Augusta Pelosi, DVM,
Dipl. ACVS and ACVIM (Cardiology)

1

CONFLICT OF INTEREST DISCLOSURE

I have financial interest, arrangement or affiliation with:

IDEXX: employee

2

OBJECTIVES

- Physiology of the ECG
- Obtaining and understanding the tracing
- Normal rhythms
- Abnormal rhythms
  - Ventricular arrhythmias
  - Supraventricular arrhythmias
  - Bradyarrhythmias

3

Indications

- Accurate heart rate
- Bradycardia or Tachycardia
- Irregular rhythm or sound
- Electrolyte (especially K^+) abnormalities
- Anesthetic monitoring

4

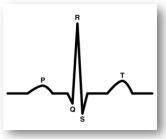
What is an ECG?

- The heart is electrically charged
- An ECG is a recording of the heart's electrical activity
- This electrical activity is measured by electrodes attached to the skin

5

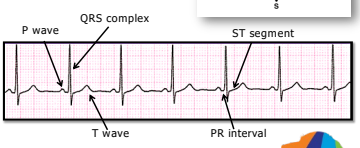
WAVES/COMPLEXES:

- P wave = atria
- QRS complex = ventricles
- T wave = reset

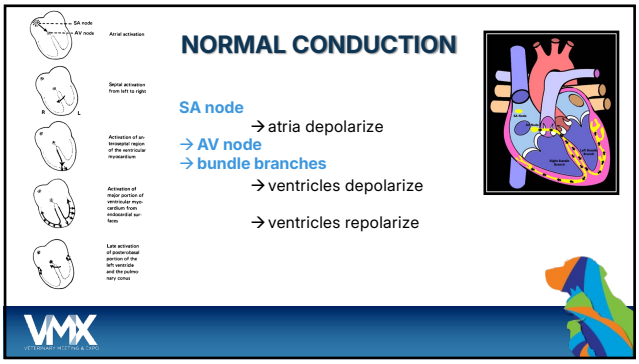


INTERVALS/SEGMENTS:

- PR = AV node conduction
- ST = ventricular recovery



6



NORMAL CONDUCTION

SA node
→ atria depolarize
→ **AV node**
→ **bundle branches**
→ ventricles depolarize

→ ventricles repolarize

7

PHYSIOLOGY - Cardiac Pacemakers

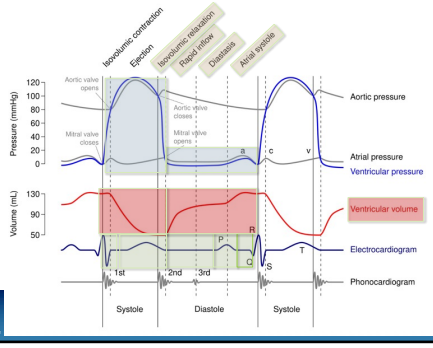
Automatic cells in the heart

- Depolarize on their own
- Rate of depolarization affected by autonomic nervous system
  - SA node (60-180 beats/min dog) (100-240 cat)
  - AV node (40-60 beats/min dog) (80-130 cat)
  - Purkinje fibers (20-40 beats/min)
  - Bundle of HIS (20-40 beats/min)
  - Ventricular myocytes (20-40 beats/min)

8

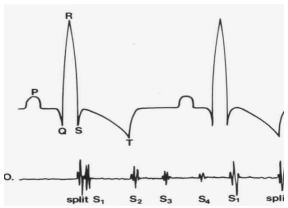
- The fastest functioning pacemaker in the heart takes over, by default
- The closer to the AV node, the more the escape beat will resemble normal QRS
- The closer to the ventricle, the more wide and bizarre the QRS will appear
- **Escape rhythm** – pacemaker other than SA node takes over, because SA node fails to fire

9



10

CARDIAC CYCLE: SYSTOLE

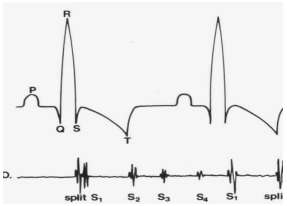


Relation to ECG
QRS is onset of ELECTRICAL systole
T wave represents repolarization

