cardioBAN BLE

Datasheet

cardioBAN BLE
Designed & Made in Portugal

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For a getting started guide, visit the following article:
https://support.pluxbiosignals.com/knowledge-base/cardioban-ble-getting-started/

For support visit support.pluxbiosignals.com

CARDIOBAN BLE (2024)

General Information

Introducing cardioBAN BLE, your go-to wireless wearable for hassle-free ECG and motion data collection.

Designed with your comfort in mind, it's the solution for seamless research in any setting. Say goodbye to bulky, uncomfortable devices – cardioBAN is designed to ensure user comfort, even during dynamic activities. Plus, it's ready to use as a medical device OEM, and you can jumpstart your work with our developer tools.

Specifications

> On-Board Sensors:	1x Single-Lead ECG 1x Triaxial Accelerometer 1x Triaxial Gyroscope
> Sensor Ranges	ECG: ±2.5mV Accelerometer: ±8g Gyroscope: ±500dps
> Communication:	Bluetooth Low Energy (BLE) (v.5.3)
> Communication Range:	Up to 10m (in line of sight)
> Internal Memory:	Up to 10h
> Battery:	Rechargeable 155mA 3.7V LiPo
> Battery Lifetime:	Up to 10h in continuous streaming
> Charging Port:	Micro-USB compatible with an standard USB Charger
> Size:	31x71x11mm
> Weight:	27g

Features

> Wearable for single-channel ECG & motion data acquisition
> Raw signal acquired at 1000Hz
> Miniaturized and bendable form factor for better adaption to the body shape

Applications

This product is designed for life science education and research. It is not a medical device and is not suitable for any kind of medical use.

> Heart Rate extraction & heart rate variability
> Life sciences studies
> Biomedical research
> Human-Computer Interaction
> Robotics & Cybernetics
> Physiology studies
> Psychophysiology
> Biomechanics
> Ergonomics

Electrical Specifications

	ECG	ACC	GYR
Number of channels	1	3	3
Resolution	16 bit	16 bit	16 bit
Input full-scale	+/- 2.5mV	+/-8G	+/-500dps
Analog bandwidth	[0.05Hz to 150Hz]	[dc to 415Hz]	[dc to 315Hz]
Sample rate	1000Hz	1000Hz	1000Hz

Application Notes

A detailed Getting Started guide covering everything needed around the cardioBAN is available on our support page:

https://support.pluxbiosignals.com/knowledge-base/cardioban-getting-started/

The cardioBAN can be used with ECG electrodes and a gel-free chest band.

While most ECG electrodes are compatible with this device, the small surface area of traditional electrodes might not be sufficient to hold the cardioBAN in place during prolonged acquisitions.

We recommend the use of our cardioBAN electrodes as their bigger surface ensures better and longer wear of the wearable:

https://www.pluxbiosignals.com/products/cardioban-electrodes-pack-of-25

Electrode Setup

Figure 1: cardioBAN On (left) & Off (right) switch

Electrode Polarities

The cardioBAN's ECG connection uses 2x Electrodes. The negative electrode collection is located on the backside of the device part that contains the Status LED. The positive electrodes is located on the backside of the device part that contains the cardioBAN logo and the Battery LED.

Figure 2: cardioBAN electrodes polarities.

Lead I & Lead II Configuration

While the cardioBAN wearable allows data acquisition of all three Eindhoven leads, the best experience is achieved in Lead I or Lead II configuration.

In Lead I configuration, the cardioBAN is placed with the negative electrode to the right of the heart (from the user's perspective) and the positive electrode to the left (from the user's perspective). In this setup, the cardioBAN is placed in a horizontal position with the logo readible from the front.

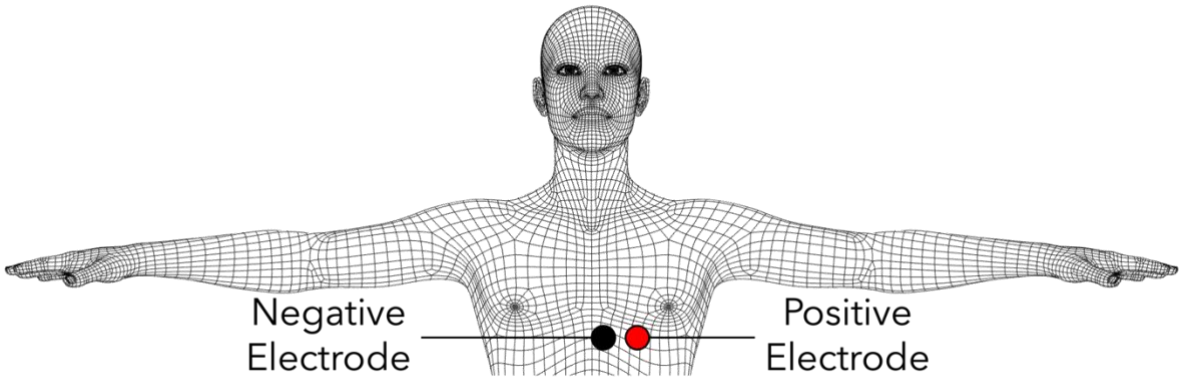


Figure 3: cardioBAN Lead I configuration.

In Lead II configuration, the cardioBAN is placed with the negative electrode to the top right of the heart (from the user's perspective) and the positive electrode to bottom left (from the user's perspective). In this setup, the cardioBAN is placed an inclined 45º position with the logo pointing downwards.

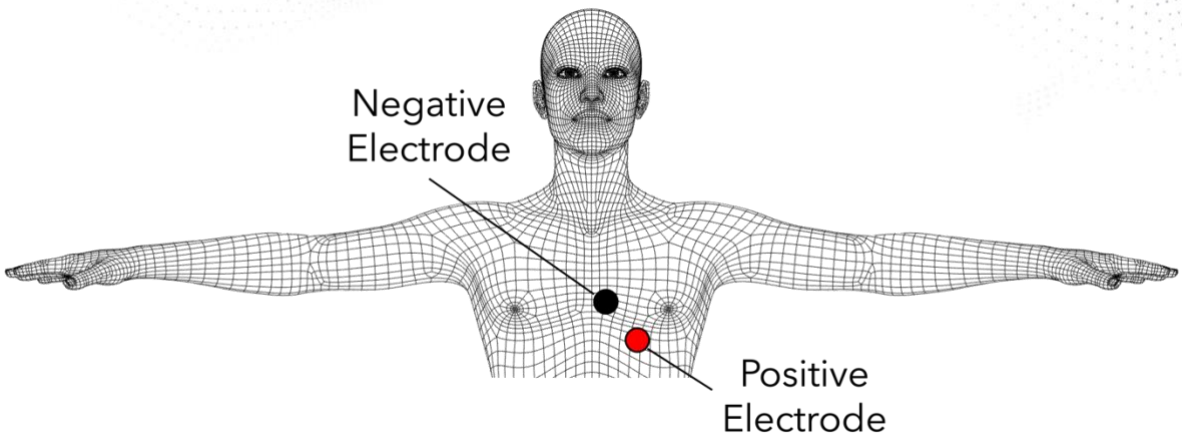


Figure 4: cardioBAN Lead II configuration.

LED Color Codes

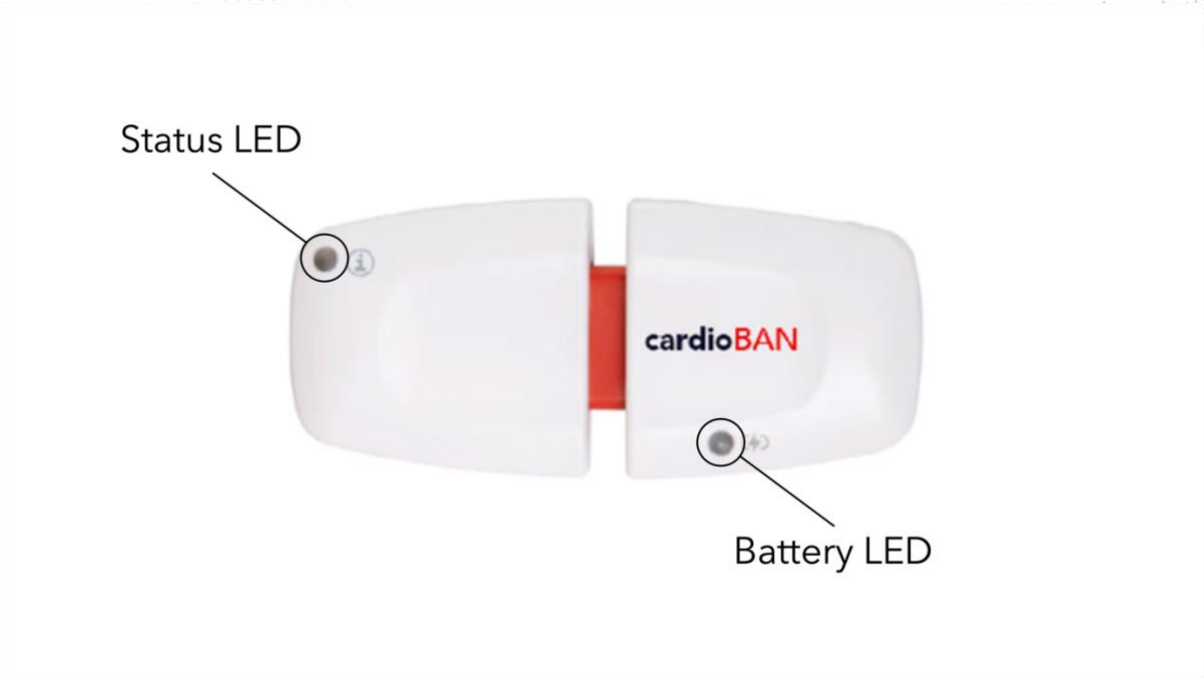


Figure 5: cardioBAN LEDs.

