ECG Recording, Interpretation and treatment for commonly occurring arrhythmias in Large Ruminants

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Introduction

Electrocardiography is the simplest form of recording and evaluating the electrical activity of heart.

It is used primarily for assessing the cardiac functions, diagnosis of various cardiac diseases and to determine the therapeutic considerations.

(Radostits et al. 2010)

Advantages

- ✓ Non Invasive
- ✓ Simple procedure
- ✓ Economical
- ✓ Used to evaluate electrolyte disturbance

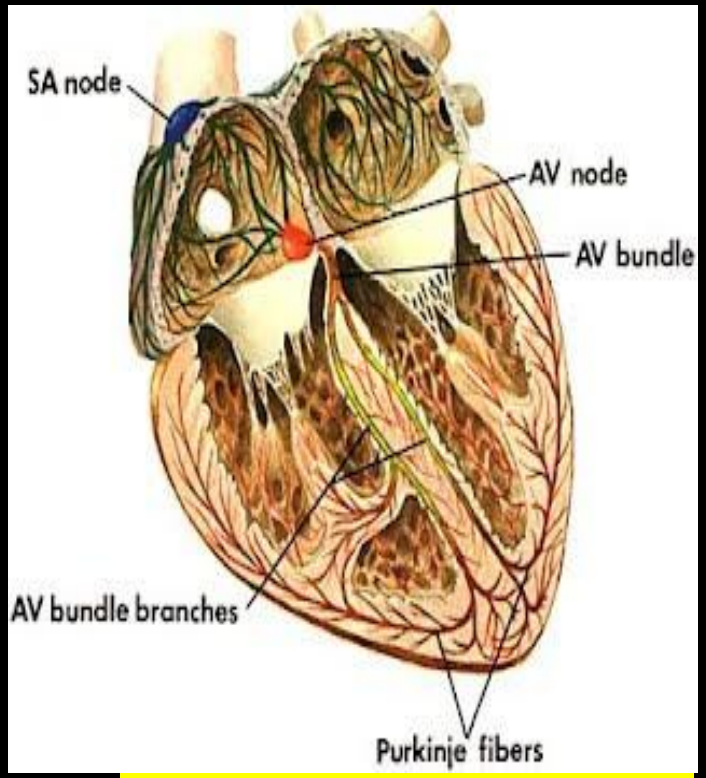
Disadvantages

- ✓ Not of prognostic value
- ✓ Chamber measurement not possible

Cannot be used for Chamber measurement

- Due to complete penetration from endocardium to epicardium by the Purkinje fibers, depolarization of both ventricular free walls occurs explosively in many directions.

- This period of ventricular activation is responsible for the electrocardiographic criteria that indicate ventricular enlargement in small animals but contribute little to generating the QRS complex of large animals.



http://www.cardio-research.com/

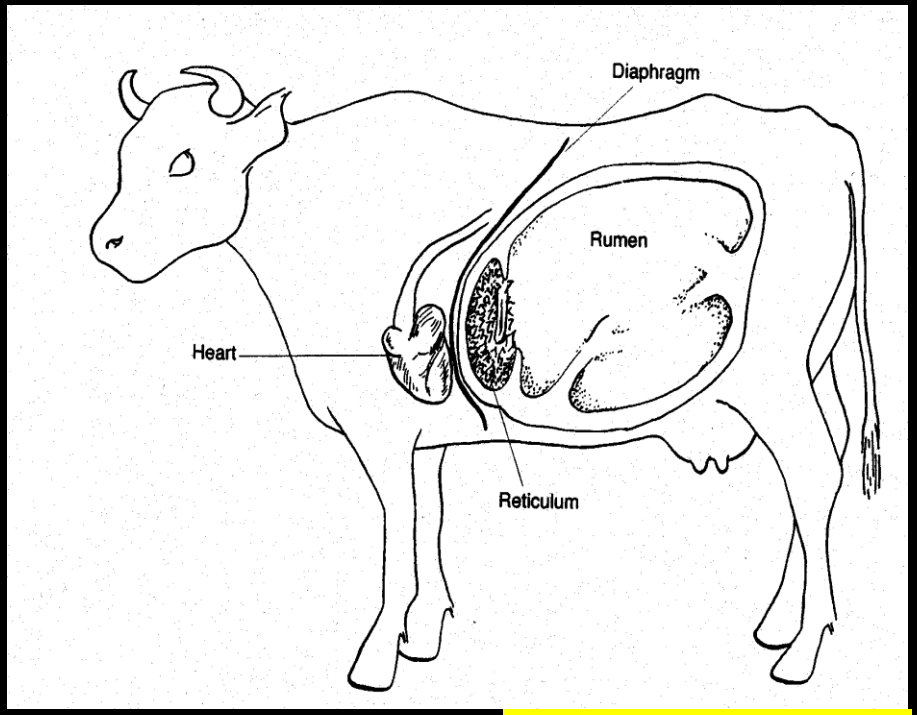
- Purkinje fibres are distributed through out the myocardium leading to cancellation of wave fronts.

- Hence, unlike small animals ECG is not useful for studying cardiac hypertrophy or myocardial abnormality in large ruminants.

Anatomical Location and Cardiac axis

- Bovine heart is located vertically in thoracic cavity and 5/7th of heart is situated in left of the median plane.
- Direction of cardiac axis in cattle (Negative) is different from small animals (Positive).
- Theoretical axis runs from the vicinity of cervical scapular angle in the regio prescapularis to the regio apices

(Norr and Johannes, 1921)



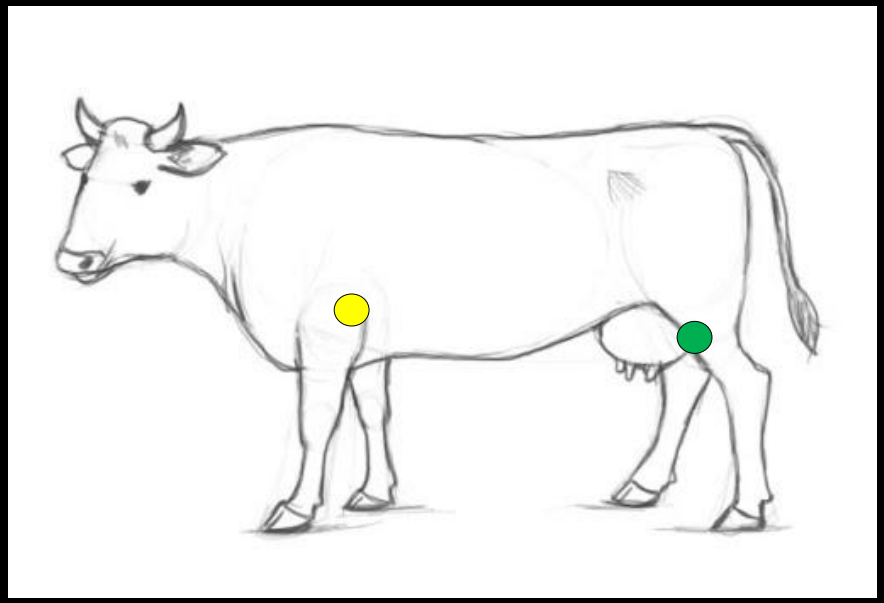
https://ag.arizona.edu/

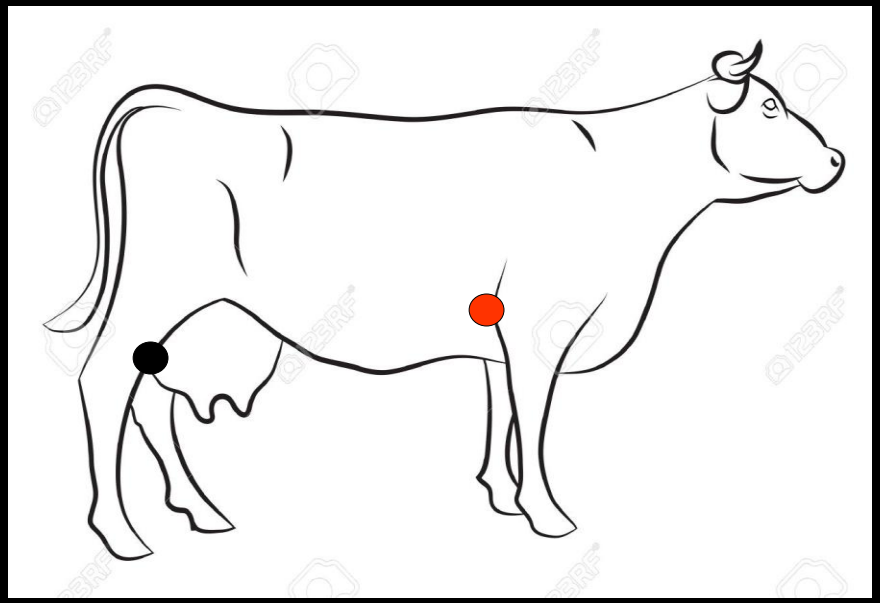
Lead System

- The primary focus of ECG recording is to detect arrhythmias, hence the lead selected should generate distinct P, QRS and T complexes.
- The lead system should be easy to apply, and the tracing free of artifacts created by muscle tremors, skin movement, shifting of weight, and changes in limb position.
- No single electrocardiographic lead system has been universally accepted for use in large ruminants.
- Bipolar limb leads (I, II, III), unipolar leads (aVF aVR, aVL) and precordial chest leads (CV6LU, CV6LL, CV6RU, CV6RL) have been described in large ruminants.

Bipolar limb leads in Einthoven Triangle

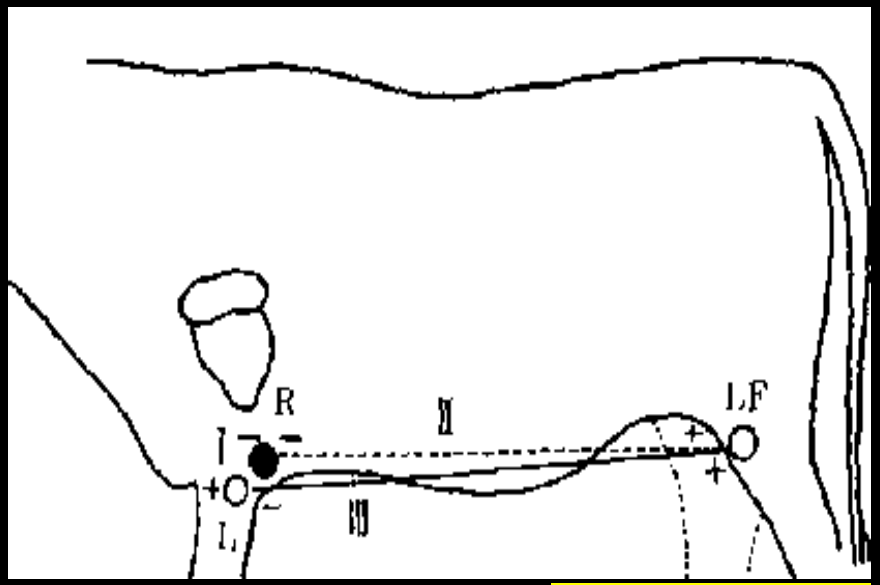
- The right and left armed electrodes will be attached proximal to olecranon process on the caudal aspects of the appropriate fore legs, whereas hind leg electrodes will be attached over stifle joint on the anterior aspects of appropriate hind legs.





