Evaluation of Arrhythmias Beyond ECG


INTRODUCTION

Most arrhythmias are diagnosed by doing the standard 12 lead ECG after the patient arrives at a medical facility due to his ongoing symptoms. However, in cases where the arrhythmia is transient patients may not be able to reach the medical facility during the symptomatic period. In these situations we need to look beyond a resting 12 lead ECG.

If arrhythmic events are sufficiently frequent then a 24 hour Holter is most useful. If the events are episodic and not frequent, a transtelephonic event recorder is better suited for recording the rhythm. Some symptoms are so fleeting that they do not permit patients to apply electrodes in sufficient time to capture the arrhythmia. In those instances, the continuous loop transtelephonic recorder is indicated. In patients whose symptoms include syncpe the use of implantable loop event recorders is indicated.

HOLTER MONITORING

Holter Recorders and Analytical Systems

In 1957, Norman J. Holter introduced a radiotelemetry system for recording the ECG signal during ambulatory activity. His cumbersome equipment was soon replaced by an analog, tape-based recorder and a complicated analysis system. Subsequent technical advances have miniaturized the recorder and vastly improved the analytical system.

The most widely used noninvasive test to evaluate arrhythmias in patients with a variety of cardiac disease states is Ambulatory (Holter) electrocardiography. Holter permits patient ambulatory activity and facilitates the diurnal electrocardiographic examination of a patient in a changing environment.

Ambulatory ECG recorders may be of two types. The ones that use magnetic tape recording and those that use electronic storage system. The analytical system is the same in both the types. The conventional 3 channel Holter recorder is a small, battery operated, electromagnetic tape-recorder that records 3 channels of electrocardiographic data on cassette or micro-cassette magnetic tape. More recent developments of digital technology have led to the ambulatory ECG disk recorder with 200 MB of storage.

Arrhythmia Monitoring

Current, most frequent indications for the use of Holter Monitoring to detect clinically meaningful cardiac arrhythmias include:

1. Evaluation of patients with unexplained syncpe, near syncpe or episodic dizziness in whom the cause is not obvious OR the patients with unexplained recurrent palpitations.
2. Evaluation of patients with known arrhythmias in order to improve the quantification of the frequency and/or the rate of the rhythm disorder.
3. For detection of cardiac arrhythmias and sudden death in high-risk patients without the symptoms from arrhythmias. These high risk patients include those with chronic heart failure, post MI patients, patients with idiopathic hypertrophic cardiomyopathy.
5. Surveillance of the function of implanted pacemakers

Supraventricular arrhythmias (SVT)

Specific cardiac conditions where Holter monitoring is useful in cases of SVTs:

1. Sinus node dysfunction: Holter monitoring remains the most reliable tool for diagnosing sinus node dysfunction.
2. Atrial Fibrillation/Flutter: Most common use of Holter in this setting is to diagnose transient atrial fibrillation. There is a unique application of Holter ECG in atrial fibrillation, that is particularly present in understanding the relationship to autonomic mediated atrial fibrillation. After the diagnosis has been made Holter is used to assess the efficacy of anti-arrhythmic drugs in suppression of atrial fibrillation. For patients who undergo Maze procedure or a catheter ablation to prevent atrial fibrillation, a Holter monitor becomes critical to assess the efficacy of the procedure.
3. In case of other supraventricular tachycardias such as Atrioventricular nodal re-entrant tachycardia, atrioventricular re-entry tachycardia 24 hour Holter monitoring is useful only if arrhythmias are frequent.

Ventricular arrhythmias

1. Ambulatory ECG monitoring after Myocardial infarction: Ambulatory ECG monitoring is now a well-accepted method to identify patient who are at higher risk of subsequent mortality among those who have recovered from an acute myocardial infarction. If the patients are symptomatic due to arrhythmias, then Holter Monitoring serves the purpose best. But asymptomatic individuals also benefit from the Holter.
2. Ambulatory ECG monitoring in Heart Failure is very helpful.
3. Ambulatory ECG monitoring in Hypertrophic Cardiomyopathy (HCM): The risk of sudden death is higher in children and adolescents with this condition than in adults. But the occurrence of transient VT on ambulatory monitoring is uncommon in this age group. In the adult with HCM, transient VT, often at a slow rate, can be found in about 25% of patients. The presence of
1. Evaluation of paroxysmal symptoms in patients with pacemakers
2. Detection of myocardial inhibitions
3. Detection of pacemaker-medicated tachycardia
4. Evaluation of antitachycardia pacing device functioning
5. Evaluation of rate-responsive physiologic pacing function

