QUARTERLY LEARNING SERIES

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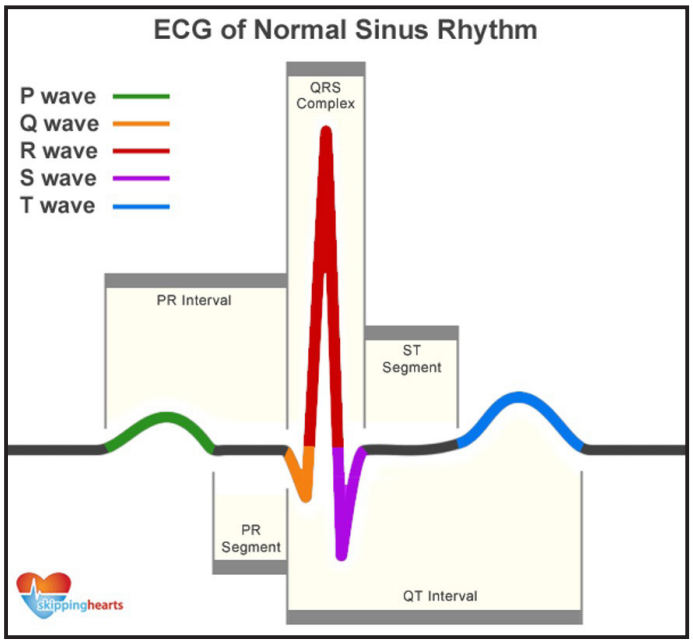
ECGs: A complete reference for your practice

by Jennifer Schneiderman, DVM, DACVIM (C)

- *Review the basics of ECGs, tips for capturing quality tracings, and expand your awareness of ECG abnormalities.*
- *This article contains a catalog of over 20 different ECG tracings for your reference. See page 5 for a list with links.*

WHAT IS AN ECG?

- The electrocardiogram (ECG or EKG) provides a graphic representation of the electrical depolarization and repolarization processes of the cardiac muscle, as "viewed" from the body surface.
- The amplitude of these electrical potential differences between various points on the body is measured in millivolts (mV) and their duration in seconds.
- ECG can provide information on heart rate, rhythm, and intracardiac conduction.
- The ECG may also reveal evidence of specific chamber enlargement, myocardial disease or ischemia, pericardial disease, certain electrolyte imbalances, and some drug toxicities.



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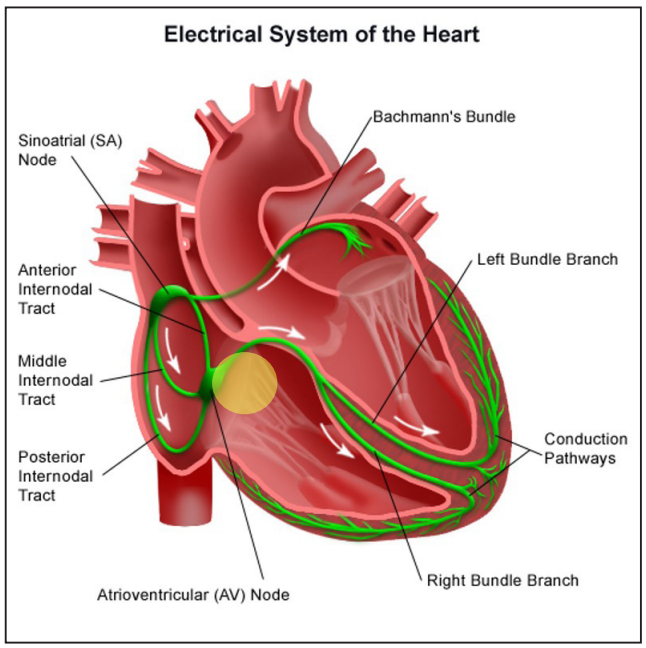
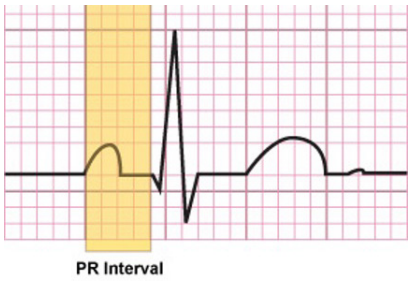
P QRS T EXPLAINED

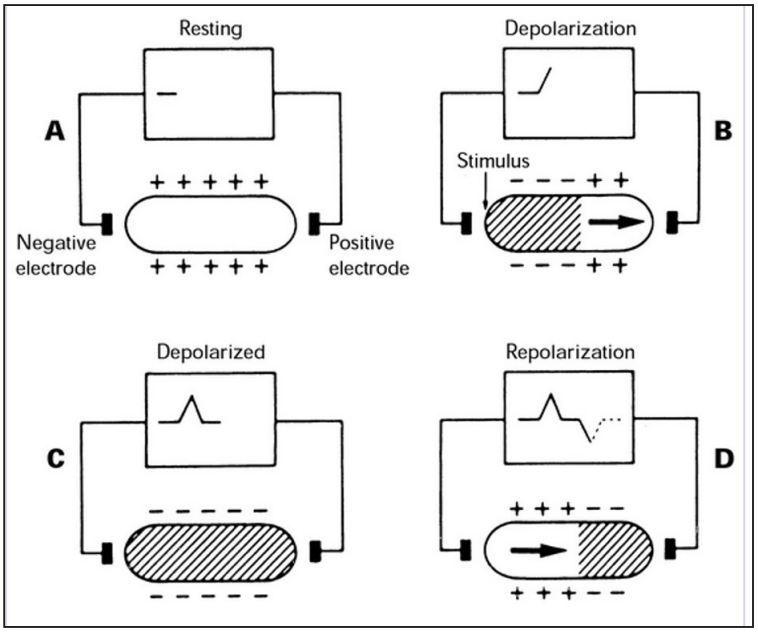


- P wave: represents atrial depolarization
- QRS complex: represents ventricular depolarization
- T wave: Represents ventricular repolarization



- The PR interval is inscribed due to a delay of depolarization at the atrioventricular (AV) node (allowing time for the ventricles to fill) and no wave is produced.

