12-Lead ECG Monitoring with EASI™ Lead System

IntelliVue Patient Monitor and Information Center, Application Note

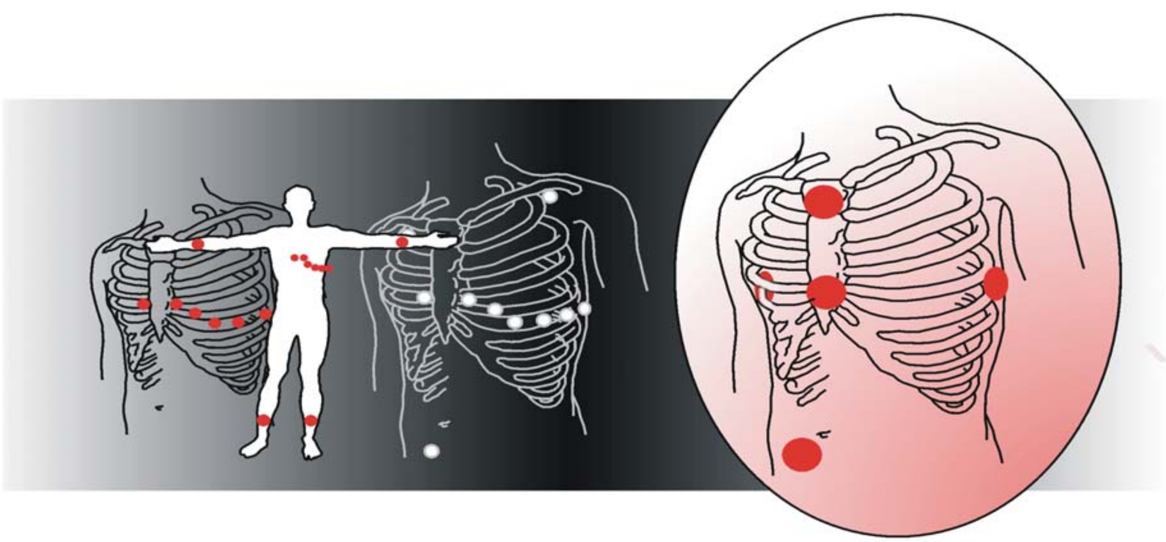
This paper:

- Describes the goals, requirements, and challenges of ECG monitoring.
- Reviews the standard 5-electrode placement for monitoring and summarizes its benefits and limitations.
- Reviews modified 12-lead ECG and the conventional 12-lead ECG and summarizes their benefits and limitations.
- Describes how the EASI™system achieves the goals of ECG monitoring while addressing the challenges.

Introduction

The conventional 12-Lead ECG, employing 10 electrodes, is the current standard for diagnostic electrocardiography. It uses four electrodes on the limbs (LA, RA, LL, RL) and six on the chest (V1-V6). Unfortunately, it is impractical for monitoring electrocardiography because movements of the extremities produce artifact. The Mason-Likar solution is simply to relocate the limb electrodes to the trunk (see Fig.1), without employing any mathematical correction. However, limb lead tracings are affected, particularly for the inferior leads (see Fig. 9) Additionally, to reduce the number of electrodes to five and the number of signal channels to four, only one chest electrode is employed. Although widely used, the Mason-Likar monitoring technique is limited, only providing one precordial lead.

The EASI™ system, invented by Dower, requires only five, optimally placed, electrodes (including ground), and only three signal channels but it gives a 12-lead ECG that is mathematically derived to resemble the conventionally recorded 12-lead ECG.[18] While it is excellent for monitoring, the physician interpreting the 12-lead derived with the EASI™ system should bear in mind that, despite its similarity, it may show significant differences from the *conventional 12-lead* taken at the same time. EASI™ derived 12-lead ECG's and their measurements are approximations to conventional 12-lead ECG's, and should not be used for diagnostic interpretations. Although the derived 12-lead EASI is not identical to the conventional 12-Lead ECG, there are many advantages to acquiring 12-leads continuously with only five electrodes.



PHILIPS

Goals of ECG Monitoring

The major goals of ECG monitoring are as follows:

- To detect and document cardiac arrhythmias.
- To detect and document ST changes, including ST changes related to coronary artery reocclusion in the post-PTCA patient.
- To detect and document QRS and T wave changes.
- To evaluate the effectiveness of therapy.

In order to meet the goals of ECG monitoring stated above, many recent clinical studies have demonstrated the benefits of continuous 12-lead ECG monitoring.[1-12] Some of the reasons are as follows: Comprehensive arrhythmia diagnosis often requires 12-lead ECG information.

- Ischemia detection and management requires monitoring of precordial leads.
- Post-PTCA reocclusion is difficult to differentiate from ischemia unless 12-lead monitoring is performed.
- Transient events of diagnostic/therapeutic importance may not persist long enough to allow using the electrocardiograph to record them.

