What is ECG

WHAT IS AN ECG

Electrocardiogram, or ECG or EKG, registers heart's electrical activity. Cardiac (heart) muscles are electrically stimulated to contract in the human body.

The heart – cardiac muscles – are electrically charged at rest. The electrical activity of a single cell changing polarization from positive to negative can be measured.

This electrical activity causes contracting and extraction and it can be registered. The ECG is a graphical representation of these electrical cardiac signals. An ECG captures this electrical activity through electrodes attached on the skin.

The heart consists of approximately 300 billion cells, and thus each creates its electrical activity. The ECG is actually an average of these billions of electrical signals.

When the heart muscle depolarizes, the direction and magnitude of this can be measured. This measurement changes every millisecond of the depolarization. The ECG recognizes and records this electrical activity within the heart. The information is visible on the monitor, but especially in diagnostic ECG, the information is also printed on ECG paper. The ECG paper is made up of small squares 1mm squared. A standard ECG is printed at 25mm per second which equals to 25 small squares per second. When ECG paper has a grid, it is normally a Class IIa medical device since it is possible to use the paper to calculate the duration of individual waves.

WHERE IS AN ECG PERFORMED

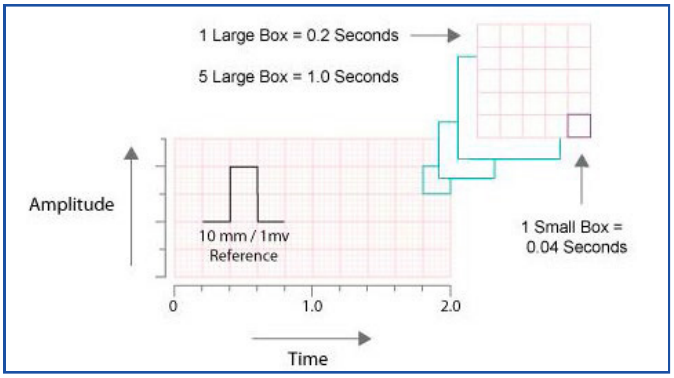
ECGs can be performed at hospitals and in doctors' offices. The traditional areas where ECGs were routinely performed were the Coronary Care Unit (CCU), Intensive Care Unit (ICU), and Operating Theaters/ Operating Rooms (OR). There are also specialty units like Cardiac Intensive Care Unit (CICU).

Other areas where there are monitors include Emergency Rooms. Here not every bed necessarily has a monitor, but in general monitors are available. Some wards may also have monitors. Ambulances also perform ECGs.

A standard doctor's office may have an ECG machine, or they may send a patient to a specialist. With software based ECGs, ECGs tests are becoming more widely available.

A special type of ECG is holter/telemetry. In this, patient wears the ECG during a standard day – anywhere from hours to multiple days. The patient may go home wearing the device.

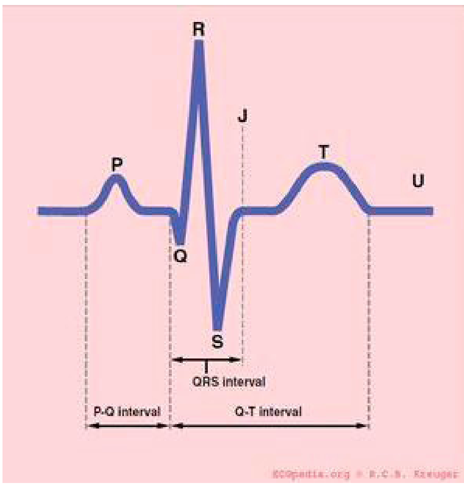
A stress test ECG includes using a machine – for example an exercise bike or treadmill. These tests are in general performed at the hospital or in special facilities set up for this purpose.

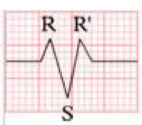


MEASURING ECG

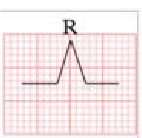
With ECG, this depolarization activity is measured as follows:

- The P wave is the result of the atrial depolarization
- The QRS complex is the average of depolarization waves of the inner (endocardial) and outer (epicardial cardiomyocytes. The inner (endocardial) depolarize slightly earlier than the outer layers, and thus the QRS pattern occurs that is seen on ECGs.
- Q wave is the first negative deflection after the p-wave.