System LED States

State	Description	LED effect
OFF	The device is switched off	Off, no lighting effect
IDLE	The device is turned on and waiting for some interaction.	Blinking yellow at 0.5Hz
IDLE + SCHEDULED	The device is turned on and waiting for some interaction, but it has a schedule loaded in memory to start an acquisition.	Alternates between yellow and blue at 0.5Hz
IDLE + CONNECTED	The device is turned on and waiting for some interaction, but a BLE Bluetooth connection has been established with a host machine.	Blinking green at 0.5Hz
IDLE + CONNECTED + SCHEDULED	The device is turned on and waiting for some interaction. It has a schedule loaded in memory to start an acquisition. A BLE Bluetooth connection has been established with a host machine.	Alternates between green and blue at 0.5Hz
START_ ACQUIRING	The device has started an acquisition.	Fast blinking blue at 5Hz during 1 second
ACQUIRING	The device is in aquation mode.	Blinking blue at 0.5Hz
ERROR	The device is in an error state.	Blinking red at 2Hz

Battery LED States

State	Description	LED effect
NORMAL/CHARGED	The LED being off occurs in two situations: (a) Device has an appropriate charge level for its operation. (b) Device is fully charged.	Off, no lighting effect
CHARGING	Device is charging	Solid red, always on
LOW_BATT	The device's battery level is getting low; it is recommended to put the device on charge.	Blinking red at 1Hz
DISCHARGED_BATT	The device's battery level is critically low. The device must be charged immediately.	Blinking red at 10Hz

Transfer Functions

Electrocardiography (ECG) Sensor

The ECG input voltage range = [-2.5mV, 2.5mV]

$$V_{ECG}[V] = \frac{V_{REF}(ADC - 2^{n-1})}{2^n \times Gain}$$

$$V_{ECG}[mV] = V_{ECG}[V] * 1000$$

Where:
V_{REF} - ADC voltage reference, 2.5[V]
$Gain$ - Analogue voltage gain, 500
$V_{ECG}[V]$ – Raw ECG value in Volt [V]
$V_{ECG}[mV]$ – Raw ECG value in millivolt [mV]
ADC – Value sampled from the channel
n - ADC number of bits, 16 bit

Accelerometer

Range: [-8G, 8G]

$$Acc(g) = \left(ADC - \frac{2^n}{2}\right).\left(\frac{16}{2^n}\right)$$

$Acc(g)$ – Accelerometer value in g
ADC – Value sampled from the channel
n – Number of bits of the channel[1]

Gyroscope

Range: [-500dps, 500dps]

$$Gyr(dps) = \left(ADC - \frac{2^n}{2}\right).\left(\frac{1000}{2^n}\right)$$

$Gyr(dps)$ – Accelerometer value in degrees per second (dps)
ADC – Value sampled from the channel
n – Number of bits of the channel[1]

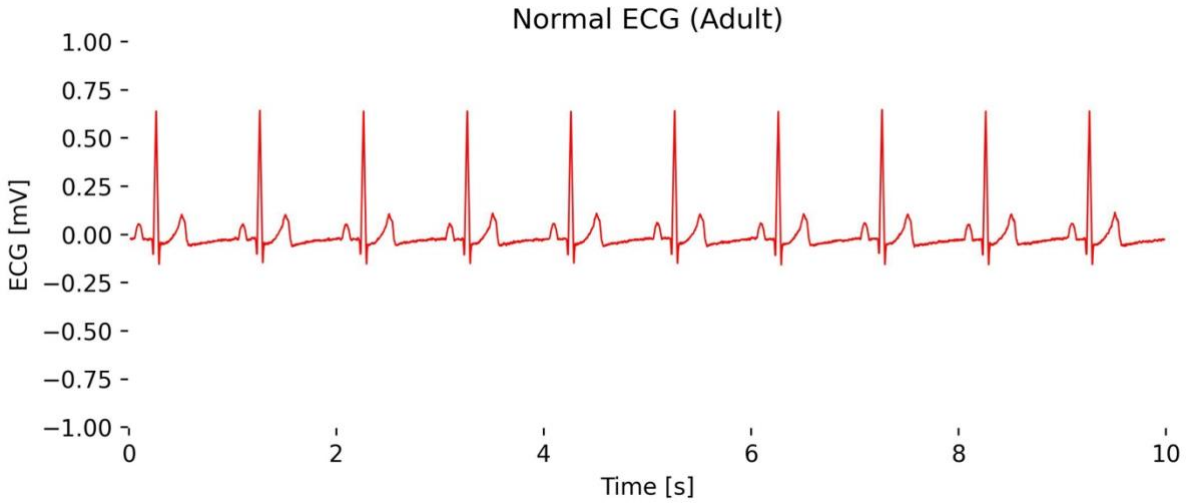
Sample Signals

The following signals were recorded using a cardioBAN wearable in a Lead I configuration. The signals were recorded from healthy adult subjects.

[1] *The number of bits for each channel depends on the resolution of the Analog-to-Digital Converter (ADC); in cardioBAN the default is 16-bit resolution (n=16)*

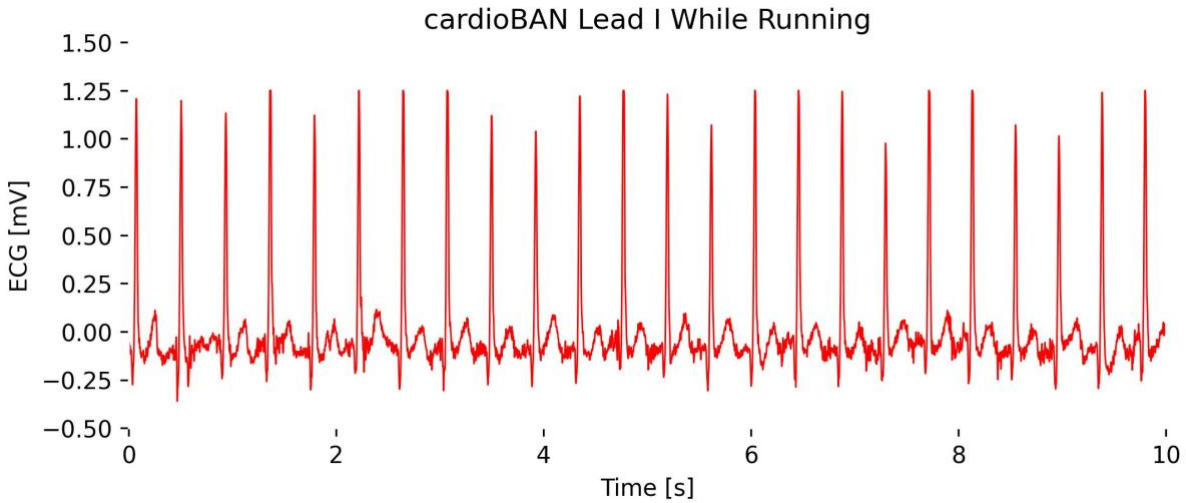
Normal ECG Signals

Normal ECG



Observation:
Regularly paced contractions with a clean baseline signal and no distortion of the ECG signal characteristics.

ECG While Jogging/Running

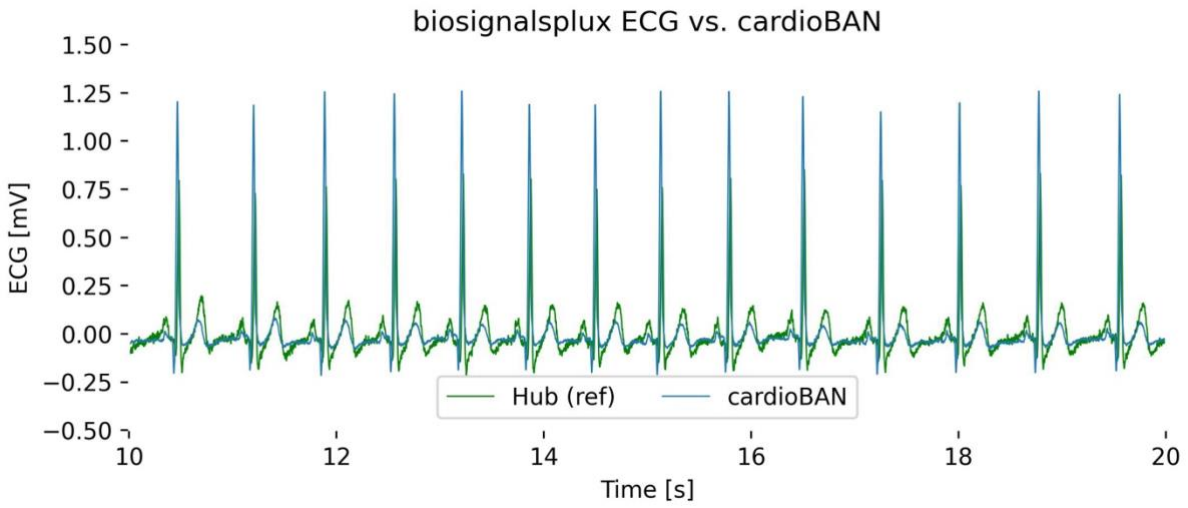


Observation:
ECG signal overall with clean QRS complexes and minor increase in baseline noise. Increased heart rate as expected under physical acitivity.

cardioBAN ECG vs. biosignalsplux ECG (Traditional Positioning)

The following signals from a cardioBAN wearable and an 8-channel biosignalsplux hub with an ECG sensor (green). The objective is to visualize the signals expected performance of the cardioBAN in comparison with traditional ECG setups.