Of course, with only one chest electrode, the Mason-Likar monitoring technique does not provide 12-Lead ECG monitoring.

An independent patient monitoring survey[13] was conducted during the 1998 American Association of Critical Care Nurses' Advanced Practice Institute Conference. The participants were 400 nurses and clinical specialists who work in the hospital environment. More than half of the participants work in some type of ICU, including cardiac, step-down telemetry, and intermediate care units.

69% of the respondents indicated that none of the beds in their hospital units have continuous 12-lead ECG monitoring capability at the bedside. Of the remaining respondents, 4% always use this capability, 24% frequently use it, 43% occasionally used it, and 30% never used it. Those who are using continuous 12-lead ECG monitoring indicated their primary reasons were for assessment of cardiac condition, changes in condition and abnormal or irregular rhythms. Their reasons for infrequent use included lack of training and requirement.

66% of the participants responded that there were barriers to continuous 12-lead ECG monitoring. They indicated that the number of electrodes and lack of training were the primary barriers. Other barriers included patient complaints and absence of need.

68% of the respondents used some level of ST segment monitoring. Their main reasons included assessment and monitoring of cardiac condition, changes in condition, and ischemia monitoring and detection. More than half use two leads for ST segment monitoring because that is the available capability. However, those participants that used 12 leads cited the accuracy and completeness of the 12-lead data.

In summary, the patient monitoring study confirmed the reasons for continuous ECG monitoring. In addition, the participants of the study indicated that they were aware of the benefits of continuous 12-lead ECG, and that the main barriers to its use were the number of electrodes, lack of training, and patient complaints.

When the Mason-Likar technique is adapted to 12-lead ECG monitoring, the number of electrodes increases to 10, and the number of signal channels increases to eight. Patient comfort is reduced and interference with clinical procedures – such as X-ray, emergency resuscitation, auscultation, and echocardiography – is increased. But not with EASI™

.

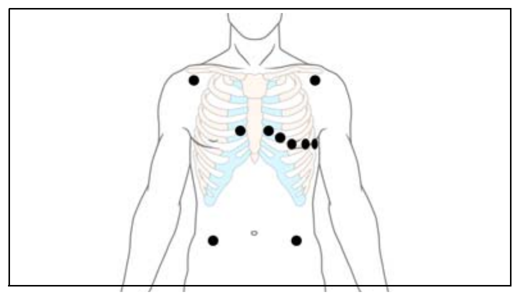


Figure 1 Mason-Likar Placement using 10 electrodes

Goals of EASI™ Electrode Placement

Electrodes are placed to give:

- high reproducibility (because landmarks for electrode placement are easily identified)
- high signal to noise ratios (for low movement artifact)
- high sensitivity to electrical events in lateral, anteroposterior and vertical directions
- patient comfort, and
- technical convenience

Satisfying these goals, the EASI electrode positions are:

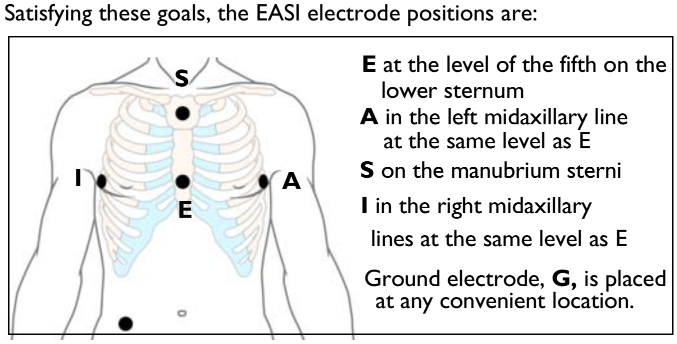


Figure 2 EASI Lead Placement

Lead Configurations

This section describes the different lead systems along with the feasibility of using these methods for continuous monitoring.

Monitoring with Mason-Likar Placement using 5-Electrodes

Description

This is a 5-electrode configuration (four monitoring electrodes and a ground electrode) commonly used in the monitoring environment today. The chest electrode can be placed in any of the standard precordial positions.

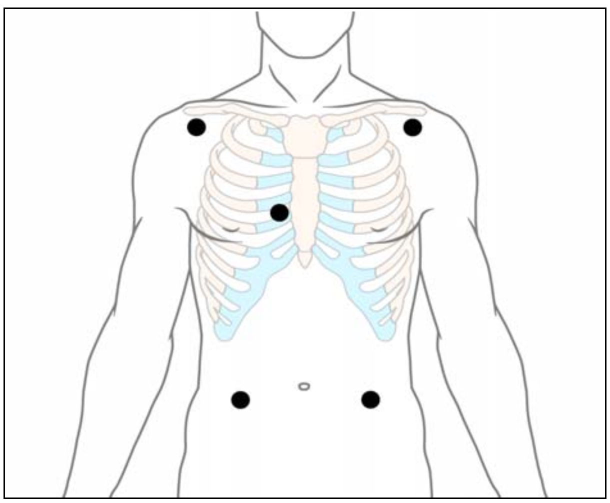


Figure 3 Mason-Likar Placement using 5 electrodes

Applicability for Continuous Monitoring

In the standard 5-electrode configuration there are only three independent ECG channels (any two limb leads plus the chest lead). These three channels are used to derive up to seven ECG leads (all three limb leads, three augmented leads, and one precordial lead).