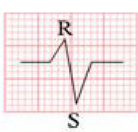




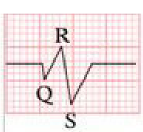
If the first deflection is not negative, then the Q is absent.



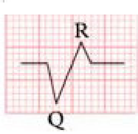
R is the positive deflection



S is the negative deflection after the R wave



Small print letters (q,r,s) rather than capital letters (Q, R, S) are used to show small amplitude deflections



R is used to describe a second

ADDITIONAL INFORMATION SOURCES:

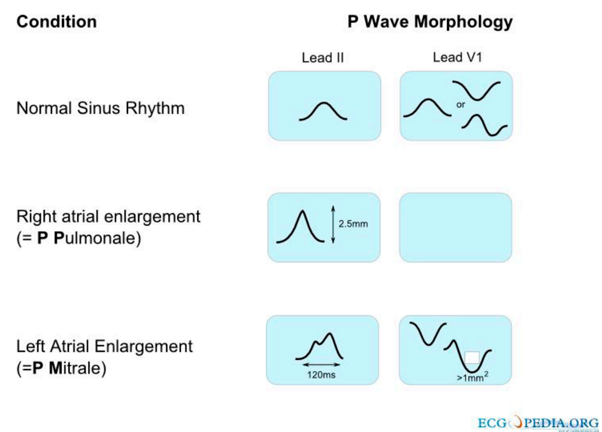
1 *To see how this works, you can visit:* *http://library.med.utah.edu/kw/pharm/hyper_heart1.html* *and watch the animation of the heart cycle and the associated ECG.*
2 *Cardiology basic teaching for those who know nothing about cardiology:* *http://www.nottingham.ac.uk/nursing/practice/resources/cardiology/index.php*
3 *Examples of different ECG cases:* *http://en.ecgpedia.org/wiki/Cases_and_Examples*
4 *Animation of the heart and associated ECG:* *http://library.med.utah.edu/kw/pharm/hyper_heart1.html*

READING AN ECG

Arrhythmias or non-normal heart rhythms are detected with an ECG. It is important for a doctor to verify that it is the patients ECG and that there are not artifacts which would affect the ECG.

The doctor looks at:

VENTRICULAR HEART RATE



- 60-100 bpm = normal (bpm = beats per minute)
- > 100 bpm = tachycardia
- < 60 pbm = brachycardia
- Existence of ectopic beats (extra beats)

P-WAVE (CHERCHEZ LE P)

- Result of the atrial depolarization
- Making sure it is visible
- In general detected from Leads II and C1/V1
- Rate of P-waves
- Morphology ("Shape") of P-waves
- **If enlarged, the atria are enlarged

RELATIONSHIP OF P WAVES AND QRS COMPLEXES

- 1:1 relation – each P wave followed by one QRS complex
  ** If not, likely causes Ventricular arrhythmia or AV block
- Interval and does it change

QRS COMPLEX

The average of the depolarization of waves of the inner (endocardial) and outer (epicardial) cardiomyocytes

QRS width / duration

- (Measures how fast the ventricles depolarize)

Normal <0.10 seconds

- ** If longer than 110 milliseconds, possible causes include:
    - Left bundle branch block
    - Right bundle branch block
    - Electrolyte disorders
    - Idioventricular rhythm and paced rhythm(means “relating to or affecting the cardiac ventricle alone“ and refers to any ectopic ventricular arrhythmia. Ectopic beats are small changes in a heartbeat that is otherwise normal – leading to extra or skipped heartbeats.

HEARTH AXIS AND IF IT CHANGED

CLINICAL SETTING

I.e. young or old patient – this can affect ECG and which diagnosis is more likely

PQ INTERVAL

- Normal between 0.12 and 0.20 seconds
- Prolonged PQ is a sign of a degradation of the conduction system or increased vagal tone, or pharma cologically induced.
- ** Called 1st, 2nd or 3rd degree AV block
- Short PQ interval: faster than normal conduction

QT INTERVAL (OR QTC INTERVAL MEANING CORRECTED QT INTERVAL)