Lead I: Left Fore Limb (Positive) – Right Fore Limb (Negative)
Lead II: Right Fore Limb (Negative) – Left Hind Limb (Positive)
Lead III: Left Fore Limb (Negative) – Left Hind Limb (Positive)

Bipolar limb leads in Einthoven Triangle



(Too *et al.*, 1959)

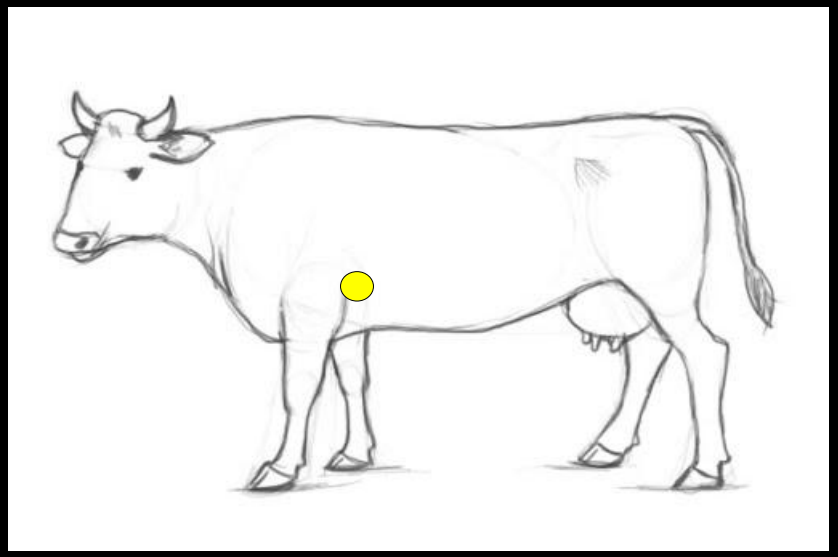
Drawbacks:

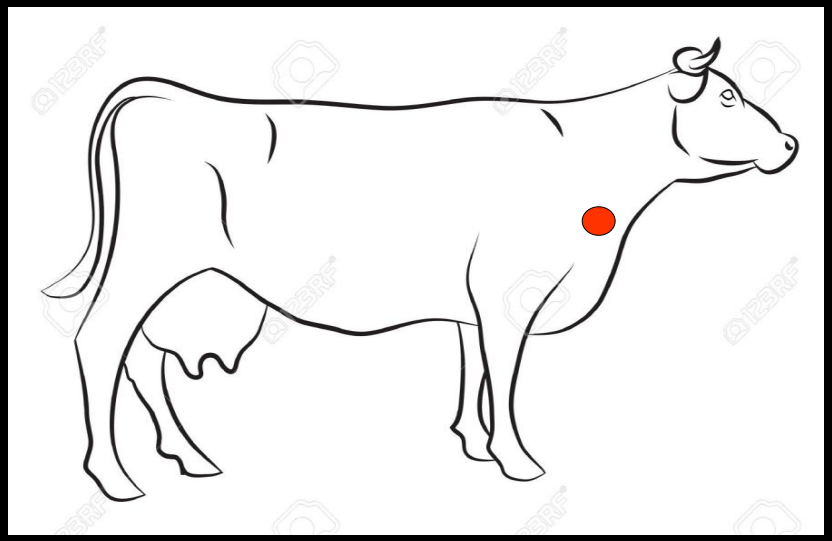
- As the position of electrodes is far from the position of heart in thoracic cavity, major electrical activity of the heart will not be recorded. Hence, the ECGs recorded using the limb leads in cattle have low polarities.

- Movement of the animal affects the recording of cardiac potential, hence there will be great variability in recorded waveforms.

Base Apex Lead System

- Positive electrode of Lead I will be placed on the left side at 5th Inter costal space just posterior to the olecranon and negative electrode in jugular furrow on right side about the level of the lower 1/3 of the neck.





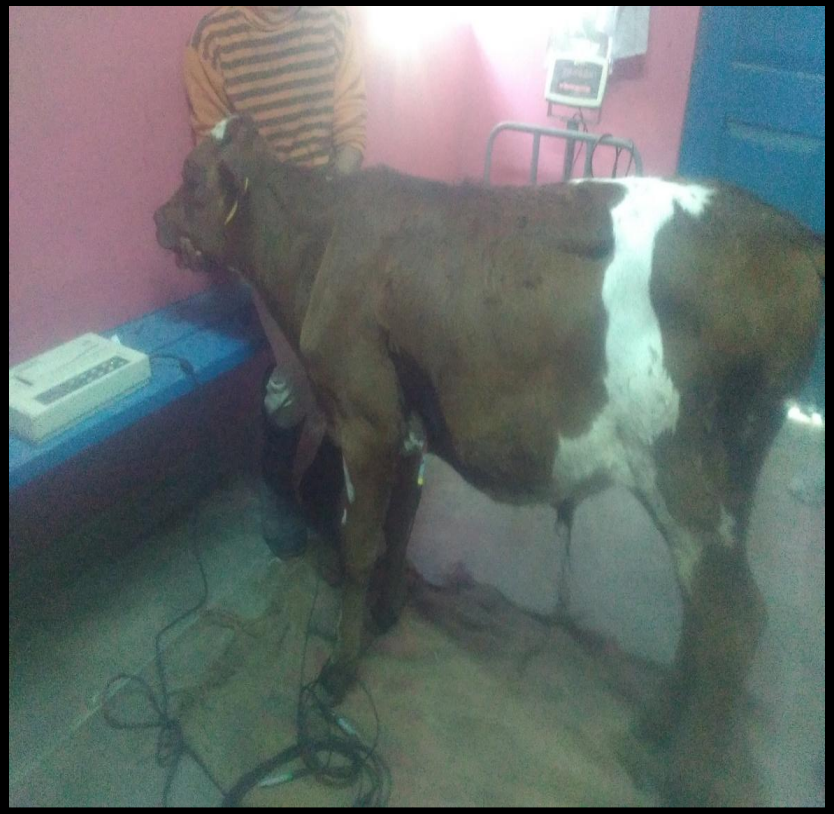
- Base apex lead has clear and large waves and complexes and animal movement has a minimum effect on the recording. Hence, this lead system is used widely in clinical practice.

Procedure of ECG Recording

- Electrocardiogram is recorded in a calm and quite surroundings using electrocardiographic machine at a paper speed of 25 mm per second and amplitude of 1 mV per 10 mm.

- Position: ECG is recorded in standing position by placing the rubber / insulation mat underneath.

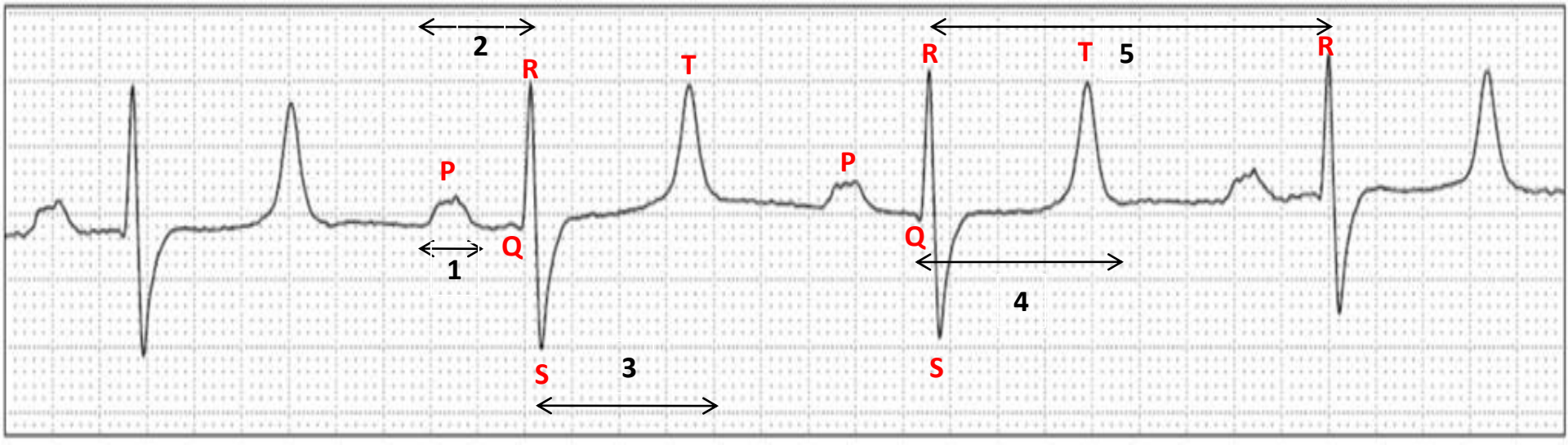
- Flattened alligator / crocodile clips are used for ECG recording.



- Sites of application are prepared by shaving and cleaning with alcohol. Gel is applied liberally on the areas of attachment of electrodes.

Configuration of waves

- Electrocardiogram of ruminants is having “P,” “QRS,” and “T” complexes, P-R interval, S-T interval, Q-T interval, and R-R intervals as also seen in other animals.



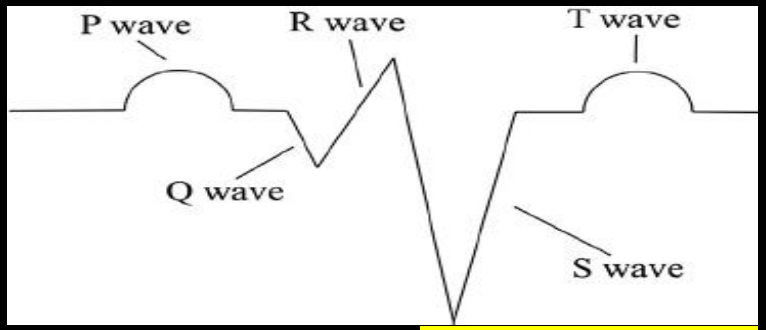
1: P Duration→ Beginning to the end of ‘’P’’ wave
2: PR Interval → Beginning of the ‘’P’’ wave to the beginning of ‘’R” wave
3: ST Interval → Beginning of the “S” wave to the end of the ‘’T” wave
4: QT Interval → Beginning of the ‘’Q’’ wave to the end of the ‘’T” wave
5: RR Interval → Time interval between two consecutive ‘’R’’ waves

Configuration of waves

P Wave: P wave represents the electrical activity through the atrial musculature after Sino atrial node discharge i.e., it indicates **atrial depolarization .** It may be round, peaked or isoelectric in appearance.

PR Interval: PR interval is isoelectric and indicates conduction delay at the AV node.

Ta Wave: Electrical activity developed during atrial repolarisation give rise to Ta wave and is usually buried into QRS complex and escapes identification.



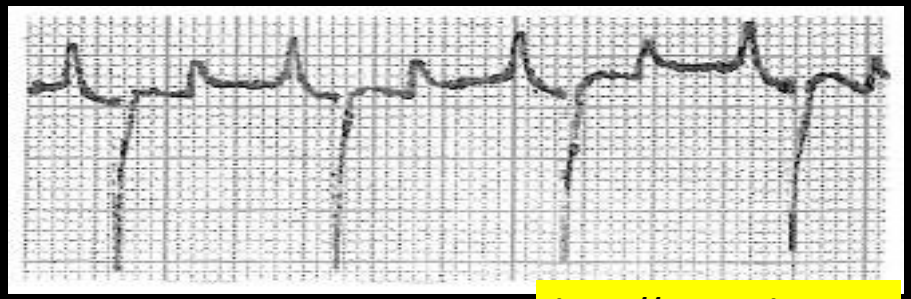
(Tiusanen *et al.*, 2015)

QRS Complex: It is produced by an electrical disturbance spreading through the ventricle. QRS complex is negative in large ruminants and indicates ventricular depolarization. It is measured from the beginning of the Q wave or the R wave to the end of the last R or S wave. The first downward deflection in QRS complex is labeled **Q**, the first upward **R**, while the second downward deflection is labeled **S**.

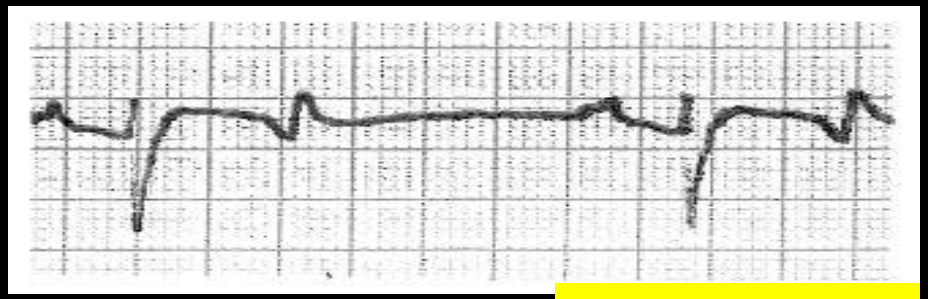
Configuration of waves

Types of QRS Complex:

In the absence of an R deflection the QRS complex would be represented by a single downward deflection; here the descending limb is labeled Q, the ascending limb S, and the wave QS type.

