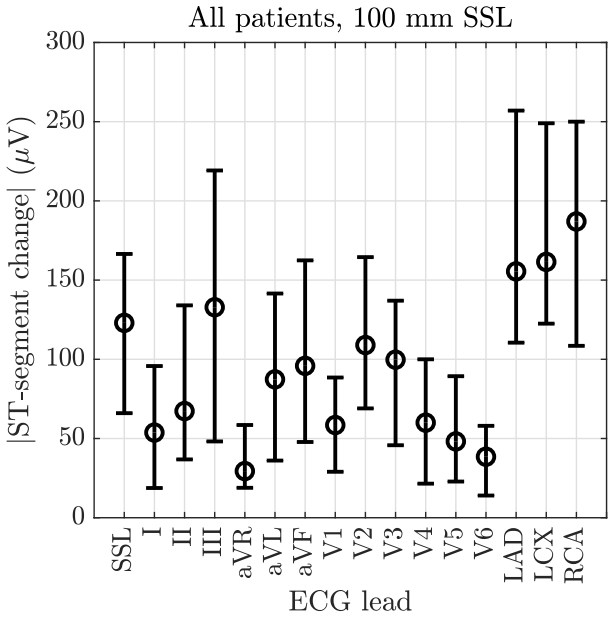

Figure 3. ΔST across all leads, all subjects (n=44)

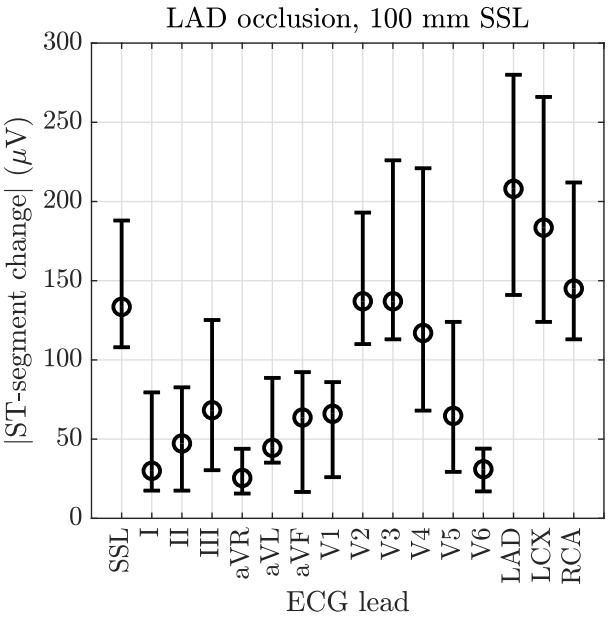

Figure 4. ΔST deviation, LAD occlusions only (n=14)

3.3. LAD occlusion

To further analyse the SSL performance, it is necessary to look at specific vessel occlusions. In this example, only subjects with LAD occlusion are considered with the same method as described in Section 2.2 (n=14). We observe a median ΔST of 134 μV in the SSL, comparable with the precordial leads V2 and V3 both showing 137 μV ΔST. This is 36% lower than the relevant VSL. The maximum SSL ΔST recorded across all subjects was during LAD occlusion at 277 μV. Figure 4 shows the performance of each lead at J + 40ms across LAD PTCA subjects.

3.4. LCX occlusion

In subjects undergoing PTCA in the LCX coronary artery (n=15), we observe a ΔST median of 65 μV in the SSL. The SSL performs comparatively to V3, with a median of 58 μV. Figure 5 illustrates the SSL characteristics. This is the lowest ΔST value observed across the three coronary arteries at 63% below the VSL. The maximum ΔST in the SSL was 166 μV.

3.5. RCA occlusion

ΔST observed in RCA PTCA subjects (n=15) possess the highest overall values. The SSL shows a median ΔST of 166 μV, 28% below the relevant VSL. The SSL exhibits similar ST-segment changes to aVF which has a median ΔST of 151 μV across subjects. Figure 6 shows the SSL performance. The maximum ΔST in the SSL was 257 μV.

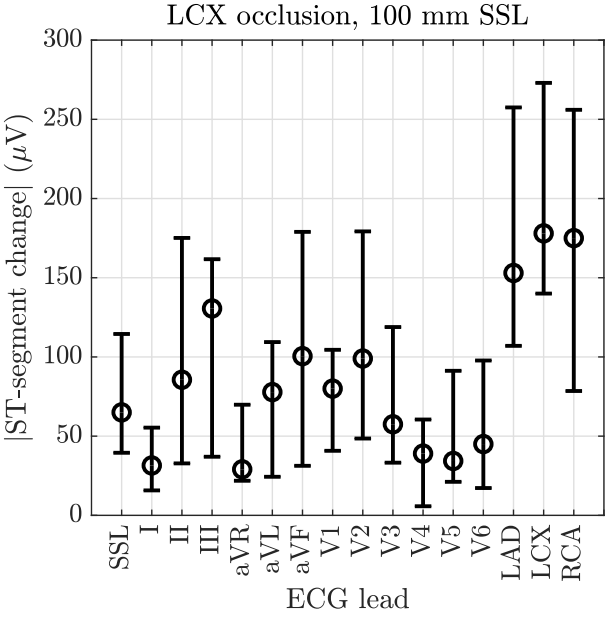

Figure 5. ΔST deviation, LCX occlusions only (n=15)

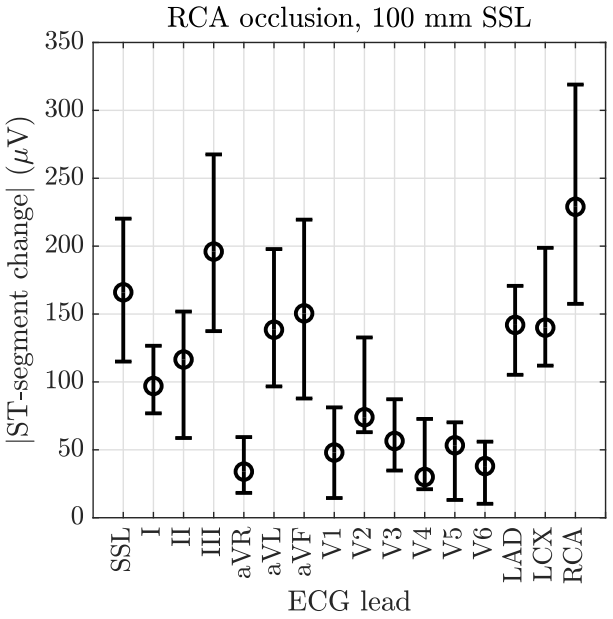

Figure 6. ΔST deviation, RCA occlusions only (n=15)

4. Conclusion

Our analysis has shown the identified SSL performs comparatively with the existing 12-lead setup for detecting ST-segment changes. The SSL shows the highest performance during RCA occlusion which has been verified by the associated body surface potential maps and previously studied vessel specific leads. Although the findings of this study support an SSL-based method of detecting ST elevation, a larger dataset is required with more complex coronary artery lesions to verify the results. Furthermore, the need for at least two contiguous leads for STEMI detection reduces the impact of an SSL for clinical use, so follow-up studies are required. Specifically, these studies may investigate the use of SSLs toward detection of MI and their use in patch-based ECG.

Acknowledgments

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