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Assessment of a widely applicable torso ECG in acute coronary syndrome

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ABSTRACT

Introduction: The time from symptom onset to arrival at healthcare facility, and door to reperfusion time in treatment of acute coronary syndrome (ACS) can be improved significantly if the patient or the relatives can record a 12-lead ECG at home and transmit it to the physician for prompt interpretation. To make this widely applicable, the 12-lead ECG recording device has to be simple and user friendly. In this regard, torso ECG (T-ECG) electrode positions that are less cumbersome than the conventional ECG (C-ECG) electrode positions are an alternative worthy of consideration.
Objective: and setting: To study the utility of T-ECG versus C-ECG in ACS patients.
Design: and intervention: We proposed torso electrode positions in which upper limb electrodes were placed in the respective deltopectoral grooves below the lateral end of the clavicle; the right lower limb electrode was placed 2 finger breadths above the umbilicus and the left lower limb electrode, 2 finger breadths to the left of the umbilicus. We then studied the ECGs recorded, to ascertain whether T-ECGs miss or over-diagnose ACS changes. Twelve lead ECGs were recorded by both techniques (C-ECG & T-ECG) in 1361 patientsfrom the coronary care unit & out-patient department of a tertiary care hospital. A total of 1526 sets of ECGs (each set consisting of one C-ECG and one T -ECG) were read by two trained cardiologists independently and in a blinded fashion. There were 457 ECG sets from 342 patients with ACS. Of these, 116 ECG sets from 112 patients of anterior infarction who had changes restricted to precordial leads were excluded. Finally, 341 ECG sets from 230 patients with ACS and 324 sets of patients diagnosed to be normal on C-ECG were considered for the purpose of this study.
Main results: All 341 ECG sets from the 230 patients of ACS diagnosed by C-ECG were correctly diagnosed by T-ECG (100% sensitivity) and all 324 normal ECGs on C-ECG were also identified as normal on T-ECG (100% specificity). Of the ACS ECGs, ST elevation was seen in 234 ECGs and ST depressions 154 ECGs. The localizations of ST elevation and ST depression were also accurately diagnosed by the T-ECG.
Conclusion: The ECG recorded by our novel proposed torso electrode positions is comparable to a conventional ECG for the diagnosis of ACS.

1. Introduction

The ECG is the cornerstone for early and accurate diagnosis of acute coronary syndrome (ACS). In ST elevation myocardial infarction (STEMI), the time to revascularization is an established predictor of mortality and infarct size. This has 2 components: time from symptom onset to arrival to the healthcare facility, and door to reperfusion time. Health establishments have successfully made efforts to reduce door to reperfusion time. However to successfully reduce the time from symptom onset to door, it is crucial to record and interpret the first ECG as early as possible. Today, contemporary telecommunication can easily be exploited to reduce ECG

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interpretation time, but presently tele-transmission of ECG is restricted to a few leads, mainly to diagnose arrhythmias. For diagnosis of STEMI, either the patient has to reach the hospital by their own means or paramedics have to reach the patient's location to record the first ECG. Both situations involve significant delays in diagnosis and treatment. This delay can be significantly reduced if the patient or relatives could record the first ECG themselves and transmit it to the physician for interpretation.

Serial 12-lead ECG monitoring is critical in patients during the early hours of suspected ACS when the clinical status and ECG findings frequently change. The current system of recording ECG by placing electrodes on ankles and wrists has been in practice for nearly 75 years.[1] In an out-of-hospital setting this is cumbersome; moreover, placement of electrodes in distal limb locations is more prone to motion artefact compounding the problem.[2] This creates a need for an alternate ECG recording system provided it is reliable, user friendly and quick to deploy. This is possible if a vest or a pad with pre-embedded electrodes (in torso positions) and a ECG recording device is worn by the patient obviating the need of training or skill on the part of patients or relatives. Prior attempts at torso electrode positions were abandoned for lack of accuracy.[3–8] We used novel torso electrode positions and validated the new T-ECG recordings against C-ECG with special focus on ACS.

2. Method

2.1. Study design

Ethics committee of the hospital reviewed this study and waived the need for approval. We conducted a prospective study with each patient serving as his/her own control. ECGs by both methods (C-ECG and T-ECG) were recorded in all patients at the time of presentation and subsequently if there were dynamic ECG changes. Patients were enrolled from the acute coronary care unit and from the outpatient clinic of a tertiary care hospital. The ECGs were recorded by both methods: C-ECG and the T-ECG, by trained technicians or nurses on GE Mac 1200 machine. The T-ECG was recorded by placing upper limb electrodes in respective delto-pectoral grooves below the lateral end of the clavicle (Fig. 1). The right lower limb electrode was placed 2 finger breadths above the umbilicus, at 12 o'clock position and the left lower limb electrode 2 finger breadths to the left of the umbilicus, at 3 o'clock position (Fig. 1). Precordial electrode positions were conventional. The ECG was recorded with breath-holding for a few secondsto avoid beat to beat changes in the QRS amplitude that occur due to respiratory abdominal movements.