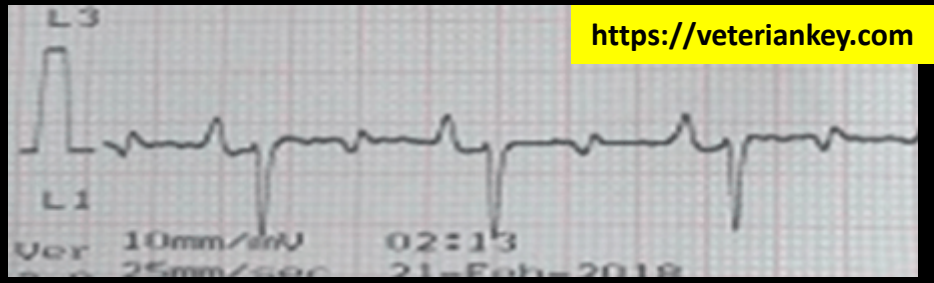


If R wave is prominent, the descending limb is labelled R, the ascending limb S and the wave RS type.



T Wave: Electrical activity generated during ventricular repolarisation give rise to T wave. It may be positive, negative or biphasic in nature.

Positive T wave



Biphasic T wave

ECG Interpretation

- Assess the quality of the recording and the sufficiency for accurate diagnosis.
- In order to avoid errors, the evaluation of the ECG recording should be performed in a methodical manner.
- The heart rate, heart rhythm, the correlation between P waves and QRS complexes, the morphology of P waves and QRS complexes and the duration of the different complexes and intervals should be evaluated.
- Heart rhythm should be assessed to determine whether it is regular or irregular although small deviations in the RR interval are physiological. If irregularities are present, their nature should be investigated: are they intermittent or persistent, do they occur at random or do they follow a possibly predictable pattern, are they induced or terminated by any form of excitement .
- The final step is to assess the morphology and duration of the different waves, and the relation between waves. Each complex should have the same morphology. Each P wave should be followed by a QRS complex and each QRS complex should be preceded by a P wave.

Arrhythmias

Abnormality in the rate, rhythm, or site of origin of the cardiac impulse and disturbance in conduction of the impulse such that normal sequence of activation of the atria and ventricles is altered.

Classification of Arrhythmias

- Physiological
- Pathological

Arrhythmias arising due to electrolyte imbalances

- ✓ Hypocalcaemia (Milk fever)
- ✓ Hyperkalemia

✓Abnormalities of impulse formation

- ✓ Supraventricular
- ✓ Junctional
- ✓ Ventricular

✓Abnormalities of impulse conduction

- ✓ Sinoatrial block
- ✓ Atrial standstill
- ✓ AV block (first degree, second degree, third degree)

Classification of Physiological Arrhythmias

- ✓ Sinus arrhythmia
- ✓ Sinus tachycardia
- ✓ Sinus bradycardia
- ✓ Sinus arrest
- ✓ Wandering sinus pacemaker

Classification of Pathological Arrhythmias

✓Abnormalities of impulse formation

- ✓ <u>Supraventricular</u>
  Atrial premature complexes (APC'S)
  Atrial tachycardia
  Atrial fibrillation

- ✓ <u>Junctional</u>
  AV junctional premature complexes
  AV junctional tachycardia
  AV junctional escape rhythm

- ✓ <u>Ventricular</u>
  Ventricular premature complexes
  Ventricular tachycardia
  Ventricular fibrillation
  Ventricular asystole
  Ventricular escape rhythm

✓Abnormalities of impulse conduction

Sinoatrial block
Atrial standstill
AV block
(first degree, second degree, third degree)

Arrhythmias arising due to electrolyte imbalances

- ✓ Hypocalcaemia (Milk fever)
- ✓ Hyperkalemia

Physiological Arrhythmias

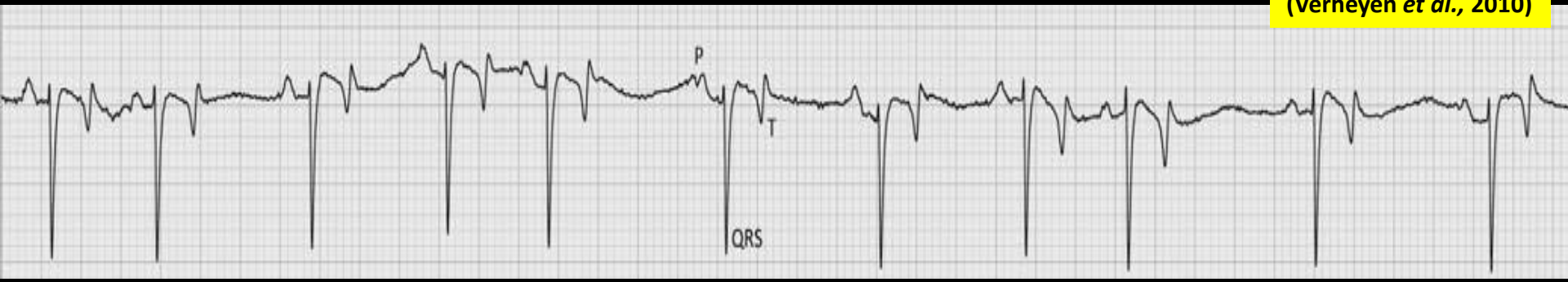
- ✓ Sinus arrhythmia
- ✓ Sinus tachycardia
- ✓ Sinus bradycardia
- ✓ Sinus arrest
- ✓ Wandering sinus pacemaker

Sinus Arrhythmias

- Sinus arrhythmia is a periodic waxing and waning of the heart rate usually caused by alterations in vagal tone.

- ECG Characteristics:
  - It is characterized by irregular RR intervals.
  - P-QRS relations are normal and QRS complexes always have a normal morphology.
  - Every P wave is followed by a QRS complex and every QRS complex is preceded by a P wave.
  - Shape of the P wave can be variable.

(Verheyen *et al.*, 2010)

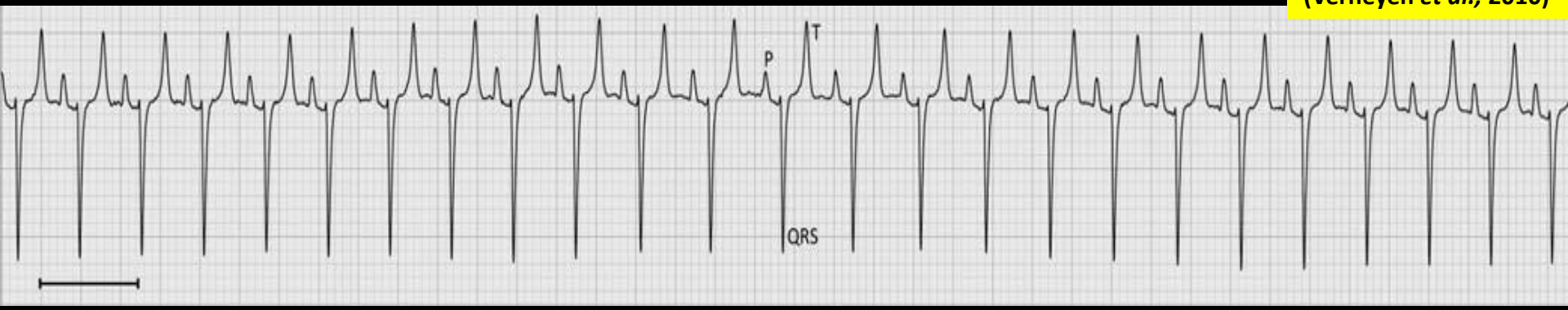


- Treatment: It is considered as normal variation, hence generally treatment is not required.

Sinus Tachycardia

- Sinus tachycardia originates from Sino atrial node and has normal sinus rhythm with higher heart rate.
- It is caused by an increase in sympathetic tone or a decrease in parasympathetic tone and can be a physiological response in order to increase cardiac output.
- It can be caused by excitement, fever, pain, hemorrhage, anemia, shock or heart failure.
- On ECG it is characterized by a resting heart rate above 80 bpm (in cattle), with regular RR intervals. The morphology, duration and relation of P waves and QRS complexes are normal. At higher rates, P waves may be masked by the preceding T wave

(Verheyen *et al.*, 2010)



- Treatment: treatment is given for underlying disease conditions.

Sinus Bradycardia

- Sinus bradycardia is decrease in heart rate caused by a decreased rate of discharge from the SA node.
- On ECG it is characterized by regular RR intervals, heart rate below 44 bpm. All waves and complexes have a normal appearance and the relation between P waves and QRS complexes is normal.
- Often sinus bradycardia is associated with sinus arrhythmia.
- Bradycardia will occur in association with an increase in arterial blood pressure, space-occupying lesions of the cranium and increased intracranial pressure, pituitary abscess, hyperkalemia, hypothyroidism, hypothermia, and hypoglycemia and following the administration of α-2-adrenergic agonists such as xylazine or detomidine.
- Bradycardia is sometimes associated with vagus indigestion and diaphragmatic hernia in cattle and also occurs in cattle deprived of food.

(Verheyen *et al.*, 2010)

- Animals with sinus bradycardia are often asymptomatic. Sometimes clinical signs of weakness, lethargy and syncope may accompany.

Sinus Bradycardia

- **Treatment:**
- The decision to treat sinus bradycardia should be based on clinical signs and the degree of bradycardia.
- In an animal with no clinical signs, sinus bradycardia may be “waited out” with close monitoring.
- If the animal appears unstable and pacemaker therapy is not an option, medical therapy aimed at abolishing high vagal tone can be attempted for temporary support.
- Patients showing partial or complete response to atropine response test may be candidates for medical management of sinus bradycardia.
- Treatment options include either a combination of a vagolytic drug (e.g., **probantheline bromide**: Pro-Banthine 0.25 to 0.5 mg/kg PO twice a day) and a sympathomimetic (e.g., **albuterol**: Proventil 0.02 to 0.05 mg/kg PO two to three times a day) or a phosphodiesterase inhibitor (e.g., **theophylline**; Theo-Dur 20 mg/kg PO twice a day).
- Medical therapy has adverse effects such as erratic and poor efficacy, anxiety, excessive panting, anorexia or other gastrointestinal signs.
- In patients experiencing syncope or episodic weakness, pacemaker therapy is indicated.

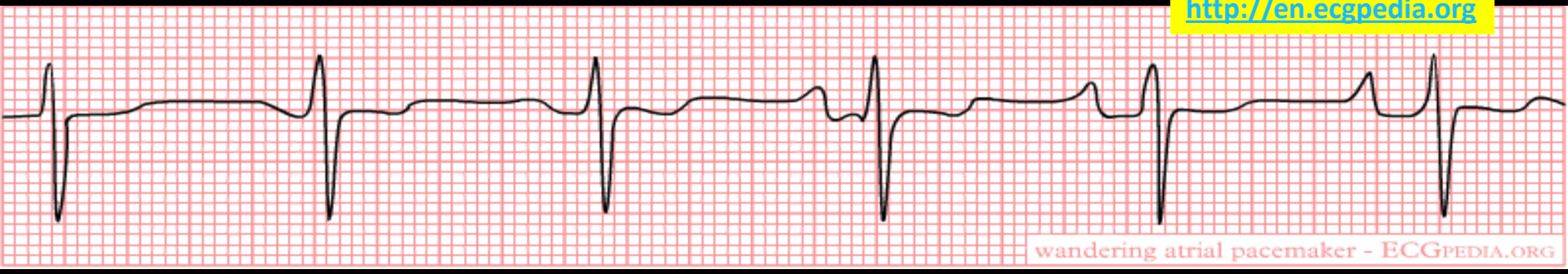
Sinus Arrest

- Sinus arrest is characterized by long pauses during which there are no P-QRS-T complexes.
- A high vagal tone is considered to interrupt with firing rate of the SA node causing sinus arrest. They are infrequent and rarely pathological. Usually it disappears during exercise and in rare cases, cardiac output can drop to such a low level that syncope can develop.
- Characteristic on the ECG is that the PP and RR intervals are greater than 2 normal PP or RR intervals.
- All other aspects of the ECG are normal: the morphology of P waves and QRS complexes is normal, every P wave is followed by a QRS complex and every QRS complex is preceded by a P wave.
- During a long pause however, a junctional or ventricular escape beat may occur on the ECG, appearing as QRS complexes with an abnormal morphology and duration, and no relation with a P wave

(Verheyen *et al.*, 2010)

Wandering pace maker

- A variant of sinus arrhythmia, in which there is a shift of the pacemaker within the SA node or from the SA to the AV node.
- ECG changes:
  - Gradual change in configuration of the P wave
  - P -R interval constant
  - QRS complexes are same
  - P wave becomes positive, diphasic, isoelectric, and negative.



