An Introduction to Acid-Base Testing

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ABAXIS

Better + Better

Outline

- Acid-Base in Practice
  - Common conditions
  - Benefits of use
  - Sample handling
  - Cases
- Conclusions

Emergency & Critical Care Evaluation and Monitoring

Immediate patient-side results

Acid-base status
- pH, HCO_3, pCO_2, AG, BE, TCO_2

Oxygen carrying capacity
- pO_2, sO_2, Hgb, HCT

Electrolytes
- Na+, K+, Cl-

Other important values
- iCa, Glu, BUN, CRE, Lactate

Your portable lab solution

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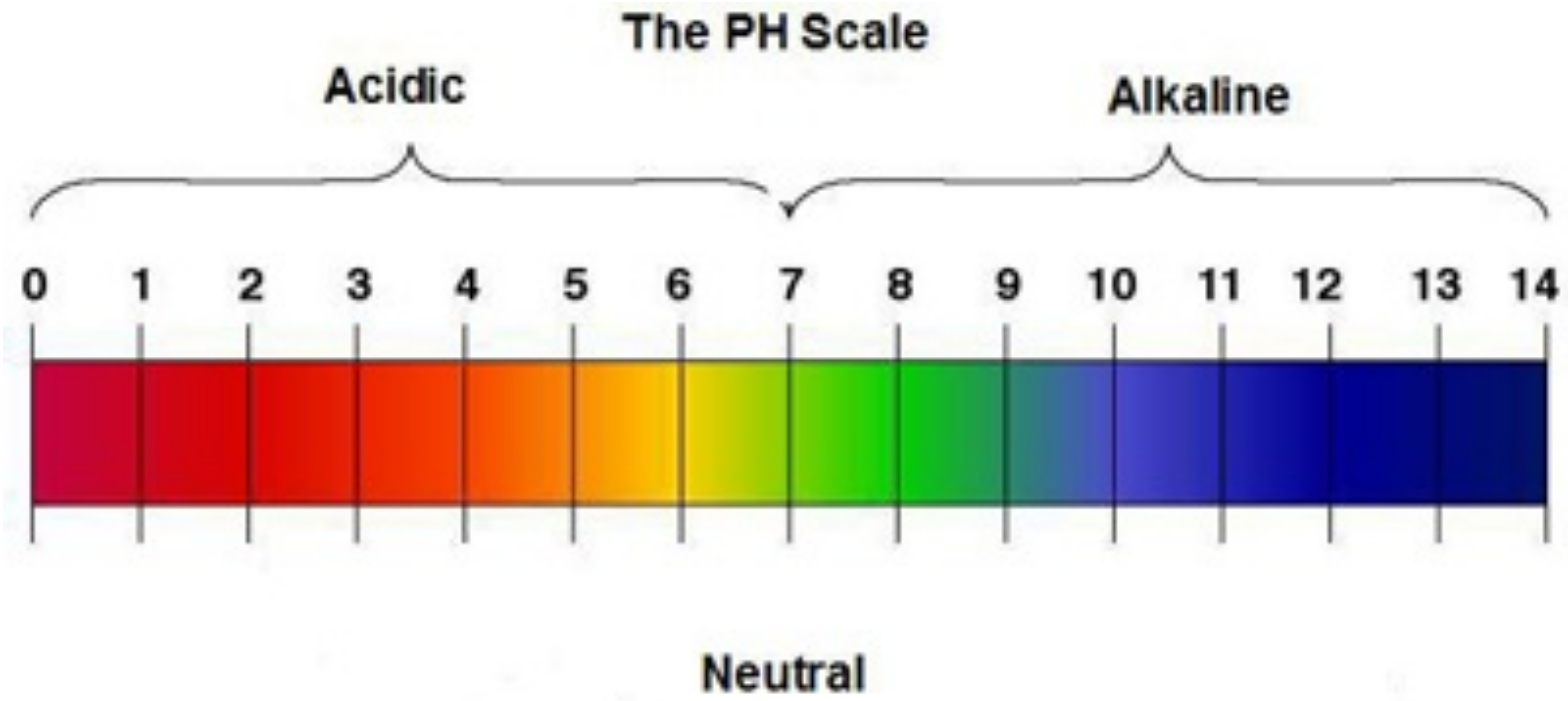
Acid- Base Testing



Shattering the Myths!!

Application

You will be amazed as to how many patients you will see each day that will benefit from acid-base analysis.

Do you routinely see any of these conditions in your practice?

