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

Ventricular cell action potential

Pacemaker cell action potential

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).

VPC and APC Pauses

VPC: Compensatory Pause

APC: Non-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
HR@ 90 bpm

R waves regularly irregular

Normal QRS morphology and the same in all complexes

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

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
HR@150 bpm

RR regularity: slight irregularity vs. regular

QRS morphology: normal and wide (two different morphologies)

Fusion beat

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
RR regularity: regular with abrupt transitions

QRS morphology: narrow/normal

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
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 Suppression Trial

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

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**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
HR-50 bpm

RR regularity: irregular; predominantly long RR cycles (some longer than 2 seconds), occasional short cycles
QRS morphology: narrow/normal
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)
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)
Wide QRSs
QRS = 4.5 mm or 4.5 X 0.02 second = 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?
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