The biosignalsplux ECG sensor was placed at the traditional electrode positionings with the + and – electrodes placed on the wrist of the subjects in Lead I configuration. cardioBAN was placed in Lead I configuration as demonstrated in Figure 3: cardioBAN Lead I configuration. The signals were synchronized in post-processing.



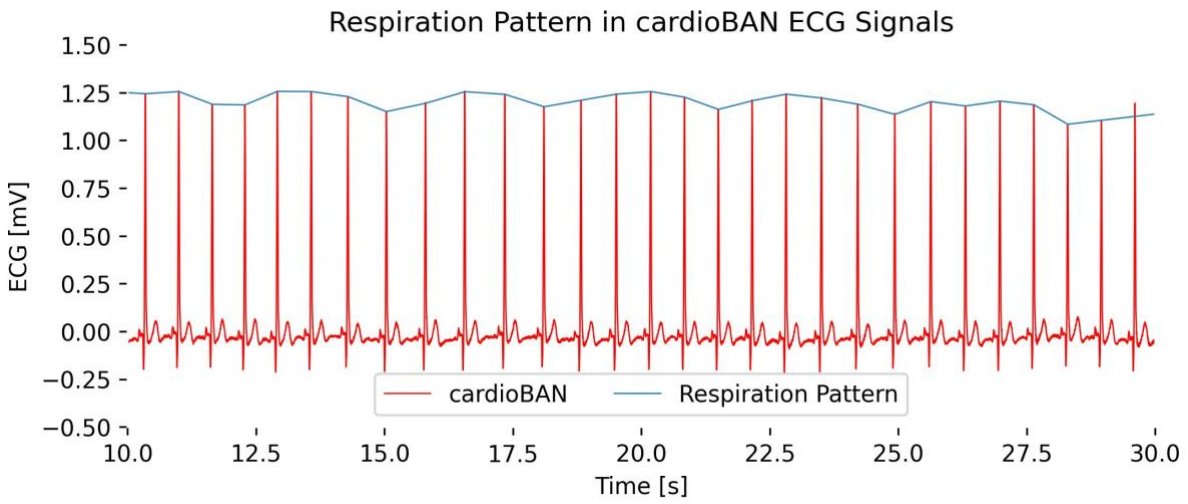
Observation:
Both signals visualize the ECG signal with the expected characteristics, with the main expected differences being:

- Signal Amplitudes: The cardioBAN, being directly placed over the ribcage thus in closer proximity to the heart, shows higher signal amplitudes as compared to the biosignalsplux ECG placed on the wrists (difference of up about 0.4mV)

- R-Peak Delays: biosignalsplux ECG R-peaks being more distanced from the heart, show minor delays (<0.25s) compared to cardioBAN R-Peaks. The delay occurs due to the time needed for the ECG signal to run through the body until the measurement locations

Respiration Patterns

cardioBAN's ECG also visualizes respiration patterns in it's R-Peak amplitudes as shown in the longer signal interval plotted below.



The R-Peak amplitude variations is the result of the changing proximity of the cardioBAN with the variying torax volume during the respiration cycle:

- inspiration → thorax volume increases → cardioBAN distance from the heart increases → R-Peak amplitude reduces
- expriation → thorax volume decreases → cardioBAN proximite to the heart increases → R-Peak amplitude increases

Arrhythmias & Other ECG Lead I Alterations with cardioBAN

The following pages visualize arrhythmias and other signal alterations simulated with a Fluke ProSim 8 Vital Sign and ECG Patient Simulator were recorded with the cardioBAN BLE.

The signals demonstrate the cardioBAN's capabilities to capture non-normal ECG signals and ECG alterations of pathophysiological origin (in this case, through simulated signals) in Lead I configuration.

It's important to highlight that not all arrhythmias are typically measured in Lead I configuration and may require other leads that are not achievable with the cardioBAN. It is possible to capture other ECG signal alterations that are not listed here.

In addition to the observations stated on the following pages, minor differences may occur due to the cardioBAN's local electrode placement compared to traditional ECG Lead I measures. All other information that is relevant to ECG Lead I configurations is provided.

DISCLAIMER
The following arrythmias can be measured with cardioBAN devices for life sciences and clinical research purposes but are not suitable for medical diagnosis or treatment.

ECG signal distortions can occur from non-physiological factors (e.g., movement artifacts, old electrodes) and may not be of pathophysiological original.

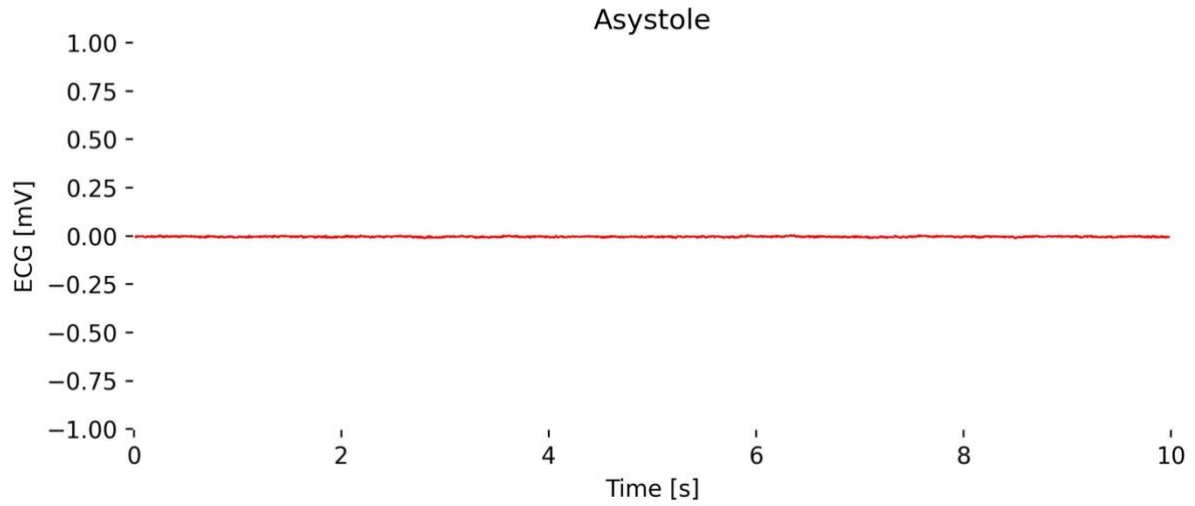
Should you experience any ECG alterations with your cardioBAN and cardiac discomfort during a recording, stop the recording and seek a healthcare professional for clinical evaluation.

Asystole

Arrhythmia Description
Asystole is a type of cardiac arrhythmia characterized by a complete absence of electrical activity in the heart, which appears as a flat line on an electrocardiogram (ECG).

This condition, often referred to as "flatline," signifies a cessation of cardiac output and requires immediate emergency intervention, such as cardiopulmonary resuscitation (CPR) and advanced life support.

Observations in Lead I cardioBAN Signal
Complete absence of heart contractions with baseline characteristics of an ECG flatline.



Atrial Fibrillation (Afib)

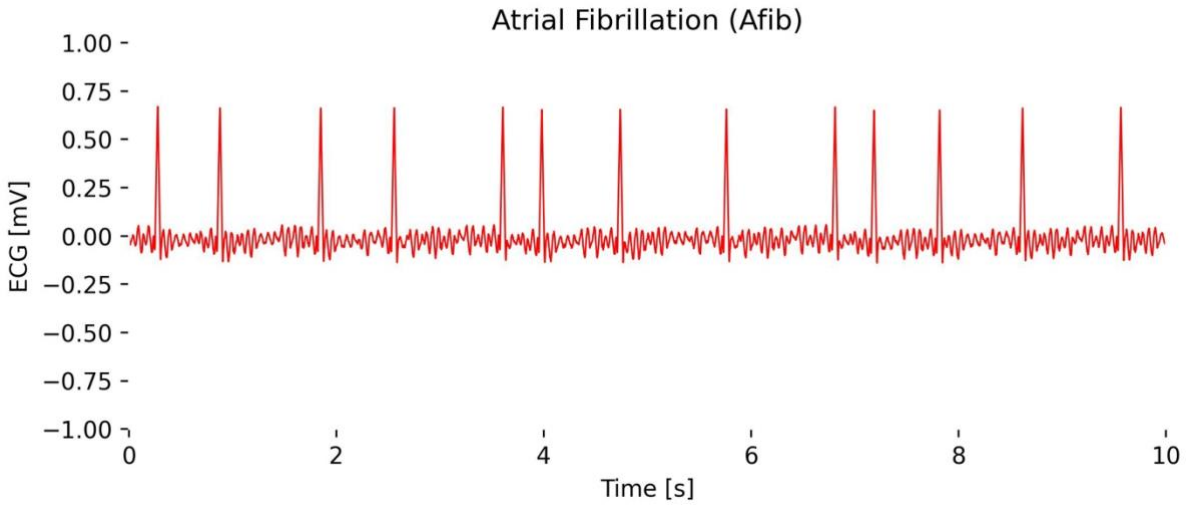
Arrhythmia Description

Atrial fibrillation is characterized by rapid and disorganized electrical activity in the atria, leading to an irregularly irregular rhythm visible on an ECG, particularly evident in Lead I.