**Heart Rate Variability (HRV)**

The fluctuation in RR interval associated with respiration is called as Respiratory Sinus Arrhythmia and clinicians have generally accepted its presence as a sign of good health. Clinical relevance of RR interval variability has further been strengthened since the time it was reported that the degree of RR variability served as a significant, independent predictor of mortality after myocardial infarction. Excellent refinement. Abnormal values of HRV have been noted in patients with dilated cardiomyopathy and Chagas disease. Diabetic and elderly individuals are more likely to have blunted HRV. HRV obtained is also a powerful and non-invasive tool for cardiovascular and physiological research and for clinical diagnosis and treatment.

**Heart Rate Turbulence (HRT)**

Initial acceleration and subsequent deceleration of sinus rhythm following a ventricular ectopic beat with a compensatory pause has been termed as heart rate turbulence (HRT). The changes in sinus rhythm are thought to be mediated by baroreflex response to the lower stroke volume of the ectopic beat. HRT has been shown to be an independent and powerful predictor of mortality after myocardial infarction.

Two common measures of HRT are turbulence onset (TO) and turbulence slope (TS) and when both these measures are abnormal, it is as powerful predictor of mortality as LVEF. HRT improves those attaining successful reperfusion. Abnormal values of HRT have been noted in patients with atrial fibrillation. Diabetic and elderly individuals are more likely to have blunted HRT. HRT cannot be measured in patients lacking ventricular ectopic beats and in patients with atrial fibrillation.

**High Resolution Electrocardiography**

Routine techniques of ECG recording can not detect several low-level ECG potentials whose manifestations on the body surface are too small. These include the potentials produced by the His-Purkinje (H-P) system and by slow, non-homogenous conduction in depressed ventricular myocardium which are usually called as Late Potentials. These potentials are small because activation front is slow and fractionated or the mass of tissue undergoing depolarization, is small, or both. However, measurement of bioelectric potentials produced by these tissues is important for diagnostic purposes.

Signal Averaging is the method that improves signal-to-noise ratio when the signals are recurrent and the noise is random. In conjunction with appropriate filtering and other methods of noise reduction, signal averaging can detect muscle potentials that are typically 5 to 25 microvolts, to less than 1 microvolt.

With this method, identification of the H-P potentials can localize the site of atrioventricular conduction disorders, and detection of late potentials may identify patients at high risk for malignant ventricular arrhythmias.

Two different techniques have been adopted to improve the signal to noise ratio (SNR). 

1. Ensemble or temporal averaging (usually referred to as signal averaging). This technique is applicable only to repetitive electrocardiographic signals and cannot detect moment by moment dynamic changes in the signals.
2. Spatial averaging. This technique can record the H-P signals and late potentials on a beat to beat basis. The averaged signal can be analyzed either in time domain, frequency domain, or a combination of both in the form of spectrotemporal maps.

**Time Domain Signal Averaged ECG (SAECG)**

Time domain analysis of the SAECG usually includes the determination of 3 typical parameters:

1. The filtered QRS duration (QRSd);
2. Root mean square voltage of the terminal 40 ms of the QRS (RMS 40);
3. The duration of the low amplitude signal, i.e. the time that filtered QRS complex remains below 40 µ volts (LAS 40).

Representative criteria that defined SAECG as normal or abnormal include following:**

1. The filtered QRS complex is greater than 114 to 120ms.
2. There is less than 20 µ volts of signal in the last 40 ms of the vector magnitude complex.
3. Terminal vector magnitude complex remains below 40 µ volts for more than 38 ms.