While lead V_1 has been shown to be a valuable lead for arrhythmia monitoring, other researchers have shown that the mid-precordial leads (V_2 - V_5) are more sensitive for the detection of ischemia.[1-3] Therefore, this 5-electrode configuration precludes the monitoring of both an ideal arrhythmia lead and a better lead for ischemia detection.

In summary, for Mason-Likar 5-electrode placement monitoring:

- Number of electrodes: five
- Patient comfort: small number of electrodes increases patient comfort.
- Processing and storage: up to seven ECG leads can be derived from three independent channels for full disclosure. 12-lead ECG information is not available.
- Interference with clinical procedures: In comparison with the conventional 12-Lead, the smaller number of chest electrodes reduces interference.
- Artifact: electrodes are located near arms and legs so there is still a moderate amount of artifact due to patient movement.

Conventional 12-Lead ECG

Description

In a conventional 12-lead ECG, electrodes are placed on the right arm, left arm, and left leg to obtain leads I, II, III, aVR, aVL, and aVF. In addition, six electrodes are placed on the chest and a ground reference is placed on the right leg, although it could be anywhere.

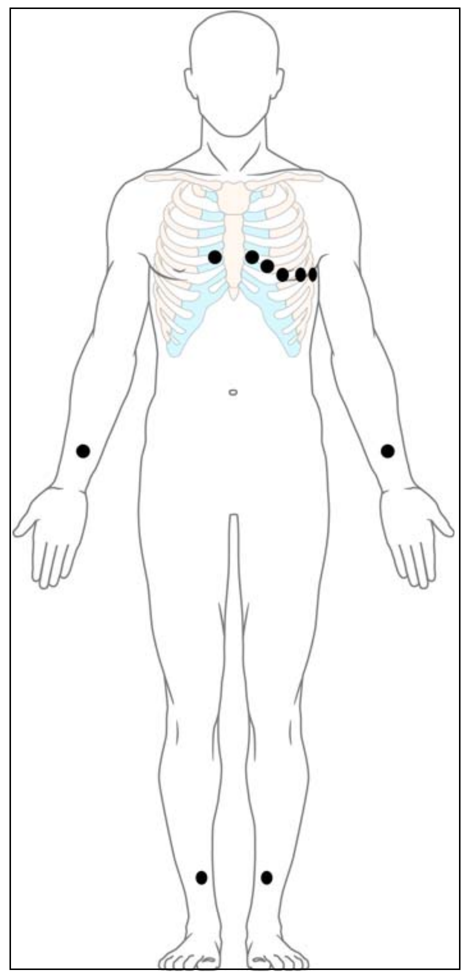


Figure 4 Conventional electrocardiograph 10-electrode placement

The bipolar leads (I, II, and III) record the electrical potentials in the frontal plane. These leads represent a difference of electrical potential between two selected sites. The augmented unipolar extremity leads, augmented vector of right arm (aVR), left arm (aVL), and left leg (aVF), are considered unipolar because they record the electrical potential at that one extremity with reference to the other two remaining extremities. The unipolar precordial (V) leads record all of the electrical events of the cardiac cycle in the horizontal plane as viewed from the selected lead site.