On the ECG, you will notice a lack of distinct P waves and a variable R-R interval, indicating the atria's erratic quivering instead of a coordinated contraction.

Observations in Lead I cardioBAN Signal

Overall, the ECG baseline is irregular, along with clear yet irregularly spaced R-peaks.



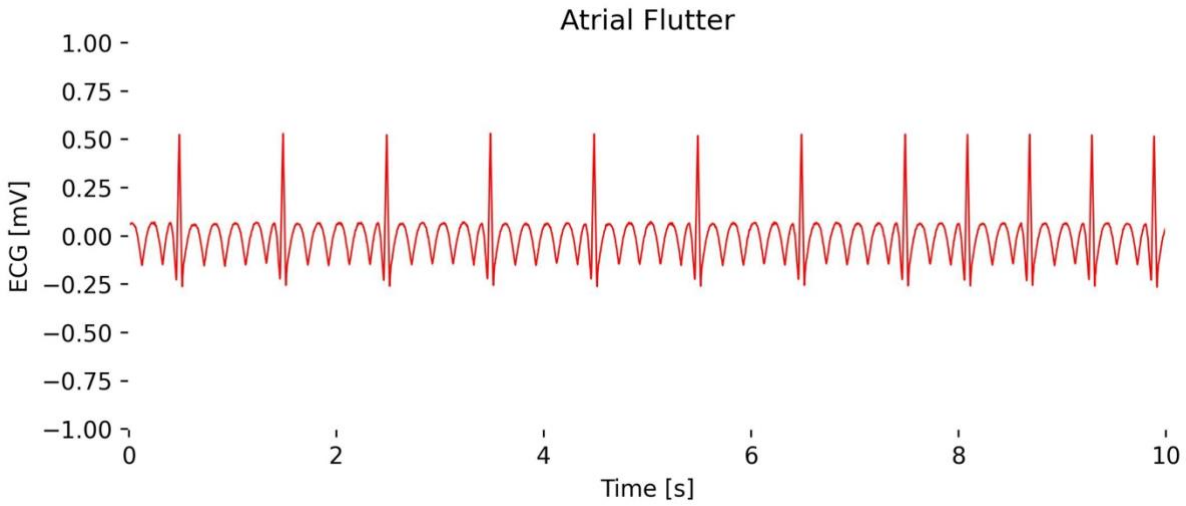
Atrial Flutter

Arrhythmia Description

Atrial flutter is an arrhythmia characterized by a rapid, regular pattern of atrial contractions, typically shown as a "sawtooth" pattern of flutter waves at a rate of about 250-350 beats per minute in Lead II, which is more diagnostic than Lead I.

Observations in Lead I cardioBAN Signal

Abnormal heart rhythm with significantly distorted baseline in “sawtooth” pattern. Heart rate decreases during expiration (see 2s to 7s) and increases during inspiration (see 7s to 10s).



Atrial Tachycardia

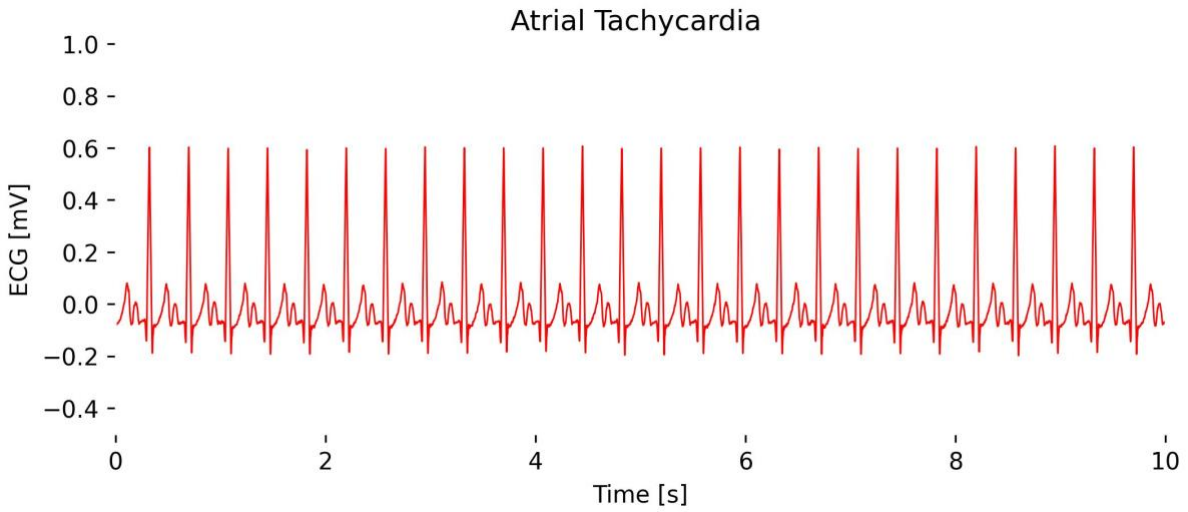
Arrhythmia Description

Atrial tachycardia is a type of supraventricular tachycardia where the heart's atria contract at an abnormally high rate of 150-250 beats per minute, typically originating from a focus above the ventricles.

In Lead I, you can see distinct P waves occurring at a rapid pace followed by a normal QRS complex, indicating the rapid atrial activation separate from the normal sinus node activity.

Observations in Lead I cardioBAN Signal

Abnormally high heart rhythm (here at 160 bpm) without QRS complex distortions.



AV Block (2nd Degree, Mobitz Type I)

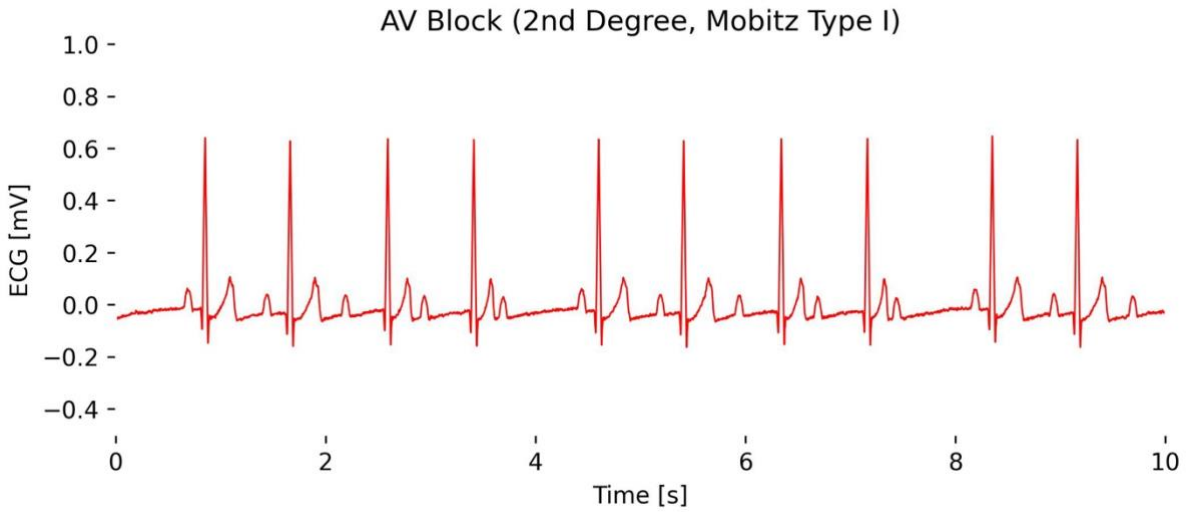
Arrhythmia Description

It is characterized by progressive prolongation of the PR interval on consecutive beats until a beat is blocked (a P wave not followed by a QRS complex).

In Lead I, you would still notice this pattern of gradually lengthening PR intervals followed by a dropped QRS complex, which reflects the increasing difficulty the electrical impulse faces in passing from the atria to the ventricles until it fails entirely for one cycle.

Observations in Lead I cardioBAN Signal

Progressive prolongation of the PR-interval in the first 4 beats until, eventually, an atrial impulse is completely blocked (here at 4s). This pattern is repeated in the following 4 betas until another impulse is completely blocked at 8s.



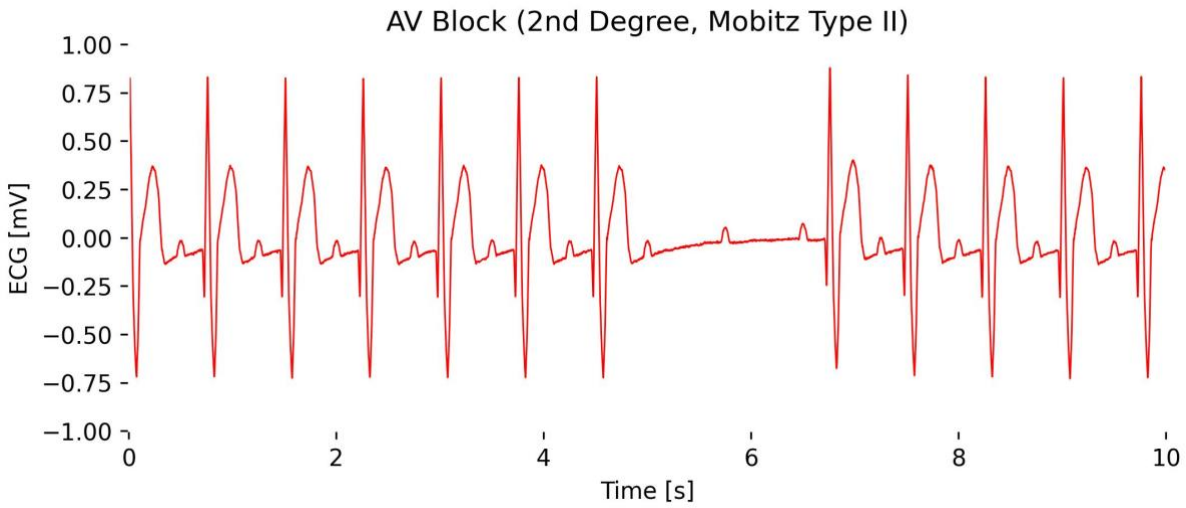
AV Block (2nd Degree, Mobitz Type I)

Arrhythmia Description

Characterized by the sudden and unexpected failure of some atrial electrical impulses to conduct to the ventricles without the progressive PR interval prolongation seen in Mobitz Type I.