- Tells how fast the ventricles are repolarized, be coming ready for a new cycle
- Normal values:
- ** <450ms for men
- ** <460 ms for women
- ** Discussions exist whether should be 470 and 480 respectively
- QTc >500ms is considered highly abnormal
- Lead II used, or lead C5/V5 alternatively if lead II cannot be read

Prolongation can occur as a result of:

- **Medication
- **Electrolyte imbalances
- **Ischemia
- Prolongation often treated with beta blockers

CHARACTERISTICS OF A NORMAL ECG

Rhythm: sinus
Rate: 60-100 bpm
Conduction:

- PQ interval 120-200ms
- QRS width 60-100ms
- QTc interval 390-450ms (use the QTc calculator for this)
- Heart axis: between -30 and + 90 degrees

P wave morphology:

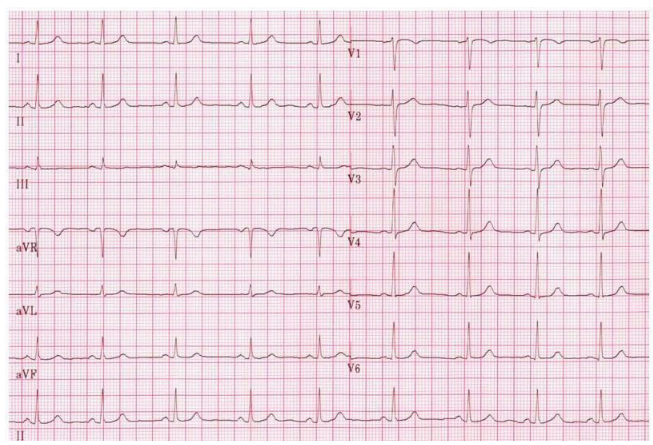
- The maximal height of the P wave is 2.5 mm in leads II and / or III
- The p wave is positive in II and AVF, and biphasic in V1
- The p wave duration is usually shorter than 0.12 seconds

QRS morphology:

- No pathological Q waves
- No left or right ventricular hypertrophy
- No microvoltage
- Normal R wave propagation.
  (R waves increase in amplitude from V1-V5)

ST morphology

- No ST elevation or depression
- T waves should be concordant with the QRS complex
- The ECG should not have changed from the previous ECG

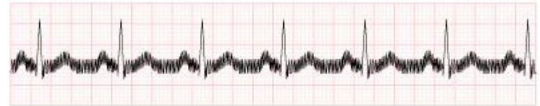


ADDITIONAL INFORMATION SOURCES:

1 *Examples of different cases:* http://en.ecgpedia.org/wiki/Cases_and_Examples and Guess the Culprit
2 http://en.ecgpedia.org/wiki/Guess_the_Culprit

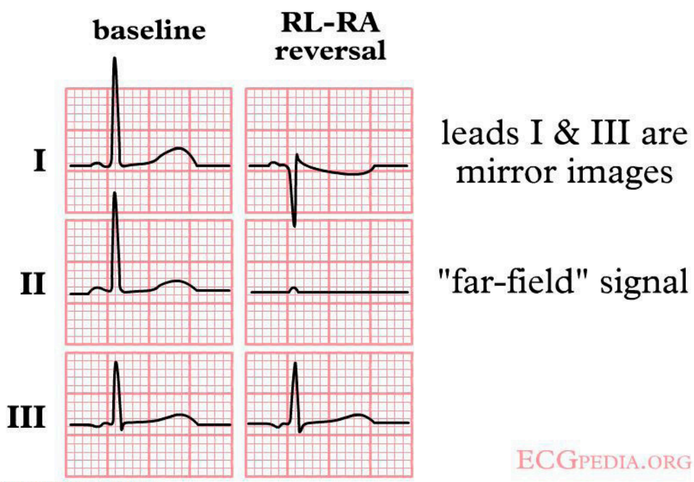
ABNORMALITIES: ARTIFIACTS

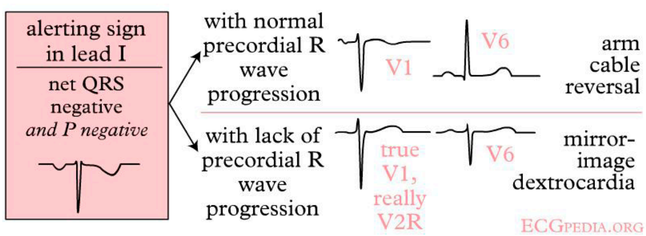
Artifact in a signal is anything on an ECG which is not caused by abnormalities in the heart – i.e. the electrical currents generated by the heart.



