Estimation of heart rate in ECG

Heart rate is the speed of the heartbeat measured by the number of contractions of the heart per minute (bpm). The heart rate can vary according to the body's physical needs, including the need to absorb oxygen and excrete carbon dioxide. It is usually equal or close to the pulse measured at any peripheral point. Activities that can provoke change include physical exercise, sleep, anxiety, stress, illness, and ingestion of drugs.

The normal resting adult human heart rate ranges from 60–100 bpm. Tachycardia is a fast heart rate, defined as above 100 bpm at rest.[2] Bradycardia is a slow heart rate, defined as below 60 bpm at rest. During sleep a slow heartbeat with rates around 40–50 bpm is common and is considered normal. When the heart is not beating in a regular pattern, this is referred to as an arrhythmia. Abnormalities of heart rate sometimes indicate disease.

The *maximum heart rate* (HR_{max}) is the highest heart rate an individual can achieve without severe problems through exercise stress,[11][12] and generally decreases with age. Since HR_{max} varies by individual, the most accurate way of measuring any single person's HR_{max} is via a cardiac stress test. In this test, a person is subjected to controlled physiologic stress (generally by treadmill) while being monitored by an ECG. The intensity of exercise is periodically increased until certain changes in heart function are detected on the ECG monitor, at which point the subject is directed to stop. Typical duration of the test ranges ten to twenty minutes.

Adults who are beginning a new exercise regimen are often advised to perform this test only in the presence of medical staff due to risks associated with high heart rates. For general purposes, a formula is often employed to estimate a person's maximum heart rate. However, these predictive formulas have been criticized as inaccurate because they generalized population-averages and usually focus on a person's age. It is well-established that there is a "poor relationship between maximal heart rate and age" and large standard deviations relative to predicted heart rates

The human heart beats more than 3.5 billion times in an average lifetime.

The heartbeat of a human embryo begins at approximately 21 days after conception, or five weeks after the last normal menstrual period (LMP), which is the date normally used to date pregnancy in the medical community. The electrical depolarizations that trigger cardiac myocytes to contract arise spontaneously within the myocyte itself. The heartbeat is initiated in the pacemaker regions and spreads to the rest of the heart through a conduction pathway. Pacemaker cells develop in the primitive atrium and the sinus venosus to form the sinoatrial node and the atrioventricular node respectively. Conductive cells develop the bundle of His and carry the depolarization into the lower heart.

The human heart begins beating at a rate near the mother’s, about 75-80 beats per minute (BPM). The embryonic heart rate then accelerates linearly for the first month of beating, peaking at 165-185 BPM during the early 7th week, (early 9th week after the LMP). This acceleration is approximately 3.3 BPM per day, or about 10 BPM every three days, an increase of 100 BPM in the first month.

After peaking at about 9.2 weeks after the LMP, it decelerates to about 150 BPM (+/-25 BPM) during the 15th week after the LMP. After the 15th week the deceleration slows reaching an average rate of about 145 (+/-25 BPM) BPM at term. The regression formula which describes this acceleration before the embryo reaches 25 mm in crown-rump length or 9.2 LMP weeks is:

$$\text{Age in days} = \text{EHR}(0.3) + 6$$

There is no difference in male and female heart rates before birth

The **QRS complex** is a name for the combination of three of the graphical deflections seen on a typical electrocardiogram (EKG or ECG). It is usually the central and most visually obvious part

of the tracing. It corresponds to the depolarization of the right and left ventricles of the human heart. In adults, it normally lasts 0.06–0.10 s; in children and during physical activity, it may be shorter. The Q, R, and S waves occur in rapid succession, do not all appear in all leads, and reflect a single event, and thus are usually considered together. A **Q wave** is any downward deflection after the **P wave**. An **R wave** follows as an upward deflection, and the **S wave** is any downward deflection after the R wave. The **T wave** follows the S wave, and in some cases an additional **U wave** follows the T wave.

Q wave

Normal Q waves, when present, represent depolarization of the interventricular septum. For this reason, they are referred to as septal Q waves and can be appreciated in the lateral leads I, aVL, V5 and V6.