Observations in Lead I cardioBAN Signal

Consistent PR-intervals in beats from 0s to 5s until a complete absence of a full contraction at 6s occurs, with only the P-wave visible without a subsequent QRS complex. Additional distortions in ST-segments can be observed in Lead I configuration.



AV Block (3rd Degree, Complete)

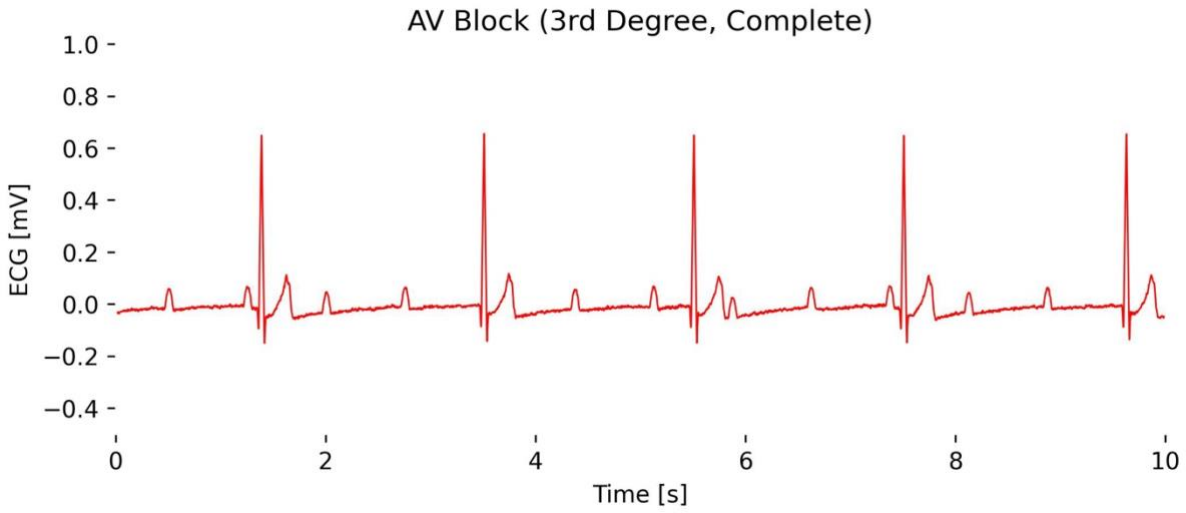
Arrhythmia Description

Third-degree AV block, or complete heart block, is characterized by the complete dissociation of atrial and ventricular activities; the atria and ventricles beat independently of each other.

On an ECG you will observe regular P-waves at a normal atrial rate, and completely unrelated, slower, regular QRS complexes often originating from an escape rhythm in the ventricles, illustrating no coordination between P waves and QRS complexes.

Observations in Lead I cardioBAN Signal

Periodic full absences of heart contractions with only the P-wave remaining in a semi-regular interval without subsequent QRS complexes.



Bradycardia

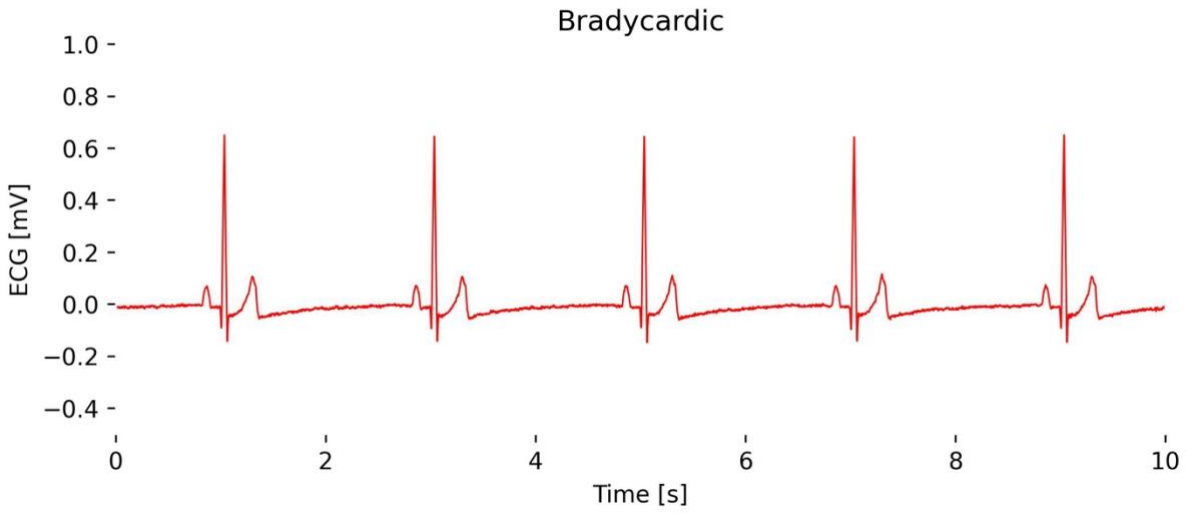
Arrhythmia Description

Bradycardia is a heart rate slower than normal, typically less than 60 beats per minute in adults, and can be seen on an ECG across all leads, including Lead I.

On the ECG, you would observe a slower rhythm with regular intervals between beats but otherwise normal P waves, PR interval, and QRS complexes, indicating that the heart's electrical activity is normal except for the reduced rate.

Observations in Lead I cardioBAN Signal

Abnormally low heart rate (here at 40 bpm) with long intervals between heartbeats and no additional signal distortions.



Tachycardia

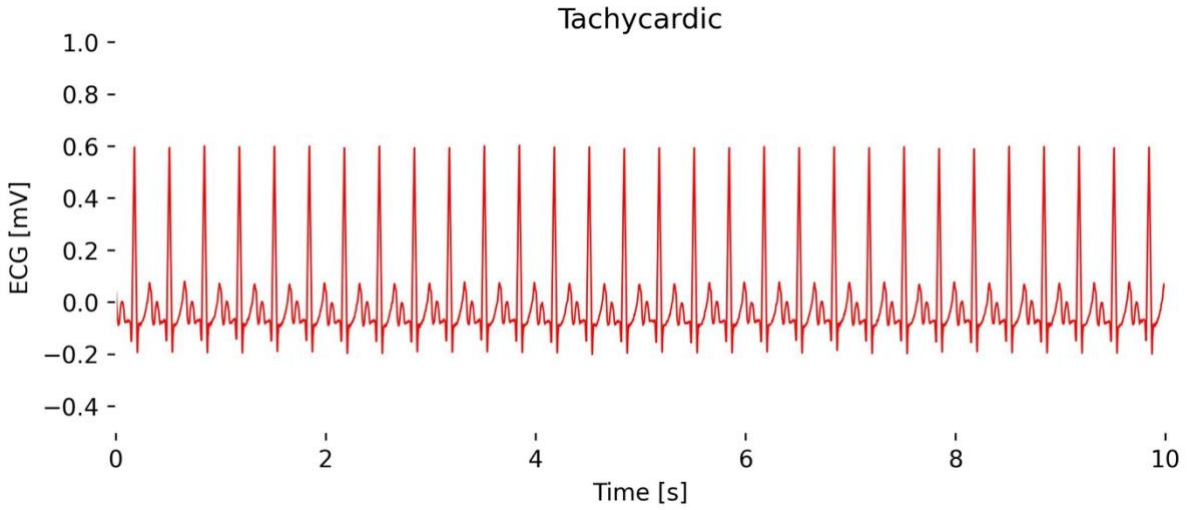
Arrhythmia Description

Tachycardia refers to a heart rate that exceeds the normal resting rate, generally defined as over 100 beats per minute in adults, observable on an ECG across all leads including Lead I.

The ECG will show a faster-than-normal rhythm with a reduced interval between heartbeats; however, depending on the type of tachycardia, the waveform features such as P waves, PR interval, and QRS complexes may vary, indicating different origins and mechanisms of the rapid rate.

Observations in Lead I cardioBAN Signal

Abnormally high heart rate (here at 180 bpm) with short intervals between heartbeats.



Hypertension & Hypotension

Note: Hypertension and hypotension are not arrhythmias, yet their results can impact the ECG waveform, which is why they're included here.

