The ABCs of ECGs
Back to Basics Part I

Meg Sleeper VMD, DACVIM (cardiology)
University of Florida Veterinary School

Lecture outline

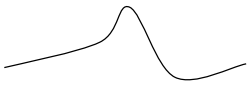
- Electrical properties of the heart
- Action potentials
- Normal intracardiac conduction
- ECG interpretation (cases)

Electrical properties of the heart

- Automaticity
- Excitability
- Refractoriness
- Conductivity

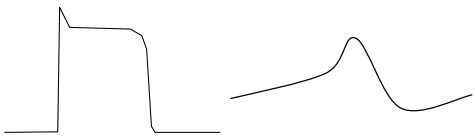
Automaticity

- Only pacemaker cells are *normally* capable of beating spontaneously
- Gradual diastolic reduction in action potential (becoming less negative) toward the cell's threshold potential.

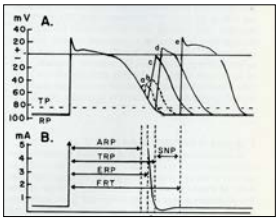


Excitability

- **All** resting myocytes are capable of responding to an effective stimulus by generating an action potential.



Refractoriness



- Period of recovery following excitation when cells cannot respond to stimuli. Excitability is gradually restored.

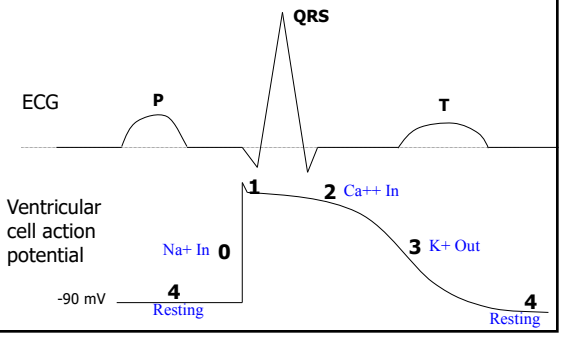
Conductivity

- Intercalated discs in the ends of muscle fibers give the atria and ventricles the property of a syncytium. Therefore, if propagation is blocked along the preferential conducting pathway, depolarization can still spread directly from one cell to the next (a slower process).
- Conduction speed is dependent on cell size (slower in smaller cells), and is normally slowest at the AV node.

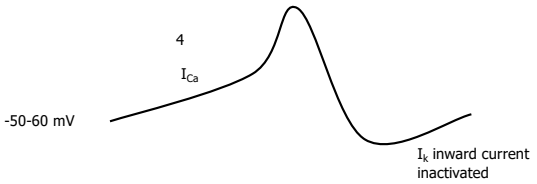
Contractility

- Peak tension developed by myocardial cells at a specific resting fiber length.
- **ECG gives no information regarding contractility or pump function**

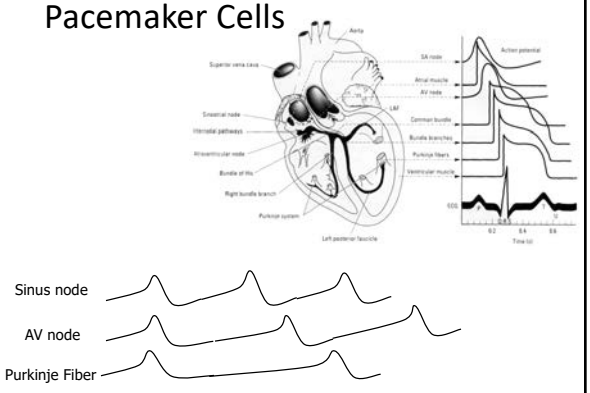
Cardiac cell action potential



Pacemaker cell action potential



Pacemaker Cells



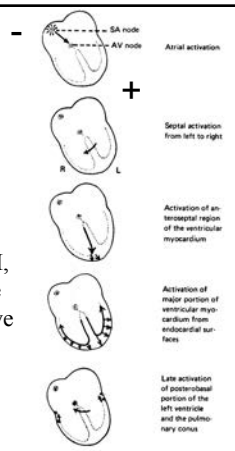
Analysis of Cardiac Arrhythmias

- Site of impulse origin
  - Supraventricular: **SA node**, atria, AV node
  - Ventricular
- Rate: atrial and ventricular
- Timing
  - Premature beats: occur early in the sequence of normal beats
  - Escape beats: occur after a pause in the sequence of beats