Patients with ACS whose ECGs had dynamic changes while in hospital had multiple ECGs recorded. Two trained cardiologists blinded to the ECG recording method made the ECG diagnoses. The ECGs (C-ECG & T-ECG) were provided to them in random fashion. All the ECG waveform measurements were made manually, using a hand-held magnifying lens to the nearest 0.25 mm both vertically and horizontally. Standard ECG criteria were used for the diagnosis of ACS.[9] Twelve lead ECGs were recorded by both techniques (C-ECG & T-ECG) in 1361 patients from the coronary care unit & out-patient department of a tertiary care hospital. A total of 1526 sets of ECGs (each set consisting of one C-ECG and one T -ECG) were analysed. There were 457 ECG sets from 342 patients with ACS. T-ECG positions differed from C-ECG in limb lead positions, precordial lead positions being identical. This was reflected in identical pre-cordial ECG and changes only in limb leads in all 1526 sets. Thus patients with anterior wall myocardial injury whose ECGs did not show changes in the limb leads were excluded. Hence, 116 ECG sets from 112 patients of ACS who had ST segment changes restricted to precordial leads were excluded.Finally, 341 ECG sets from 230 patients with ACS and 324 sets of patients diagnosed to be normal on C-ECG were considered for the purpose of this study.

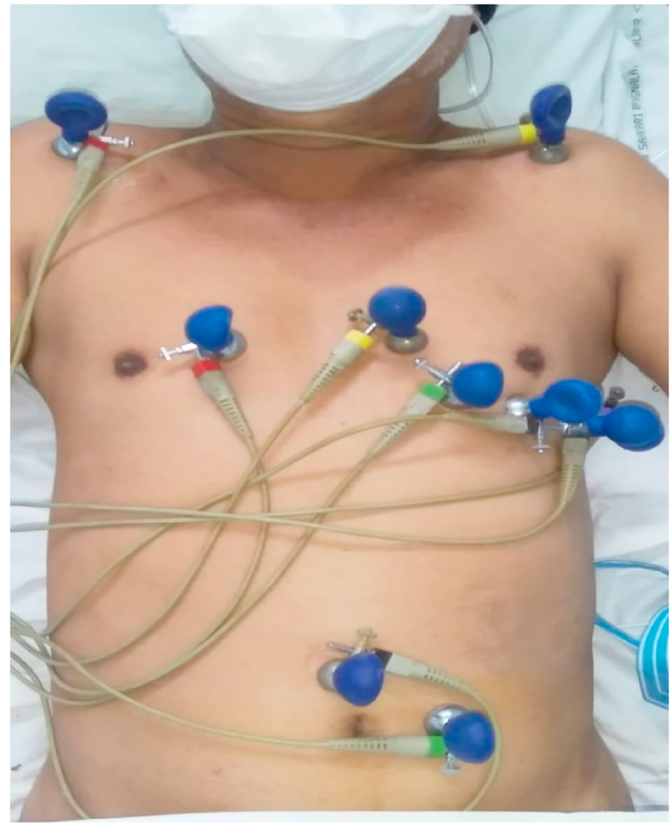

Fig. 1. Our proposed new torso only electrode positions.

2.2. Statistical analysis

The C-ECG was considered the 'gold standard' against which the T-ECG was compared. The comparison between C-ECG and T-ECG diagnosis was quantified in terms of the number of ECGs that were a diagnostic match between T-ECG and C-ECG.

Based on the number of diagnostic matches and differences, we intend to calculate Clopper-Pearson binomial confidence inter-valsfor sensitivity and specificity, based on the exact correct distribution rather than an approximation standard logit confidence intervals given by Mercaldoetal, if required.[10]

3. Results

From the 230 ACS patients, 341 sets of ECG were studied for ECG changes in inferior or lateral myocardial areas. Sub-categorization of ACS was done as per leads showing ST elevation or depression. As a control, 324 ECG sets were also analysed, where the C-ECG had been diagnosed asnormal (Table 1).These 665 ECG sets were used for subsequent analysis. Of the ACS ECGs, ST elevation was seen in 234 ECGs and ST depressions 154 ECGs.