- Might be caused by high vagal tone and is rarely pathological, hence does not require treatment.

Supraventricular Arrhythmias

- ✓Atrial premature complexes (APC'S)
- ✓Atrial tachycardia
- ✓Atrial fibrillation

Atrial premature complex

- Atrial premature contractions are early abnormal (ectopic) beats arising from atria.
- They are the most common arrhythmias occurring in cattle.
- APCs occur secondary to structural heart disease, systemic disease, myocarditis, trauma, anaemia, electrolyte imbalance or it can be a normal variation.
- In cattle, APCs are frequently associated with gastrointestinal disease in cattle.
- Hypervagotonia in gastrointestinal diseases will depress sinus node allowing subsidiary pacemakers to depolarize at a faster rate, resulting in ectopic atrial activation. In addition, hypervagotonia results in atrial heterogeneity due to non-uniform decrease in effective refractory period.
- ECG Characteristics:

  Premature P wave is present and its morphology can be normal or abnormal.

  Ectopic P wave may be superimposed on the preceding T wave.

  QRS morphology is identical or nearly identical to normal QRS.

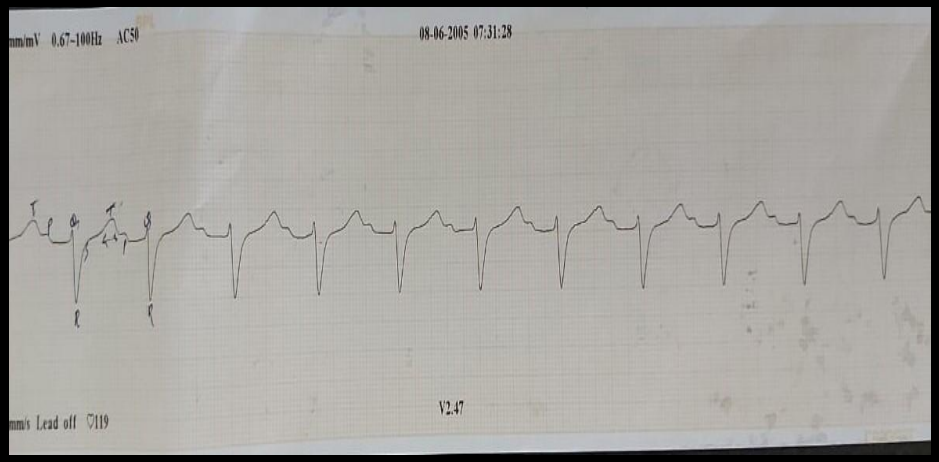
(Verheyen *et al.*, 2010)

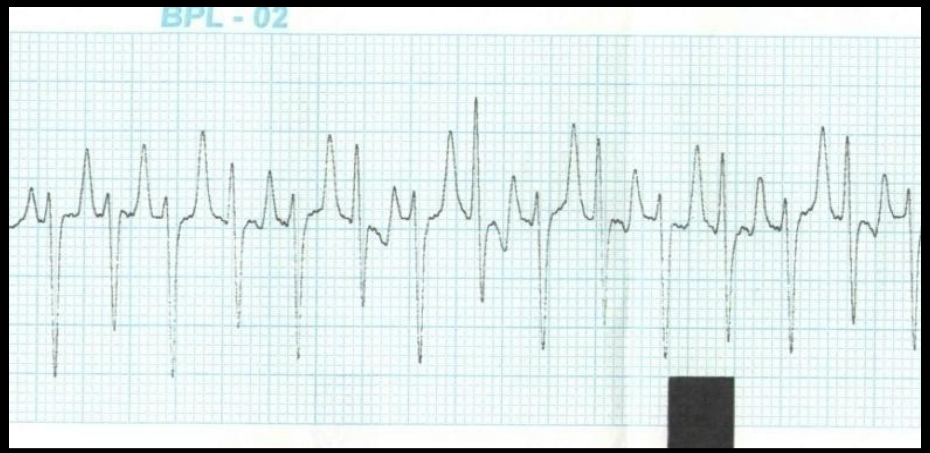
Atrial premature complex

- Single APCs will not result in any overt clinical signs. However, a run of APCs will generally result in signs of labored breathing, exercise intolerance, weakness and collapse. Surprisingly, some animals will be largely asymptomatic despite having a rapid sustained heart rate.
- Generally treatment of APCs consists of addressing primary causes.

Atrial Tachycardia (AT)

- When 4 or more than 4 APCs occur successively, it is known as atrial tachycardia.
- Atrial tachycardia is also known as supra ventricular tachycardia.
- Can be caused by underlying atrial myocardial disease, myocarditis, electrolyte disturbance, pulmonary disease or systemic disease.
- On the ECG, P' waves occur at an increased rate, they may show irregular rhythm and usually have abnormal morphology (Figure 1). At higher rates, P' waves are buried in the preceding T wave and become invisible (Figure 2). P' waves that conduct to the ventricles result in a QRS complex with normal morphology.





- It should be distinguished from sinus tachycardia.

Atrial Tachycardia (AT)

Atrial Tachycardia

- P waves occur at a speed of >200-300/min.
- P wave, if it is visible at all, typically has a different configuration and axis than that during sinus rhythm.
- Supraventricular tachyarrhythmias typically have an abrupt onset and termination.
- Vagal maneuvers are often ineffective.

Sinus Tachycardia

- Regularly occurring P waves (>50–60/min).
- P wave has normal configuration and axis.
- Sinus tachycardia has gradual initiation and termination of a rapid rhythm with regular R-R intervals.
- Successful vagal maneuver gradually slows the rate of sinus tachycardia.

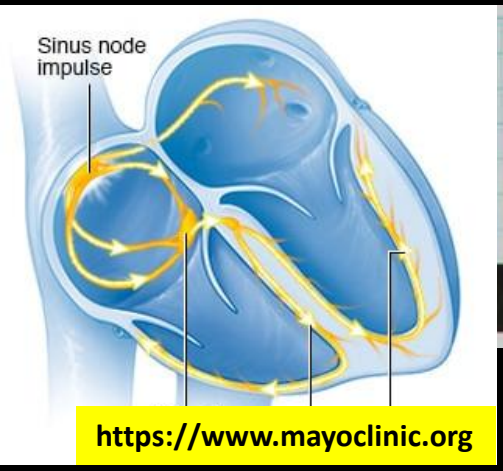
(Verheyen *et al.*, 2010)

Atrial Tachycardia (AT)

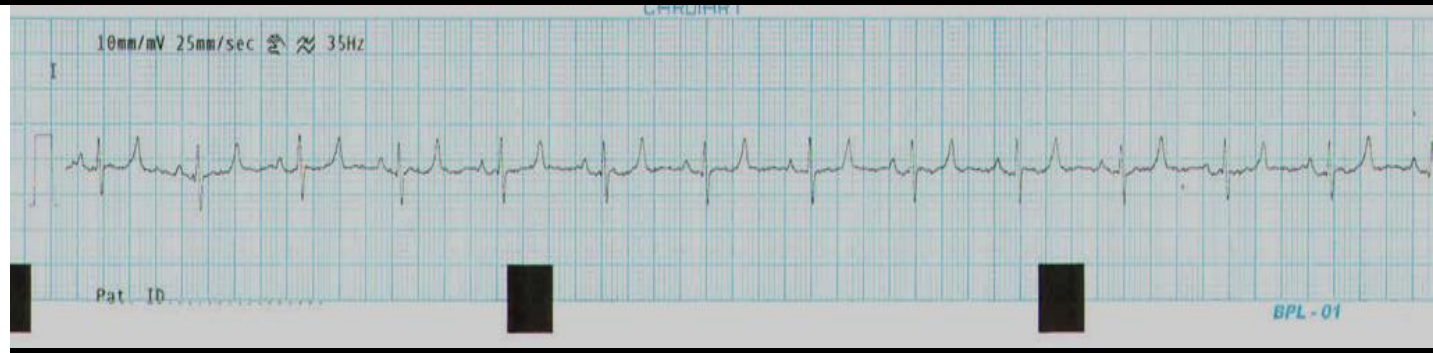
- Clinical Signs:
  - Signs of labored breathing, exercise intolerance, weakness and collapse. Surprisingly, some animals will be largely asymptomatic despite having a rapid sustained heart rate.
- Treatment consists of addressing any primary causes and when necessary, the addition of anti-arrhythmic medications. There are several anti-arrhythmics which may be used include beta blockers (such as sotalol, atenolol, carvedilol) and calcium channel blockers (diltiazem).

Atrial Fibrillation

- Atrial fibrillation (AF) is a cardiac arrhythmia which occurs when normal pacemaker activity and impulse formation in the atria are lost, and is replaced by numerous, erratic fronts of depolarization spread throughout the atrial muscle mass.
- Coordinated and rhythmic contractions of the atria are replaced by rapid quivering of the muscle and effective atrial pumping no longer occurs.



https://www.mayoclinic.org



Normal Sinus rhythm

https://www.mayoclinic.org

Atrial fibrillation

(Verheyen *et al.*, 2010)

Atrial Fibrillation

- Atrial fibrillation (AF) is the most commonly observed arrhythmia of cattle.
- AF has been reported to develop in cattle with a variety of disease conditions, the most common of which are gastrointestinal disturbances such as dysfunction of forestomachs or displacement of the abomasum. Other cases of AF in cattle may be induced by heart diseases such as myocarditis, valvular endocarditis or traumatic pericarditis. Ketosis, other electrolyte imbalances such as hypocalcaemia, hypochloremia, and hypokalemia are associated with AF.
- On ECG, Atrial fibrillation (AF) is characterized by the absence of P waves and the presence of fibrillation waves or f waves that occur with a frequency of between 300 and 600 beats/min. The morphology of the f waves varies from coarse to fine, often alternating within recordings.
- QRS-T complexes are normal in configuration but there is wide variation and no pattern in the R-R intervals. In case of very short RR intervals, the T wave will be opposite to the QRS complex, which might differ from the other T waves. Such a complex should not be mistaken for a ventricular premature beat.
- In the absence of underlying cardiac disease, the ventricular rate at rest is normal. During excitement or exercise, the heart rate easily surpasses the maximal heart rate.

Atrial Fibrillation

- Clinical Signs:
  - Usually there are no clinical signs of AF in cattle. Chronic anorexia, listlessness and marked reduced milk yield is observed in few animals.
  - On clinical examination irregular heart rhythm with varying intensity of heart sounds, increased heart rate and pulse deficit are noticed.

- Treatment:
  - Cattle with AF usually do not have detectable cardiac disease.
  - Treatment of AF usually consists of treating underlying disease condition followed by correction of acid-base and electrolyte balance.
  - If the cow is hypophagic or anorexic, it is advisable to provide oral potassium supplementation, such as 50 to 100 g of KCl daily.
  - In most cattle, atrial fibrillation resolves within 5 days of treatment.
  - If atrial fibrillation persists, treatment with quinidine sulfate intravenously is warranted.