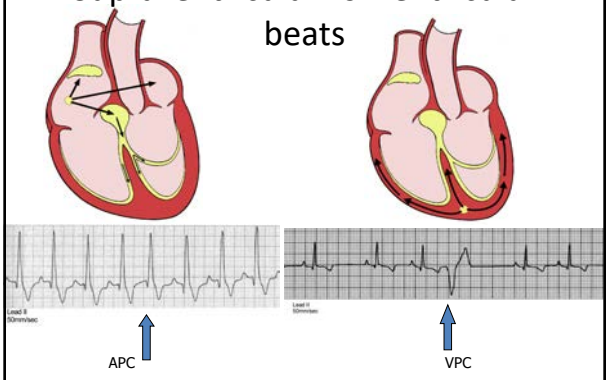
Normal wave morphology

In lead II, the RA is negative and the LL is positive.

Therefore, normally in lead II, the P wave is positive and the QRS is predominantly positive (R wave).



Supraventricular vs. ventricular beats



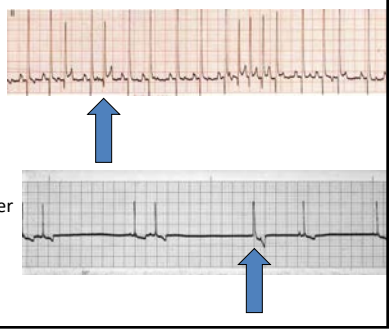
VPC and APC Pauses

APC: Non-Compensatory Pause

VPC: Compensatory Pause

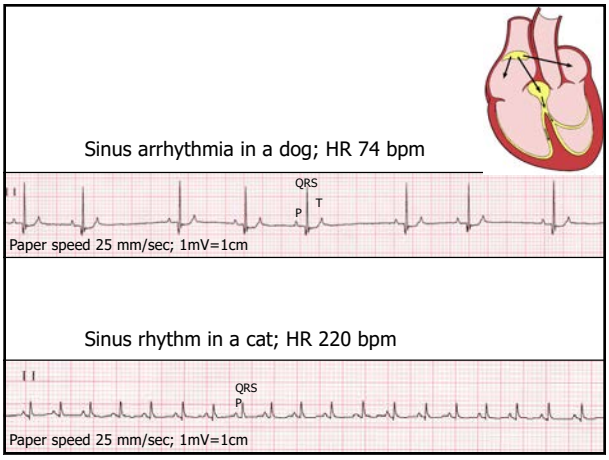
Premature vs. escape ectopics

- Premature beats occur earlier than the next expected beat
- Escape beats occur after a pause



Basic ECG classification

- Arrhythmias
  - Supraventricular origin
    - Normal (sinus)
    - Bradycardias
    - Tachycardias
  - Ventricular origin
- Aberrant conduction
  - AV block (may also be bradycardia)
  - Bundle branch block



ECG #1
7 year old mc Jack Russell terrier
50 mm/sec; 1mV=1cm

ECG #1
7 year old mc Jack Russell terrier
50 mm/sec; 1mV=1cm
HR@ 90 bpm

R waves regularly irregular

ECG #1
7 year old mc Jack Russell terrier
50 mm/sec; 1mV=1cm
HR@ 90 bpm

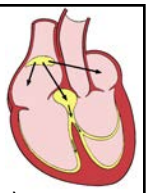
Normal QRS morphology and the same in all complexes

ECG #1
7 year old mc Jack Russell terrier
50 mm/sec; 1mV=1cm
HR@ 90 bpm

P waves present for every QRS with consistent PR

P waves have variable amplitude

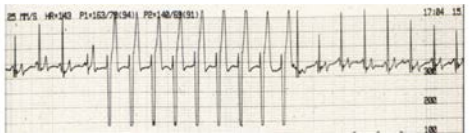
Summary



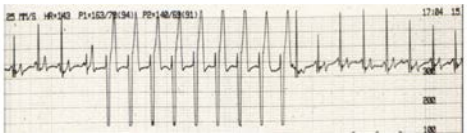
- Normal heart rate
- Supraventricular (normal morphology)
- Variable P wave with normal and consistent PR intervals
- Wandering pacemaker/Sinus arrhythmia