Frontal Plane

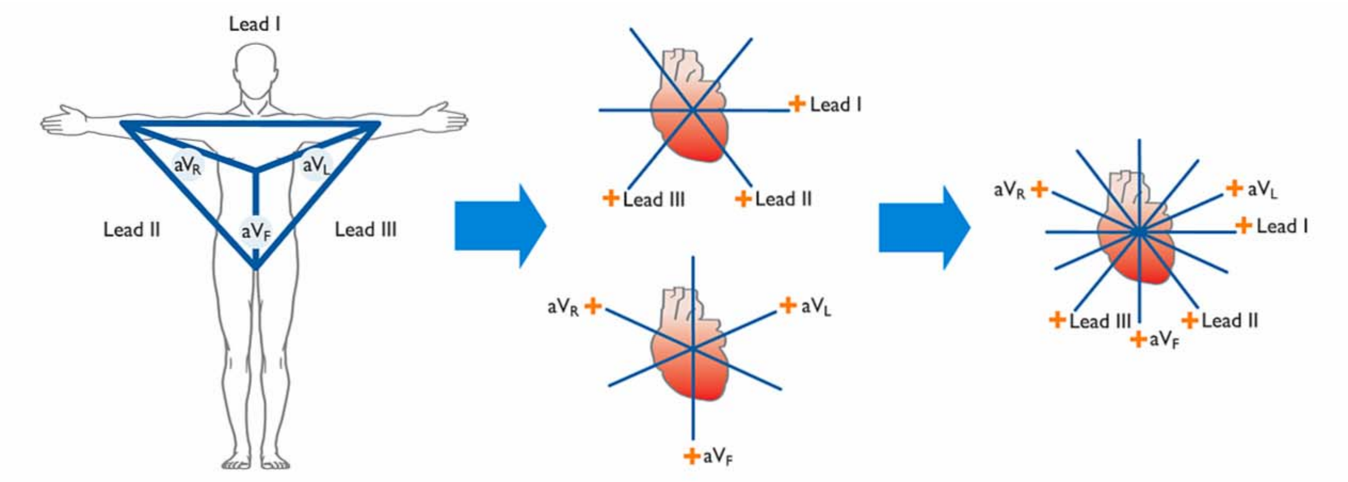


Figure 5 Limb Leads and Augmented Leads

Horizontal Plane

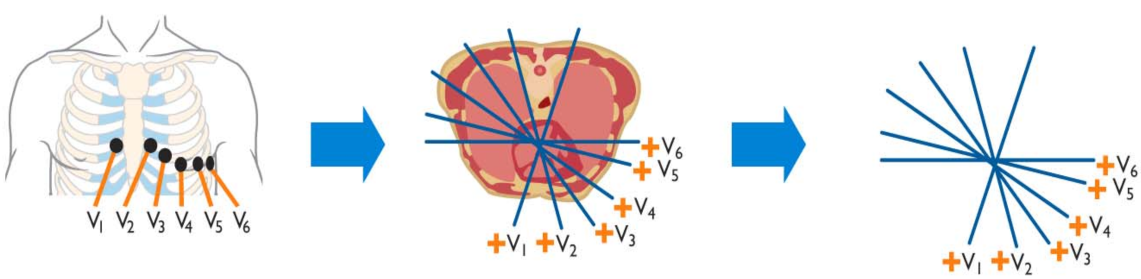


Figure 6 Chest Leads

The following table describes how the specific leads are obtained.

Table 1: Conventional 12-Lead Acquisition

Lead	Type	Calculation
I	limb	LA-RA
II	limb	LL-RA
III	limb	LL-LA
aVR	augmented	RA-(LA+LL)/2
aVL	augmented	LA-(RA+LL)/2
aVF	augmented	LL-(RA+LA)/2
V_1	precordial	V_1-(RA+LA+LL)/3
V_2	precordial	V_2-(RA+LA+LL)/3
V_3	precordial	V_3-(RA+LA+LL)/3
V_4	precordial	V_4-(RA+LA+LL)/3
V_5	precordial	V_5-(RA+LA+LL)/3
V_6	precordial	V_6-(RA+LA+LL)/3

The table illustrates that in the conventional 12-lead ECG, 12 leads are derived from nine electrodes (six chest leads and three limb leads (RA, LA, and LL) and a ground electrode. The three limb electrodes are used in every calculation of the limb, augmented, and precordial leads. In addition, in order to obtain a specific precordial lead, an electrode must be placed in the exact appropriate location.

Also note that the six frontal plane limb leads are not independent. In fact, there are only two independent signal channels from three limb electrodes.

Applicability for Continuous Monitoring

Although the conventional 12-lead ECG is routinely used for diagnostic purposes, it is not practical for continuous monitoring. The following list summarizes potential drawbacks of continuously monitoring using conventional 12-lead ECG electrode placement:

- Number of electrodes: Ten; the large number of electrodes increases the cost of supplies and increases the time required for application and maintenance.
- Patient comfort: The ten electrodes and ten lead wires are inconvenient and uncomfortable for the patient.
  This is especially true of the limb electrodes. They are tolerated for resting 12-Lead ECGs but are impractical for continuous monitoring.
- Processing and storage: Processing and 12-lead ECG full disclosure require eight independent ECG channels (six precordial leads plus two limb leads).
- Interference with clinical procedures: The placement of the electrodes, especially the chest electrodes, impedes other procedures such as portable chest x-rays, emergency resuscitation, chest auscultation, and echocardiography.
- Artifact: Limb electrodes are highly susceptible to movement artifact.

Modified 12-Lead ECG

Description

The following electrode configuration (Mason-Likar) is often used for continuous 12-lead ECG monitoring. In this modified 12-Lead ECG placement, the three limb electrodes and the ground electrode are placed close to the shoulders and lower abdomen. Thus the limb electrodes are placed in the same locations as used for Mason-Likar continuous monitoring.