Junctional Arrhythmias

- ✓ AV junctional premature complexes
- ✓ AV junctional rhythm
- ✓ Accelerated junctional rhythm
- ✓ Junctional tachycardia
- ✓ AV junctional escape rhythm

Atrio Ventricular junctional arrhythmias

- Junctional arrhythmia occurs when the electrical activation of the heart originates near or within the atrioventricular node, rather than from the Sinoatrial node.

- Causes:
  - When the electrical activity of the SA node is blocked or is less than the automaticity of the AV node/His bundle, a junctional arrhythmias originates. There are several disease conditions such as dioxin toxicity, electrolyte imbalance (hypokalemia), digitalis toxicity, cold water immersion etc., which decrease the electrical activity of SA node.

  - Other conditions such as myocarditis can also lead to junctional arrhythmias.

- Junctional arrhythmias are classified as
  - Junctional premature complexes
  - Junction rhythm: heart rate is 40 to 60 beats per minute
  - Accelerated junctional rhythm: heart rate is 60 to 100 beats per minute
  - Junctional tachycardia: heart rate above 100 beats per minute
  - Junction escape rhythm

ECG Characteristics of AV junctional arrhythmias

- As the electrical activation originates at or near AV node, the P wave is frequently not seen.

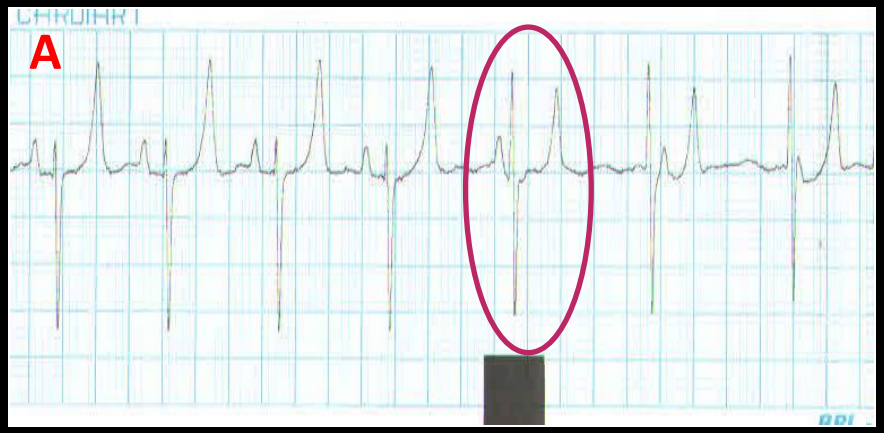
- Sometimes, abnormal electric impulses generated can spread backward (retrograde) through the atrium and/or forward (antegrade) to the ventricles leading to abnormal ‘P’ waves of different configuration.

- Because the normal ventricular conduction system (His-Purkinje) is used in junctional arrhythmias, the QRS complex is usually normal or near normal in appearance with shorter duration.

ECG Characteristics of AV junctional arrhythmias

- If antegrade and retrograde conduction are intact, a beat arising from the A-V junction produces both a retrograde P wave and QRS of supraventricular configuration. The timing of this retrograde P wave in relation to the QRS is dependent upon the site of origin of the impulse.

- A beat arising in the proximal A-V junction region is more likely to have a retrograde P wave preceding the QRS (Figure A), while a beat arising distally is more likely to have a retrograde P wave following the QRS (Figure B).



Junctional premature complexes

- Junctional premature complexes also known as junctional ectopics are premature cardiac electrical impulses originating from the atrioventricular node of the heart or junction.
- Junctional ectopics are much less common than premature atrial or ventricular contractions.
- On ECG, premature junctional contractions will appear as a normally shaped QRS complex, not preceded by any P wave or preceded by an abnormal P wave with a shorter PR interval. Rarely, the abnormal P wave can follow the QRS.
- Junctional ectopics will be followed by compensatory pause.

QRS complexes with black asterisks are junctional beats
(Note the absence of "P" wave and near normal appearance of QRS complexes)

- Usually no treatment is required and the rhythm reverts spontaneously, especially with correction of the underlying disorder.

Atrio Ventricular junctional rhythm

- Continuous presence of more than three JVPC is known as junctional rhythm.

- AV junctional rhythm should be differentiated from atrial tachycardia, sick sinus syndrome, slow atrial fibrillation.

- Treatment
  - Usually no treatment is needed and the rhythm reverts spontaneously, especially with correction of the underlying disorder.
  - If weakness or syncope is associated with a slow AV junctional rhythm, atropine, dobutamine, or isoproterenol may be used in an attempt to accelerate the sinus node to help regain function as the primary pacemaker.
  - If CHF is present with an enhanced AV junctional rhythm, administer digitalis.

Junctional escape rhythm

- A junctional escape beat is a delayed heartbeat originating from an ectopic focus in the atrioventricular junction.
- It occurs when the rate of depolarization of the Sinoatrial node falls below the rate of the atrioventricular node. This dysrhythmia also may occur when the electrical impulses from the SA node fail to reach the AV node because of SA or AV block. It can also occur following a premature ventricular contraction or blocked premature atrial contraction.

- ECG Characteristics:
  - Heart Rate is low
  - P waves: Depends on the site of the ectopic focus. They will be inverted, and may appear before or after the QRS complex, or they may be absent, hidden by the QRS.
  - QRS Complex: Usually normal in duration and morphology.
  - No relationship between the QRS complexes and any preceding atrial activity (e.g. P-waves, flutter waves, fibrillatory waves)
- Treatment:
  - Atropine, dobutamine, or isoproterenol may be used to accelerate the sinus node to regain it's function as the primary pacemaker.
  - If CHF is present with an enhanced AV junctional rhythm, administer digitalis.

Ventricular Arrhythmias

- ✓ Ventricular arrhythmias originate from the ventricular myocardium.
- ✓ **Morphology**: As the impulse conduction is different in ventricular myocardium and depend on cell to cell conduction, resulting QRS complexes will be of different morphology and longer duration.

If ectopic impulses involve partial conduction over the His bundle, resulting QRS complexes will be near normal in appearance and they should be differentiated from junctional rhythm.

Ventricular Arrhythmias

✓ **Causes:**

– Myocardial damage, systemic disease, hypoxia, acid–base or electrolyte
– disturbance, drugs, and toxicity.

✓ **Classification**:

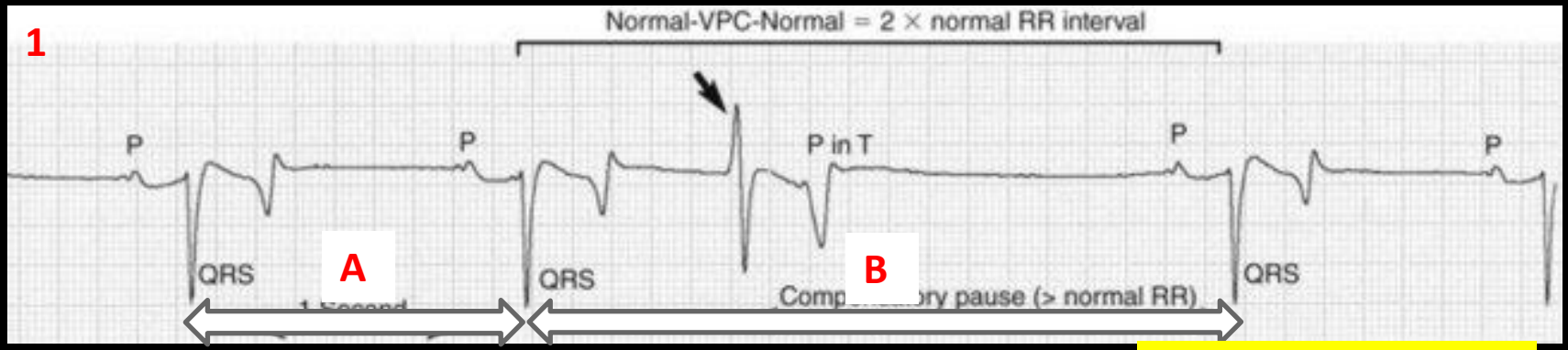
Ventricular premature complexes
Ventricular tachycardia
Ventricular fibrillation
Ventricular escape rhythm
Ventricular asystole

Ventricular Premature Complexes

- A ventricular premature complex (VPC) occurs when an abnormal electrical impulse originates within the ventricle. These abnormal impulses cause the ventricles to contract prematurely, before the completion of diastole.

- Usually VPCs are not conducted retrogradely to atria, hence the underlying sinoatrial nodal activity is not affected. To fall back into the underlying sinus rhythm, VPCs are followed by a compensatory pause.

- Compensatory pause means that the RR interval enclosing the VPC equals twice the normal RR interval (Fig 1).



Compensatory pause (B) = 2A

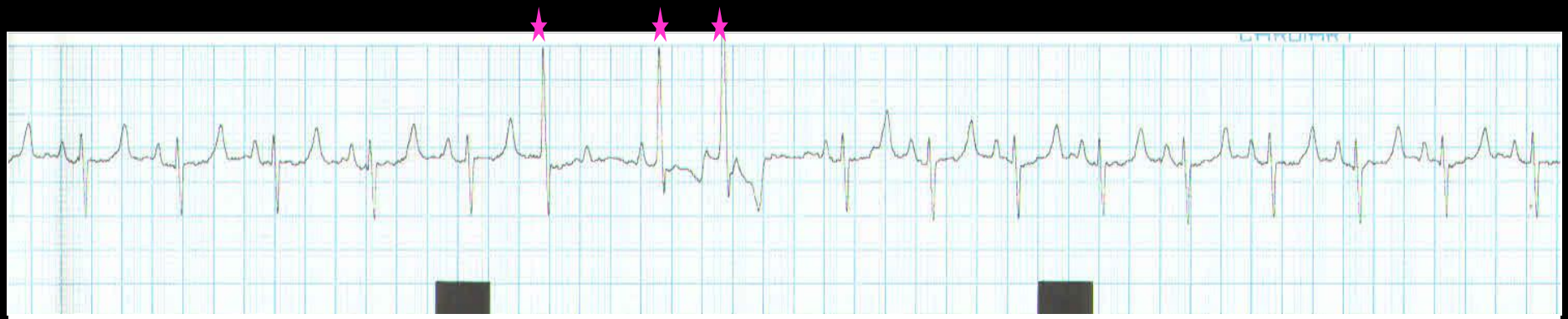
Ventricular Premature Complexes

- Occasionally, VPCs occur in between 2 normal beats (interpolated) without changing the underlying rhythm.

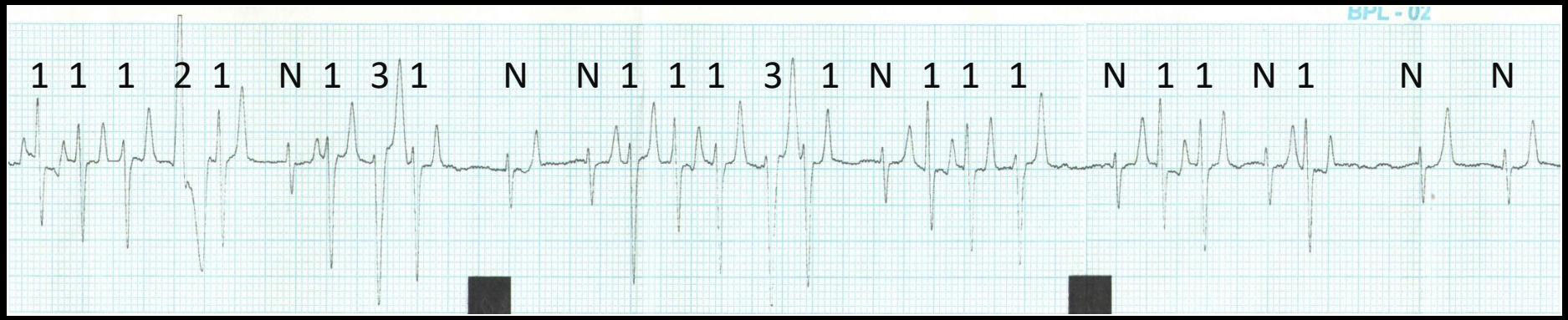
- ECG features
  - Broad QRS complex (≥ 120 ms) with abnormal morphology
  - Premature — i.e. occurs earlier than would be expected for the next sinus impulse
  - Discordant ST segment and T wave changes.
  - Usually followed by a full compensatory pause.
  - Retrograde capture of the atria will not occur usually.