Treatment: None necessary

ECG #2
3 year old mc MIXB; automobile accident
25 mm/sec; 1mV=1cm

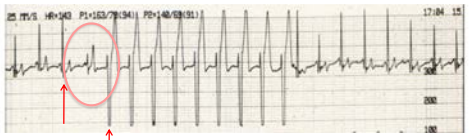


ECG #2
3 year old mc MIXB; automobile accident
25 mm/sec; 1mV=1cm
HR@150 bpm



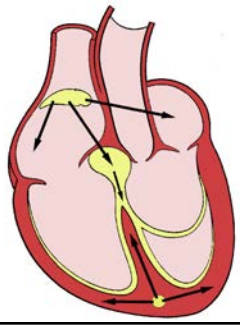
RR regularity: slight irregularity vs. regular

ECG #2
3 year old mc MIXB; automobile accident
25 mm/sec; 1mV=1cm
HR@150 bpm

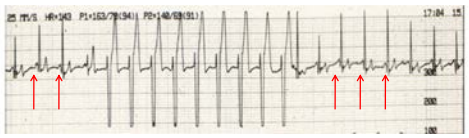


QRS morphology: normal and wide (two different morphologies)

Fusion beat



ECG #2
3 year old mc MIXB; automobile accident
25 mm/sec; 1mV=1cm
HR@150 bpm



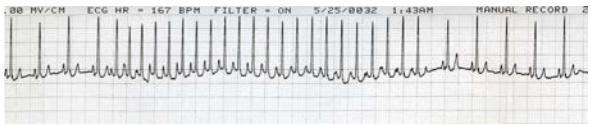
P waves: present for some of the QRSs (narrow QRSs)

Summary

- Normal heart rate
- Episode of ventricular rhythm with a normal heart rate
- Diagnosis:
  - ***Accelerated idioventricular rhythm with underlying sinus arrhythmia***

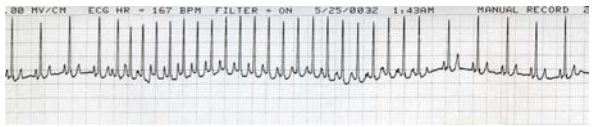
Treatment: Ventricular antiarrhythmic only if rate is fast enough to negatively impact blood pressure; generally self limiting

ECG #3
Paper speed 25 mm/sec; 1mV=1cm
3 year old Labrador retriever; presenting for an episode of weakness



ECG #3
Paper speed 25 mm/sec; 1mV=1cm
3 year old Labrador retriever; presenting for an episode of weakness

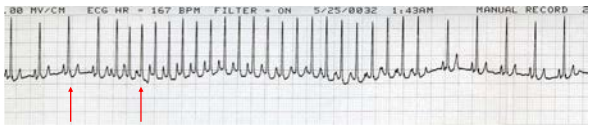
HR@ 300/150 bpm



RR regularity: regular with abrupt transitions

ECG #3
Paper speed 25 mm/sec; 1mV=1cm
3 year old Labrador retriever; presenting for an episode of weakness

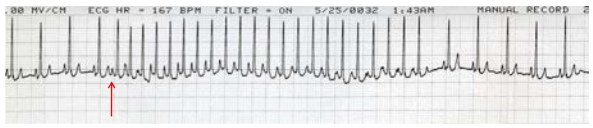
HR@ 300/150 bpm



QRS morphology: narrow/normal

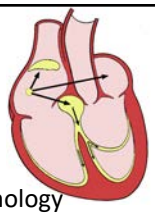
ECG #3
Paper speed 25 mm/sec; 1mV=1cm
3 year old Labrador retriever; presenting for an episode of weakness

HR@ 300/150 bpm



P waves: not always visible; transition begins with premature P wave

Summary



- Tachycardia with normal QRS morphology
  - >>supraventricular
- Paroxysmal transitions
  - >>not sinus
- Diagnosis:
  - ***Supraventricular tachycardia or paroxysmal atrial tachycardia***

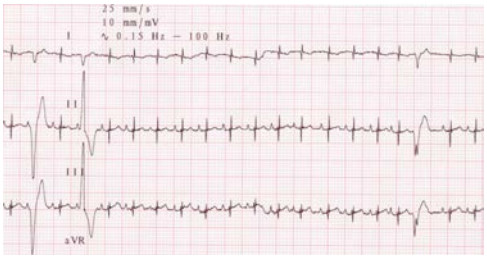
Treatment for supraventricular tachycardia