Relation to heart sounds
S1 is onset of MECHANICAL systole
S2 marks end of systole (coincides with end of T wave)

11

CARDIAC CYCLE: DIASTOLE



Electrical diastole (repolarization)
Repolarization begins at end of QRS and ends as QRS complex begins (start of depolarization)

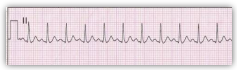
Relation to heart sounds
Between S2 and S1
Early filling (E wave, S3)
Atrial kick (A wave, S4)

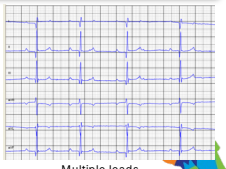
12

TYPES

- Single lead rhythm strip - monitor
  Anesthesia monitoring/ER
- Multiple lead (6 or 12 leads)
  'Diagnostic' ECG
- Telemetry
  ICU
- Ambulatory
  Holter/Event monitors

Single lead rhythm strip





Multiple leads

13

WHAT IT DETECTS

HEART AXIS & HEART CHAMBER ENLARGEMENT

Eccentric hypertrophy
- Dilation and growth of heart chambers
- Due to volume overload

Concentric hypertrophy
- Wall thickening of heart chambers
- Due to pressure overload

MEA

HEART RHYTHM

CONDUCTION DISTURBANCES

14

WHAT IT DOES NOT DETECTS

Type of Heart chamber enlargement
- Eccentric vs. Concentric hypertrophy
- Congestive Heart Failure

A Short ECG won't detect many arrhythmias
- Arrhythmias can be intermittent
- 10 minutes is <1% of the day

** **A normal ECG does not confirm nor exclude heart disease!** **

15

TECNIQUES (surface ECG)

RIGHT lateral recumbency – standardized wave appearance

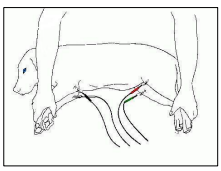
Typically 4 electrodes/clips:

1. **Black (LA)**
2. **White (RA)**
3. **Green (RL) – ground**
4. **Red (LL)**

Alcohol or gel is applied to the skin and electrodes/clips at the point of contact

16

We read the newspaper in the AM (black and white)



Christmas comes at the end of the year

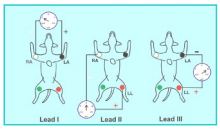
Snow and Grass are on the ground

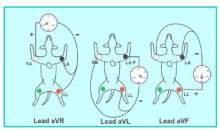
17

6 LEADS

LIMB LEADS
- **I** LA+ RA-
- **II** LR+ RA-
- **III** LR+ LA-

AUGMENTED LIMB LEADS
- **aVR** RA+ (summation lead III)-
- **aVL** LA+ (summation lead II)-
- **aVF** LR+ (summation lead I)-





18

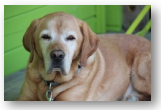
ECG – SYSTEMATIC INTERPRETATION

1. ***Heart Rate and Rhythm***
2. ***Measurements of the waves and segments***
   - P wave - width and height
   - PR interval - length
   - QRS - width and height
   - QT interval – length
     - ST segment – relative to PR interval
   - T wave - width and height
3. ***Mean Electrical Axis***
4. ***Rhythm determination***

20

HEART RATE

- Fast, slow or reasonable/appropriate
  -- Dog: 70-160 bpm
  -- Cat: 150-240 bpm
- Prefer the term appropriate over 'normal' (Has to be taken into clinical context)



21

Giant dogs 60-140 Med-Lg dogs 70-160
Toy dogs 80-180 Puppies 70-220

Cats 100-240

Get Baseline heart rates for individuals on every visit

22

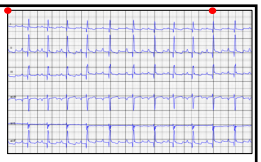
How to .....