Classification of VPCs

- Based on the origin of ectopic foci, VPCs are classified as unifocal (arising from a single ectopic focus; each VPC is identical) and multifocal (arising from two or more ectopic foci; multiple QRS morphologies).



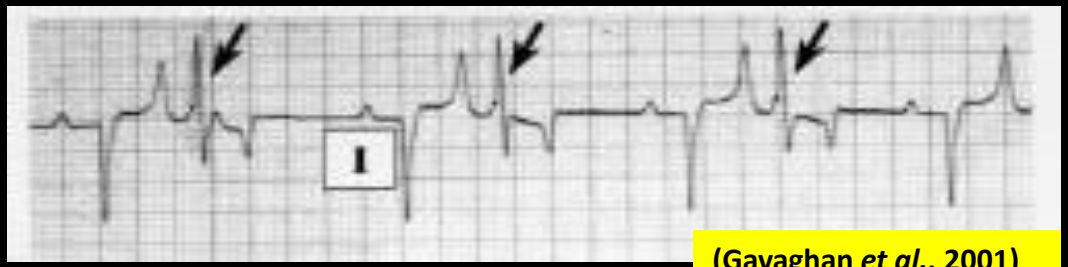
Electrocardiogram showing unifocal ventricular premature complexes; all the three VPCs have similar morphology★



There are three different types of VPCs i.e., multifocal (labeled with 1, 2 and 3) along with normal beats (labeled as N) in the above ECG

Classification of VPCs

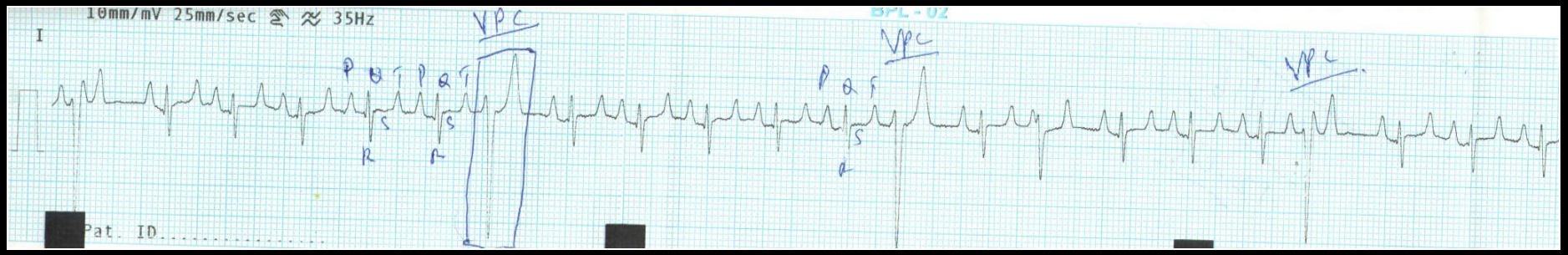
- Based on repeating patterns
  - Bigeminy: every other beat is a VPC



(Gavaghan *et al.*, 2001)

  - Trigeminy: every third beat is a VPC
  - Quadrageminy: every fourth beat is a VPC

  - Pentageminy: every fifth beat is a VPC
  - Hexageminy: every sixth beat is a VPC



Classification of VPCs

- Based on repeating patterns
  - Singlets- VPC conducted in single
  - Couplet s - two VPCs are conducted consecutively

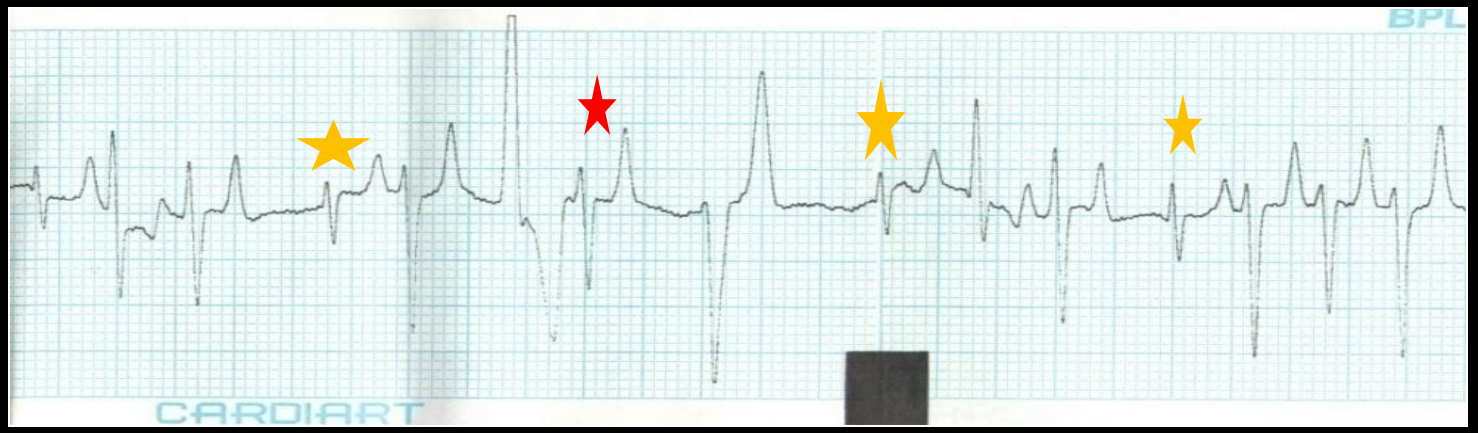
Couplets Singlet

  - Triplets – three VPCs are conducted consecutively

Triplets

Capture beat and Fusion beat

- Capture beat is a heart beat resulting from the production of ventricular complex from supraventricular region following a period of atrioventricular dissociation
- Fusion beat: A VPC that originates almost simultaneously with the normal ventricular depolarization. The morphology of this fusion beat is a mixture between the normal QRS and the VPC morphology.



Electrocardiogram showing multifocal ventricular premature complexes with capture and fusion beats (Capture beats and fusion beats are indicated by asterisk marks of golden yellow and red colour respectively) (Lead: Base apex, Paperspeed : 25 mm /sec, Sensitivity : 1 mV = 1 cm)

Ventricular Premature Complexes

Aetiology:

Ventricular myocardial disease (Myocardial inflammation, degeneration, or necrosis caused by bacterial, viral, parasitic infection), intoxication (cardiac glycosides, monensin), or neoplasia, electrolyte and metabolic disturbances, hypoxia, anemia, fever, toxemia, high sympathetic tone etc.

Clinical Signs:

- Anorexia, weakness, exercise intolerance
- Irregular rhythm on auscultation.
- The VPC may have an increased intensity of the first heart sound and is usually followed by a compensatory pause.
- Depending on the prematurity, a pulse deficit may be palpated.

Ventricular Premature Complexes

- **Treatment:**
  - Treat underlying systemic or cardiac disease.
  - Give adequate rest.
  - Corticosteroids such as dexamethasone are administered @ 0.05 - 0.2 mg/kg intravenously.
  - Antiarrhythmic drugs such as Lidocaine or Phenytoin are only administered in symptomatic or clinical cases.

Ventricular Tachycardia

- Presence of three or more consecutive VPCs in quick succession are termed Ventricular Tachycardia (VT).

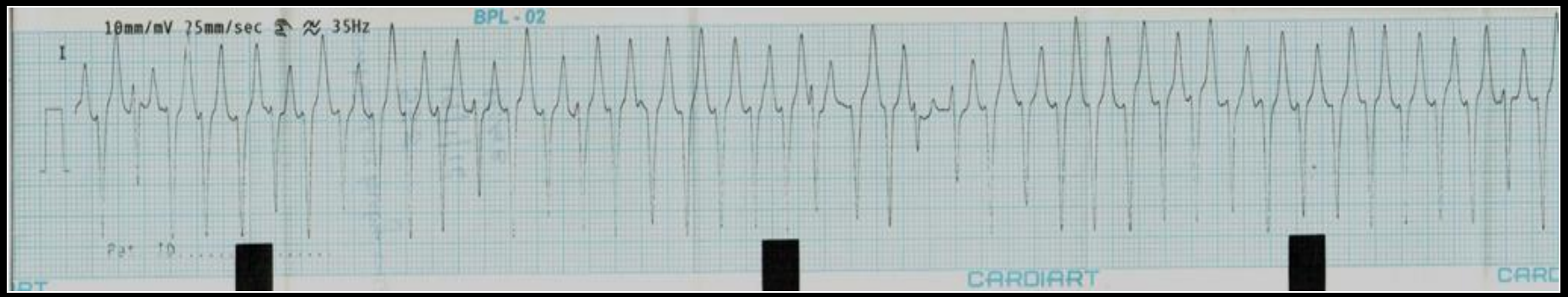
- **Classification:**

- Based on the rhythm
- Sustained VT: if rhythm persists for more than 30 secs
- Paroxysmal: if terminates spontaneously

- Based on the rate
- Benign VT (accelerated idioventricular rhythm): If the rate is slow
- Malignant VT: If the rate is fast

- Based on the morphology of QRS Complex
- Polymorphic or multiform: Presence of more than one ectopic QRS morphology (Figure 1)
- Monomorphic: Presence of only one type of ectopic QRS morphology (Figure 2)

Ventricular Tachycardia



ECG showing Sustained Ventricular Tachycardia

ECG showing Paroxysmal Ventricular Tachycardia (Red arrow shows the abrupt onset and termination of VT)

Ventricular Tachycardia

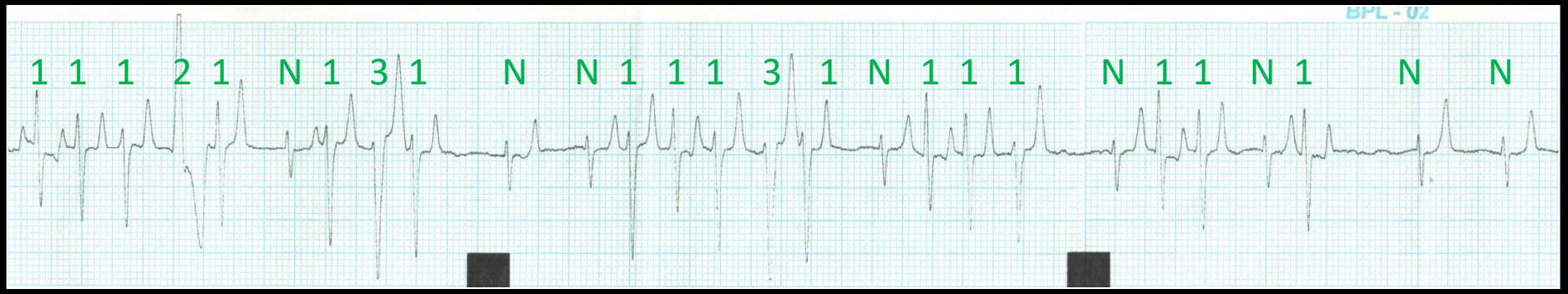
(Loon, 2018)

