

On the Feasibility of Locating Myocardial Bridge through the 12-Lead Electrocardiogram: a Case Study

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Abstract

Myocardial bridge (MB) is a coronary artery variation where the artery tunnels through the myocardium rather than running on its surface, potentially causing ischemia and sudden cardiac death. Locating MB typically requires various imaging modalities, making widespread screening impractical. Consequently, clinical tests are usually performed after symptoms occur. We aimed to explore the feasibility of using a 12-lead electrocardiogram (ECG) to detect and locate MB by utilizing a 12-lead Holter ECG from a male patient with MB proximal to the anterior descending branch of the left coronary artery, as assessed via echocardiography. Additionally, a synthetic 12-lead ECG simulating the presence of ischemia in the same location and normal sinus rhythm, respectively, was used to feed CineECG, which processes the 12-lead ECG to generate a video where a moving vector represents the average electrical activation sequence in the heart. Visual inspection of the CineECG images indicated that, in correspondence with the ST segment, typically displaced in case of ischemia, the vector pointed towards the left anterior wall and septum rather than towards the heart apex, as observed in the normal resting ECG, suggesting that CineECG can detect ischemic-like changes associated with MB, appears to be a promising method for detecting and locating MB.

1. Introduction

Myocardial bridge (MB) presents an anatomical variation in coronary arteries, where the artery tunnels through the myocardium rather than running on its surface. This intramyocardial part of the artery is referred to as “tunneled artery” while the muscles surrounding the artery known as “bridge”[1]. When the heart contracts, *i.e.*, during systole, the bridge can apply pressure on the tunneled artery affecting the amount of blood passing through it. This effect may lead locally to ischemia, located in the tissues to which the tunneled artery provides the

blood supply, which can go undetected leading to sudden cardiac death.

Diagnosing MB cases is a difficult task, with postmortem autopsy studies considered the gold standard in determining the actual prevalence of MB [2]. Regarding the *in vivo* studies, high-resolution computed axial tomography scanning [2], and coronary angiograms are considered the golden standard [3]. Despite high-resolution imaging being available, these gold standard methods do not allow intensive analysis of MB, which actual statistical prevalence, estimated as approximately one-third of individuals[4] is still not perfectly defined.

The role of the standard 12-lead electrocardiogram (ECG) in MB diagnoses is limited, as reported by a review article published in 2015 by Rovai et. al. [5]. They found that the resting ECG for MB patients is generally normal, with some patients showing abnormalities in the ST segments, which is often associated with ischemia. While, during the exercise and stress test, the ECG of MB patients showed non-specific signs of ischemia, making MB hard to distinguish from other types of ischemia.

Although standard 12-lead ECG has been a limited role till now in the case of MB, it is still the cornerstone of diagnosis in the field of cardiology, due to its being cheap, non-invasive and comfortable for patients. Thus, it represents the perfect candidate to detect useful information about MB, like the location of the bridge.

Recently, a novel method for the spatial-temporal representation of the electrical activity of the heart was presented, called CineECG[6] Thus, in this research, we investigate the application of it for processing standard 12-lead ECG acquired by a Holter device from an MB case.

2. Material and Method

2.1. Simulated Data

For this study, two 12-lead ECG were generated using ECGsim software[7]. generating ECG by defining the distribution of electrical source strength across the surfaces surrounding the myocardium.