Arrhythmia Description

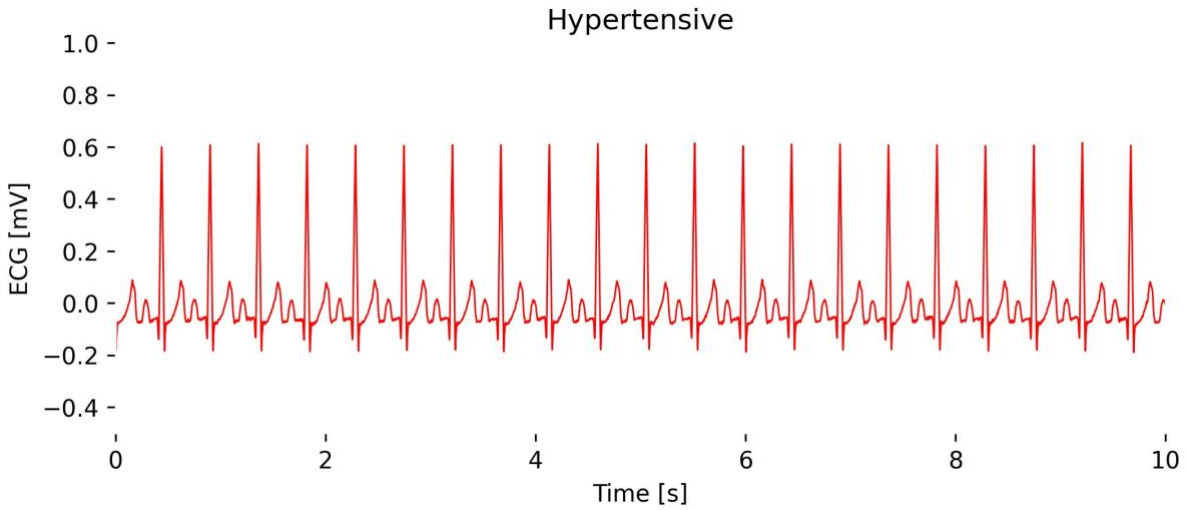
Chronic hypertension can lead to changes observable on an ECG, such as left ventricular hypertrophy.

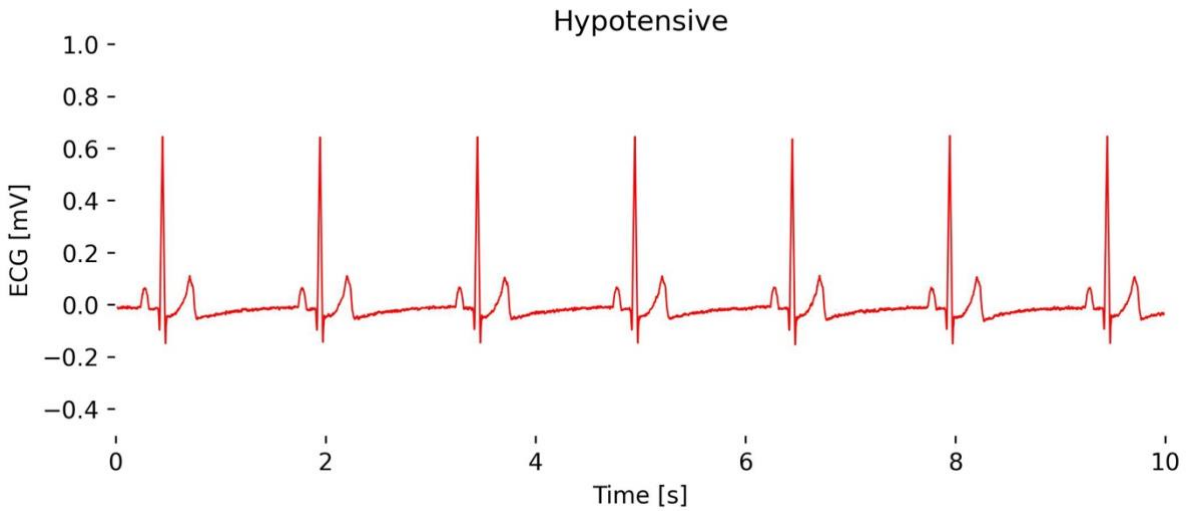
In an ECG, this might manifest as higher amplitude R waves in leads I, aVL, V5, and V6, and deeper S waves in V1 and V2, reflecting the increased muscle mass of the left ventricle working harder against elevated blood pressure. This may be accompanied by increased heart rate.

Observations in Lead I cardioBAN Signal

The effects of Hypertension, primarily the increased R-peak amplitudes, are not clearly visible in cardioBAN Lead I recordings. This is due to the comparatively short electrode distance and placement close to the heart compared to traditional Lead I placements.

The impact of Hypertension and Hypotension may only be noticeable in changes in heart rate.





Left Bundle Branch Block (LBBB)

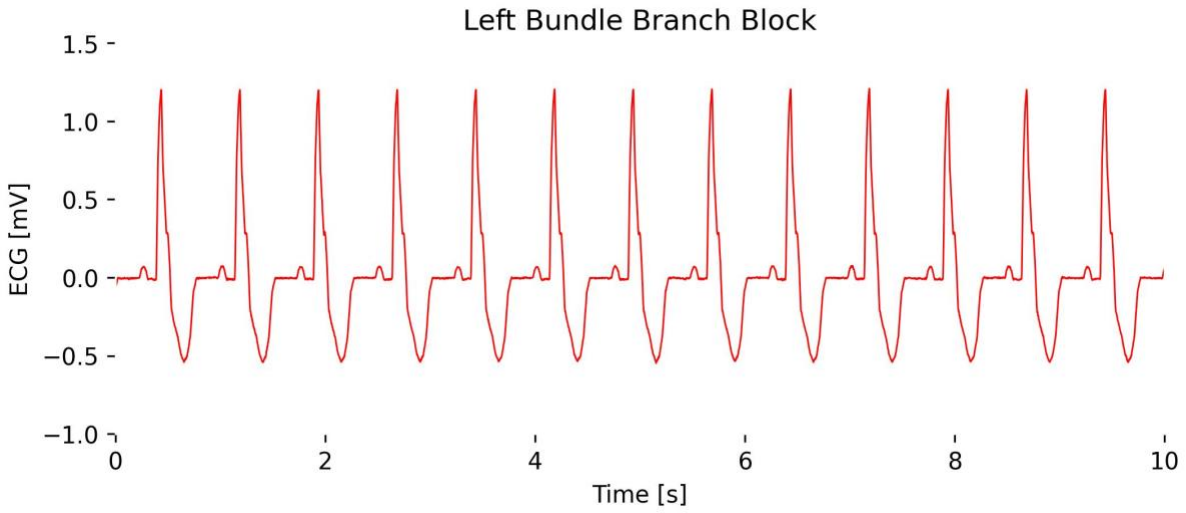
Arrhythmia Description

Left Bundle Branch Block (LBBB) is a cardiac conduction abnormality where the electrical impulse is delayed in the left bundle branch, causing the left ventricle to contract later than the right.

On an ECG, particularly noticeable in Lead I, you'll see a broadened QRS complex exceeding 120 ms with an absent Q and distorted, deep S-wave, reflecting the altered sequence of ventricular activation.

Observations in Lead I cardioBAN Signal

Periodic distortion of the QRS complex, with an absent Q wave and distorted, deep S wave.



Right Bundle Branch Block (RBBB)

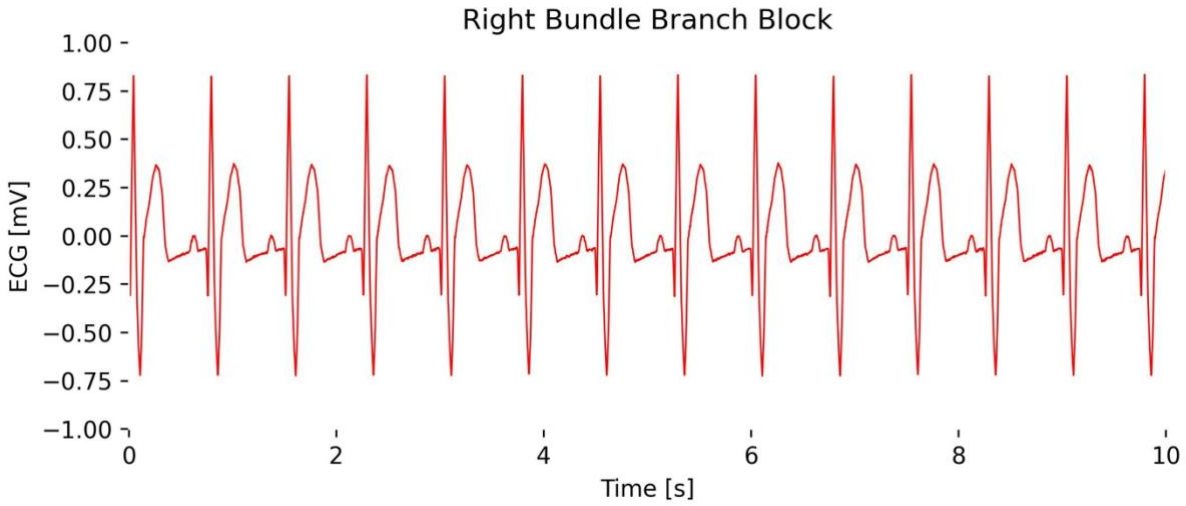
Arrhythmia Description

Right Bundle Branch Block (RBBB) is a cardiac conduction abnormality where the electrical impulse is delayed or blocked in the right bundle branch, causing the right ventricle to contract later than the left.

On an ECG, RBBB is identified by a widened QRS complex greater than 120 ms and a broad slurred S-wave. These changes are due to the delay in right ventricular depolarization.