At 25 mm/sec, 150mm = 6 sec

- 1/25 = 0.04 × 5 = 0.2 × 30 = 6
- 60/6=10
- Bic Pen Times Ten
- Accurate within 10 beats per minute

At 50 mm/sec, 300mm = 6 sec

- 1/50 = 0.02 × 5 = 0.1 × 30 = 3
- 60/3=20
- Bic Pen times Twenty
- Accurate within 20 beats per minute



25 mm/sec : 100 bpm
50 mm/sec : 200 bpm

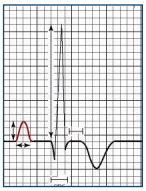
23

MEASUREMENT OF WAVES AND SEGMENTS

P wave

SA node fires
Atrial depolarization (contraction)

Internodal tracts (shortcut to AV node)



24

P wave

Normal Dog:

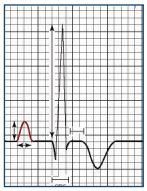
<0.4 mV x <0.04 sec
<0.5 sec in giant breeds

4 boxes tall
25 mm/sec (1-1.25 boxes wide)
50 mm/sec (2-2.5 boxes wide)

Normal Cat:

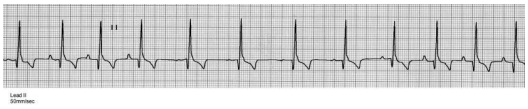
<0.2 mV x <0.04 sec

2 boxes tall



25

P wave – NORMAL VARIATIONS



"wandering pacemaker" – increased vagal tone

Origin of impulse shifts slightly within the SA node resulting in changes in the P wave morphology (a form of sinus arrhythmia)
Usually associated with changes in vagal tone due to respiration
Inspiration: P wave taller
Expiration: P wave smaller

26

P wave – ABNORMAL VARIATIONS

Wide P wave (Sometimes Notched)
- P Mitrale - LA enlargement

25 mm/sec > 1 box wide
50 mm/sec > 2 boxes wide

Tall P wave (often spiked)
- P Pulmonale - RA enlargement

Dog > 4 boxes tall
Cat > 2 boxes tall

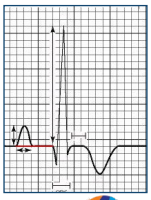
Lack of P wave
- Atrial standstill

27

MEASUREMENT OF WAVES AND SEGMENTS

PQ interval

Beginning of P wave to beginning of QRS
Conduction from atria to ventricles (AV node)
Establishes the ECG baseline

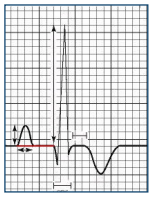


AV node *most of the PQ interval is here*
Bundle of HIS
Bundle branches (R&L)
Purkinje fiber network

28

PQ interval

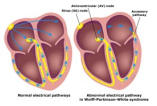
Normal Dog: 0.06-0.13 sec
Normal Cat: 0.05-0.09 sec

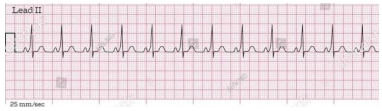


29

PQ interval – ABNORMAL VARIATIONS

Short PQ Interval (tachycardia)
- AV node is bypassed
- "Accessory pathway" (Wolff-Parkinson-White)
- Sudden onset of tachycardia in a dog

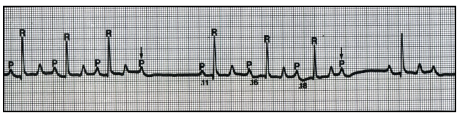




30

PQ interval – ABNORMAL VARIATIONS

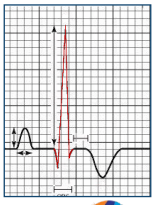
Prolonged PR Interval (bradycardia)
- Slow conduction through abnormal AV node
- AV Blocks



31

MEASUREMENT OF WAVES AND SEGMENTS

QRS complex



Ventricular depolarization (systole)

- **Q wave** 1st negative deflection
- **R wave** 1st positive deflection
- **S wave** 2nd negative deflection

32

QRS complex

Normal Dog:

<40 lbs: <0.05sec x <3.0 mV

30 boxes tall
25 mm/sec 1.25 boxes wide
50 mm/sec 2.5 boxes wide

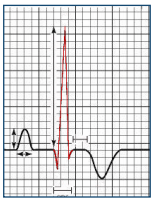
>40 lbs: <0.06sec x <3.0 mV

25 mm/ sec 1.5 boxes wide
50 mm/sec 3 boxes wide

Normal Cat:

