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Similarity of ST and T waveforms of 12-lead electrocardiogram acquired from different monitoring electrode positions

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Abstract

Background: It is not always feasible to use standard electrode placement for limb leads when recording the 12-lead electrocardiogram (ECG). Other electrode placements have been accepted during monitoring. Nonstandard electrode positions, however, fail to produce waveforms identical to those recorded from the distal limb positions that are standard for diagnostic interpretation. The purpose of the present study was to validate the ST-T-segment for an alternative "Lund system" of proximal limb electrode sites.

Methods: Twelve-lead ECGs (standard, Mason-Likar, and Lund lead placement) were collected from 167 patients.

Results: There were systematic differences between measurements from standard vs Mason-Likar, but not vs the Lund system. The 95% confidence intervals of measurement agreement were similar or less when comparing measurements from the Lund system vs the first standard recording with measurements for the 2 standard recordings.

Conclusion: The Lund system might constitute a uniform convention for "diagnostic" ECGs as well as for monitoring ECG applications with regard to ST-T waveforms.

Keywords: Mason-Likar; Standard ECG; ECG monitoring; Lund system

Introduction

The standard 12-lead electrocardiogram (ECG) is still a very important tool for evaluating many cardiac conditions, although many different modalities in cardiology have been developed over the years. The standard ECG uses 9 recording electrodes, 3 of which are placed distally on the limbs and 6 of which are placed on anatomically well-defined places on the torso. A 10th ground electrode can be placed anywhere.

Diagnostic criteria used to interpret the standard 12-lead ECG have been developed for recordings done with the 3 limb electrodes placed on the left and right wrists and on the left ankle. In some settings, however, it is not optimal to use distal electrode placement for the limb leads. In monitoring situations, for either ischemia or rhythm, distal electrode placement creates a high noise level due to myoelectric activity and restricts patient mobility. Different lead systems have been proposed for continuous ECG monitoring. One of the most commonly used lead systems in this setting is the Mason-Likar system,[1] where limb electrodes are placed on the torso. It has been found, however, that this lead system produces significant changes in the waveforms compared with standard 12-lead ECG.[2-6] When limb electrodes are moved to the torso, there is influence on the Q, R, and S waves, rightward frontal plane axis shift, and poor reproduction especially of those waveforms that indicate inferior myocardial infarction. Situations may occur when an ECG with distal electrode placement is compared with an ECG with other electrode placements, such as Mason-Likar, for detection of changes between the 2 times of recording, which can lead to misdiagnosis from waveform distortion.[7]

It is clear that there is a need for an ECG lead system that can be used both in resting and in monitoring situations, that produces waveforms similar to the standard 12-lead ECG, and that has a noise immunity close to that of Mason-Likar.[8] Different ECG recordings could then easily be compared for significant changes, and no further databases of resting ECGs with other electrode placements would be needed. Proximal, but off-torso electrode sites ("Lund system") have been found to better approximate

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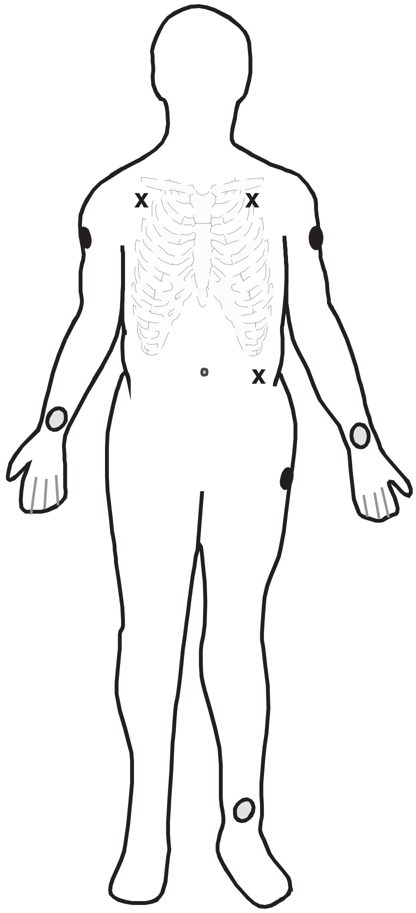