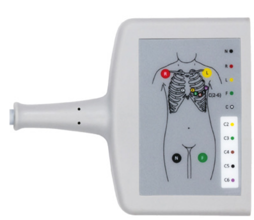
LEAD REVERSAL

One of the most common errors is switching the place of left and right arm leads. This can be recognized by having a negative P wave in lead one.





Another one is switching arm and foot leads. This causes a very small signal ("far-field") in leads II or III. Chest lead reversal can often be easily recognized. This is visible in inappropriate R wave progression. The progression is the increase then decrease followed by an increase. If there is any right axis or small signal in an extremity lead, lead placement should be checked. The AirLife® ECG cables show how leads should be placed helping avoid these errors. All ECG leads are color-coded.

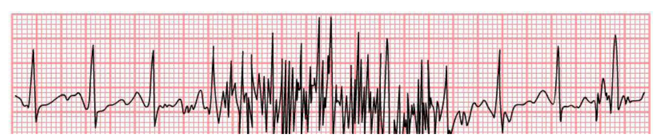


ARTIFACTS: ELECTRICAL INTERFERENCE

Electrical interference is also known as low frequency noise. This originates up to 60Hz current which supplies power to electrical wall outlets or from remote devices such as cell phones. Monitors have filters where these filters can be adjusted. Having these set incorrectly can affect signal quality. This is often seen as a base drift of the ECG. If this occurs, the customer can contact the monitor manufacturer to learn about their filter settings. All of the electrical interference may not be able to be filtered out without compromising the ECG signal. If the electrical interference is a new occurrence and no settings on the filters of the monitor have been changed, good questions to ask are:

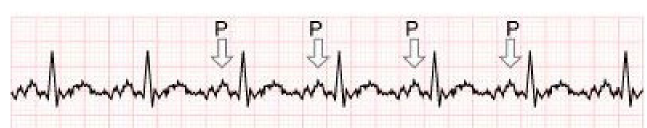
- Has the position of the monitors changed? By positioning the monitor away from other electrical equipment, this interference can be potentially reduced.
- How are the cables and leadwires positioned? It is beneficial to verify that cables and leadwires do not cross the power cables of other equipment or vent tubing to reduce electrical interference.
- Age and condition of leadwires and cables? If the cables and leadwires are ripped, old or the protective cover is broken, electrical interference can increase.
- Connection of cables to monitor, cables to leadwires, leadwires to electrodes, and electrodes to skin.
- Electrodes using good quality electrodes can help improve signal quality. Check expiration date on electrodes.

ARTIFACTS: MOVEMENT



Patient movement

Parkinson patient movement



Muscle tremor

AirLife®

Movement can affect ECG. For example, a shivering patient causes movement. Thus, it is beneficial to attempt to warm a shivering patient to reduce muscle tremor. For a resting ECG, the patient can also be more comfortable in a reclined position and this can reduce patient movement. For high-movement areas (telemetry, stress test), using the right types of electrodes with good skin contact supports good signal quality.

Electrode movement

Steps to reduce movement include comforting the patient, using good quality electrodes, drugs to control symptoms, warming the patient, using different placement of the electrodes and adjusting leadwire location.

For example, if the electrodes have been in place for a prolonged period of time, the stickiness of the electrode may be reduced or the moist inner pad can dry up and the connection becomes poor. This can both cause movement of the electrode as well as signal quality reduction.

The weight of the leads can pull the electrode away from the skin or they may get stuck in an item of clothing. Then, the signal contact can be lost intermittently, especially when the patient moves. Placing the leadwires so that this movement is reduced can help. The single patient use leadwires are also lighter, so in difficult cases, switching to single patient use leadwires could help. Electrodes with stronger adhesive can also be used in these cases. helping keep the electrode in contact with the skin.

ECG LEAD LABELING AND COLORING

There are two standards for leads – IEC and AHA. AHA stands for American Heart Association. IEC stands for International Electrotechnical Commission. For example, United States and Australia utilize AHA while European countries, New Zealand, Japan and many countries in Asia and Africa use IEC.