Observations in Lead I cardioBAN Signal

Periodic occurrences of deep distorted S-waves.



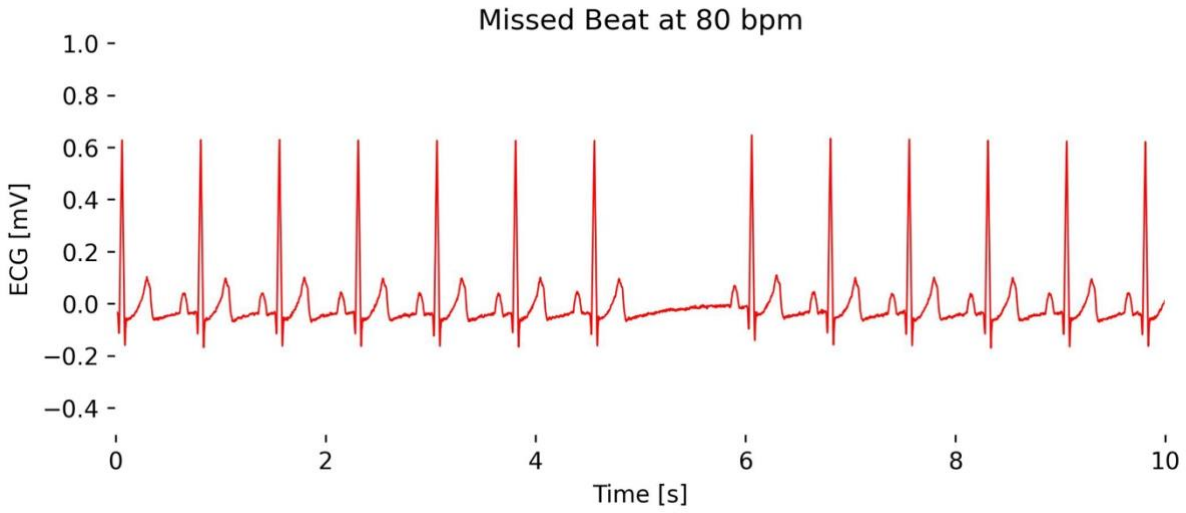
Missed Beat

Arrhythmia Description

A missed heartbeat, often referred to as a "skipped beat," is typically the result of a premature contraction or a brief pause following a premature contraction, and is not an arrhythmia but rather a common variation in normal heart rhythm.

Observations in Lead I cardioBAN Signal

Normal ECG segments with missing, skipped heartbeat at 5s.



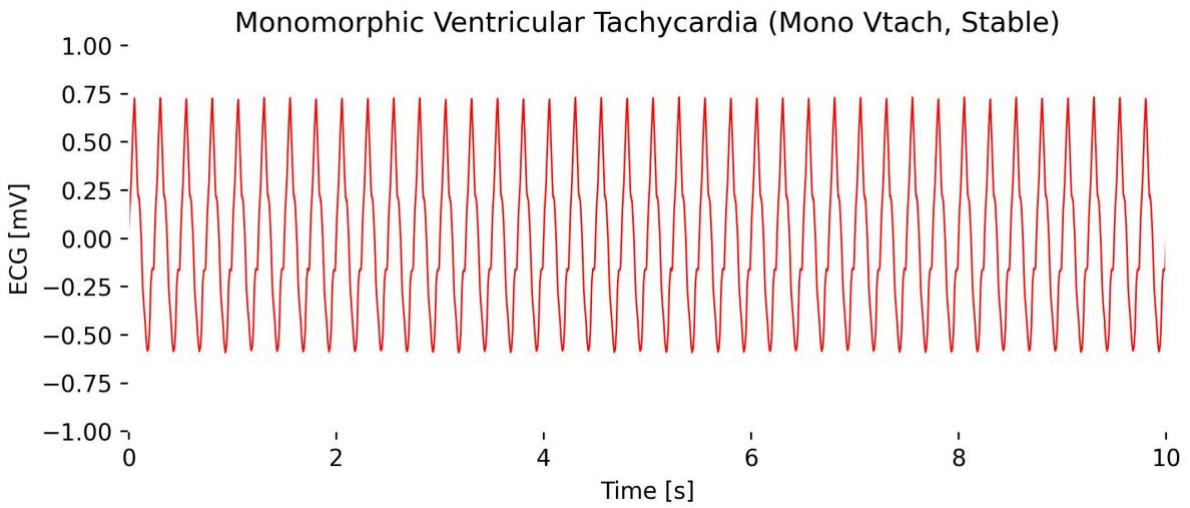
Monomorphic Ventricular Tachycardia (Mono Vtach, Stable)

Arrhythmia Description

Monomorphic Ventricular Tachycardia (VT), stable type, is a potentially life-threatening rhythm where the ventricles contract at a rapid rate, generally between 100 to 250 beats per minute, with the electrical activity originating from a single focus within the ventricles.

On an ECG, monomorphic VT typically shows a series of wide QRS complexes that are similar in shape, indicating that each beat originates from the same ventricular focus; in Lead I, these QRS complexes would be wide and consistent in morphology but without the typical preceding P wave of normal sinus rhythm, reflecting the ventricular origin of the beats.

Observations in Lead I cardioBAN Signal



Poly-Ventricular Tachycardia (Poly Vtach)

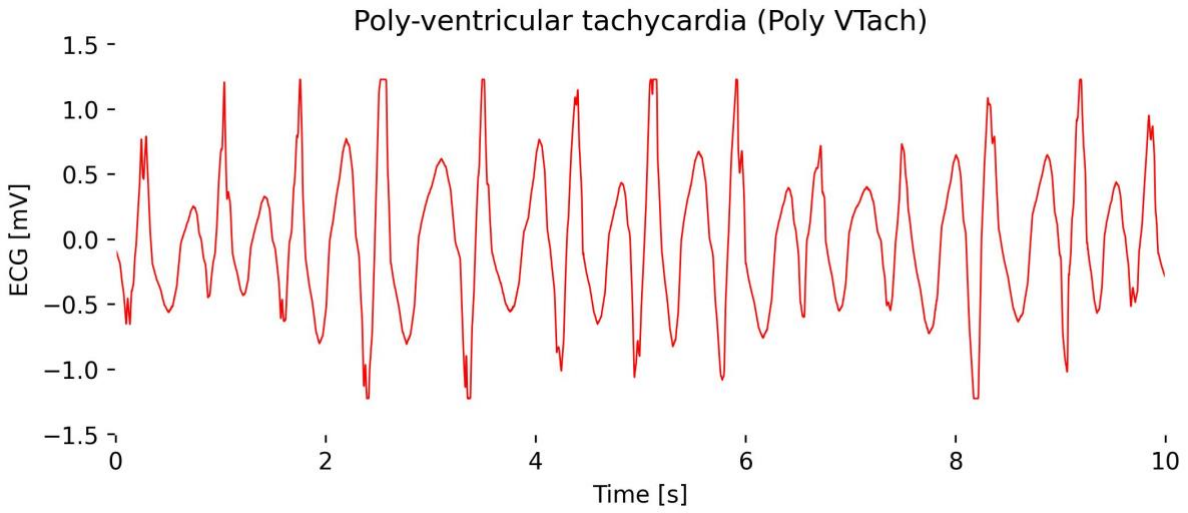
Arrhythmia Description

Poly-ventricular tachycardia is a variation in the shape of the QRS complexes on the ECG. This variation reflects the multiple foci in the ventricles that are generating the electrical impulses.

It is characterized by a fast heart rate with a series of wide QRS complexes that change in amplitude, axis, and duration, creating a pattern that may appear to twist around the isoelectric baseline. In Lead I, as with other leads, you would see this pattern of varying QRS complexes without discernible P waves, indicating chaotic ventricular activity.

Observations in Lead I cardioBAN Signal

Roughly distinguishable R-Peaks with repeated highly distorted and chaotic QRS complexes.



Sinus Arrhythmia

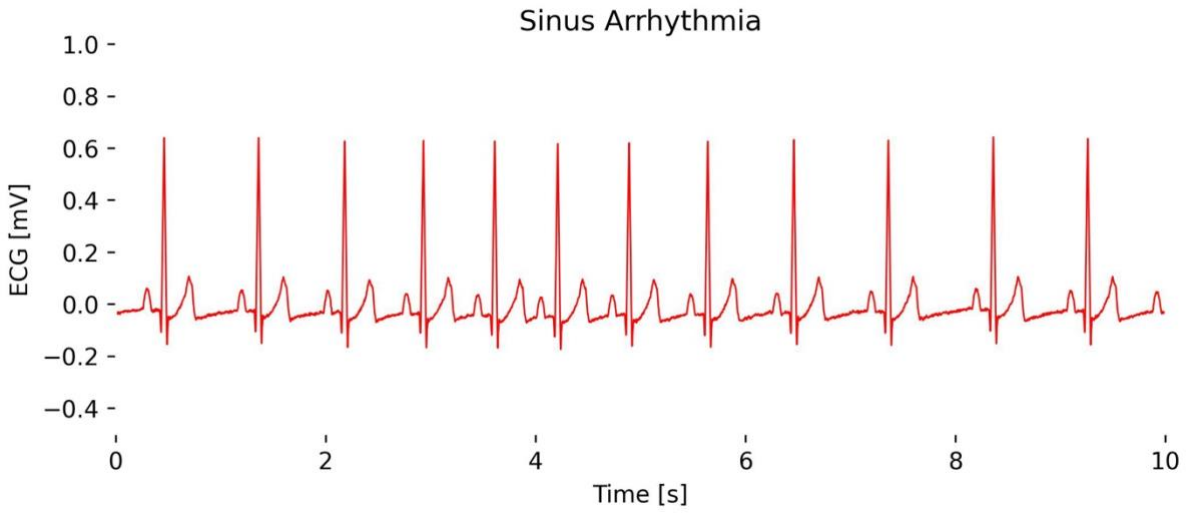
Arrhythmia Description

Sinus arrhythmia is typically a benign condition characterized by a slight heart rate irregularity that varies with breathing—increasing during inspiration and decreasing during expiration.