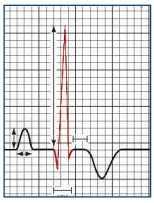
<0.04sec x <0.9 mV

9 boxes tall
25 mm/sec 1 box wide
50 mm/sec 2 boxes wide



33

QRS complex– ABNORMAL VARIATIONS



Tall R wave, wide QRS

- LV enlargement
- Left Bundle branch block

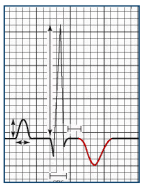
Deep S wave in leads I, II & III

- RV enlargement

34

MEASUREMENT OF WAVES AND SEGMENTS

T wave

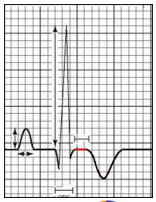


Ventricular repolarization (diastole)

35

MEASUREMENT OF WAVES AND SEGMENTS

ST segment



- Between S & T waves
- Between ventricular contraction (depolarization and ventricular relaxation (repolarization – diastole)
- Relationship with baseline

36

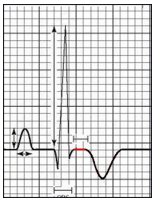
ST segment– ABNORMAL VARIATIONS

ST segment depression or elevation

>0.2mV between baseline and ST

CAUSES:

- Hypothermia
- Hypokalemia
- Digitalis toxicity
- Bundle branch block
- Myocardial infarction
  - Rare in dogs - hypothyroidism
  - Can be seen in feline HCM

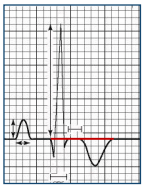


37

MEASUREMENT OF WAVES AND SEGMENTS

QT interval

- beginning of QRS to end of T wave ventricular depolarization & repolarization
- Pulse generated
- Drug-inducted QT changes



38

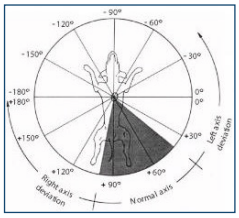
MEAN ELECTRICAL AXIS (MEA)

- when a wavefront spreads toward an electrode, the largest possible deflection will occur
- When a wavefront spreads perpendicular to a lead, the smallest or no deflection occurs
- ECG shows the sum of all wavefronts relative to the lead being used to measure (MEA)

ISOELECTRIC LEAD

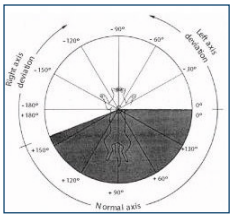
- lead with the smallest deflection
- Perpendicular to the MEA

39



Normal Canine MEA

40-110°



Normal Feline MEA

0-160°

40

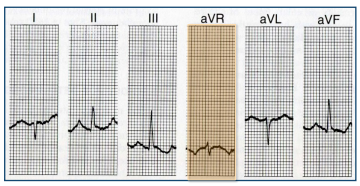
- The normal MEA is 40° to 100° in the dog
- Lead II is most perpendicular to the normal MEA
  - largest deflections
  - best for measurements
- aVL is most often the isoelectric lead. Approximates MEA in normal dogs

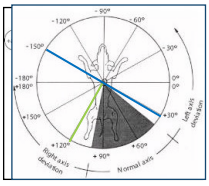
41

ESTIMATING MEA

- Find the isoelectric lead
  - NOT the lead with smallest deflections
  - Lead with smallest NET DEFLECTION
- MEA is perpendicular to that, in the direction of net deflection

42





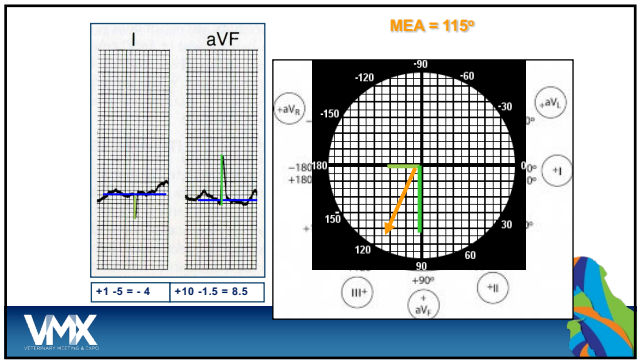
MEA = +120°
Right Axis Shift

43

CALCULATING MEA

1. Calculate the net deflection in lead I
   Graph on "x axis"
2. Calculate net deflection in lead aVF
   Graph on "y axis"
3. Draw the vector between the two (MEA)