All 341 ECG sets with ACS changes on C-ECG were diagnosed correctlyby T-ECG as well, giving the new test T-ECG a sensitivity of 100% (Clopper Pearson CI: 98.89–100%). Similarly, the 324 ECGs diagnosed as normal on C-ECG, were correctly labeled as normal by T-ECG, proving the new method to be 100% specific (Clopper Pearson CI: 98.87–100%). The distributions of ST elevation and ST depression were identical in C-ECG and T-ECG (Table 2). In 189

Table 1
Comparison of ACS ECGs with normal ECGs.

	C-ECG					
	ACS (341)			Normal (324)		
	Yes	No	Total	Yes	No	Total
T-ECG	341	0	341	324	0	324

Table 2
Territory wise distribution of ECG changes in ACS.

		C-ECG					
		ST elevation			ST depression		
		Inferior	Lateral	Inferolateral	Inferior	Lateral	Inferolateral
T-ECG	Yes	189	43	02	107	43	04
	No	0	0	0	0	0	0

Note: When there was ST elevation and ST depression in the sameECG, it was included in the both categories.

cases, the C-ECG was diagnosed as inferior wall STEMI; in 43 patients, lateral wall STEMI; in 2 patients, inferolateral wall STEMI. These C-ECG interpretations were identical with the T-ECG diagnoses. Representative examples comparing T-ECG with C-ECG in different subsets of ACS are shown in Figs. 2–4.

The following were some of distinctive features on C-ECG which were reproduced on T-ECG.

1) ST elevation in anterior and inferior leads (Fig. 2).
2) ST depression in inferior lead changes in anterior wall MI (Fig. 3).
3) Subtle ST elevations in acute evolving inferior wall STEMI (Fig. 4).

In some of the ECGs, as shown in Figs. 2 and 3, there were minor differences in the amplitude of R or S wave differed between C-ECG and T-ECG; however, the ECG diagnosis remained unchanged. It is also obvious from ECG figures that ECG morphology in precordial leads is identical in both C-ECG and T-ECG.

4. Discussion

This large prospective study has proved conclusively that our proposed torso acquired 12-lead ECG (T-ECG) is as accurate as the conventional ECG (C-ECG) in the diagnosis of ACS. Though R and S wave amplitude differed between C-ECG and T-ECG (as has been mentioned below ECG figures) it did not have impact on the final ECG diagnosis of particular type of ACS. A few earlier studies have compared ECGs based on conventional limb electrode placements withthose recorded using electrodes placed on torso. Sevilla et al[4,5] used exercise test torsolead placements to acquire 12-lead ECGs. They observed loss of inferior wall pattern in majority of ECGs (11 of 16), and false lateral infarcts were observed in 19% of patients. In contrast, our study included a large number of patients with ST depression and ST elevation in inferior or lateral leads. Importantly, none of these were missed on the T-ECG. Similarly, in 324 normal C-ECGs there was not a single false positive finding for ACS in the T-ECG. In the small study by Takuma et al[7] of 30 emergency room patients with torso electrode placements, there was only one inferior wall infarction. Limb leads were placed on both anterior acromial regions and anterior superior iliac spines. Though quality of ECG recording was improved, the authors recommended against routine use because of the observed change in QRS amplitude. Jowett et al[8] used similar torso positions as Takuma in their relatively larger study of 100 patients, but reported that 5 of 6 inferior infarcts were missed along with 1 false positive lateral infarct 8 false positive inferior infarcts. Accordingly, they recommended against use of torso lead placements. Unlike previous studies with torso positions our study was restricted to ACS patients looking at ST segment deviation not Q, R or S wave amplitudes. While Q, R S wave amplitudes and axis did change in T-ECG in our study also, as observed in previous studies, STsegment deviation the diagnostic marker in ACS the main focus of our study was similar in T-ECG and C-ECG. The absence of false positivity and false negativity in our study as against above studies could be attributed to the fact that