- Vomiting / Diarrhea
- Diabetes
- Renal insufficiency
- Procedures requiring anesthesia or fluid therapy
- Toxicity ingestion (ethylene glycol, medications etc)

Benefits of Acid-Base Monitoring

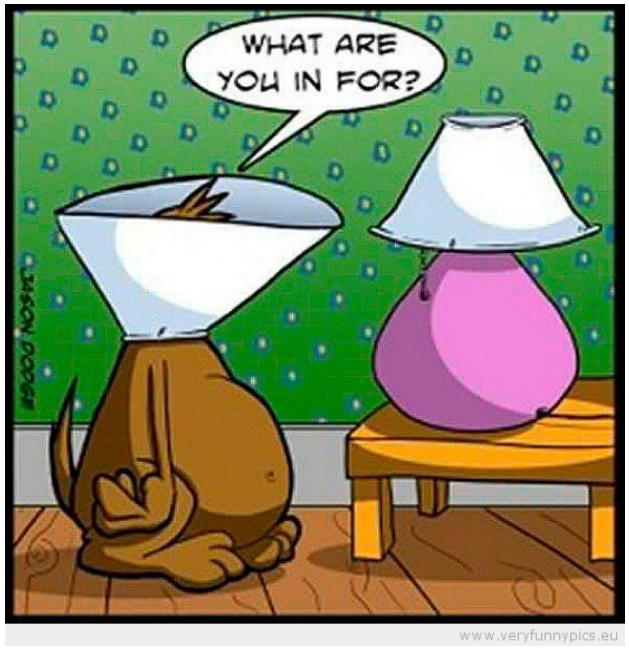
Aggressive vs. conservative treatment

- Hospitalization or outpatient
- Respiratory status
  - O_2 supplementation
  - Mechanical ventilation
- Fluids
  - Route, type, additives

Length of therapy

- normalized chemistry values
- abnormal pH/electrolytes

Response to therapy



Arterial vs. Venous Sampling

Arterial: Respiratory
- Oxygenation
- Ventilation
- Verify pulse-ox

Venous: Acid-Base
- Chemistry
- Hematology

**Always include electrolytes!

Normal Values	Arterial	Venous
Canine		
pH	7.35- 7.45	7.35-7.45
PO_2 (mmHg)	90-100	30-42
PCO_2 (mmHg)	35-45	40-50
HCO_3 (mmol/L)	20-24	20-24
Feline		
pH	7.34 +/- 0.1	7.30+/-0.08
PO_2 (mmHg)	102.9 +/- 15	38.6+/-11
PCO_2 (mmHg)	33.6+/- 7	41.8 +/- 9
HCO_3 (mmol/L)	17.5+/-3	19.4 +/- 4

Waddell, 2012, NAVC Clinician's brief

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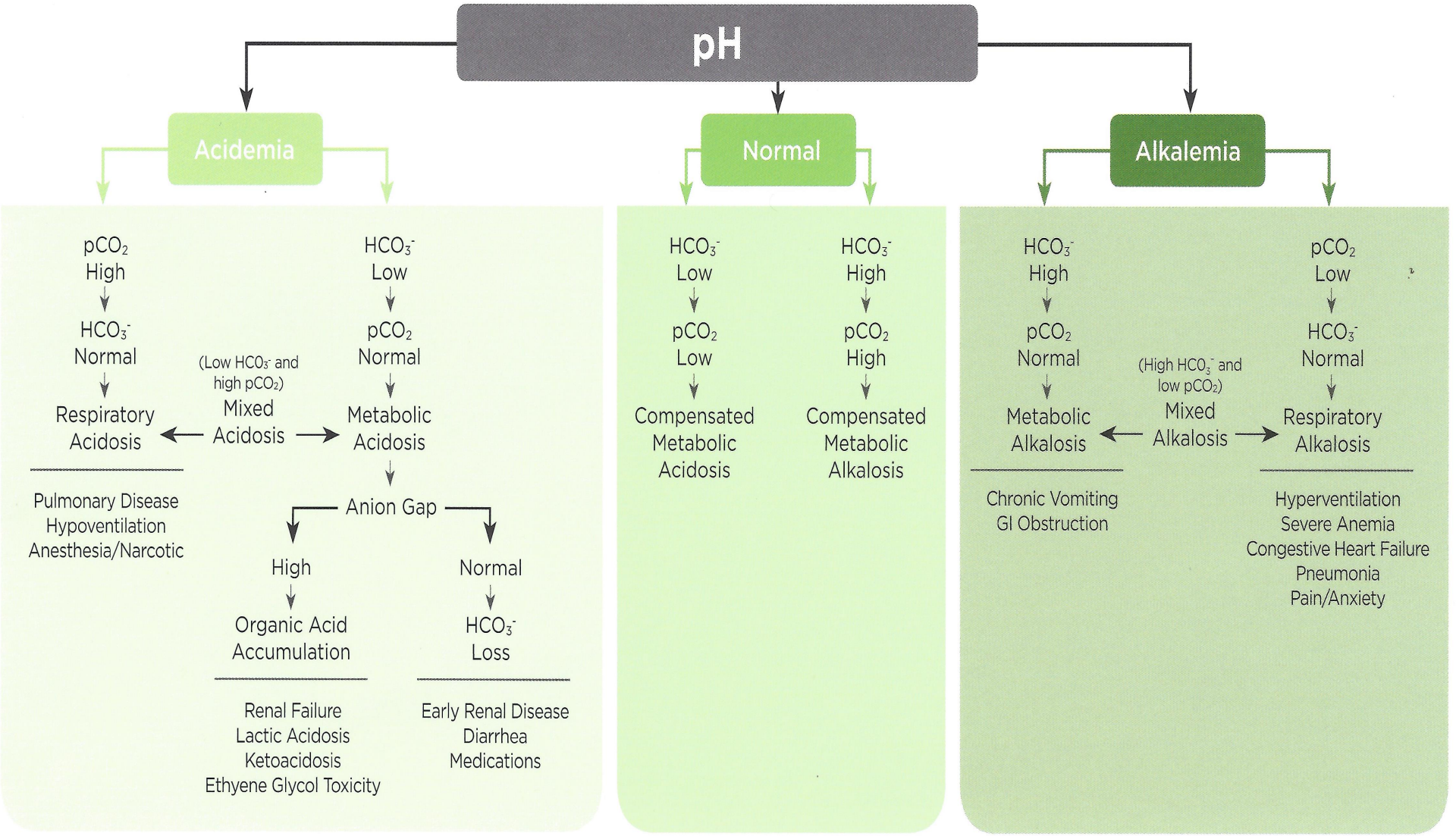
Venous Reference Ranges