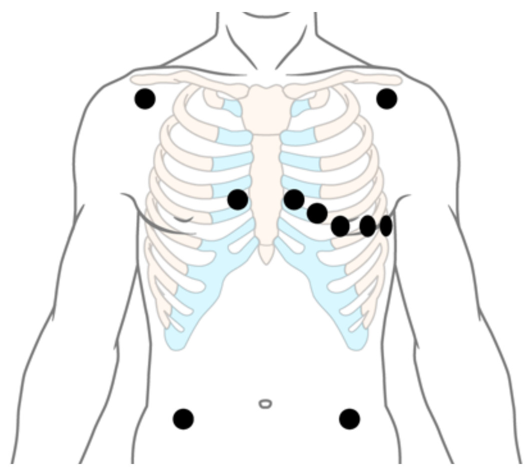


Figure 7 Mason-Likar Placement using 10 electrodes

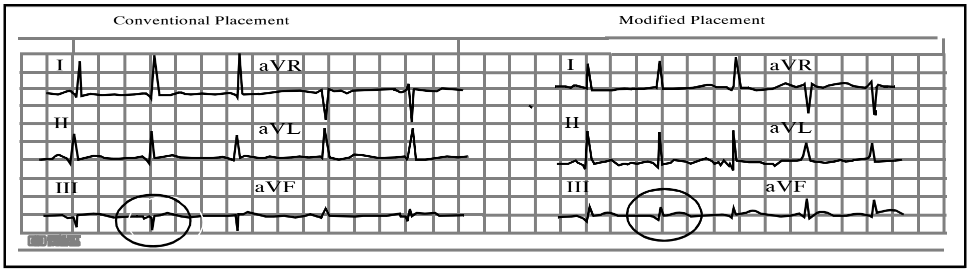
Applicability for Continuous Monitoring

The 12-lead ECG modified for continuous monitoring is less susceptible to movement artifact than conventional 12-lead ECG electrode placement (because the limb electrodes are moved to the torso), although movement artifact may still be encountered. All of the problems associated with continuous monitoring described for the conventional 12-lead ECG also apply to the modified 12-lead ECG.

For quality and accurate 12-lead measurements, precise accuracy of the electrode placement on the trunk is required.[14] Even when precise placement is achieved, there may still be differences. Some studies have shown that the modified 12-lead electrode placement causes amplitude changes and axis shifts when compared to conventional placement.[15] Thus there is the issue of accuracy which could affect serial comparisons.

Note lead III in the following example, recorded on an actual patient using an electrocardiograph. The QRS complex in the conventional 12-lead ECG, where the electrodes were placed on the limbs, differs from the modified 12-lead ECG, where the electrodes were placed on the torso.

.



Comparison of Conventional 10-electrode and Modified 10-electrode placement

In summary, for modified 12-lead ECG monitoring:

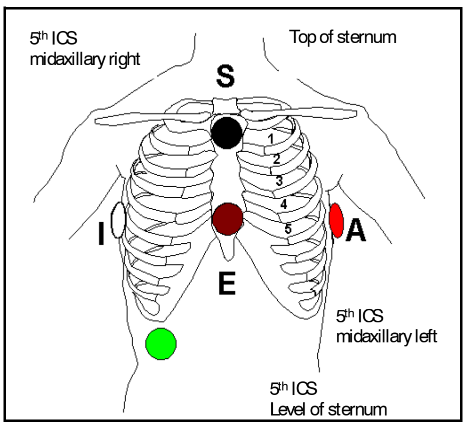
- Number of electrodes: Ten (nine monitoring and a ground electrode).
- Patient comfort: The modified limb electrode placement is more comfortable for the patient than the conventional limb electrode placement but the ten electrodes and lead wires are still cumbersome.
- Processing and storage: Processing and 12-lead ECG full disclosure require eight independent ECG channels (six precordial leads plus two limb leads).
- Interference with clinical procedures: The placement of the electrodes, especially the large number of chest electrodes impedes other procedures such as portable chest x-rays, emergency resuscitation, chest auscultation, and echocardiography.
- Artifact: Moderate risk of movement artifact due to large number of electrodes, some located on the parts of the torso that have a large amount of movement.

EASI™ Method

Description

The EASI™ system, a method of deriving 12 ECG leads using a five-electrode configuration (4 monitoring electrodes and a ground electrode), has been developed to better address the goals and challenges of continuous ECG monitoring. EASI™ monitoring makes it possible to obtain 12-lead ECG information under continuous monitoring conditions across the continuum of care. The science behind the EASI™ 12-lead system and its embedded algorithm is based on the work of Dr. Gordon Dower.

The EASI™ method of obtaining a 12-lead ECG requires only five electrodes.