44



45

MEA – ABNORMAL VARIATIONS

RIGHT AXIS SHIFT

- Right ventricular enlargement
  - RV hypertrophy or dilation
- Right bundle branch block

LEFT AXIS SHIFT

- HCM in cats
- Hyperkalemia

46

ECG – Helpful Hints

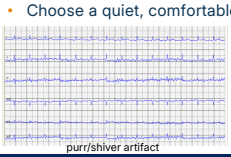
- Always in right lateral recumbency
- Patient on a towel or rubber mat
- Metal tables are more problematic
- Limbs perpendicular to body
- Place leads below the elbow and knee
- No one moves while the ECG is being recorded
- Enhance lead contact with gel or alcohol
- Place a towel between the legs

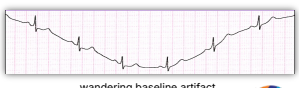
Alcohol is FLAMMABLE!!

47

Minimizing Artifact

- Lots of alcohol (or gel)
- Avoid metal on metal contact between the clips/electrodes
- Reduce motion
- Choose a quiet, comfortable environment

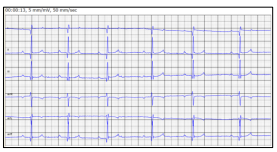

purr/shiver artifact


wandering baseline artifact

48

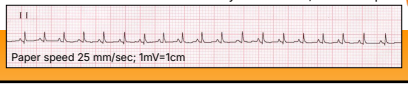
NORMAL PHYSIOLOGIC RHYTHMS

NORMAL SINUS RHYTHM (NSR)



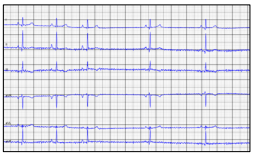
- Regular and consistent R-R interval
- 'Reasonable' heart rate
- P, QRS and T waves in each complex
- P wave for every QRS complex

Sinus rhythm in a cat; HR 220 bpm



49

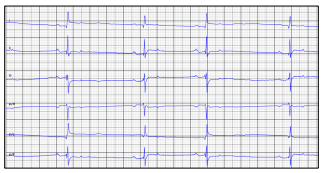
SINUS ARRHYTHMIA



- 'Regularly irregular' R-R interval
- P, QRS and T waves in each complex
- P wave for every QRS complex
- Reasonable heart rate, may be a little slow
- Speeds up with inhale, slows with exhale (vagal tone variance, in a regular cycle)
- Secondary to high vagal tone
- Normal in dogs
- Variable P wave – wandering pacemaker
- Heart rate less than 200

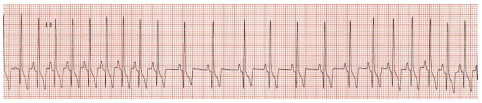
50

SINUS BRADYCARDIA



- P wave for every QRS complex
- Regular and consistent R-R interval
- Low heart rate (within reason)
- Typically seen with high vagal tone
- No treatment is necessary; only warranted in case it is associated with clinical signs

51



SINUS TACHYCARDIA

- Regular and consistent R-R interval
- P wave for every QRS complex
- Elevated heart rate (within reason)

52

ABNORMAL RHYTHMS

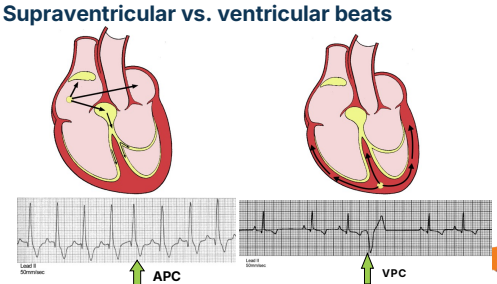
Atrial arrhythmias (supraventricular)
- Atrial premature complexes (APCs)
- Atrial tachycardia
- Atrial fibrillation

Ventricular arrhythmias
- Ventricular premature complexes (VPCs)
- Idioventricular rhythm (IVR)
- Ventricular tachycardia
- Ventricular fibrillation