ECG showing Accelerated idioventricular rhythm; HR 68bpm

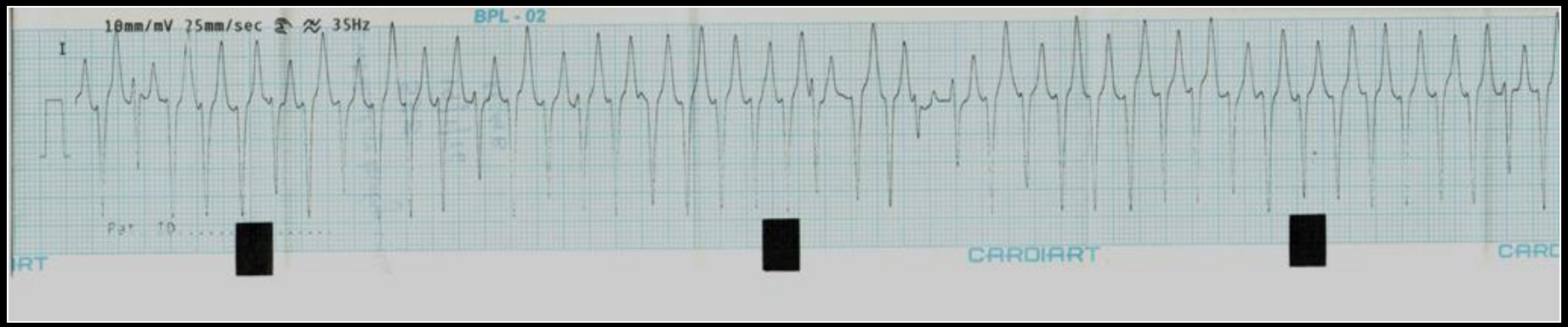
(Loon, 2018)

ECG showing Malignant Ventricular tachycardia; HR 180bpm

Ventricular Tachycardia



ECG showing Polymorphic Ventricular Tachycardia; Normal sinus beats are labelled as N and different foci of VPCS as 1, 2 and 3

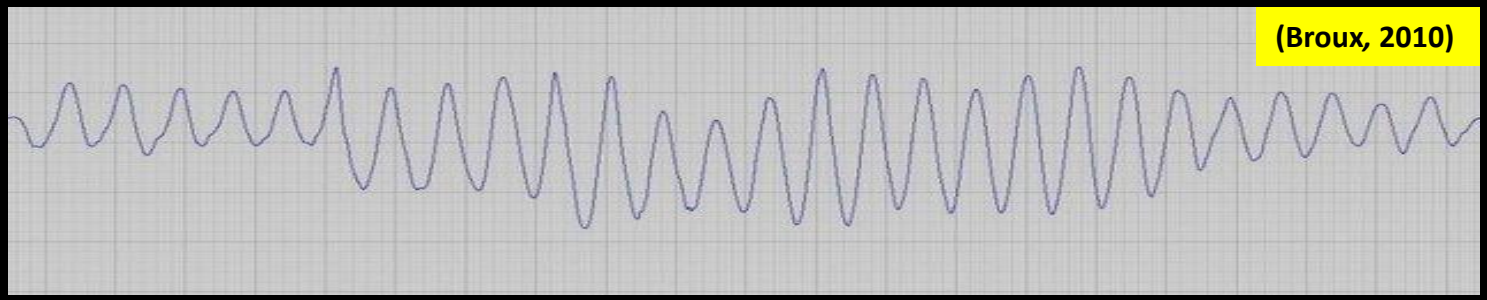


ECG showing Monomorphic Sustained Ventricular Tachycardia

Ventricular Tachycardia

- R-on-T phenomenon: It is an electrocardiographic diagnosis in which an ectopic QRS merges with the preceding T wave.

- Torsades de pointes: It is a type of wide complex polymorphic VT in which QRS complexes and T waves twist around the baseline of the ECG.



- R-on-T phenomenon and torsades de pointes represent an unstable electrical activity that can deteriorate to ventricular fibrillation and cardiac arrest.

Ventricular Tachycardia

- **Treatment:**

✓ Treatment of underlying disease condition
✓ Adequate rest
✓ Avoiding stress
✓ Antiarrhythmic drugs

– Lidocaine, a class IB sodium channel blocker, is most commonly used antiarrhythmic drug. It is given @0.25 to 0.5 mg/kg slow intravenous injection every 5 minutes up to 1.5 mg/kg followed by a constant rate infusion of 0.05 mg/kg/min.

Or

– Phenytoin has similar effects and is usually given @20 mg/kg orally twice a day for 2 days followed by 10 to 15 mg/kg twice a day.

Or

– Magnesium sulfate (2–6 mg/kg/min intravenously, up to a total dose of about 55–100 mg/kg) might be useful, especially to treat or avoid Torsade de pointes.

Or

– Other drugs to treat ventricular arrhythmias include procainamide and quinidine gluconate.

Ventricular Fibrillation

- Ventricular fibrillation (VF) is an irregular, chaotic rhythm of the ventricles in which there is no effective ventricular contraction.
- The ECG shows a fine to coarse zigzag pattern with no detectable P waves or QRS complexes .

ECG showing undulating baseline with no identifiable QRS complexes or T waves.

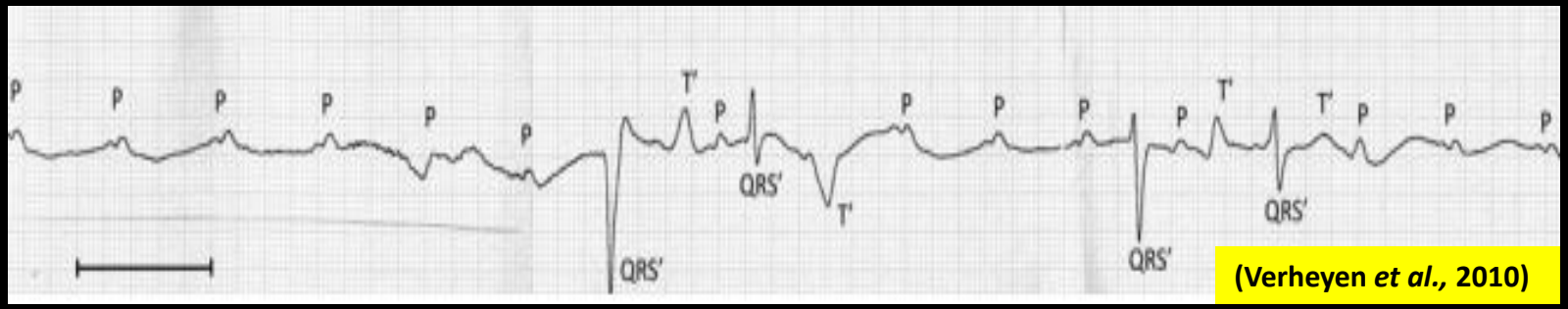
- Causes: It occurs in the terminal stages of most suddenly fatal diseases, including lightning stroke, poisonings, overdose with anesthetics, severe toxemia, and in the terminal phases of most acquired cardiac diseases.

- Clinical Signs: There is complete absence of the pulse and heart sounds, and the animal rapidly becomes unconscious and dies within a minute or two of onset.

- Treatment is usually impractical, although deaths during anesthesia may be prevented by immediate and aggressive external cardiac massage.

Ventricular escape rhythm

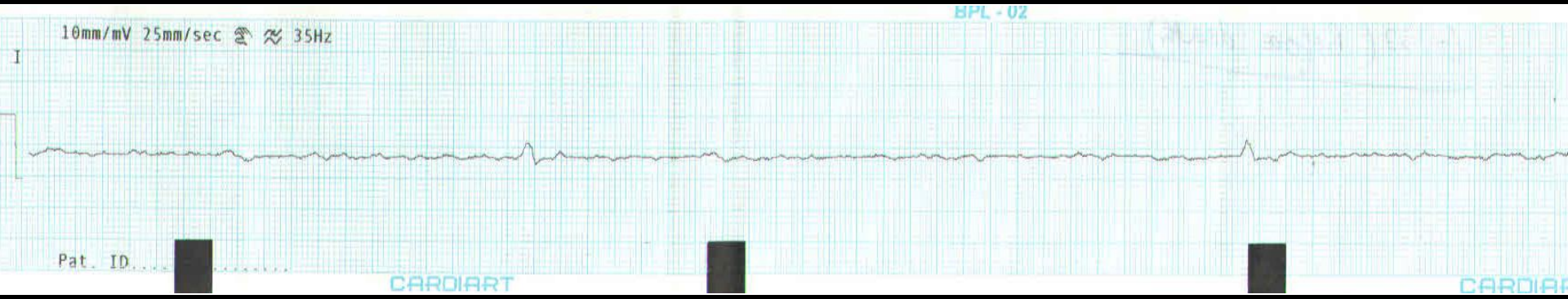
- Ventricular escape rhythm is a self-generated electrical discharge initiated by, and causing contraction of the ventricles of the heart.
- It occurs when the rate of electrical discharge reaching the ventricles falls below the basic rate due to underlying atrial or junctional disease resulting in bradycardia.
- An escape beat usually occurs 2–3 seconds after an electrical impulse has failed to reach the ventricles and can be said to “rescue” the ventricles from asystole.
- The ECG shows a longer than normal RR’ interval and the QRS’ complex has an abnormal morphology and duration. P wave can be absent, or is non-conducted with no correlation to the QRS’ complex. When escape beats arise in close proximity to the AV node, they may have a fairly normal appearance.



ECG showing Third degree AV block. Please note that first QRS Complex is an example of ventricular escape beat.

Ventricular Asystole

- Ventricular Asystole, colloquially referred to as flat line, represents the cessation of electrical and mechanical activity of the heart.
- It typically occurs as a deterioration of the ventricular arrhythmias such as ventricular fibrillation or ventricular tachycardia.
- It represents the terminal rhythm of a cardiac arrest.
- On ECG, P waves may be present if AV block exists, but no QRS complexes are observed.



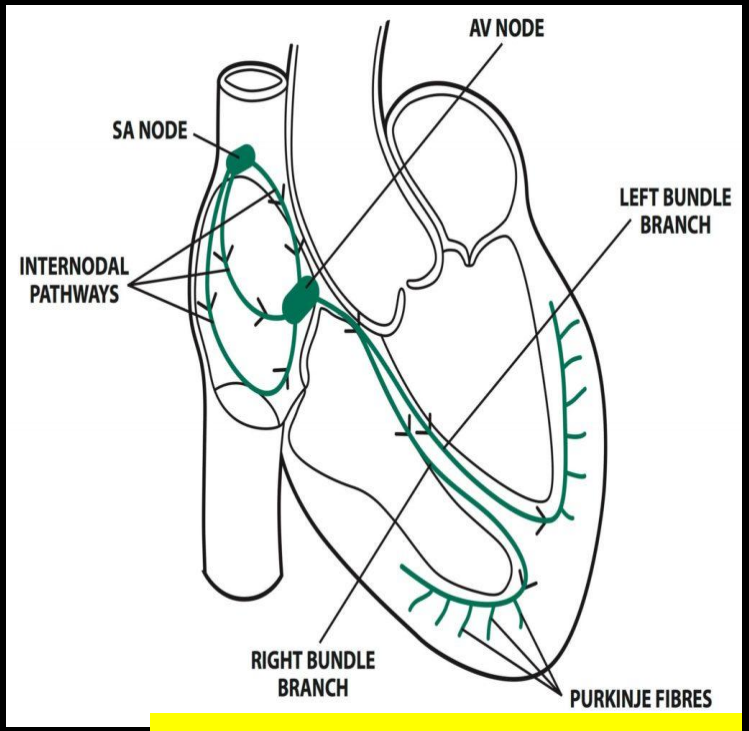
- Treatment: Intracardiac injections of epinephrine are often used in the treatment, but mortality rate is very high.

Abnormalities of Impulse conduction

- Abnormalities of impulse conduction are the disorders in which the generation of electrical signal or the transmission of the electrical signal or both is affected leading to the occurrence of arrhythmias.