Fig. 1. Lead placements for limb electrodes. Cross denotes locations of electrodes of the Mason-Likar electrode placement. Filled circle denotes locations of electrodes of the Lund electrode placement system. Open circle denotes distal (criterion standard) electrode placement site.

standard 12-lead ECGs than the Mason-Likar electrode placement.[5,6,9] Pahlm and Wagner[5] and Welinder et al[6] investigated the Lund system by investigating differences in noise immunity[6], QRS changes of inferior myocardial infarction,[6] and QRS frontal axis[5,6] between standard lead placement, Mason-Likar, and Lund system. They found that the Lund system was significantly more noise immune than standard, whereas the differences in noise immunity between Mason-Likar and Lund system were not significant. They also concluded that QRS axis differences were small between standard and Lund ECGs, but large between standard and Mason-Likar ECG, and that QRS scores in patients with inferior myocardial infarction differed significantly between standard and Mason-Likar, but not between standard and Lund system. Krucoff et al[10] investigated the effect of lead placement on ST-segment measurements during transient coronary occlusion using a monitoring-compatible lead placement similar to Mason-Likar. They concluded that, in most patients, peak ST-segment elevation was slightly less with the modified lead positions compared with standard ECG, but that the differences were small. The more marked the ST elevation, the greater the difference measured between the different ECGs.

The aim of the present study is to further validate the Lund system by comparing ST and T waveform measurements between Lund, Mason-Likar, and standard ECGs.

Methods

Study population

Data were collected from 100 patients admitted to the Clinical Physiology or Cardiology Unit, Skåne University Hospital, Malmö, Sweden, during December 2009 to March 2010 and 67 patients admitted to the Clinical Physiology or Cardiology Unit, Skåne University Hospital, Lund, Sweden, during December 2008 to March 2009. Of these 67 patients, 6 had normal standard ECG according to computer interpretation. For the Lund patients, patients were enrolled consecutively, regardless of ECG diagnosis. Some patients from the Lund cohort were also included especially for their ECG diagnosis, such as prior myocardial infarction, left bundle-branch block (LBBB), and right bundle-block (RBBB). For the Malmö patients, patients were enrolled consecutively; and only patients with a computer-based interpretation other than "normal ECG" on standard ECG were included. This was done to ascertain a more differentiated patient population. Informed consent to participate in the study was given by each patient. The Ethics Committee at Lund University made an advisory statement in which it considered the study to be valuable and that there were no objections against it from an ethics point of view.

ECG acquisition

The ECG recordings were made with a MAC 5500 recording device (GE Healthcare, Waukesha, WI) or with a Megacart recorder (Siemens-Elema AB, Solna, Sweden). For each patient, 4 ECGs were recorded within a few minutes of each other: 2 standard 12-lead ECGs, 1 Lund ECG, and 1 Mason-Likar ECG. The order of the recordings of the different lead systems was not randomized. The 2 standard ECGs were recorded immediately after one another, and no electrodes were moved between these 2 recordings. For the standard ECGs, distal placement of limb electrodes was used. For the Lund 12-lead ECGs, the limb electrodes were placed proximally on the limbs (arm electrodes were placed laterally at the level of axillary fold, and the left leg electrode was placed at the

Table 1
T wave and STJ measurements (mean ± SD) for all 4 ECGs

	1st standard	2nd standard	Lund	Mason-Likar
T wave axis	63 ± 76	63 ± 73	63 ± 74	50 ± 83
QRS-T angle	−64 ± 94	−62 ± 89	−62 ± 90	−17 ± 103
T amplitude V_2	351 ± 396	355 ± 390	352 ± 398	341 ± 366
T amplitude V_5	104 ± 273	100 ± 267	101 ± 270	104 ± 277
T amplitude I	72 ± 188	71 ± 196	75 ± 177	84 ± 157
T amplitude aVF	83 ± 157	74 ± 143	86 ± 147	103 ± 223
STJ V_2	52 ± 107	52 ± 104	56 ± 103	50 ± 95
STJ V_5	−16 ± 63	−19 ± 60	−16 ± 60	−17 ± 64
STJ I	−8 ± 43	−9 ± 40	−6 ± 43	−1 ± 35
STJ aVF	0 ± 38	−2 ± 36	−2 ± 37	−11 ± 54

Values are shown in microvolts.