Observations in Lead I cardioBAN

Variations in heart rate during different segments of respiration. Here, increased heart rate (R-peaks are closer to each other) during 2s to 6s of inspiration and greater intervals afterward during expiration.

Depending on the placement of the ECG on the thorax, additional changes in R-peak amplitude may occur, such as amplitude increase during expiration (ECG sensor closer to the heart) and amplitude ecrease during inspiration (ECG sensor is more distanced from the heart due to chest expansion).



Sinus Bradycardia

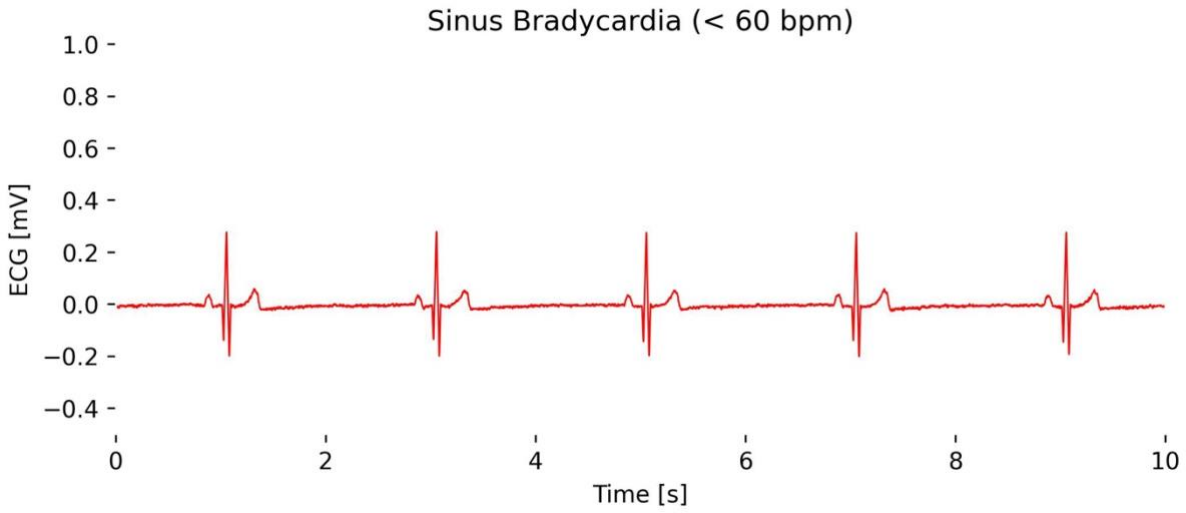
Arrhythmia Description

Sinus bradycardia is a heart rhythm originating from the sinoatrial node with a rate less than 60 beats per minute, considered normal in many well-conditioned athletes and during sleep.

On an ECG, sinus bradycardia appears as a regular rhythm with normal P waves, PR interval, and QRS complexes, with the primary distinction being the slower rate; in Lead I, you would observe these normal waves occurring at a decreased frequency, reflecting the heart's reduced pace but maintaining the typical characteristics of sinus rhythm.

Observations in Lead I cardioBAN Signal

Normal QRS complexes at reduced frequency with no signs of pathological distortions.



Supraventricular Tachycardia (SVT)

Arrhythmia Description

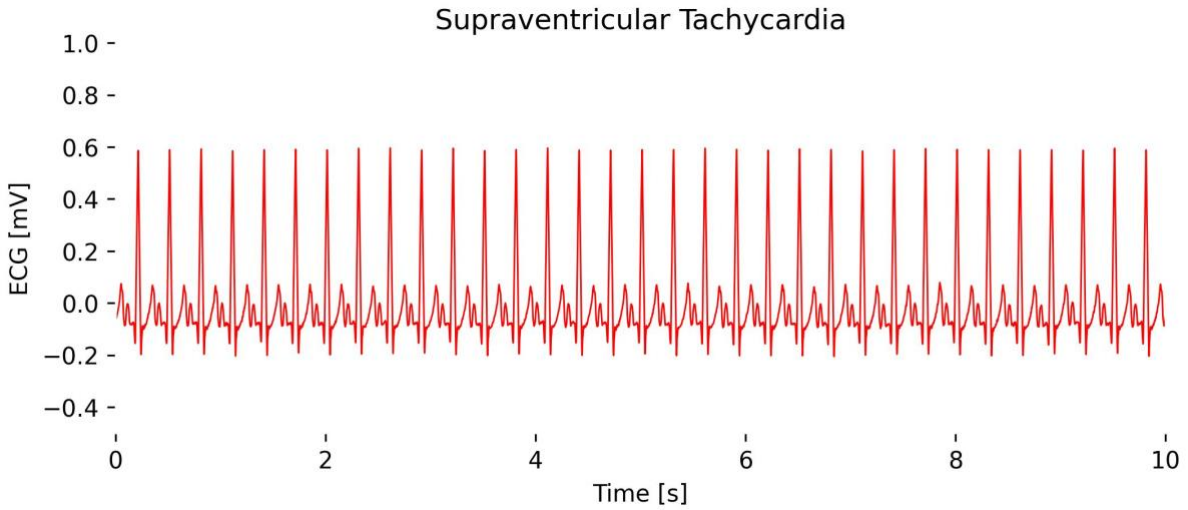
Supraventricular Tachycardia (SVT) is a rapid heart rhythm originating from above the ventricles, typically involving the atria or the AV node.

On an ECG, SVT presents as a very fast heart rate, usually between 150 and 250 beats per minute, with narrow QRS complexes due to the impulse originating above the ventricles.

In Lead I, the P waves may be absent, hidden within the QRS complexes, or appear just after the QRS complexes depending on the specific type of SVT, making it sometimes challenging to discern the atrial activity. The rapid and regular appearance of the QRS complexes is the hallmark on the ECG, indicating the rapid firing from the supraventricular region.

Observations in Lead I cardioBAN Signal

Rapid and regular QRS complexes. Although appearing in an abnormally high heart rate, no distortions of the QRS complexes are visible.



Ventricular Fibrillation (Coarse)

Arrhythmia Description

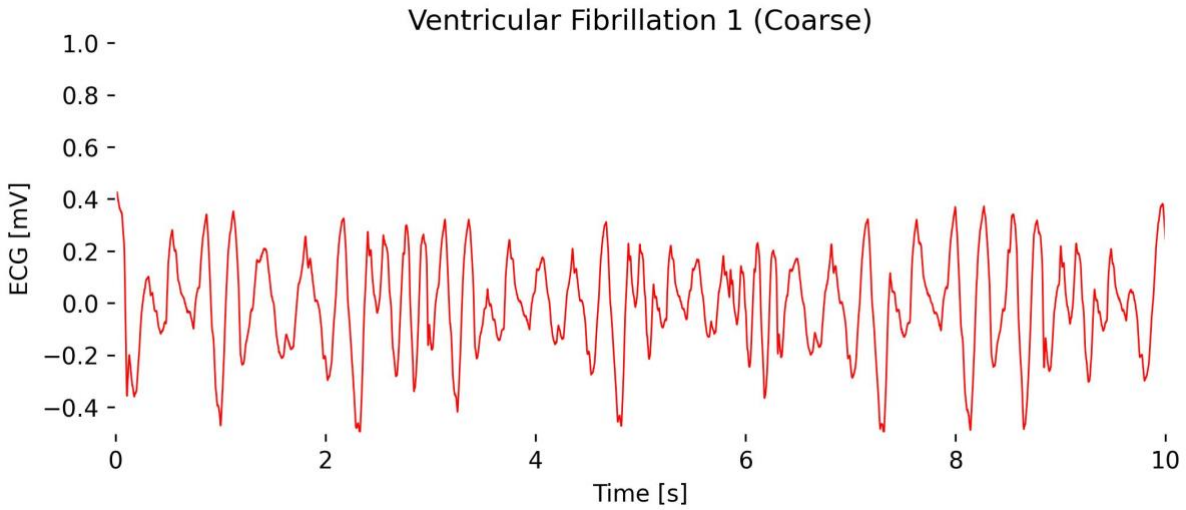
Coarse Ventricular Fibrillation (VFib) is an advanced and life-threatening cardiac arrhythmia characterized by irregular and erratic electrical activity in the ventricles, resulting in an ineffective, quivering movement rather than a coordinated contraction.

On an ECG, coarse VFib is identified by irregular, large-amplitude waveforms that vary in size and shape, appearing chaotic without any discernible P waves, QRS complexes, or T waves. Other than in Atrial Fibrillation (Afib), which contains a chaotic, noisy baseline while still having identifiable R-peaks.

In Lead I, as in other leads, this arrhythmia manifests as a turbulent and unpredictable pattern, indicating a severe disruption in ventricular electrical activity, which requires immediate medical intervention, typically defibrillation.

Observations in Lead I cardioBAN Signal

Chaotic baseline and not definable QRS complexes.



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