- This schematic represents a positive and negative electrode that have been placed on either side of a strip of myocardium. (A)
- The left end is activated and the wave of depolarization spreads from left to right, toward the positive electrode. (B)
- This produces a positive (upright by convention) deflection on the recording paper of the electrocardiograph. (C)
- When fully depolarized the deflection returns to baseline. Repolarization results in the opposite. (D)



(From Tilley LP: Essentials of Canine and Feline Electrocardiography, ed 3, Philadelphia, 1992, Lea & Febiger.)

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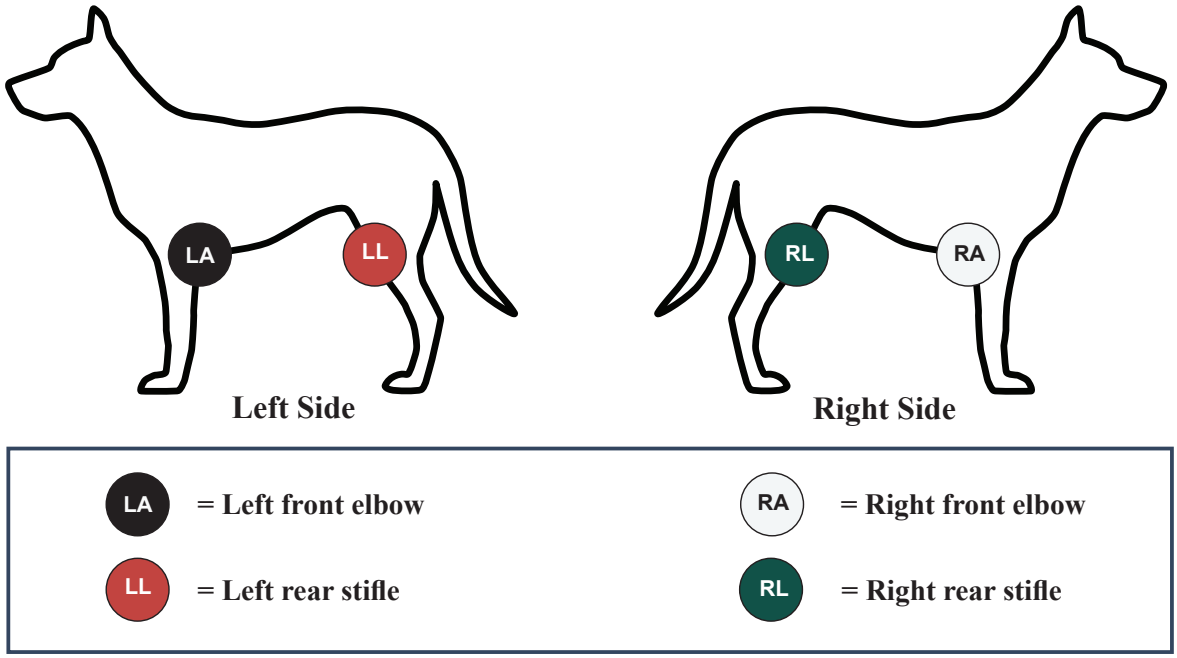
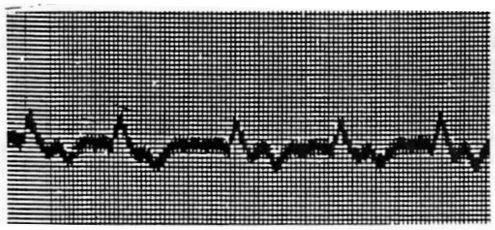
LEAD PLACEMENT



ECG Best Practices

- Place the animal in right lateral recumbency. Make sure the animal is calm and does not move during the recording.
- Make sure the patient and ECG unit are not touching a metal surface. Metal interferes with the ECG reading. Place the patient on a rubber mat, towel, or blanket.

Example of an ECG with interference. Note the fuzziness of the ECG tracing.



- Having the ECG machine well grounded is an important factor for obtaining an accurate reading. Ensure that the machine is plugged into a grounded outlet as well as checking the ECG machine for loose wires or cracked insulation on wires.
- To prevent base line wavering, roll-up a towel or use a pillow to separate the front paws of the patient while in lateral recumbency.
- Attach the 4 color-coded electrode cables to the limbs using low-force alligator clips.
- Apply 70% rubbing alcohol to the skin under each clip to ensure a good connection. For pets with long hair, clipping some fur may be necessary to ensure a good connection.