	AHA		IEC	
LOCATION	INSCRIPTION	COLOR	INSCRIPTION	COLOR
Right Arm	RA	White	R	Red
Left Arm	LA	Black	L	Yellow
Right Leg	RL	Green	N	Black
Left Leg	LL	Red	F	Green
Chest	V1	Brown/Red	C1	White/Red
Chest	V2	Brown/Yellow	C2	White/Yellow
Chest	V3	Brown/Green	C3	White/Green
Chest	V4	Brown/Blue	C4	White/Brown
Chest	V5	Brown/Orange	C5	White/Black
Chest	V6	Brown/Purple	C6	White/Violet

ECG CONFIGURATIONS AND LEAD PLACEMENT

The positioning of leads for an ECG is universal. This helps to compare ECGs of a person over time to see if changes occur. These standards are universal throughout the world. The positioning of the leads may differ slightly.

For example, the extremity leads can be also placed on shoulders and lower abdemon rather than wrists and ankles. This helps avoid movement artifacts from limbs.

For some cases leads have to be moved due to procedure type or due to patient condition (e.g. hypothermia, muscle tremors, open wounds). 3- and 5-Lead configurations are most common in the Operating Room (Operating Theatre). These are quick to set up and provide basic monitoring function. In general, 3- and 5-leads are most common in ECG monitoring.

In diagnostic cardiology, 12-lead and 15-lead ECGs are used. Special cases during ECG monitoring use 6-lead and 12-lead ECG. For a 12-lead diagnostic ECG, 10 leads are placed which allow a 12-lead ECG. These include 6 chest leads (V1-V6 for AHA and C1-C6 for IEC) and 4 limb or peripheral leads. The fourth of these leads is neutral. Electrical activity going through the heart can be measured by external (skin)electrodes. The electrocardiogram (ECG) registers these activities from electrodes which have been attached onto different places on the body. In total, twelve leads are calculated using ten electrodes.

THE TEN ELECTRODES ARE

The four extremity electrodes:

LA - left arm (AHA) / **L** –left arm (IEC)
RA - right arm (AHA) / **R**- right arm (IEC)
RL – Right Leg (AHA) / **N** - neutral, on the right leg
(= electrical earth, or point zero, to which the electrical current is measured)
LL – Left Leg (AHA) / **F** - foot, on the left leg

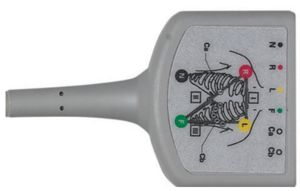
It makes no difference whether the electrodes are attached proximal or distal on the extremities. However, it is best to be uniform in this. (eg. do not attach an electrode on the left shoulder and one on the right wrist).

The six chest electrodes:

V1/C1 - placed in the 4th intercostal space, right of the sternum
V2/C2 - placed in the 4th intercostal space, left of the sternum
V3/C3 - placed between V2 and V4
V4/C4 - placed 5th intercostal space in the nipple line
V4 is normally placed under the breast in women.
V5/C5 - placed between V4 and V6
V6/C6 - placed in the midaxillary line on the same height as V4/C4 (horizontal line from V4/C4, so not necessarily in the 5th intercostal space)

The 10 leads (for a 12-lead ECG) are positioned as follows.

AHA



IEC

The poisoning of the chest leads (V leads / C leads) needs to be accurate for correct measurement. Here the diagrams on the ECG cables help in case proper placement is forgotten.
Here you can see how the positioning of ECG electrodes and leadwires is shown please visit: https://www.youtube.com/watch?v=HK1NHr0JcqQ

In this video, the electrodes used are for resting ECG.
The 3-lead ECG uses 3 electrodes. These are placed in the Right Arm (RL/R), Left Arm (LA, L) and Left Leg (LL, F). These basic leads yield enough information for rhythm-monitoring. For determination of ST elevation, these basic leads are inadequate as there is no lead that gives (ST) information about the anterior wall. ST changes registered during 3-lead ECG monitoring should prompt acquisition of a 12 lead ECG. The 5-lead (5-channel) ECG uses 4 extremity leads and one precordial (chest) lead. This improves ST segment accuracy, but is still inferior to a 12-lead ECG.