The most common clinical application of time domain SAECG are:

1. The risk stratification of post-infarction patients for vulnerability to malignant ventricular arrhythmias: The late potentials on SAECG have been found to be present in 70 to 90 percent of the patients with sustained and inducible VT after Myocardial infarction and in only 0 to 6 percent of normal volunteers. Thus an abnormal SAECG with late potentials will predict a poor outcome in the post MI patients.
2. The SAECG can be used for the evaluation of the results of thrombolytic therapy. The late potentials usually appear within 3 hours post myocardial infarction, increase in the first week and then persist for an year or more. Early use of thrombolytic agents may reduce the appearance and prevalence of late potentials after coronary occlusion.
3. The SAECG can also be used to study the efficacy of antiarrhythmic surgery. Successful surgical resection of the VT can eliminate late potentials.
4. In patients with arrhythmogenic right ventricular cardiomyopathy, SAECG can identify those with more extensive involvement, and those more likely to have inducible ventricular tachycardia. It also helps in risk stratification for serious arrhythmic events in patients with hypertrophic cardiomyopathy, idiopathic dilated cardiomyopathy.
5. Signal averaging of P-wave has also been used to detect patients susceptible to paroxysmal atrial fibrillation (AF). SAECG is found to be superior to the standard ECG for detecting atrial conduction delay, and the prolonged conduction times of SAECG are associated with AF.

**Frequency Domain Signal-Averaged ECG**

Current techniques for time-domain late potential analysis have several limitations. As mentioned earlier, there is a lack of agreement at present to the optimal filter characteristics, as well as to the best numerical criteria of abnormality. Because late potentials are high frequency signals, Fourier transform can be applied to extract high frequency content from signal average ECG, called frequency domain analysis. A novel frequency-domain analysis technique, which may overcome some of the disadvantages of both time domain late potential analysis and old methods of frequency analysis, is called spectral turbulence analysis.

**Combined time- and frequency-domain analysis of SAECG**

One limitation of time domain late potentials analysis of the SAECG is that partial obscuring of late potentials may occur if the abnormal myocardial region is activated relatively early during the QRS complex. This occurs more often with anterior wall myocardial infarction (AWMI) than inferior wall (IW) MI and may partially explain the higher incidence of false positive abnormal recordings in patients with IWMI. On the other hand there is a higher incidence of abnormal spectral turbulence in AWMI patients. Combined time domain / spectrotemporal analysis was found to significantly improve the positive predictive accuracy of the test.

In conclusion we can say: With improved therapeutic modalities, risk stratification has become an important task. Recognizing the patients at risk before the arrhythmic event is necessary. Noninvasive methods are desirable for such purposes. SAECG is one such technique that has a definite independent role in improving the predictive accuracy of conventional risk-evaluation techniques. Hence the signal averaged (SA) technique has gained more popularity in the last few years.

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**EXERCISE TESTING**

Exercise testing (ET) is useful in patients who have symptoms associated with exercise. It can uncover arrhythmia and help selecting the therapy and its response. The ACC / AHA guidelines recommend ET testing in patients with known or suspected exercise induced arrhythmia. (Class II).

Normally monomorphic VPC or couplets or three to six beats of nonsustained VT can occur. Premature supraventricular beats are also common.*

Exercise testing is useful in pts with adrenergic dependent arrhythmia (Monomorphic Ventricular tachycardia and Polymorphic Ventricular tachycardia related to Long QT syndrome) where Holter and EP may not be helpful. In 10 to 15 % of pts with an episode of sustained VT spontaneous occurring arrhythmia can be seen only during ET testing.*

**Exercise testing and various arrhythmias:**

Preexcitation Syndrome: In 20 to 50 percent of cases the delta wave can disappear during an exercise testing. If there is an abrupt disappearance of the delta wave it suggests a longer antegrade effective refractory period of the accessory pathway. It is more frequent with left side pathway than the right side. When tacharyrhythmia, rarely, appear during ET testing in WPW syndrome it helps to study the AV conduction velocity. Progressive disappearance of the delta wave is less assuring as it would not mean that a critical shortening of the antegrade refractory period of the accessory pathway would not occur during sympathetic stimulation.

Atrial Fibrillation: ET testing can be used to see the effect of rate controlling drugs on reducing the rapid rise of heart rate in early phase of exercise in patients with chronic atrial fibrillation.