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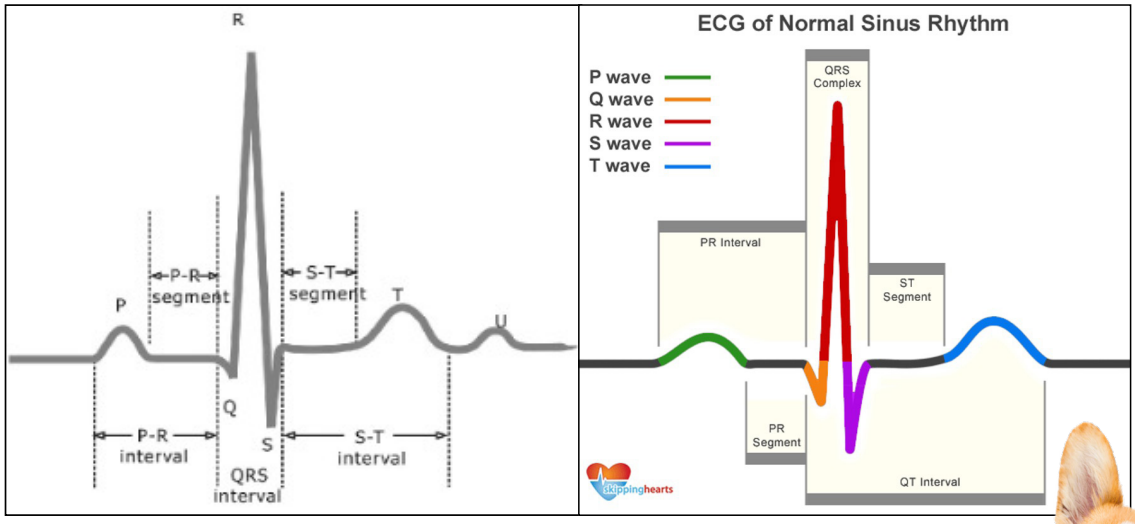
P-QRS-T COMPLEX EVALUATION



Start by asking these questions:

- Is the height and width of the P wave normal?
- How long is the P-R interval?
- How wide is the QRS complex
- How tall is the R wave?
- How long is the S-T segment?
- How deep is the T- wave?
- How long is the Q-T interval?

Parameter Normals	Dog	Cat
Heart rate (beats/min): resting-excited	Giant breeds: 60-140 Adult dogs: 70-160 Toy breeds: 80-180 Puppies: up to 200	100 (asleep)-240 (excited)
P wave (upper limit)	Width: 0.04 sec Height: 0.4 mV	Width: 0.04 sec Height: 0.2 mV
P-R interval	0.06-0.13 sec	0.05-0.09 sec
QRS complex (upper limit)	Width: 0.06 sec Height: 3.0 mV	Width: 0.04 sec Height: 0.9 mV
Q-T interval	0.15-0.25 sec depending on heart rate	0.07-0.20 sec depending on heart rate
S-T segment	No more than 0.2-mV elevation or depression	No depression or elevation
T wave	Positive, negative, or biphasic	Positive, Negative, or biphasic
Mean electrical axis	+40 to +100 degrees	0 to +160 degrees

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RHYTHM DIAGNOSIS

A systematic approach is also required for rhythm diagnosis.

1. Criteria used in assessing arrhythmias include:
- Is the rate fast or slow (tachycardia or bradycardia)?
- Is the rhythm regular or irregular?
- If irregular, is the rate slow, fast, or are there premature beats?
- Are there P waves and are they of normal morphology?
- Is there a P wave for every QRS complex and a QRS complex for every P wave?
- Are the QRS complexes normal or abnormal in appearance?

2. Supraventricular arrhythmias must be differentiated from ventricular arrhythmias

3. Types of arrhythmias: Arrhythmias are supraventricular vs ventricular in origin and based on rate.
- Bradycardias: sinus, SA node arrest or standstill, AV block, junctional escape, ventricular escape
- Tachycardias: sinus, atrial/supraventricular, atrial flutter, atrial fibrillation, junctional or ventricular

A CATALOG OF ECG EXAMPLES

Scroll to continue viewing or download a PDF copy to click titles and advance to each example.

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Normal Sinus Rhythm

Sinus Rhythms

Sinus rhythm is the normal cardiac rhythm. The P waves are positive in lead II, the P-Q intervals are consistent and the R-R intervals occur regularly

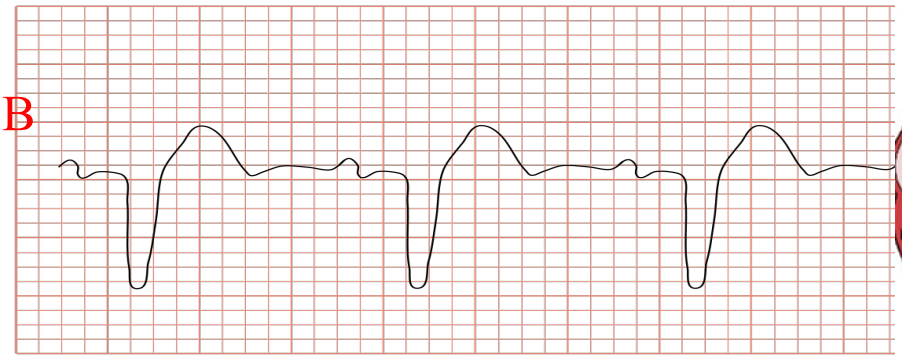
Sinus bradycardia is a rhythm that originates in the sinus node and is conducted normally but has too slow a rate

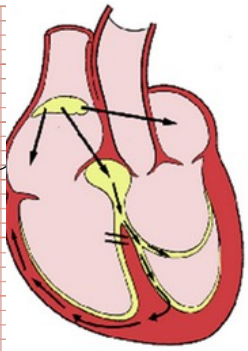
Sinus tachycardia also originates in the sinus node and is conducted normally but is too rapid.

Sinus arrhythmia is characterized by a cyclical slowing and speeding of the sinus rate, most commonly associated with respiration.