Pathologic Q waves occur when the electrical signal passes through stunned or scarred heart muscle; as such, they are usually markers of previous myocardial infarctions, with subsequent fibrosis. A pathologic Q wave is defined as having a deflection amplitude of 25% or more of the subsequent R wave, or being > 0.04 s (40 ms) in width and > 2 mm in amplitude. However, diagnosis requires the presence of this pattern in more than one corresponding lead.

Myocardial infarctions with pathological Q waves are referred to as ST elevation MIs.

R wave progression

Looking at the precordial leads, the r wave usually progresses from showing a rS-type complex in V_1 with an increasing R and a decreasing S wave when moving towards the left side. There is usually an qR-type of complex in V_5 and V_6 with the R-wave amplitude usually taller in V_5 than in V_6. It is normal to have a narrow QS and rSr' patterns in V_1, and so is also the case for qRs and R patterns in V_5 and V_6. The *transition zone* is where the QRS complex changes from predominately negative to predominately positive (R/S ratio becoming >1), and this usually occurs at V_3 or V_4. It is normal to have the transition zone at V_2 (called "early transition"), and at V_5 (called "delayed transition"). In biomedical engineering, the maximum amplitude in the R wave is usually called "R peak amplitude", or just "R peak".[7][8] Accurate R peak detection is essential in signal processing equipment for heart rate measurement and it is the main feature used for arrhythmia detection.

The definition of *poor R wave progression* (PRWP) varies in the literature, but a common one is when the R wave is less than 2–4 mm in leads V_3 or V_4 and/or there is presence of a reversed R wave progression, which is defined as R in V_4 < R in V_3 or R in V_3 < R in V_2 or R in V_2 < R in V_1, or any combination of these.[6] *Poor R wave progression* is commonly attributed to anterior myocardial infarction, but it may also be caused by left bundle branch block, Wolff–Parkinson–White syndrome, right and left ventricular hypertrophy as well as by faulty ECG recording technique.

J-point

The point where the QRS complex meets the ST segment is the J-point. The J-point is easy to identify when the ST segment is horizontal and forms a sharp angle with the last part of the QRS complex. However, when the ST segment is sloped or the QRS complex is wide, the two features do not form a sharp angle and the location of the J-point is less clear. There is no consensus on the precise location of the J-point in these circumstances. Two possible definitions are:

Filtering in ultrasound

Ultrasounds are sound waves with frequencies higher than the upper audible limit of human hearing. Ultrasound is no different from 'normal' (audible) sound in its physical properties, except in that humans cannot hear it. This limit varies from person to person and is approximately 20 kilohertz (20,000 hertz) in healthy, young adults. Ultrasound devices operate with frequencies from 20 kHz up to several gigahertz.

Ultrasound is used in many different fields. Ultrasonic devices are used to detect objects and measure distances. Ultrasound imaging or sonography is often used in medicine. In the nondestructive testing of products and structures, ultrasound is used to detect invisible flaws. Industrially, ultrasound is used for cleaning, mixing, and to accelerate chemical processes. Animals such as bats and porpoises use ultrasound for locating prey and obstacles Scientist are also studying ultrasound using graphene diaphragms as a method of communication.

An ultrasonic level or sensing system requires no contact with the target. For many processes in the medical, pharmaceutical, military and general industries this is an advantage over inline sensors that may contaminate the liquids inside a vessel or tube or that may be clogged by the product.

Both continuous wave and pulsed systems are used. The principle behind a pulsed-ultrasonic technology is that the transmit signal consists of short bursts of ultrasonic energy. After each burst, the electronics looks for a return signal within a small window of time corresponding to the time it takes for the energy to pass through the vessel. Only a signal received during this window will qualify for additional signal processing.

A popular consumer application of ultrasonic ranging was the Polaroid SX-70 camera which included a light-weight transducer system to focus the camera automatically. Polaroid later licensed this ultrasound technology and it became the basis of a variety of ultrasonic products.

Principle of flaw detection with ultrasound. A void in the solid material reflects some energy back to the transducer, which is detected and displayed.