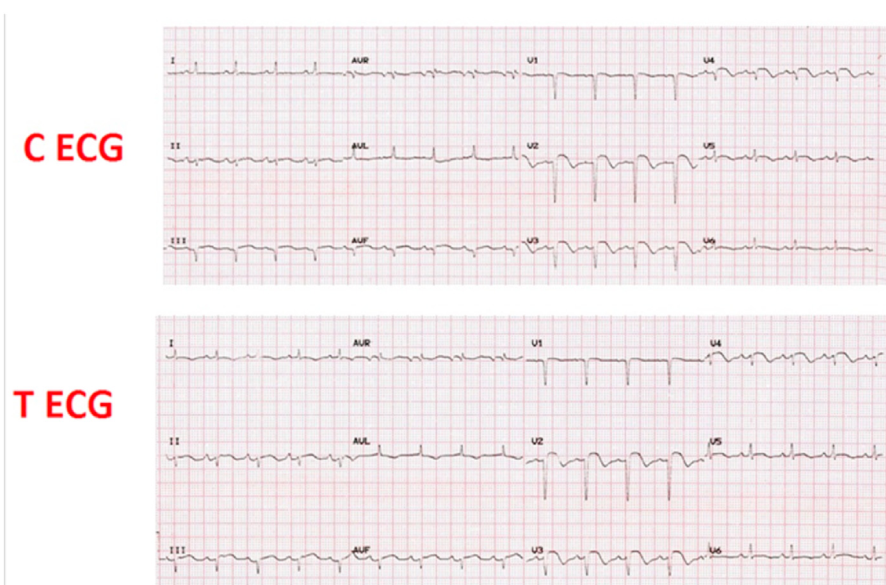

Fig. 2. An evolved anterior wall myocardial infarction due to non-proximal occlusion of the left anterior descending artery (as evidenced by ST coving in the inferior leads). C ECG indicates conventional ECG; T ECG, Torso ECG. Note: the R wave amplitude in lead I is higher in C ECG while the S amplitude in lead II is higher in the T ECG; however, the diagnosis remains unchanged.

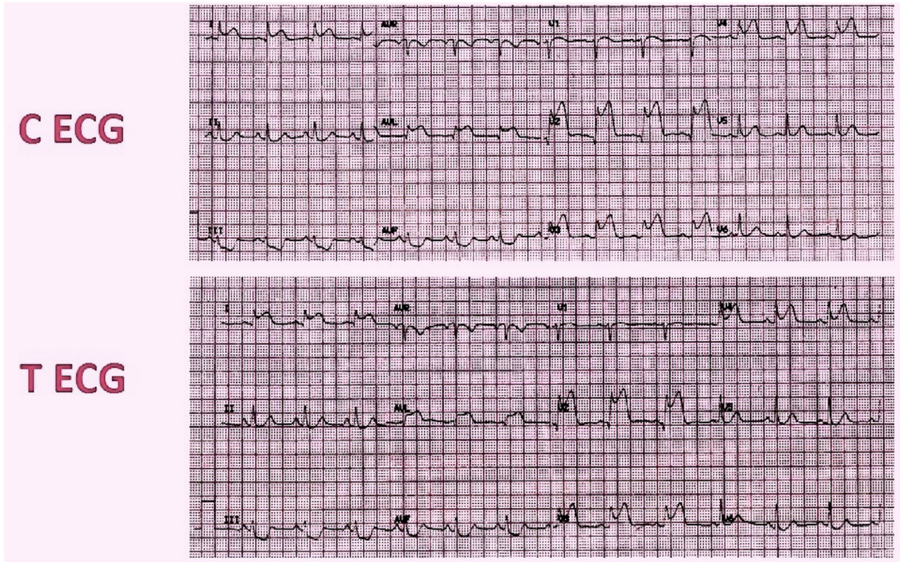

Fig. 3. Acute anterior wall myocardial infarction due to proximal occlusion of the left anterior descending artery, as evidenced by with ST depression in the inferior leads. Note: The QRS complex amplitude is more in the inferior leads in the T ECG, though the diagnosis remains unchanged.