Bradyarrhythmias
- AV block
  - 1st degree
  - 2nd degree
    - Mobitz type I
    - Mobitz type II
  - 3rd degree
- Sinus arrest
  Atrial Standstill
- Sick Sinus Syndrome

53

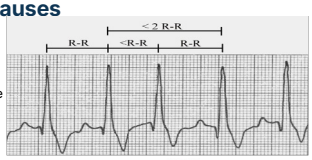
Supraventricular vs. ventricular beats



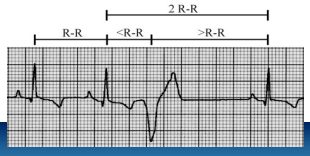
54

VPC and APC Pauses

APC:
Non-Compensatory Pause



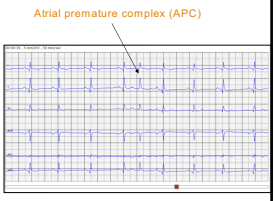
VPC:
Compensatory Pause



55

SUPRAVENTRICULAR ARRHYTHMIAS

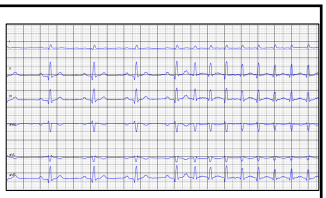
ATRIAL PREMATURE COMPLEXES (APC)



- Premature beat (occurs early)
- Normal QRS morphology
- +/- P wave
  - Often hidden in the previous complex or T wave
- Can be confused with sinus arrhythmia

56

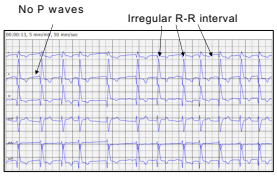
ATRIAL TACHYCARDIA



- Run of APCs
- QRS complexes normal to narrow
- Very rapid rate (often > 200)
- Not a common arrhythmia
- Associated with atrial disease *or* systemic disease

57

ATRIAL FIBRILLATION (A FIB)



- Very common arrhythmia
- Chaotic, disorganized atrial activity
- Three classic criteria:
  1. No P waves (fibrillation waves)
  2. 'Irregularly irregular'
     - Tennis shoes in a dryer
  3. Rapid rate
- Often associated with significant underlying structural heart disease

58

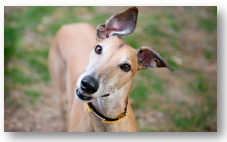
Tuesday, 10 yo, FS, Greyhound

Presented for a dental

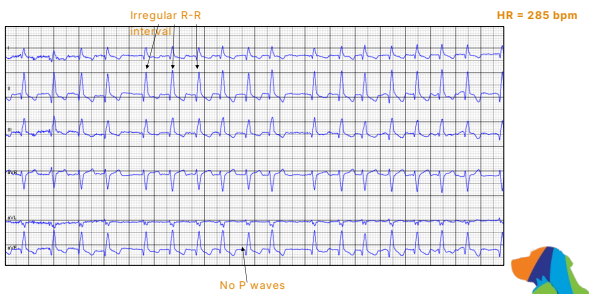
No clinical signs

Auscultation:

- Tachycardia
- No murmur



59



60

Which drug would you select?

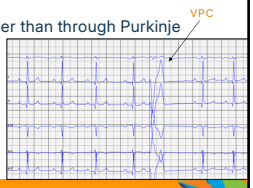
1. Lidocaine
2. Sotalol
3. Diltiazem
4. Atenolol

61

VENTRICULAR ARRHYTHMIAS

VENTRICULAR PREMATURE COMPLEX (VPC)

- Depolarization wave through myocardium rather than through Purkinje network on affected side
- Abnormal QRS morphology (wide and bizarre)
- Premature beat (occurs early)
- No P waves
- Very common



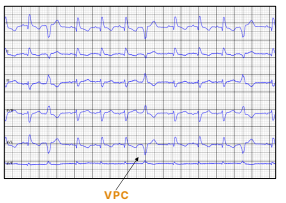
62

- Caused by systemic or cardiac disease
- VPCs can be persistent or intermittent
- Multiform VPCs are more serious - Multifocal areas of LV pathology