- ✓ Sinoatrial block
- ✓ Atrial standstill
- ✓ AV block (first degree, second degree, third degree)

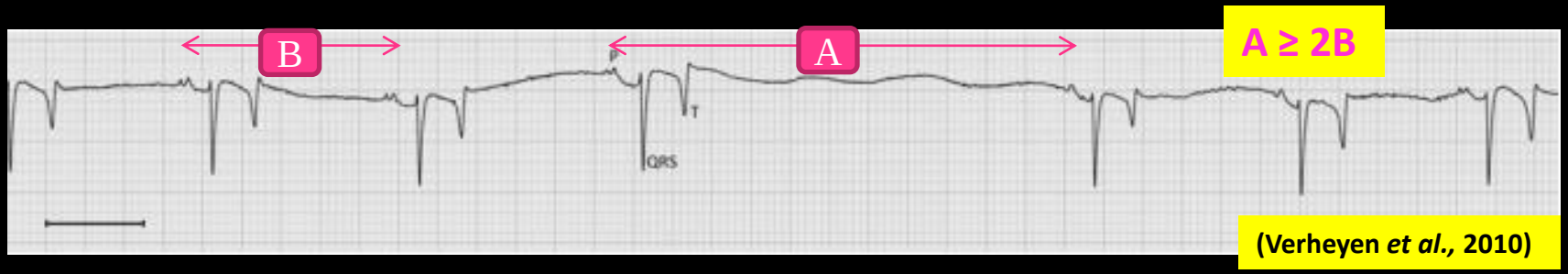
- These are the commonly observed conduction disorders in cattle.



Website Medical exam Prep, 2016

Sinoatrial block

- In SA block the sinus node fails to discharge or its impulse is not transmitted over the atrial myocardium.
- SA block is associated with the complete absence of heart sounds, of jugular atrial wave, and of an arterial pulse for one beat period.
- ECG features:
  - There is complete absence of the P, QRS, and T complex for one beat.
  - The underlying rhythm is regular unless sinus arrhythmia is present.
  - The distance between the preblock and postblock P waves is twice the normal PP interval or sometimes slightly longer.



- Causes: High vagal tone.
- If SA block does not persist during and following exercise, it is considered as a physiologic variant of normal rhythm.
- Treatment: Generally treatment is not required, it disappears with exercise. In severe cases vagolytic drugs atropine or glycopyrrolate, 0.005 to 0.01 mg/kg IV are administered.

Atrial Standstill (AS)

- Atrial standstill is also known as silent atrium or atrial arrest.
- It is an arrhythmogenic condition, characterized by lack of electrical and mechanical activity in the atria.
- It can be either transient (in hyperkalemia) or persistent (in structural heart diseases).
- Electrocardiographic features of AS include an absence of P waves in any lead and a slow regular escape rhythm of junctional or ventricular origin, with a nearly normal QRS complex.

ECG showing atrial standstill; note the absence of 'P' waves, ventricular escape beats and bradycardia

- Causes: Hyperkalemia, myocarditis, atrial myopathy etc.,
- Treatment: Treatment of underlying disease conditions .

Atrio-ventricular nodal block (AV Block)

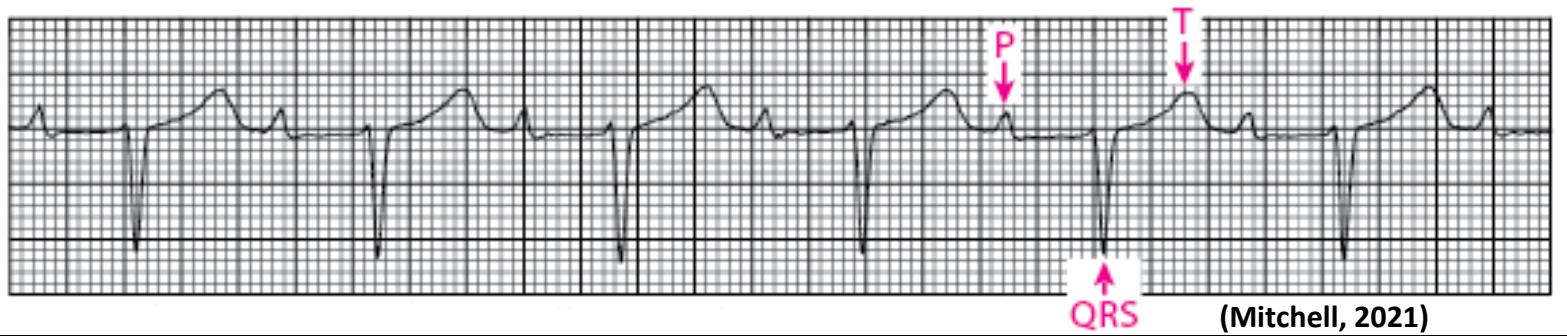
- Normally AV node passes the impulse from Atria to Ventricles. In AV Block there is alteration in the impulse conduction through AV node.

- Depending on the degree of interference with conduction at the AV node, AV block is divided into three categories (first, second, and third degree).

- In first degree AV block, this conduction towards the ventricles is delayed; in second degree block, conduction is intermittently blocked and in third degree block, conduction is completely absent.

First degree AV Block

- In first degree AV block conduction through AV node is delayed.
- Generally caused by high vagal tone and goes unnoticed.
- It is generally physiological and clinically insignificant.
- **ECG Features:**
  - Each P wave is followed by a QRS complex and every QRS complex is preceded by a P wave.
  - PR interval is prolonged (>0.26 seconds).
  - The morphology of P waves and QRS complexes is normal.

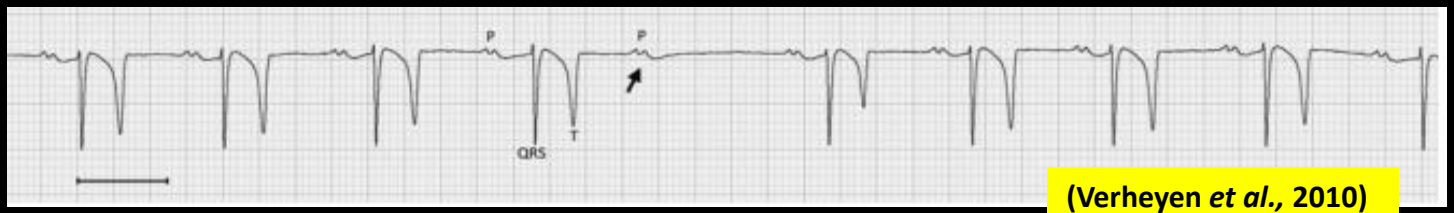


(Mitchell, 2021)

- **Treatment:**
  - **Generally treatment is not required.**

Second degree AV Block

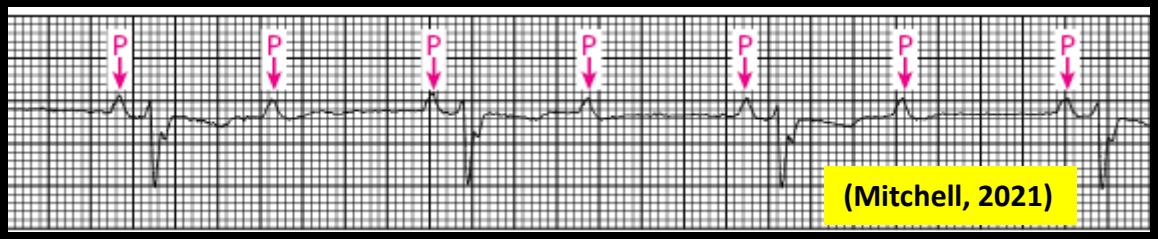
- Also known as partial heart block. It occurs when there is periodic hindrance with conduction at the AV node so that some atrial complexes are blocked and not followed by ventricular complexes.
- ECG Features:
  - P wave will be present, but there will be complete absence of the subsequent QRS and T waves at the blocked beat.
- There are two types of second degree AV block
  - Mobitz type 1 (Wenckebach): There is a gradual increase in the PQ interval up to the point of the blocked beat; however, the PQ interval immediately before the blocked beat does not have to be the longest in the series. This is generally considered as physiological.



(Verheyen *et al.*, 2010)

(There will be gradual increase in PQ interval until blocked beat)

  - Mobitz type 2: PQ interval remains unchanged. It always indicates presence of pathological conditions of heart such as myocarditis.



(Mitchell, 2021)

(No changes in PQ interval)

Second degree AV Block

- Causes:
  - It can be associated with myocarditis, electrolyte imbalance, overdosing with calcium salts, digoxin toxicity, cardiomyopathy, and myocarditis associated with nutritional and infectious disease.

- Treatment:
  - Generally treatment is not required.
  - Addressing underlying issue will restore normal cardiac rhythm.
  - In cases where the block leads to frequent syncopal episodes, short term therapy with atropine will alleviate the frequency of the block.
  - Second-degree heart block may progress to third-degree (complete) heart block.

Third degree AV Block

- Also known as complete heart block.
- In 3rd degree block none of the atrial impulses are conducted through AV node resulting in independent contraction of ventricles according to their own intrinsic rhythm.
- Causes: Degenerative or inflammatory AV nodal disease.
- ECG Features:
  - P waves will be of normal morphology with regular PP interval.
  - No relationship is seen between P waves and QRS complexes.
  - The rate of the P waves is usually high.
  - QRS complexes will be bizarrely shaped with slower rate.
  - Ventricular escape rhythm is noticed often.

- Prognosis of the affected animals is poor.

Arrhythmias due to electrolyte imbalance

- Electrolytes such as calcium, potassium, sodium play an important role in the electrical activity of heart.
- Disturbances in the electrolyte balance leads to arrhythmias and other ECG changes.
- Arrhythmias due to hyperkalemia and milk fever are noticed very commonly in large ruminants.

Hyperkalemia

- Hyperkalemia is a condition where serum or plasma potassium levels are more than >5.5 mmol/L and is commonly noticed in neonatal ruminants with diarrhea, dehydration and metabolic acidosis. In adult ruminants it is seen in exertional rhabdomyolysis.

- ECG changes such as suppression in P wave amplitude or loss of the P wave, widened QRS complexes, increased J point, increased ST segment angle, and symmetric T waves (narrowing of T wave duration and “tenting” of the T wave) are noticed in severe hyperkalemia (6.5 to 8.0 mmol/L).

- Cardiotoxic effects and life threatening arrhythmias such as atrial standstill and ventricular escape rhythm are evident when the serum potassium concentration is 8–11 mmol/L.

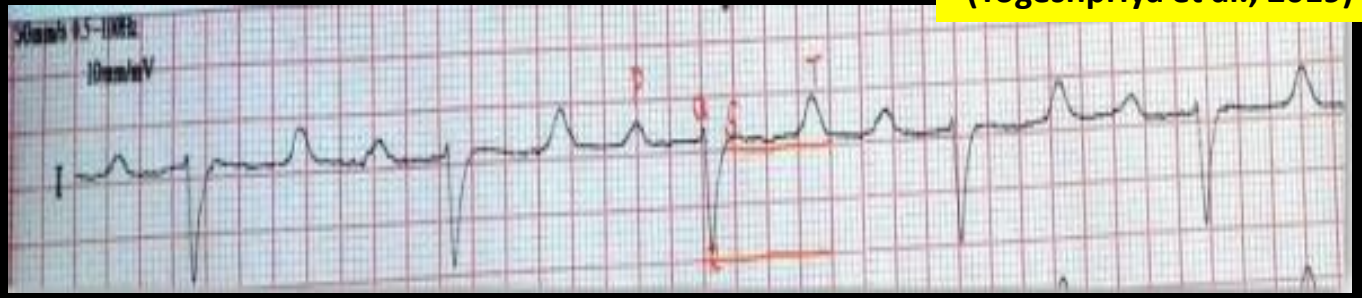
- Hyperkalemia can be treated by Intravenous administration of isotonic saline or isotonic sodium bicarbonate solutions or hypertonic saline or hypertonic sodium bicarbonate, calcium, or glucose solutions based on the severity and need.

Milk Fever

- As calcium is vital for the contraction of cardiac muscles, its deficiency leads to ECG changes.

- ECG changes such as prolonged QT and ST interval are observed in cows with milk fever.

(Yogeshpriya et al., 2019)



ECG showing prolonged QT interval in cow suffering from Milk fever