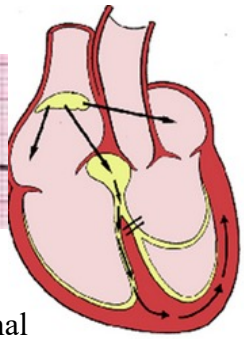
Bundle Branch Blocks

RBBB





LBBB

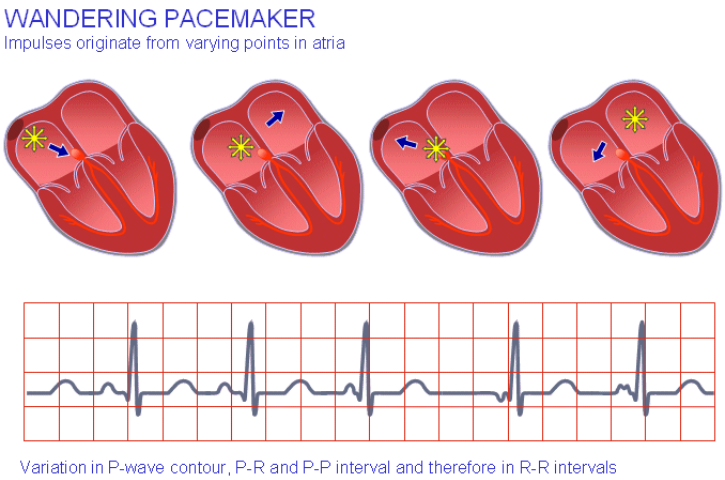


The portion of the ventricles served by the diseased bundle branch is activated late and slowly, resulting in widening of the QRS with the terminal forces oriented toward the area of delayed activation.

Sinus Arrhythmia

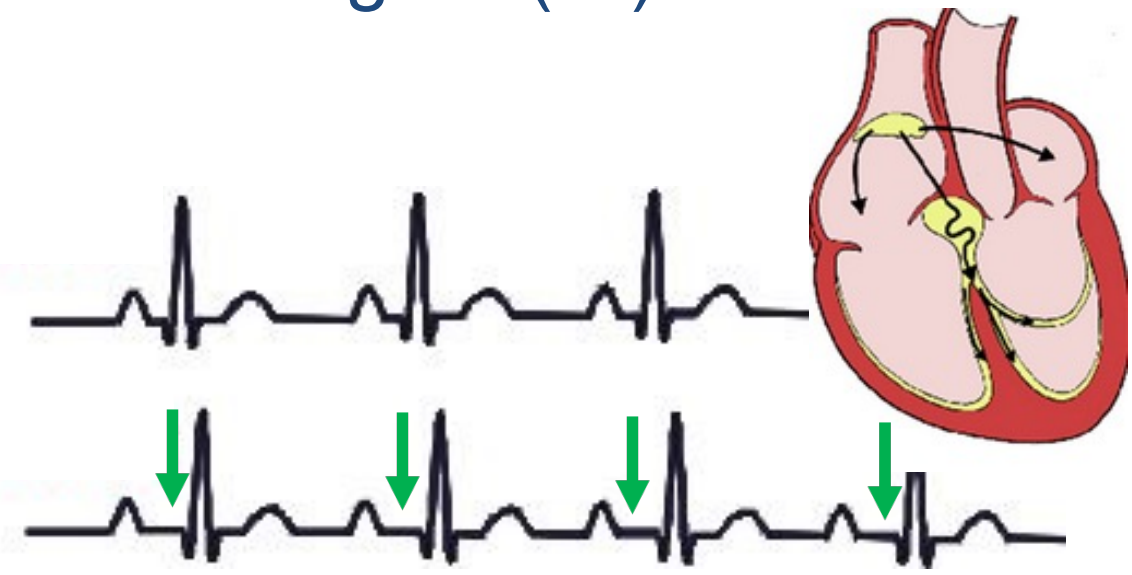
a. Heart rate is normal to slow (usually < 140 BPM in the dog).
b. Variability in PP interval
c. Normal P wave morphology and every P wave is followed by a QRS complex in a 1:1 ratio
d. QRS complexes are normal in appearance.

Wandering Atrial Pacemaker



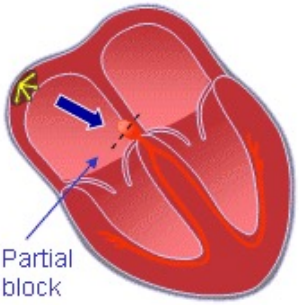
a. natural cardiac pacemaker site shifts
b. may occur with sinus arrhythmia
c. P wave change shape and size from beat to beat
d. Normal heart rate
e. Normal QRS complex

First Degree (1°) AV Block



a. Prolonged PR interval ($\geq$ 0.13 second)
b. Normal P wave and QRS complexes that occur at a 1:1 ratio
c. Can be associated with increased vagal tone

Second Degree (2°) AV Block



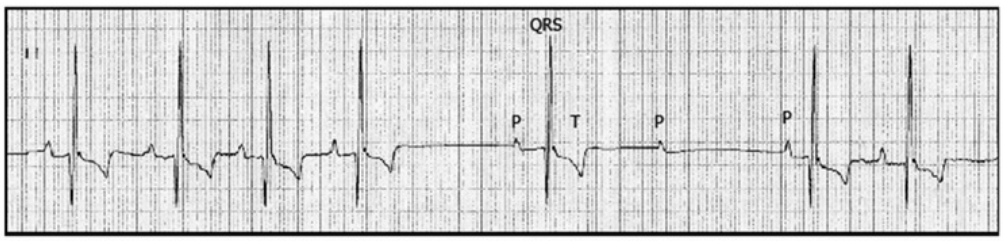
a. Intermittent AV conduction
b. Some P waves are not followed by a QRS complex
c. When many P waves are not conducted, the patient has "high-grade" 2° heart block.