AV block: ET testing is useful in some patients to distinguish between AN nodal and infranodal level of AV block. In patient with
congenital AV block who develop symptomatic junctional rhythm during exercise, DDD devices can be use.

Ventricular Arrhythmia: ET testing provokes repetitive VPC in patients with history of sustained ventricular tachycardia. If the PVCs occur frequently in the early exercise period it suggests a worse long term prognosis.

**EVENT RECORDER**

*Non-loop:* It’s a hand held device with no chest electrodes which can be worn continuously or applied to the chest only at the time of recording. It has to be activated by the patient and then it records and stores data.

Those applied to the chest are credit card size and are applied by the patient on the chest once symptoms occur and are activated.

The data can be sent transtelephonically to a central station.

Event recorder → ECG data → Audio signal → via telephone line to Central station that converts audio signal → ECG reading

*Limitation:* Inability to capture the ECG prior to the symptoms.

**Loop event recorder**

It has to be worn continuously and can save data both before and after the symptom. It records the ECG continuously and discards the oldest one. When an event is triggered it freezes the presymptom ECG and the post symptom ECG. It is useful for people who lose consciousness when the arrhythmia occurs.

These are of two types:

1. **External Loop recorder**
   
The device is about a size of a pager is attached to a belt and it has two electrodes which are attached to the chest wall. It has to be activated by the patient and the data can be sent transtelephonically. This can be used for about 30 days.

   Event recorder is useful for infrequent events as Holter will fail to document an arrhythmia in these situations, to evaluate syncope and when initiating or seeing the recurrence of the arrhythmia on discontinuation of the antiarrhythmic drug. It is of less value if symptoms are at a frequency of less than a month.\(^8\)

   *Disadvantage:* Patient discomfort as patch electrode have to be applied on a daily basis.

2. **Implantable Loop Recorder:** (ILR)
   
The device is smaller than a pack of chewing gum and works like a black box in an airplane. It is implanted subcutaneously in the precordial region under local anesthesia, and records single lead ECG. It has a shelf life of at least 14 months. It is activated by a hand held activator by the patient (after the episode if a syncope occurs) or a relative when the symptoms occur. It then stores the ECG before and after the episode. But the data cannot be sent transtelephonically.

   It is useful in infrequent problems associated with incapacitating symptoms such as syncope. It is generally used when an arrhythmia is suspected and External loop recorder does not yield a diagnosis within a month.

   *Disadvantage:* It is costlier, requires a surgical procedure and there is chance of infection.

**Advantage of Event recorder over Holter**

Can be used for longer periods and has high degree of specificity as it is activated by the patient.

Event recorders can automatically trigger when certain arrhythmia occurs and hence need not be activated by the patient.

In a randomized trial the device was found to be cost effective and improved diagnostic yield compared to Head up tilt and Electrophysiological testing.\(^38\)

ILR is useful in finding arrhythmia as a cause of syncope, near syncope and palpitations as well as an acute life threatening event when conventional testing such as ECG, Holter and external loop recorder is inconclusive.\(^26\) Loop recorders have a higher diagnostic yield for patient with syncope than Holter monitoring and HUTT (head up Tilt testing).\(^58\)

**INVASIVE ELECTROPHYSIOLOGICAL STUDIES (EPS)**

The ACC / AHA guidelines for use of EPS for various arrhythmias.

AV block: When the site of block cannot be determined from the analysis of an ECG
IVCD: Symptomatic patient in whom the cause of the symptoms is not known.

Sinus node dysfunction: EPS can be considered in patient in whom sinus node dysfunction is suspected but a cause not found after extensive evaluation.

Tachycardia: EPS can be used to diagnose the arrhythmia, determine and deliver therapy, determine the anatomical sites involved in tachycardia, identify patients at high risk for developing serious arrhythmia and gain insights into the mechanisms responsible for arrhythmia.

Unexplained Syncope: The guideline recommends a low threshold for the use of EP procedure for pts with unexplained syncope if they also have a structural heart disease. Head up tilt testing is more useful in patients without heart disease.

Unexplained palpitations: The procedure of choice is ambulatory ECG. EP testing is suggested in patients with palpitations preceding the syncope and in whom the ECG fails to document a cause but the pulse rate was high when seen by a medical attendant.

REFERENCES