- Diltiazem
  - 0.5-5 mg/kg q 8 hours (oral)
  - 0.1-0.2 mg/kg IV bolus, then 2-6 mcg/kg/min CRI
- Digoxin
  - 0.003-0.005 mg/kg q 12 hours (oral)
- Beta blocker
  - Atenolol: 0.25-2.0 mg/kg q 12-24 hours (oral)
  - Esmolol: 50-100 mcg/kg IV bolus every 5 min up to 500 mcg/kg maximum; 25-200 mcg/kg/min CRI

ECG #4
Paper speed 25 mm/sec; 1mV=1cm
5 year old great Dane, no clinical signs

ECG #4
Paper speed 25 mm/sec; 1mV=1cm
5 year old great Dane, no clinical signs

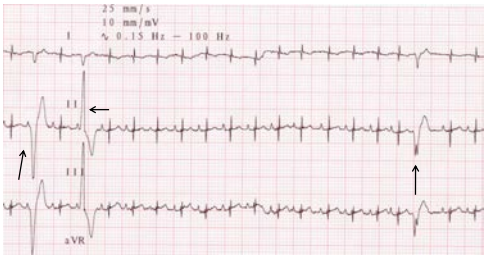
HR- 160 bpm



RR regularity: irregular

ECG #4
Paper speed 25 mm/sec; 1mV=1cm
5 year old great Dane, no clinical signs

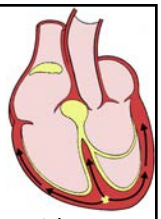
HR- 160 bpm



QRS morphology: normal width to increased with variable morphology

P waves present for most complexes but not all

Summary



- Normal to mildly increased heart rate with irregular rhythm
- Occasional premature, wide morphology complexes
- Rhythm diagnosis:
  - ***Ventricular premature complexes; multiform***

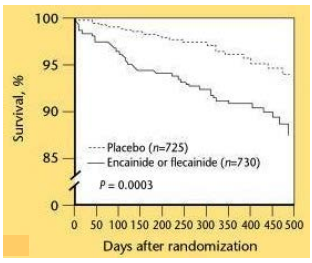
Treatment ventricular ectopy

- In asymptomatic dogs, there is no evidence that starting anti-arrhythmic therapy will reduce the risk of a fatal arrhythmia
- The arrhythmia may be a sign of structural myocardial disease, particularly in breed predisposed to acquired heart disease.
- Recommend further evaluation:
  - Echocardiogram
  - Holter monitor

CAST

Cardiac Arrhythmia Supression Trial

(N Engl J Med. 1989;321:406–412.)



There was an increased mortality in post-myocardial infarction patients given Class 1c antiarrhythmic agents.

ECG example #5
Paper speed 25 mm/sec; 1mV=1cm
5 year old Boxer, an episode of syncope

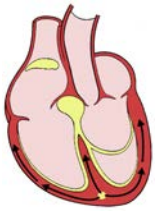
ECG example #5
Paper speed 25 mm/sec; 1mV=1cm
5 year old Boxer, an episode of syncope
HR- 160 bpm; brief period of 300 bpm

RR regularity: irregular

ECG example #5
Paper speed 25 mm/sec; 1mV=1cm
5 year old Boxer, an episode of syncope
HR- 160 bpm; brief period of 300 bpm

QRS morphology: normal width and increased width complexes
P waves present for most complexes but not all

Summary

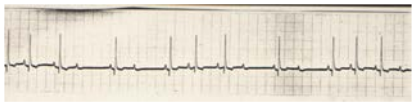


- Normal to mildly increased heart rate with periods of rapid heart rate
- Some premature, wide morphology complexes
- Rhythm diagnosis:
  - ***Ventricular premature complexes and non-sustained ventricular tachycardia***