EASI™ 5-Electrode Placement

How the EASI™ 12-Lead ECG is derived

Dower showed that a good simulation of a 12-lead ECG could be derived from the XYZ signals of the Frank vectorcardiographic lead system.[17] This meant that only three channels were required to store the 12-lead ECG, instead of eight. However, Frank's electrode positions were unsuitable for ambulatory monitoring. For EASI™ lead system, Dower chose three of them (A, E, and I) and added an electrode (S).

Derivation of the time-varying voltage, ν, in a ECG lead is a solution of the following equation:

$$\nu = \mathbf{a}\nu_{ES} + \mathbf{b}\nu_{AS} + \mathbf{c}\nu_{AI}$$

where the subscripted ν's are the time-varying voltages of the three electrode pairs ES, AS, and AI; and **a, b, c** are fixed coefficients appropriate to the lead being this derived.[18] The coefficients define a three-dimensional lead vector. There is lead vector for each ECG lead. The concept of the heart vector originated with Einthoven but the mathematical basis of the lead vector concept was laid by Burger and van Milaan.[16] Lead vectors are unique for each patient. However, extensive research has determined an optimal set of lead vector coefficients for deriving the EASI™ 12–lead ECG for the typical adult patient. Initially, coefficients were based on empirically adjusted interpolation of Frank's experimental data. In order to increase the accuracy of the derivation, an additional electrode was used in the V_4 position. Several clinical studies showed very good results. Subsequently, data from a large number of subjects were computer-optimized to give a new set that did not use Franks data or the V_4 electrode. Recent studies have shown this new set to yield excellent results.[19]

Applicability for Continuous Monitoring

To assure reproducibility, accurate lead placement, is important for accurate diagnosis. QRS morphology in the precordial leads, which are close to the heart, can be greatly altered if an electrode is moved just one intercostal space away from its correct location. However, clear anatomical landmarks make accurate lead placement of the EASI™ electrodes an easily obtainable goal. Not being on the limbs or over large muscles, the electrodes pick up minimal artifact. The small number of electrodes is much less cumbersome than the usual ten. Precordial electrodes over pendulous female breasts are avoided. Hirsute male chests require less preparation.[20] Multiple electrodes and lead wires may interfere with taking portable chest x-rays, echocardiography, cardiac auscultation, and initiating emergency resuscitation. With the EASI™ lead configuration, the left precordial is always free. These considerations favor EASI™ 12-Lead ECG monitoring to record transient events of diagnostic or therapeutic importance that do not persist long enough to allow documentation using an ECG cart. Transient events can thus be documented with a complete 12-lead ECG.

Other Considerations

Electrocardiographers are trained to identify patterns. When a precordial lead is in an incorrect position, the clinician typically becomes aware of a change. With EASI accurate lead placement is more easily obtained because of the obvious anatomical landmarks. Comparisons of serial ECG data benefits from improved reproducibility.[21]However, a potential problem exists when serial ECG data generated by conventional 12-Lead ECG monitoring are compared with EASI derived 12-Lead ECG monitoring. Measurements are approximations to those of conventional 12-Lead ECG used for diagnostic interpretations. The derived 12-Lead ECG is not identical to the conventional 12-Lead ECG but there are many advantages to acquiring such a 12-Lead tracing continuously at the bedside with only five electrodes.

These considerations remove reasons for comparison with other lead systems

The table below illustrates that EASI™ is an optimal lead system due to these characteristics:

- Fewer required electrodes.
- Increased patient comfort.
- Low storage requirements.
- Simultaneous display of all twelve leads.
- Low interference with clinical procedures.
- Reduced movement artifact.

Table 2: Comparison of 12-Lead Systems

12-Lead ECG	Conventional	Modified	Frank Method	EASI™
Number of Electrodes	10	10	8	5
Patient Comfort	Low	Low	Low	High
Number of data channels	8	8	3	3
Interference with Clinical Procedures	High	High	Low	Low
Artifact	High	Moderate	Moderate	Low

Summary of Clinical Advantages of EASI™ 12-Lead ECG

Using the same number of electrodes, EASI™ provides the following advantages over standard placement with a 5-electrode leadset.

- Documents ST changes with a full 12-lead ECG.
- Documents arrhythmia changes with a full 12-Lead ECG

EASI™ provides the following advantages over conventional and modified 12-lead ECG:

- Easy to locate, convenient, and stable electrode positions, enhancing reproducibility.
- Time and cost savings.
- Increased patient comfort and mobility.
- Fewer information channels result in increased monitoring system storage capacity. While conventional and modified 12-lead ECG require eight channels stored for 12-lead full disclosure, EASI™ requires only three channels.

Clinical Validation of EASI™

The validation of the EASI™System usefulness both in arrhythmia monitoring and ST Segment analysis has been studied extensively. A reference list of published articles related to arrhythmia and ST segment analysis using the EASI™ system is provided in Appendix A.