Second Degree (2°) AV Block

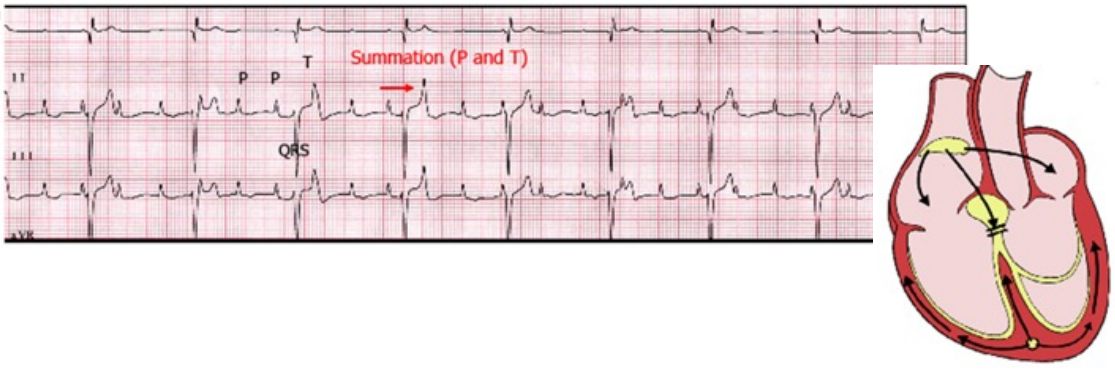
There are two subtypes of 2° block:

1. Mobitz type I (Wenckebach): progressive prolongation of the P-R interval until a nonconducted P wave occurs

2. Mobitz type II: uniform P-R intervals preceding the blocked impulse

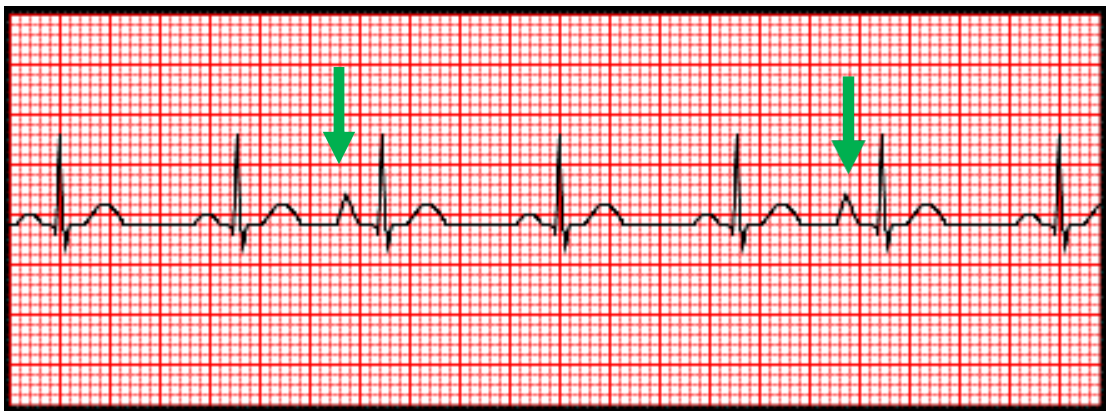


Third degree (3°) or complete AV block



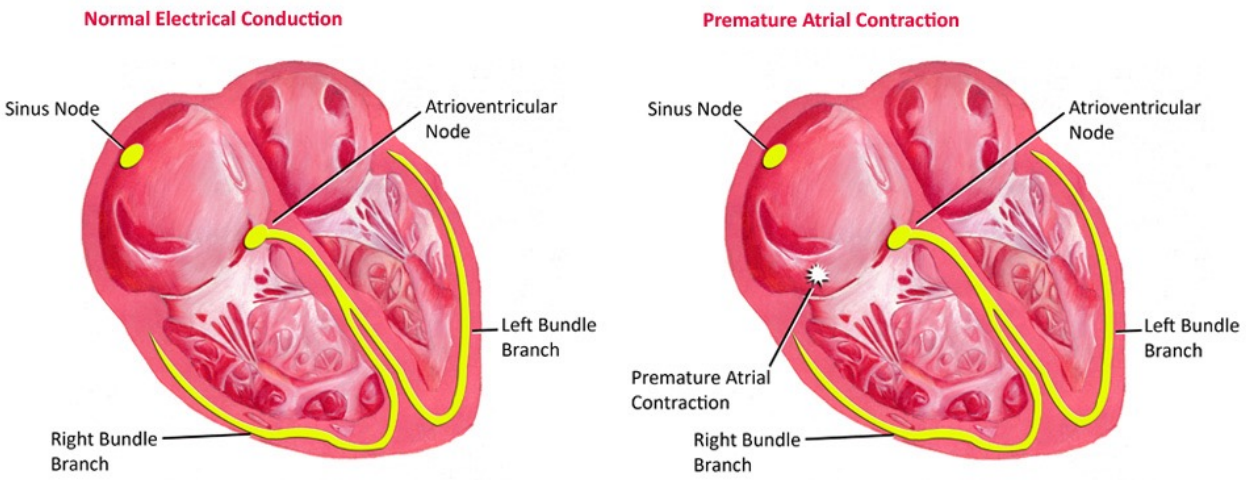
a. The atrial rate and ventricular electrical depolarizations are unrelated to each other
b. The atrial rate is faster than the ventricular rate.
c. The rhythm is usually regular.
d. Escape beats may arise from 2 sites of subsidiary pacemakers:
    1. AV node-bundle of His below the site of AV block
    2. Ventricular Purkinje fibers.