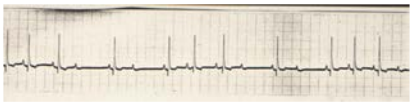
Treatment ventricular ectopy

- In symptomatic dogs, while there is no evidence that starting anti-arrhythmic therapy will reduce the risk of a fatal arrhythmia, effective therapy will reduce clinical signs
- Ventricular anti-arrhythmics to consider for non-sustained ventricular tachycardia:
  - Mexilitine: 5-8 mg/kg three times daily (oral)
  - Sotalol: 1-2 mg/kg twice daily (oral)
- The arrhythmia may be a sign of structural myocardial disease, particularly in breed predisposed to acquired heart disease.
- Recommend further evaluation:
  - Echocardiogram
  - Holter monitor

ECG # 6
3 year old MIXB; normal
25 mm/sec; 1 mV=1cm



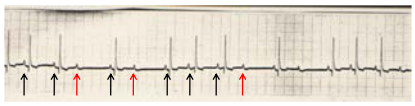
ECG # 6
3 year old MIXB; normal
25 mm/sec; 1 mV=1cm
HR@ 100bpm



RR regularity: irregular

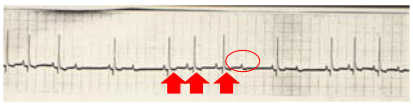
QRS morphology: narrow/normal

ECG # 6
3 year old MIXB; normal
25 mm/sec; 1 mV=1cm
HR@ 100bpm



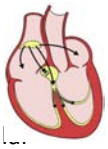
P waves: occasional un-conducted P waves (↑)

ECG # 6
3 year old MIXB; normal
25 mm/sec; 1 mV=1cm
HR@ 100bpm



PR interval progressively lengthens prior to blocked P wave
Pattern mirrors sinus arrhythmia RR variation

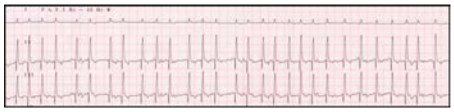
Summary



- Normal heart rate with irregular rhythm
- Occasional blocked P waves
- QRS morphology normal
- Rhythm diagnosis:
  - ***Second degree AV block type 1 (Wenchebach)***

Treatment: Generally none necessary; usually asymptomatic and athletic dogs

ECG # 7
9 year old toy poodle with degenerative valve disease; currently on furosemide, enalapril and pimobendan
25 mm/sec; 1 mV=1 cm



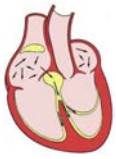
ECG # 7
9 year old toy poodle with degenerative valve disease; currently on furosemide, enalapril and pimobendan
25 mm/sec; 1 mV=1 cm
HR@ 160 bpm

Rhythm: irregularly irregular

QRS morphology: normal/narrow

No P waves

Summary



- Irregularly, irregular rhythm
- Lack of P waves
- Normal QRS morphology
- Rhythm diagnosis:
  - ***Atrial fibrillation***

Treatment: in a small breed dog with underlying heart disease, control heart rate with digoxin and/or diltiazem

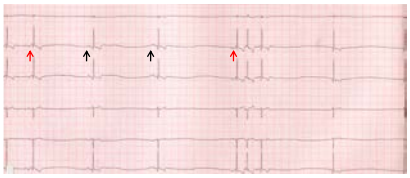
ECG example #8
Paper speed 25 mm/sec; 1mV=1cm
9 year old cocker spaniel; no clinical signs

ECG example #8
Paper speed 25 mm/sec; 1mV=1cm
9 year old cocker spaniel; no clinical signs
HR-50 bpm

RR regularity: irregular; predominantly long RR cycles (some longer than 2 seconds), occasional short cycles

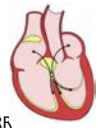
QRS morphology: narrow/normal

ECG example #8
Paper speed 25 mm/sec; 1mV=1cm
9 year old cocker spaniel; no clinical signs
HR-50 bpm



P waves: intermittent; morphology variable

Summary



- Bradycardia (sinus bradycardia)
- Negative P waves correspond to long RR cycles>>junctional escape beats
- Occasional premature beats

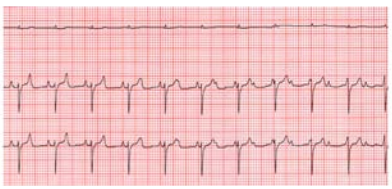
- Diagnosis:
  - ***Sick sinus syndrome***

  Differentiate from high vagal tone>> Atropine response test (0.04 mg/kg IV or IM)