VPCs vs. ESCAPE BEATS

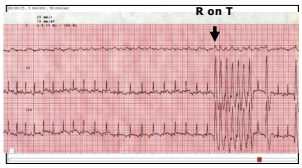
- VPCs are like escape beats as they originate from the ventricular myocardium
- VPCs are abnormal due to primary LV pathology or secondary to metabolic disease
- Escape beats are the normal life saving response to a failure of cardiac pacemaker cells

63



64

VENTRICULAR TACHYCARDIA



- Run of VPCs
- Wide and bizarre QRS complexes
- Very rapid rate (often > 200)
- Potentially life threatening
  - Lidocaine (1ml/20 lbs)
- Associated with heart disease or systemic disease

65

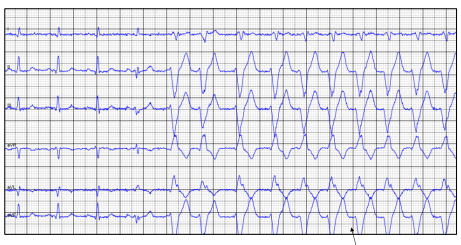
Tucker, 12 yo MN Labrador

Presented for lethargy and weakness

Auscultation:

- Tachycardia
- No murmur

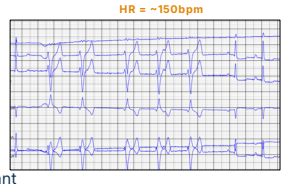
66



67

IDIOVENTRICULAR RHYTHM (IVR)

- 'Slow v-tach'
- Run of VPCs
  - Not tachycardic
  - HR >160-180
- Typically not hemodynamically significant
- May begin and end with a fusion beat
- Most commonly associated with non-cardiac disease (GDV, Splenectomy, Sepsis, Trauma)



68

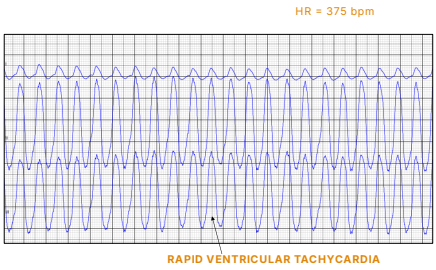
Zeus, 8 MN Boxer

Presented for syncope

Auscultation:

- Tachycardia
- No murmur

69



70

How would you treat this patient?

ACUTE vs CHRONIC

LIDOCAINE bolus and CRI

SOTALOL

71

BRADYARRHYTHMIAS

AV blocks P waves are 'blocked' with variable conduction at the AV node

- Most commonly secondary to idiopathic fibrosis
- Tends to be an age-related change
- 3 types AV bocks

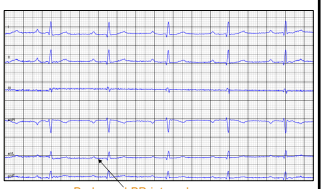
1st degree AV block
2nd degree AV block
3rd degree AV block

Sinus arrest
Atrial standstill
Sick Sinus Syndrome

72

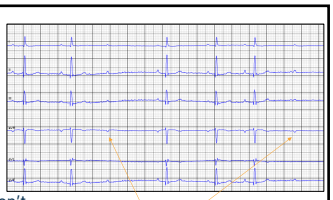
FIRST DEGREE AV BLOCK

- Prolongation of the P-R interval
- Every P wave gets through
- May be normal or due to high vagal tone
- Due to increased vagal tone
- Non-pathogenic
- No treatment required



73

SECOND DEGREE AV BLOCK

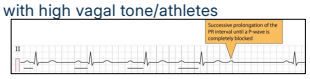


- Some P waves get through, some don't
- Can be associated with primary AV node disease *or* from high vagal tone
- Commonly seen with anesthesia
- Occasionally symptomatic (syncope)

74

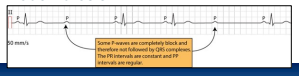
Mobitz Type I

- Progressive prolongation of the PR interval before a blocked P wave
- Also known as Wenckebach phenomenon
- Typically associated with high vagal tone/athletes