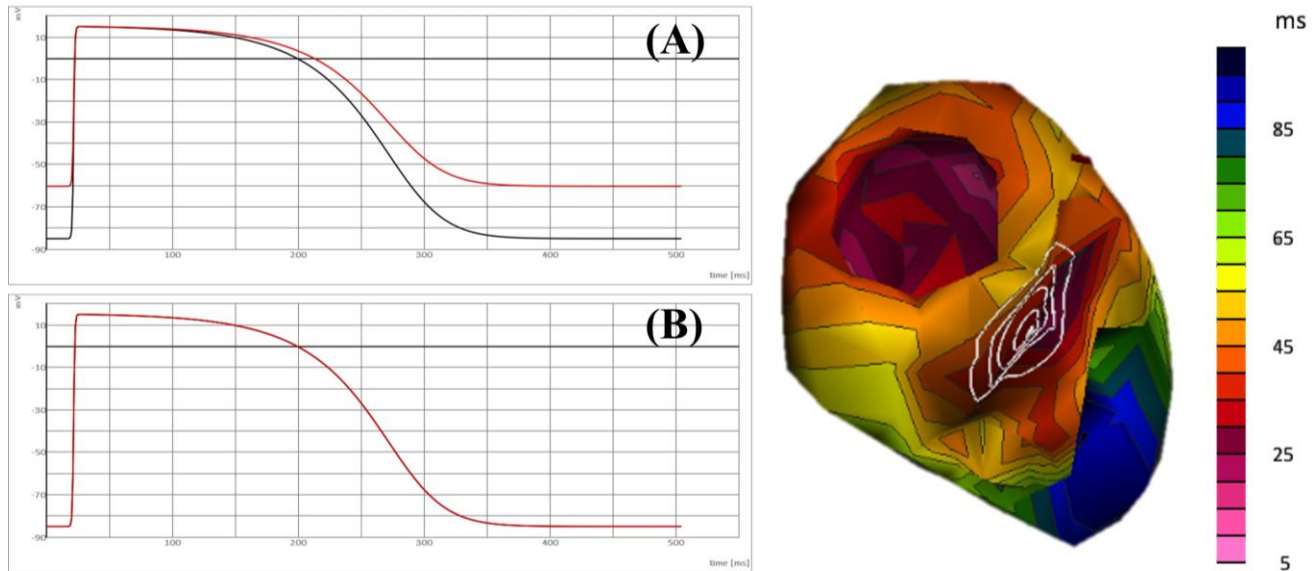


Figure 1 - The signal simulation in ECGsim: normal sinus rhythm present TMP while MB present an ischemic TMP (panel B) in the location of the bridge.

The source strength at any given moment is proportional to the varying local transmembrane potential (TMP). This TMP is determined at n nodes, where n represents the number nodes of the heart model. Thus, it is possible to change the TMP of a selection of nodes in the heart in order to simulate a disfunction.

The simulated ventricular activity of normal sinus rhythm 12-lead ECG (sNSR-ECG) was obtained by considering the standard setting of ECGsim (Figure 1.A). While the simulated ventricular activity of MB (sMB-ECG) was obtained by increasing the resting potential of the local TMP (Figure 1.B) where the bridge is located (Figure 1.C), simulating ischemia.

2.2. Clinical Case Data

For this study, real data of a healthy subject and of a subject affected by MB were considered. The 12-lead ECG of a healthy male subject showing normal sinus rhythm (NSR-ECG) was obtained from the PTB-XL dataset[8], [9] from Physionet[10], sampled at 500Hz.

The 12-lead ECG of a male subject affected by showing MB (MB-ECG) was obtained from the pre-surgical evaluation in the Ospedali Riuniti di Ancona [11]. Via ultrasound imaging, an expert located the MB in the anterior descending branch of the left coronary artery. A continuous 12-lead ECG recording was obtained over 18 hours, which was performed using a 12-lead M12R Holter ECG recorder with sampling rate of 1000Hz. Throughout the recording period, the patient engaged in routine activities allowed during hospitalization, spending most of the time resting in bed. A segment of 5minutes of each

recording was considered for this study.

2.3. CineECG

CineECG [6] is a novel method based on vectorcardiography, that transforms the standard 12-lead ECG into a moving (dipole) vector representing the average location of the anatomical center of cells undergoing changes in transmembrane potential at a given moment. The algorithm employs models of the torso and heart to determine an anatomical correct position. In 3D, it shows the trajectory of the moving vector throughout the heart cycle, and it can also display the vector direction at a specific time point or in 2D, projecting the vector using the heart's axes: apex–base, right-left, and anterior-posterior.

CineECG analysis the two simulated and the two real signals, extracting the following ventricular features: the QRS duration (QRSd; ms), the QT interval (QT; ms), the location of the T-wave peak (Tpeak; ms), the percentage of PathECG QRS within healthy trend (%QRS;%), the percentage of PathECG ST within healthy trend (%ST;%), the percentage of PathECG T wave within healthy trend (%Twave; %).

3. Results

Figure 2 shows the PathECG generated by CineECG, displaying also the vectors of the direction during at 20ms after the J point. It is clear that in normal sinus rhythm (panels A and B), the PathECG propagates through the septum, followed a movement toward the apex/left free wall; then, it makes a turn towards the base during the peak