Treatment

- If atropine response test is normal, look for underlying disease that is causing elevated vagal tone (respiratory, GI, ocular or neurologic)
- If abnormal atropine response test, gold standard therapy would be pacemaker. If not possible consider medical management with:
  - Propantheline bromide: 0.25-5 mg/kg q 8-12 hour (oral)
  - Terbutaline: 1.25-5 mg/dog PO q 8-12 hour (oral)
  - Theophylline: 10 mg/kg q 12 hour (extended release; oral)

ECG #9
12 year old DSH; no clinical signs
25 mm/sec; 1 mV= 1 cm

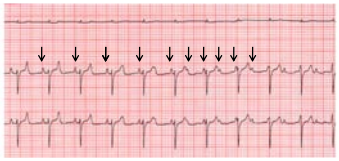


ECG #9
12 year old DSH; no clinical signs
25 mm/sec; 1 mV= 1 cm
HR@100 bpm

RR regularity: regular

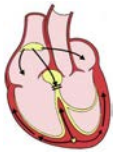
QRS morphology: normal width to slightly increased with right axis deviation

ECG #9
12 year old DSH; no clinical signs
25 mm/sec; 1 mV= 1 cm
HR@100 bpm



P waves: regular and asynchronous with QRSs

Summary

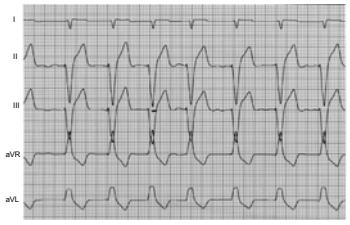


- Bradycardia
- Regular RR and PP, but asynchronous
- PR intervals variable
- Diagnosis:
  - ***Complete heart block or third degree AV block***

Treatment complete heart block

- Depends on symptoms
- If asymptomatic:
  - No treatment, monitoring for secondary heart disease
- If symptomatic:
  - Pacemaker vs medical management
    - Terbutaline
      - 0.1 mg/kg q 8 hours (oral)
    - Theophylline
      - 4 mg/kg q 12 hours (oral)
      - 19 mg/kg q 24 hours (extended release; oral)

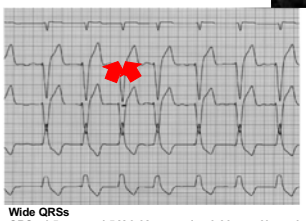
ECG #10
Paper speed 50 mm/sec; 1mV=1cm
7 year old Newfoundland; no clinical signs



ECG #10
Paper speed 50 mm/sec; 1mV=1cm
7 year old Newfoundland; no clinical signs
HR@ 150 bpm

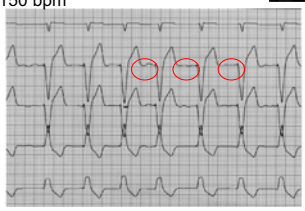
RR regularity: irregular

ECG #10
Paper speed 50 mm/sec; 1mV=1cm
7 year old Newfoundland; no clinical signs
HR@ 150 bpm



Wide QRSs
QRS= 4.5 mm or 4.5 X 0.02 seconds= 0.90 sec; Normal ≤ 0.60 sec (canine)

ECG #10
Paper speed 50 mm/sec; 1mV=1cm
7 year old Newfoundland; no clinical signs
HR@ 150 bpm

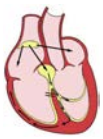


No P waves

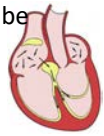
Differentials for wide complex QRS

- Ventricular in origin
- Electrolyte disturbance- most often hyperkalemia
- Aberrant conduction- bundle branch block

Summary



- Irregular RR
- No P waves
- QRS prolongation most likely due to right bundle branch block (ventricular rhythm should be regular)
- ***Rhythm diagnosis: atrial fibrillation with RBBB***



Diagnostics and treatment

- Bundle branch blocks
  - No treatment
- Lone atrial fibrillation vs. rapid atrial fibrillation
  - Echocardiogram to evaluate heart structure
  - Rate control if necessary
    - Digoxin: 0.003-0.005 mg/kg q 12 hours (oral)
    - Diltiazem: 0.5-5 mg/kg q 8 hours (oral)
  - Cardioversion

Any questions?

margaretmsleeper@ufl.edu