All clinical results in the reference list were based on the Zymed Inc. or Totemite Inc. implementation of the EASI™System.

Summary

This paper has reviewed the various ECG 12-Lead systems and their applicability in the continuous monitoring environment. A comparison of these systems has shown that the EASI™ system which derived a 12-Lead ECG using only 5 electrodes (4 monitoring electrodes and a ground electrode) is the optimal system. In addition, the research has demonstrated the validity of the EASI™ system to accomplish the goals of continuous 12-Lead ECG monitoring.

Appendix A

EASI™ 12-Lead Article Reference List

General

Wung, She-Fen RN, MS; Caldwell, Mary A. RN, MS Cardiac Rhythm Monitoring Advances: Barbara Drew, RN, Ph.D. From: Dunbar SB, Ellenbogen KA, Epstein AE, (eds). "Sudden Cardiac Death: Past, Present, and Future. Armonk, NY: Futura Publishing Co. Inc. 1997; Ch 8.

Multilead ST-segment monitoring in patients with acute coronary syndromes: a consensus statement for healthcare professionals. ST- Segment Monitoring Practice Guideline International Working Group. [Review] [92 refs]: Drew BJ, Krucoff MW, American Journal of Critical Care. 8(6):372-86; quiz 387-8, 1999 Nov.

Arrhythmia Analysis

Comparison of a Vectorcardiographically Derived 12-Lead Electrocardiogram with the Conventional Electrocardiogram During Wide QRS Complex Tachycardia, and Its Potential Application for Continuous Bedside Monitoring: Barbara Drew, RN, Ph.D., M. Scheinman, MD., G. Thomas Evans, Jr., MD. Am J Cardiol 1992;69:612-61.

The Importance Of Derived 12-Lead Electrocardiography In The Interpretation Of Arrhythmias Detected By Holter Recording: Pablo Denes. Am Heart J 1992;124:905-911.

Morphologic Characteristics Of Nonsustained Ventricular Tachycardia Detected During Holter Monitoring Associated With Atherosclerotic Coronary Artery Disease: Pablo Denes. Am J Cardiol 1993;71:57-62.

ST Analysis

Derived 12-Lead ECG - Comparison With The Standard ECG During Myocardial Ischemia And Its Potential Application For Continuous ST-Segment Monitoring: Barbara J. Drew, RN, Ph.D., Randall R. Koops, RN, MS, Mary G. Adams, RN, MS, and Gordon E. Dower, MD. Journal of Electrocardiology; Vol 27 Supplement; 1992; 249-255.

ST Monitoring with a Derived 12-Lead Electrocardiogram Is Superior To Routine Cardiac Care Unit Monitoring: Barbara Drew, RN, Ph.D., Mary G. Adams, RN, MS., Michele M. Pelter, RN, MS., She-fen Wung, RN, MS., American Journal of Critical Care; May 1996, Volume 5, No. 3.

Comparison of Standard and Derived 12-Lead Electrocardiograms for Diagnosis of Coronary Angioplasty-Induced Myocardial Ischemia: Barbara Drew, RN, Ph.D., Mary G. Adams, RN, MS., Michele M. Pelter, RN, MS., Shu-fen Wung, RN, MS., Mary A Caldwell, RN, MS. Am J Cardiol 1997;79:639-644.

12-Lead ST-Segment Monitoring vs Single-Lead Maximum ST-Segment Monitoring For Detecting Ongoing Ischemia in Patients With Unstable Coronary Syndromes: Barbara J. Drew, RN, Ph.D., Michele M. Pelter, RN, MS, Mary G. Adams, RN, MS, Shu-Fen Wung, RN, MS, Tony M. Chau, MD, and Christopher L. Wolfe, MD. American Journal of Critical Care; September 1998, Volume 7, No. 5; 355-363.

Accuracy of the EASI 12-Lead electrocardiogram compared to the standard 12-Lead electrocardiogram for diagnosing multiple cardiac abnormalities: Drew BJ, Pelter MM, Wung SF, Adams MG, Taylor C, Evan GT Jr., Foster E. Journal of Electrocardiology. 32 Suppl:38-47, 1999.

Comparison of the Standard ECG with the EASIcardiogram for Ischemia Detection During Exercise Monitoring: C.L. Feldman, G. MacCallum, L.H. Hartley. Computers in Cardiology 1997; Vol.24.

Comparison of Direct and Vectorcardiographically Derived (EASI) Electrocardiograms Recorded During Exercise: Charles L. Feldman, Gail MacCallum, Dirk Q. Field, L. Howard Hartley. (Abstract) Electrocardiology '96 (Proceedings of the XXIII International Congress of Electrocardiology)

References

1. Krucoff MW. Identification of high-risk patients with silent myocardial ischemia after percutaneous transluminal coronary angioplasty by multilead monitoring. *Am J Cardiol* 1988;61:29F-34F.