Mobitz type II

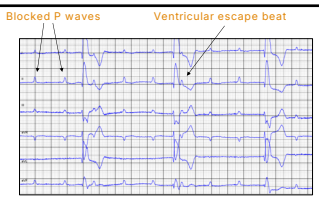
- Sporadically occurring blocked P waves
- High vagal tone or AV node fibrosis



Images from: https://ecgwaves.com/second-degree-av-block-ii-2nd-2/

75

THIRD DEGREE AV BLOCK



- No relationship between P waves and QRS
- P waves have their own rate (faster), determined by the normal SA node
- QRS has its own rate (slower), determined by the automaticity of the fastest remaining functioning pacemaker

77

Escape rhythm – life saving mechanism of the ventricles **NOT** a VPC!

Often symptomatic: Syncope, weakness

Treatment

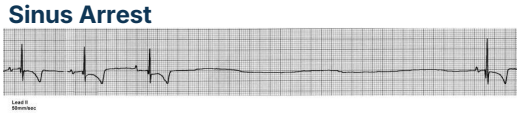
- pacemaker
- EMERGENCY - Pacemaker often required

Prognosis

- Cats – without anesthesia, potentially very good
- Dogs – eventual asystole is likely, if no pacemaker implanted

79

Sinus Arrest



- SA node fails to depolarize
  - Depression of normal automaticity
- Definition: pause > 2 R-R intervals
- Causes: vagal tone, injury to SA node, hyperkalemia, drug induced
- May cause clinical signs if extended period of asystole

80

Atrial Standstill

Atrial tissue no longer conducts impulse to the AV node

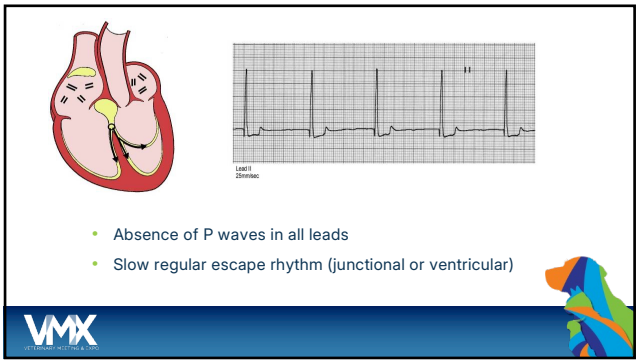
- Ventricles controlled by a junctional or ventricular escape rhythm

Two main causes

- Severe hyperkalemia (sinoventricular rhythm)
- Idiopathic destruction of the atrial myocardium

- Idiopathic disease: English Springer Spaniels
- Hyperkalemic disease: Hypoadrenocorticism

81



- Absence of P waves in all leads
- Slow regular escape rhythm (junctional or ventricular)

82

Sick Sinus Syndrome

83

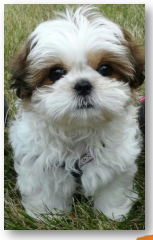
Dolly, 6 mo, FI Shih Tzu

Presented for spay

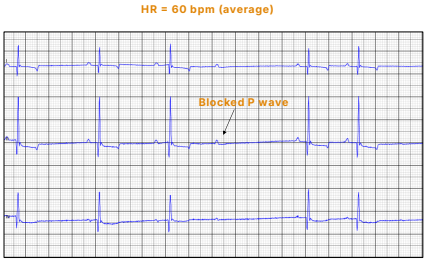
Auscultation:

- Bradycardia and irregular rhythm
- No murmur

Pre-op ECG performed



84



85

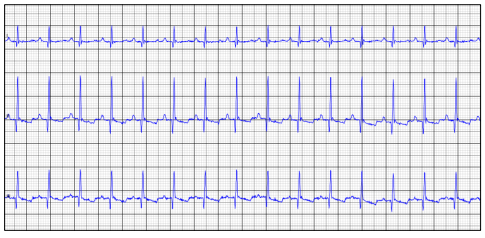
Should we anesthetize this patient?

YES or NO?

Which test should we consider prior to anesthesia?

86

Post-atropine 0.04mg/kg IV



87


2023
THANK YOU
DON'T FORGET TO RATE YOUR SPEAKER
AND SESSION IN THE APP!
Presented By
NAVC
YOUR VETERINARY COMMUNITY

88