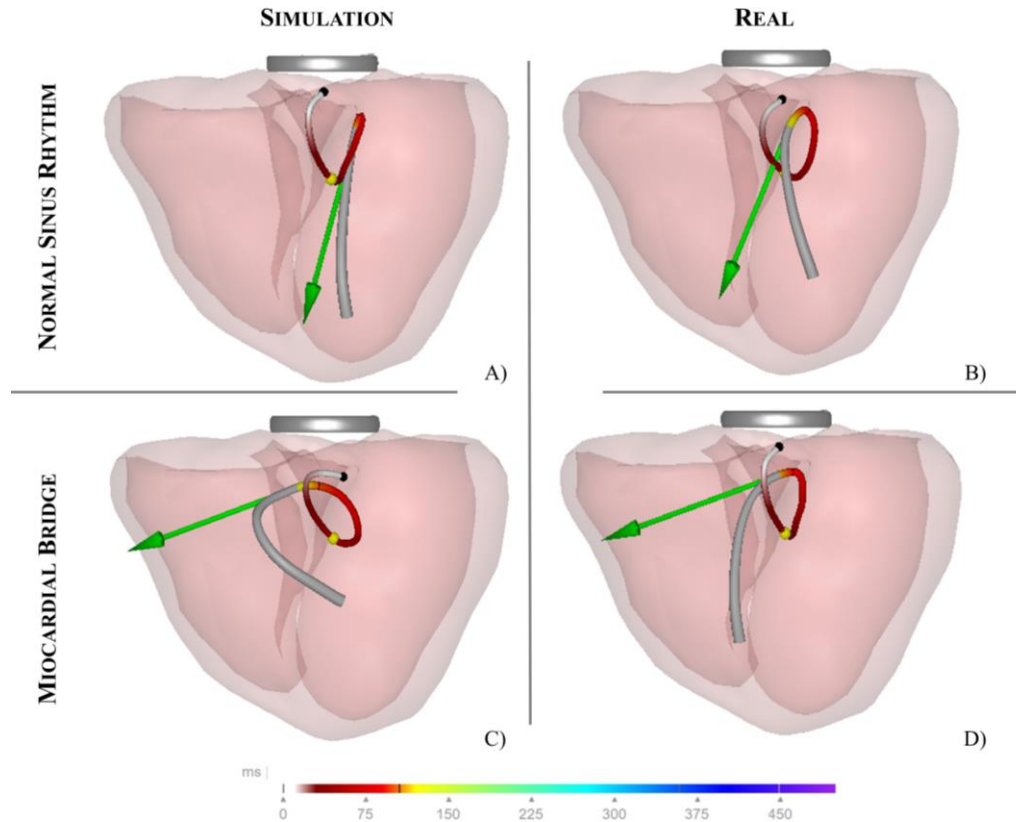


Figure 2 - PathECG (panel A: sNSR-ECG; panel B: sMB-ECG; panel C: NSR-ECG; panel D: MB-ECG) generated by CineECG with vector showing the direction during at 20ms after the J point.

Table 1 – Features extracted by CineECG from the two simulated (sNSR-ECG and sMB-ECG) and the two real (NSR-ECG and MB-ECG) signals.

	QRSd (ms)	QT (ms)	Tpeak (ms)	%QRS (%)	%ST (%)	%Twave (%)
sNSR-ECG	90	372	279	100	100	100
sMB-ECG	90	372	279	51	65	100
NSR-ECG	91	323	252	100	100	100
MB-ECG	99	411	324	76	19	100

of the depolarization and moves toward the apex during the T-wave. Moreover, in both simulation and real cases, the vectors of the direction during at 20ms after the J point are directed to the apex of the heart. While, in the PathECG obtained by using the MB ECG signals, at 20ms after the J point PathECG deviates through the septum, pointing the ischemic tissue created by the MB.

This evidence can be also quantified; indeed, Table 1 collects the features extracted by CineECG from the two simulated and the two real signals. The main difference is associated to the %ST, that decrease from 100% in both sNSR-ECG and NSR-ECG, to 65% in sMB-ECG and 19% in MB-ECG.

4. Discussion

The aim of the present work was to investigate the

application of the CineECG approach for processing standard 12-lead ECG of subjects affected by MB. With this aim, we applied CineECG to an MB simulation and to a real case of MB. For comparison, both simulated and real ECG signal of normal sinus rhythm were used as controls.

CineECG path of the normal sinus rhythm shows that during the ST-segment the direction of the path is pointing towards the apex of the heart, this continues during the T-wave as well. While in the PathECG of MB, terminal QRS is different from normal, and the vector was pointing towards the left wall of the septum indicating that this could be the center of the ischemic tissues. This hypothesis is supported by the PathECG of the simulations, that show the same directions of the ST vector. Based on that we can hypothesize that the bridge is located on the anterior descending branch of the left coronary artery, with the

tunnel probably located on the same location the ST vector is pointing. This hypothesis is confirmed by the visual inspection of the expert, that located the tunnel in that exact position.

Previous studies have shown that CineECG has shown promising result in many in case of early detection if ischemia as shown in the work of Van der Schaaf, et al., 2024 [12] where each 10s from the first 150s of continuous ECG data recorded during a percutaneous coronary intervention with prolonged balloon inflation of 94 patients were analyzed using CineECG. The angles between the CineECG at the baseline and at every 10s of the inflation were quantified and the changes were able to show immediate changes during the inflation. On the other hand, the amplitudes were almost stable, which indicates that CineECG has potential to early detect ischemia, showing small changes.

However, this study shows that CineECG was able to highlight an altered ischemic-like electrical activation in the heart of the patient, directly related to the MB; thus, the localization of the MB is possible. Moreover, while the two trajectories of the simulations are similar during the ST-segment, there are different moving on, specifically in the T-wave, this could indicate an ability of the CineECG to distinguish between different types of the ischemia. Thus, CineECG could help in diagnosing MB based on the electrical activity of the 12-lead ECG.

Despite the very good results, the paper is not free of limitation. Indeed, the result of the study is limited to only one subject; thus, further studies with larger populations are indeed needed in the future.

5. Conclusion

In conclusion, this preliminary study suggests that CineECG analysis of 12-lead ECG is a promising method to detect and locate MB, which could easily be applied for large-scale screening. Future studies will evaluate the goodness in MB location of CineECG in a larger and heterogeneous population.

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