AHA

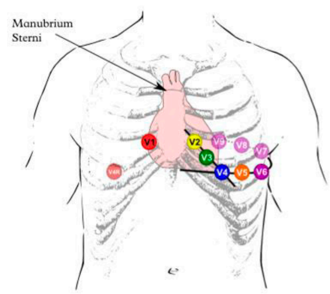
IEC

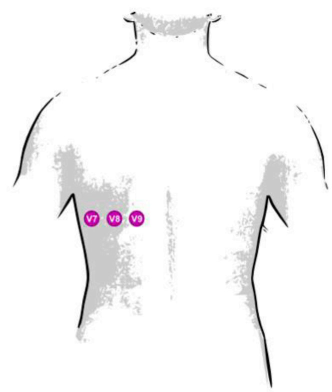
Some facilities are moving to standard 5-lead ECG since it provides more information on the ST segment than a 3-lead ECG. To better understand how information from ECG is acquired and which directions which lead gets information, please watch the following video or search for something similar: https://www.youtube.com/watch?v=JSxd0UTt5gQ

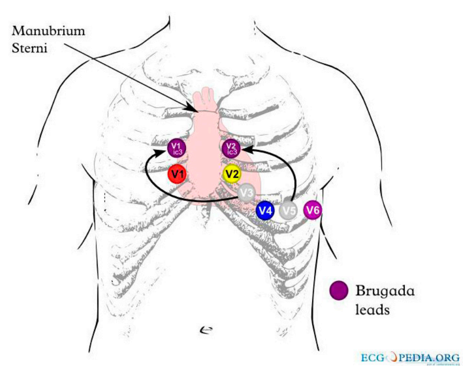
LEAD PLACEMENT VARIANTS

In some instances, a non-standard, special configuration for lead placement will be used. These are done to identify specific conditions. In addition, sometimes leads have to be placed in different location due to patient physiology or exam type. Thus, you may see different lead placements than what is displayed on the cables.

Some of these configurations are below.







IMPROVED ECG SIGNAL QUALITY

Improved signal quality can lead to quicker set-up in OR, less frustration, higher staff satisfaction (success factor), and better patient care. A number of factors contribute to signal quality:

- Patient skin preparation
- Electrode quality
- Use of quality electrodes
- Use of right electrodes for the right application
- Proper placement of electrodes
- Good electrode contact to the patient
- Quality leadwires and cables
- Removal of artifacts *(e.g. patient movement)*

PATIENT SKIN PREPARATION

Where time is of essence, often in OR, skin prep is not always conducted. Skin prep can include shaving of hair, cleaning of skin to remove skin oils and residue, microdermabrasion to remove dead skin cells. Appropriate skin prep can help with good signal quality.

ELECTRODES

Electrode quality and age can affect signal quality. The Vital Signs electrodes can be used with GE Monitors. AirLife® recommends using the SilverTrace and Mactrode electrodes with more demanding applications such as in cardiology.

For longer procedures or procedures where the patient moves a lot (e.g. stress test), stronger adhesives are often used. The larger size electrodes have a larger adhesive area and as long as they fit on patient can help keep the electrode in place. The foam electrodes are quick to place, but backing materials like clear tape or cloth can be better when patient may move or has sensitive skin or sweats profusely.

QUALITY OF LEADWIRES AND CABLES

The AirLife® cables and leadwires are validated for use with the GE monitors and Cardiology ECG equipment. It is important to use validated accessories. The ECG machine is tested as a system, including the cable and leadwires.

To comply with the Essential Requirements of Annex I of MD Directive 93/42/EEC with amendments, medical device design, manufacture, and usability testing are carried out in compliance to applicable standards. Usability standards, such as:

- EN 60601-1-6 Medical electrical equipment. General requirements for basic safety and essential Performance. Collateral standard. Usability.
- EN 62366 Medical devices - Application of usability engineering to medical devices.

Are used to create validation procedures and tests to show the safe function of accessories with host/main devices including GE CARESCAPE monitors. This validation helps to ensure that these products provide high level of quality, performance, and safety when used together as a system.

When host devices are used with non-validated accessories, the design and usability of which has not been optimized and tested with the main device, safety of the user and the patient may be compromised.