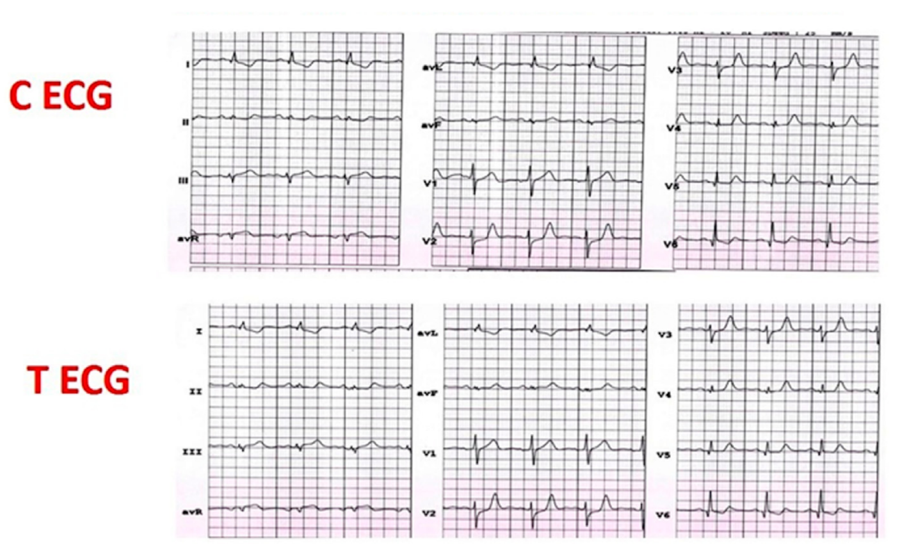

Fig. 4. Acute evolving inferior wall myocardial infarction. Note that even the subtle early ST elevations are picked up by the T ECG.

the three angles of the Einthoven triangle are similar in our proposed torso positions and conventional positions and we looked at ST segment and not at Q waves. This was not the case with the positions suggested by either Sevilla et al (Mason Likar configuration) or in the other studies (Fig. 5).

In a study of 1112 ECGs by Khan,[2] the torso positions of the lower limb electrodes were 3 inches below the umbilicus and 2 inches to either side. The upper limb electrodes were attached on mid upper arms. Their study was focused on old inferior wall MI and found excellent sensitivity and specificity for the same. Roy et al[11] used a single piece prepositioned torso electrodes on both shoulders, left anterior superior iliac spine and conventional precordial positions. They found ECG thus recorded was 96% equivalent to conventional ECG.Their study was based on 100 patientsusing different torso electrode positions and did not look specifically at ACS patients.

The 2007 AHA/ACC guidelines on ECG Part 1[12] recommends that studies look at modified leads and our study may be a step in that direction. To the best of our knowledge, ours is the largest study in ACS, looking at torso electrode positions. We propose this set of torso electrode positions as an alternative to the conventional positions, especially in an out of hospital environment, since this will be easier, with shorter electrode cables. Our findings do not suggest that C- ECG be replaced with T-ECG in the hospital setting. Our intention is to widen the easy utilization of ECG recording by enabling lay persons or paramedics to record ECGs at home, ambulance or even in remote inaccessible areas, thus saving precious time and lives in ACS. Similarly ECG if found normal can avoid unnecessary visits to hospital, saving time of patients as well of physicians.We chose the torso positions instead of wrist or ankle

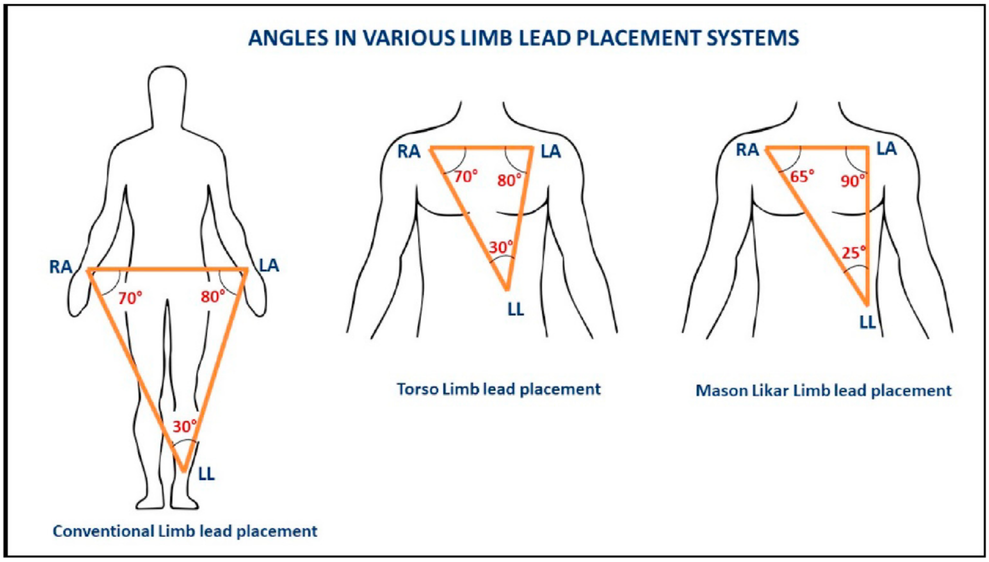

Fig. 5. Angles of Einthoven triangle with different electrode position configurations.

electrodes to pave the way for the development of an electrode embedded vest or pad in future.

5. Conclusion

Twelve lead ECGs acquired from withour torso electrode position are comparable to conventional ECGs for the identification and characterisation ofacute coronary syndrome.

Funding

Nil.

Declaration of competing interest

Nil.

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