Ultrasonic testing is a type of nondestructive testing commonly used to find flaws in materials and to measure the thickness of objects. Frequencies of 2 to 10 MHz are common but for special purposes other frequencies are used. Inspection may be manual or automated and is an essential part of modern manufacturing processes. Most metals can be inspected as well as plastics and aerospace composites. Lower frequency ultrasound (50–500 kHz) can also be used to inspect less dense materials such as wood, concrete and cement.

Ultrasound inspection of welded joints has been an alternative to radiography for non-destructive testing since the 1960s. Ultrasonic inspection eliminates the use of ionizing radiation, with safety and cost benefits. Ultrasound can also provide additional information such as the depth of flaws in a welded joint. Ultrasonic inspection has progressed from manual methods to computerized systems that automate much of the process. An ultrasonic test of a joint can identify the existence of flaws, measure their size, and identify their location. Not all welded materials are equally amenable to ultrasonic inspection; some materials have a large grain size that produces a high level of background noise in measurements.

Non-destructive testing of a swing shaft showing spline cracking

Ultrasonic thickness measurement is one technique used to monitor quality of welds.

Analysis of EMG signal

Electromyography (**EMG**) is an electrodiagnostic medicine technique for evaluating and recording the electrical activity produced by skeletal muscles. EMG is performed using an instrument called an **electromyograph**, to produce a record called an **electromyogram**. An electromyograph detects the electrical potential generated by muscle cells when these cells are electrically or neurologically activated. The signals can be analyzed to detect medical abnormalities, activation level, or recruitment order, or to analyze the biomechanics of human or animal movement.

One basic function of EMG is to see how well a muscle can be activated. The most common way that can be determined is by performing a maximal voluntary contraction (MVC) of the muscle that is being tested.

Muscle force, which is measured mechanically, typically correlates highly with measures of EMG activation of muscle. Most commonly this is assessed with surface electrodes, but it should be recognized that these typically only record from muscle fibers in close approximation to the surface.

Several analytical methods for determining muscle activation are commonly used depending on the application. The use of mean EMG activation or the peak contraction value is a debated topic. Most studies commonly use the maximal voluntary contraction as a means of analyzing peak force and force generated by target muscles. According to the article, Peak and average rectified EMG measures: Which method of data reduction should be used for assessing core training exercises?, concluded that the "average rectified EMG data (ARV) is significantly less variable when measuring the muscle activity of the core musculature compared to the peak EMG variable." Therefore, these researchers would suggest that "ARV EMG data should be recorded alongside the peak EMG measure when assessing core exercises." Providing the reader with both sets of data would result in enhanced validity of the study and potentially eradicate the contradictions within the research.

EMG can also be used for indicating the amount of fatigue in a muscle. The following changes in the EMG signal can signify muscle fatigue: an increase in the mean absolute value of the signal, increase in the amplitude and duration of the muscle action potential and an overall shift to lower frequencies. Monitoring the changes of different frequency changes the most common way of using EMG to determine levels of fatigue. The lower conduction velocities enable the slower motor neurons to remain active.

A motor unit is defined as one motor neuron and all of the muscle fibers it innervates. When a motor unit fires, the impulse (called an action potential) is carried down the motor neuron to the muscle. The area where the nerve contacts the muscle is called the neuromuscular junction, or the motor end plate. After the action potential is transmitted across the neuromuscular junction, an action potential is elicited in all of the innervated muscle fibers of that particular motor unit. The sum of all this electrical activity is known as a motor unit action potential (MUAP). This electrophysiologic activity from multiple motor units is the signal typically evaluated during an EMG. The composition of the motor unit, the number of muscle fibres per motor unit, the metabolic type of muscle fibres and many other factors affect the shape of the motor unit potentials in the myogram.

Nerve conduction testing is also often done at the same time as an EMG to diagnose neurological diseases.

Some patients can find the procedure somewhat painful, whereas others experience only a small amount of discomfort when the needle is inserted. The muscle or muscles being tested may be slightly sore for a day or two after the procedure.