In addition, cables and leadwires can be visually inspected to verify age and condition. There should be no rips, and tears. They should be clean. Cables and leadwires sometimes are run over with carts or beds, pulled or cleaned improperly. This may be visually seen on the cable. In addition, some facilities use cables and leadwires that are very old (3-7 years old). This can cause them not to function properly. In general, it is recommended that cables and leadwires are replaced each year even though often they are used successfully much longer at a facility. Improper handling of the cables and leadwires can reduce this time.

If signal quality issues are present, have the customer switch to a new set of leadwires and cables. A great way to verify leadwire quality is to place a Single Patient Use (SPU) leadwire on the patient to see if signal quality improves. These are easy to carry with and provide also opportunities to discuss with the facility their cleaning processes, management of infectious patients and special cases like burn patients that are at higher risk of infections.

Hospitals can convert to single-patient-use leadwires to help prevent potential infection from reusable leadwires.

- The Division of Infectious Diseases at the University of Texas Medical Branch at Galveston linked a reusable ECG leadwire to the source of cross-contamination in a burn unit.[1]
- The University of Wisconsin Hospital and Clinics found antibiotic-resistant pathogens on 77 % of ECG leadwires.[2]
- In the study, potential for cross-infection with multi-use electrocardiogram lead wires, 100 % of 59 lead sets were contaminated. Forty-nine leads harbored bacillus, staphylococcus, corynebacterium, streptococcus viridans and/or micrococcus. Ten leads had acinetobacter, aspergillus, pseudomonas and/or mold.[3]

REMOVAL OF ARTIFACTS

Artifacts such as patient movement and electrical interference can affect signal quality. Please see section above on artifacts.

For patient movement there are some potential remedies such as:

- If patient is shivering, warming the patient
- Placement of electrodes and leads to locations that do not move
- Medication
- Good quality electrodes right for the application
- Placing leadwires and cables so that they do not pull

For electrical interference:

- Location of machine
- Location of other equipment
- Move power cables away from ECG cables and leadwires

LEAD PLACEMENT VARIANTS

In some instances, a non-standard, special configuration for lead placement will be used. These are done to identify specific condi-tions. In addition, sometimes leads have to be placed in different location due to patient physiology or exam type. Thus, you may see different lead placements than what is displayed on the cables.

ECG SIGNAL QUALITY / POTENTIAL FIX CHECKLIST

- Electrodes: proper storage of electrodes is important for gel and signal quality. In addition, if pouches have been open too long, electrodes dry out. Different type of electrode may be required for special cases (e.g. for diaphoretic patients).
- Electrode contact and location: verify the contact of electrodes is good on the skin. For example if oily skin, cleaning the skin prior to electrode application can help. Have the healthcare practitioner check that location of the electrodes on the body is correct.
- Patient: verify patient is not moving/shivering which could cause artifacts.
- Leadwires: verify that validated AirLife® leadwires are being used. The ECG cables and leadwires should be reasonably new. Verify the condition and age of VitalSigns leadwires. A good way to test this is to carry a SPU leadwire set with you. If good quality signal is received with the SPU set, then it is likely that switching to a new set of reusable leadwires or switching completely to SPU leadwires can help the customer. If leadwires are often run over by carts and beds, stepped on, or lost, it can beneficial to test out Single Patient Use Leadwires – especially if quick turnover of beds is required with insufficient time allocated for leadwire cleaning.
- Cables: verify that validated VitalSigns leadwires being used. Verify the condition and age of VitalSigns cables and leadwires . Have the customer try out a new cable. If the exact cable in use is not available, you can still verify the signal quality for example using a 12-lead cable to get a 5-lead signal (only ½ used).
- Electrical interference: no power cables over or underneath ECG cables/leadwires. Move other equipment away from ECG machine. Position of ECG machine away from other power sources.
- ECG machine: local GE rep can help run diagnostics on the ECG machine if the signal is not improved with the above steps. The quick check would be to change the machine to another one temporarily to see if issue is fixed.

ADDITIONAL INFORMATION SOURCES:

1. *Cardiology basic teaching for those who know nothing about cardiology:* http://www.nottingham.ac.uk/nursing/practice/resources/cardiology/index.php
2. *Examples of different ECG cases:* http://en.ecgpedia.org/wiki/Cases_and_Examples
3. *Animation of the hearth and associated ECG:* http://library.med.utah.edu/kw/pharm/hyper_heart1.html

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