Atrial Premature Contractions (APCs)



1. Atrial premature complexes (APC) originate in the atria but in a location other than the sinus node.
2. ECG characteristics:
    a. QRS morphology looks similar to normal sinus impulse.
    b. The QRS complex of the APC occurs earlier than expected compared to the normal sinus rhythm.
    c. The P wave morphology may appears different from the normal sinus P wave.

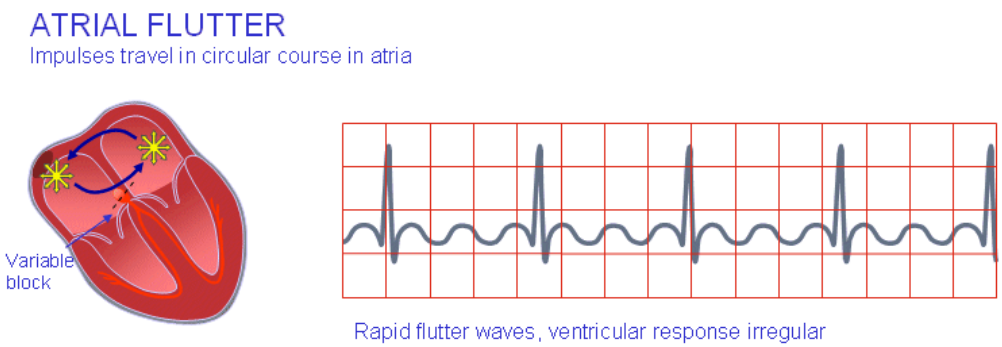
Atrial Premature Contractions (APCs)



Atrial Fibrillation

1. Caused by multiple simultaneously occurring disorganized atrial impulses that bombard the AV node.
2. ECG characteristics:
    a. QRS complexes are usually narrow
    b. P waves are absent.
    c. Atrial activity is represented by fibrillatory (f) waves of varying amplitudes.
    d. Ventricular rhythm is irregular.
    e. At very rapid rates the rhythm can appear regular.

Atrial Flutter



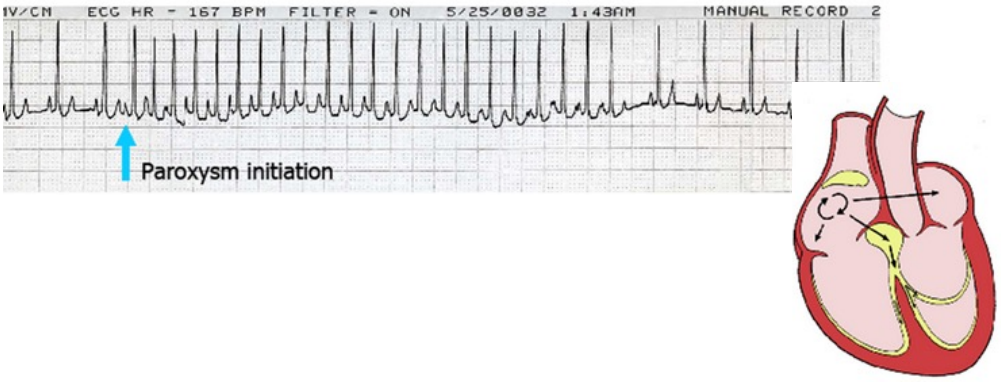
1. Form of reentry tachycardia that utilizes the anatomy of the right atrium to sustain a loop of continuous depolarization.
2. ECG characteristics:
    a. Rapid regular rhythm; may be irregular.
    b. Saw tooth undulation of the baseline (flutter waves).
    c. Atrial rate usually > 300 BPM.
    d. Normal appearance of QRS complexes.