2. Bush HS, Ferguson JJ, Angelini P, Willerson JT. Twelve-lead electrocardiographic evaluation of ischemia during percutaneous transluminal coronary angioplasty and its correlation with acute reocclusion. *Am Heart J* 1991;121:1591-1599.

3. Mizutani M, Freedman SB, Barns E, Ogasawara S, Bailey EP, Bernstein L. ST monitoring for myocardial ischemia during and after coronary angioplasty. *Am J Cardiol* 1990;66:389-393.

4. Krucoff MW, Parente AR, Bottner K, Renzi RH, Stark KS, Shugoll RA, Ahmaed SW, DeMichele J, Stroming SL, Green CE, Rackley CE, Kent KM. Stability of multilead ST segment "fingerprints" over time after percutaneous transluminal coronary angioplasty and its usefulness detecting reocclusion. *Am J Cardiol* 1988:61:1232-1237.

5. Krucoff MW, Jackson YR, Kehoe MK, Kent KM. Quantitative and qualitative ST segment monitoring during and after percutaneous transluminal coronary angioplasty. *Circulation* 1990;81:suppllV20-26.

6. Wellens HJJ, Bar FW, Lie KI. The value of the electrocardiogram in the differential diagnosis of a tachycardia with a widened QRS complex. *Am J Med* 1978;64:27-33.

7. Kindwall KE, Brown J, Josephson ME. Electrocardiographic criteria for ventricular tachycardia in wide complex left bundle branch block morphology tachycardias. *Am J Cardiol* 1988;61:1279-1283.

8. Wellens HJJ, Bar FW, Vanagt EJ, Brugada P, Farre J. The differentiation between ventricular tachycardia and supraventricular tachycardia with aberrant conduction: The value of the 12-lead electrocardiogram. In: Wellens HJJ, Kulbertus HE, eds. *What's New in Electrocardiography*. Martinus Nijhoff, The Hague 1981;184-199.

9. Sandler JA, Marriott HJJ. The differential morphology of anomalous ventricular complexes of RBBB-type in lead V_1: Ventricular ectopy versus aberration. *Circulation* 1965;31:551-556.

10. Swanick EJ, LaCamera F, Marriott HJJ. Morphologic features of right ventricular premature beats. *Am J Cardiol* 1972;30:888-891.

11. Drew BJ, Scheinmann MM. Value of electrocardiographic leads MCL1, MCL6, and other selected leads in the diagnosis of wide QRS complex tachycardia. *J Am Coll Cardiol* 1991;18:1025-1033.

12. Brugada P, Brugada J, Mont L, Smeets J, Andries EW. A new approach to the differential diagnosis of a regular tachycardia with a wide QRS complex. *Circulation* 1991;83:1649-1659.

13. Patient monitoring study. *1998 Advanced Practice Institute Conference*, American Association of Critical Care Nurses, 1998.

14. Dubin D. *Rapid Interpretation of EKGs*, *5th Edition*. Cover Publishing, Tampa, FL 1996;53.

15. Meyers J, Froelicher VF. Exercise testing: procedures and implementation. *Cardiol Clinics* 1993;11(2):199-213.

16. Burger HC, van Milaan JB: Heart vector and leads, Part III. Geometric representation. *British Heart J* 10:229 1948.

17. Editorial The ECGD: a derivation of the ECG from VCG leads. *J Eclectrocardiol* 1984: 17; 189-192.

18. Dower GE. *EASI 12-Lead Electrocardiography*. Totemite Inc., Point Roberts, WA 1996;A1-A2.

19. Dower GE. Yakush A, Nazzal SB: Deriving the 12-lead electrocardiogram from four EASI electrodes. *J Electrocardiol supplement 1988: S182-187*.

20. Drew BJ. Cardiac Rhythm Monitoring Advances. In: Dunbar SB, Ellenbogen KA, Epstein AE, eds. *Sudden Cardiac Death: Past, Present, and Future*,

21. Cremons J. A critical review of derived 12-lead electrocardiography. *J Cardiovascular Mgmt* May/June 1996.

Philips Medical Systems is part of
Royal Philips Electronics

Interested?
Would you like to know more about our imaginative products? Please do not hesitate to contact us. We would be glad to hear from you.

On the web
www.medical.philips.com

Via e-mail
medical@philips.com

By fax
+31 40 27 64 887

By mail
Philips Medical Systems
Global Information Center
P.O Box 1286
5602 BG Eindhoven
The Netherlands

By phone
Asia
Tel: +852 2821 5888

Europe, Middle East, Africa
Tel: +49 7031 463 2254

Latin America
Tel: +55 11 2125 0764

North America
Tel: +1 800 229 6417

Printed in The Netherlands.
4522 981 84471 Apr2007