Atrial Fibrillation with conduction abnormality

No P waves

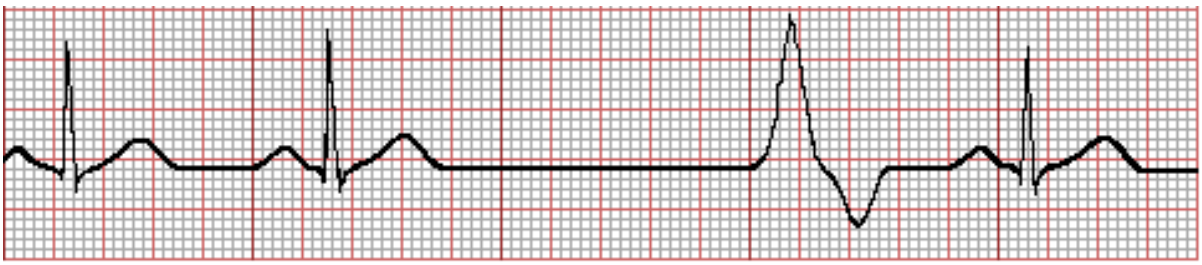
Irregularly irregular R-R interval

Supraventricular Tachycardia

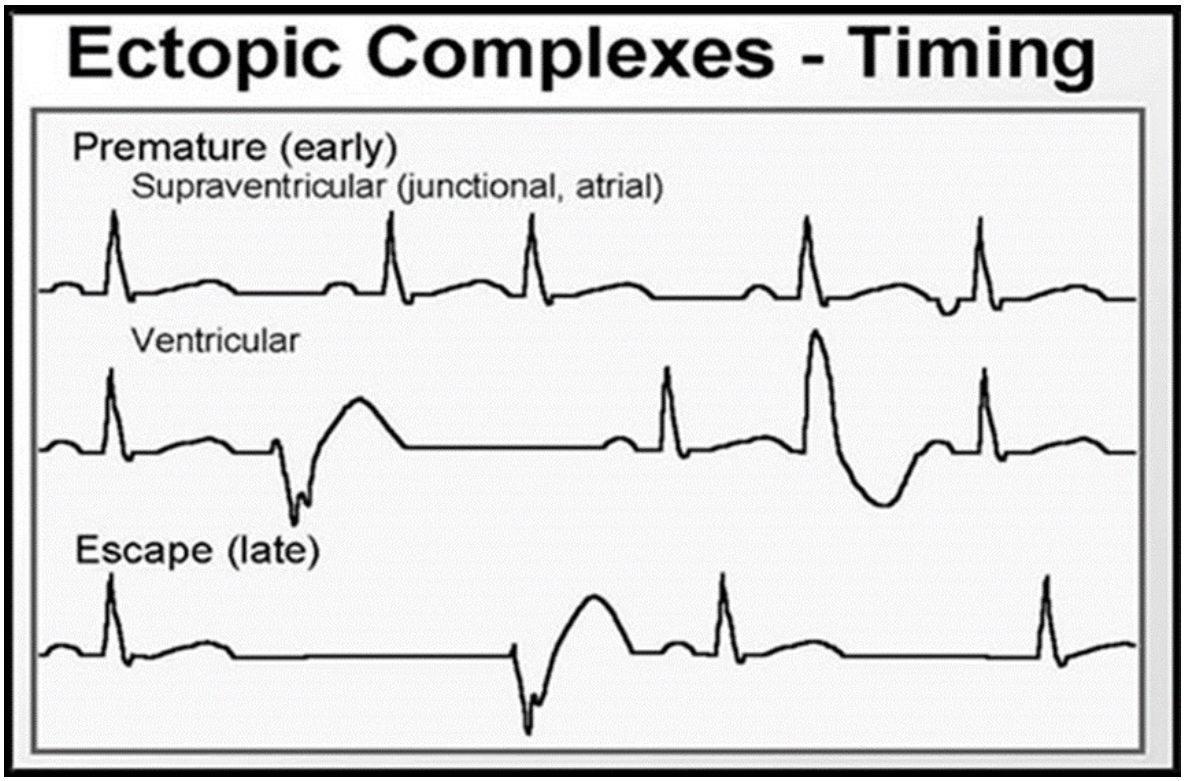


1. Abnormal rhythm originating from an ectopic focus above the ventricles.
2. ECG characteristics:
    a. Ectopic P waves are different in morphology from sinus P waves.
    b. The QRS complexes appear normal because they are supraventricular in origin

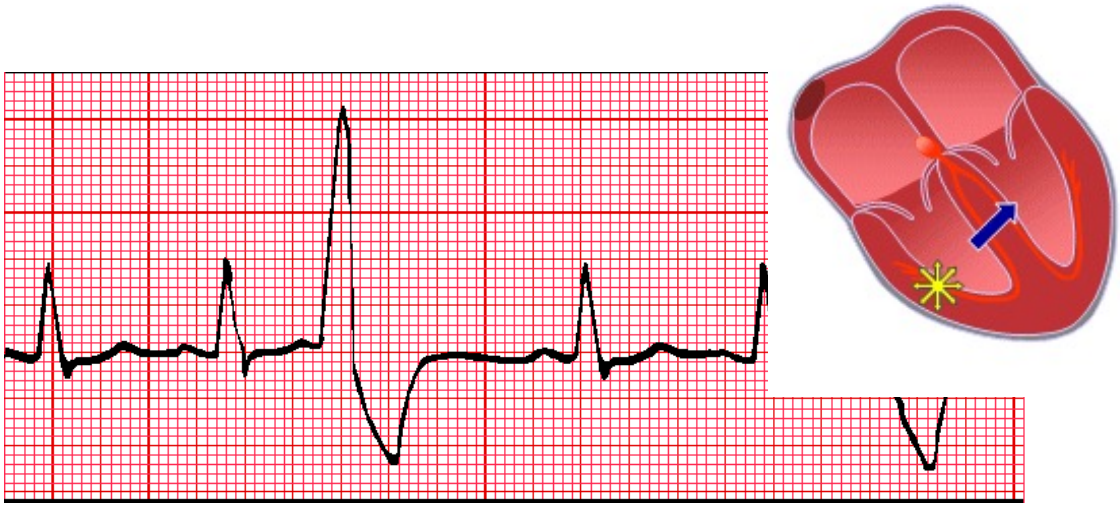
Sinus Arrest with Ventricular Escape Beats



- Abnormal or ectopic impulses are described based on:
    - Their **site of origin** (atrial, junctional, supraventricular, ventricular)
    - They are also characterized by **timing**, that is, whether they occur earlier than the next expected sinus impulse (**premature**) or whether they occur late (**escape**), as a rescue mechanism.



Ventricular Premature Contractions

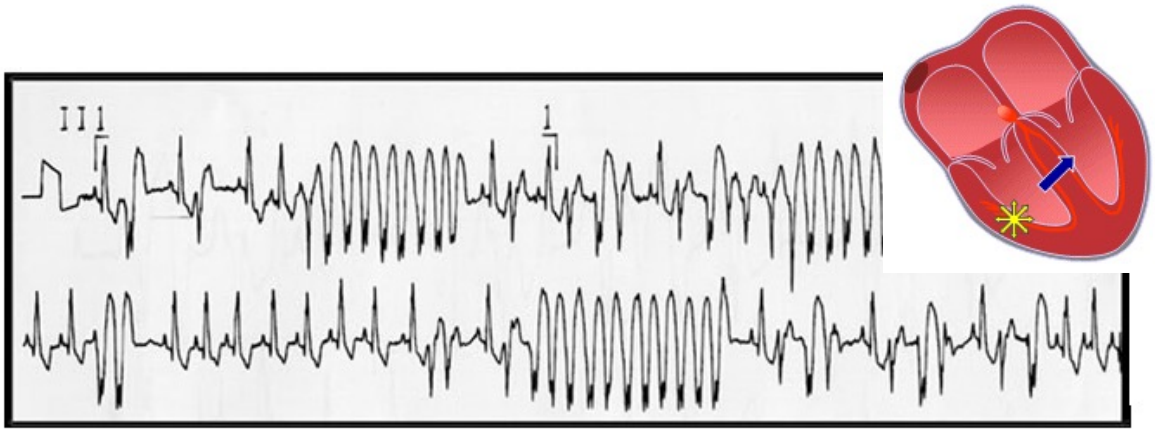


Ectopic impulses that originate in the ventricles (distal to the His Purkinje system).

ECG characteristics:

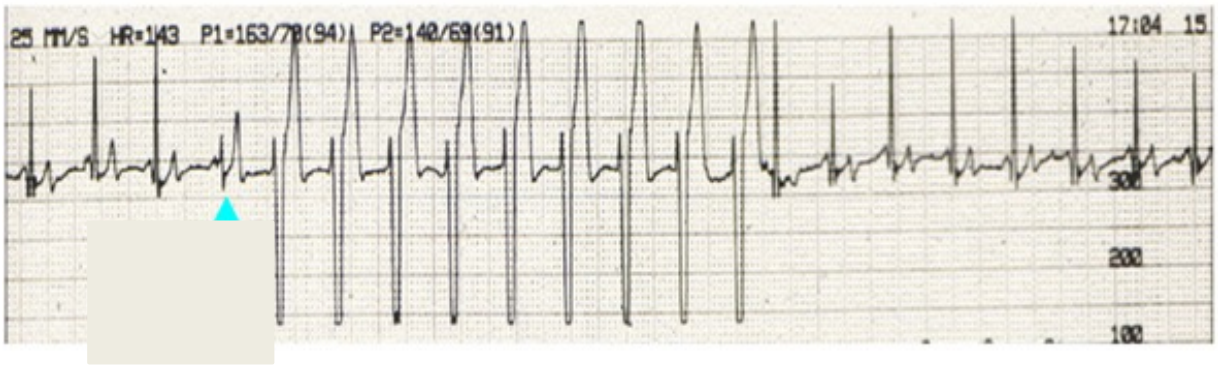
a. Abnormal wide QRS complexes occurring early.
b. No associated P wave.

Ventricular Tachycardia



- Rapid series of VPCs (≥180 beats/minute in the dog)
- The R-R interval is usually regular, although some variation is not uncommon.
- Sinus P waves may be seen superimposed on or between the ventricular complexes
    - When the configuration of VPCs is consistent, the complexes are described as being uniform/unifocal/monomorphic.
    - When the VPCs have differing configurations, they are said to be multiform/polymorphic.

Accelerated Idioventricular Rhythm (AIVR)



Accelerated Idioventricular rhythms are ventricular ectopic rhythms (faster than a ventricular escape rhythm of 20-40bpm) that depolarize at a rate similar to the sinus rate (100-160bpm).

- These rhythms are often seen in hospitalized patients with severe metabolic derangements, but they often do not have underlying primary cardiac disease.
- It is commonly observed in dogs following gastric dilatation-volvulus surgery, in dogs with severe trauma or metabolic disease, etc...
- Tend to be monomorphic

Ventricular Fibrillation

1. Ventricular fibrillation (VF) is an irregular, chaotic rhythm in which there is no effective ventricular contraction.
2. Ventricular fibrillation is always a terminal rhythm if not successfully defibrillated.
3. ECG characteristics:
    a. Chaotic and irregular deflections of varying amplitudes.
    b. No P--waves, QRS complexes, or T waves are observed.

Table 27-1. Arrhythmia characteristics

Rhythm	P wave rate (bpm)	P wave rhythm	P wave configuration	QRS complex rate	QRS complex rhythm	QRS configuration	P-QRS relationship
Sinus	Normal	Regular	Normal	Same as *P*	Regular	Normal	1:1
Sinus bradycardia	<Normal	Regular	Normal	Same as *P*	Regular	Normal	1:1
Sinus tachycardia	>Normal	Regular	Normal	Same as *P*	Regular	Normal	1:1
Sinus arrhythmia	Normal	Irregular	Normal or wandering	Same as *P*	Irregular	Normal	1:1
Supraventricular tachycardia	>Normal	Regular	Positive, negative, absent, or buried	Same as *P*	Regular	Normal	1:1
Atrial flutter	>350	Regular	Positive (sawtooth)	Less than *P* wave rate	Regular or irregular	Normal	More Ps than QRSs
Atrial fibrillation	>500	Irregular	None to baseline undulation (f waves)	Less than *P* wave rate (100-280)	Irregular	Normal	No *P* waves; more undulations than QRSs
Accelerated idioventricular rhythm	Normal	Regular	Normal (often buried in QRS)	70-150	Fairly regular; may be irregular	Wide	Dissociated; more QRSs than Ps
Ventricular tachycardia	Normal	Regular	Normal (often buried in QRS)	150-350	Regular or irregular	Wide	Dissociated; more QRSs than Ps
Ventricular flutter	Normal	Regular	Not discernible	>350	Regular	Sine wave	Dissociated; more QRSs than Ps
Ventricular fibrillation	Normal	Regular	Not discernible	>400	Grossly irregular	No QRS complexes	Dissociated; no QRSs
Second-degree AV block	Normal	Regular	Normal	<*P* wave rate	Irregular	Normal or wide	More Ps than QRSs
Third-degree AV block	Normal	Regular	Normal	20-60	Regular	Normal or wide	Dissociated; more Ps than QRSs; irregular P-R interval