iSTAT ranges		Dog	Cat
pH		7.35-7.45	7.25-7.40
pCO_2	(mmHg)	35-38	33-51
HCO_3	(mmol/L)	15-23	13-25
TCO_2	(mmol/L)	17-25	16-25
AG	(mmol/L)	8-25	10-27

Acid-Base Diagnostic Chart



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Common Disease States Where Acid-Base Analysis Is Beneficial

DIARRHEA

- Loss of sodium bicarbonate ($Na^+HCO_3^-$)
- Electrolyte abnormalities
- Potential loss of free body water

RENAL FAILURE

- Loss of sodium bicarbonate ($Na^+HCO_3^-$)
- Hydrogen (H^+) retention
- Electrolyte abnormalities
- BUN and Creatinine (plus others) buildup and act as toxins
- Lactate elevation with anemia

DIABETIC KETOACIDOSIS
(COMPLICATED DIABETES MELLITUS)

- Ketoacids
- Electrolyte abnormalities
- Elevated anion gap

VOMITING OR UPPER GI OBSTRUCTION

- Loss of H^+Cl^- (hydrochloric acid)
- Loss of K^+ (usually K^+Cl^-)
- Electrolyte abnormalities
- Potential loss of free body water
- Lactate elevation with gastric torsion (GDV)

EXPECTED ACID-BASE ABNORMALITIES pH < 7.35
(DEPENDING ON SPECIES)

- Most common presentation in veterinary patients – metabolic acidosis

CARTRIDGE CHOICES

CG4+: Acid-base, lactate
CG8+: Acid-base, HCT, electrolytes, acidosis often elevates **iCa^+**
EC8+: Acid-base, HCT, electrolytes, best if high Anion Gap expected

FLUID THERAPY – COMMONLY USED

- Normosol, Ringer's and Lactated Ringer's often best to correct acidosis
  - Fluids without lactate indicated for elevated lactate levels or hepatic disease
- Severe acidosis (i.e. pH < 7.25) consider bicarbonate therapy

EXPECTED ACID-BASE ABNORMALITIES pH > 7.45
(DEPENDING ON SPECIES)

- Metabolic alkalosis

CARTRIDGE CHOICES

CG4+: Acid-base, lactate especially helpful with emergency or GDV

CG8+: Acid-base, HCT, electrolytes, alkalosis can affect iCa^+

EC8+: Acid-base, HCT, electrolytes (especially Cl^-)

FLUID THERAPY – COMMONLY USED

- Saline (Na^+Cl^-): 0.45% vs. 0.9% based on hydration status and electrolyte levels
- K^+Cl^- supplementation common for vomiting patients (due to loss of K^+)
  - Low K^+ dictates addition to fluids

Review a real case!!

Patient: 7 month old SF Labrador Retriever

History / Physical exam:

- Frequent diarrhea for 2 days
- Vomited a couple times
- Not eating well
- TPR is WNL
- Slightly dehydrated
- Depressed
- Abdominal palpation: a bit gassy

Owner reports she carried home a decomposing opossum a few days ago.

PLAN: CBC & Biochemistry profile

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CBC Abnormalities

Test	Findings	Normal
HCT ↑	59%	37-55%
HgB ↑	19.5 g/dL 195 g/L	12-17 120-170

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Chemistry Abnormalities

Test	Findings	Normal
Amylase ↑	1810	200-1200 IU/L
BUN ↑	30 12	7-25 mg/dl 2.5-8.9mmolurea/L
TP ↑	8.5 g/dl 85 g/L	5.4-8.2 g/dl 54-82 g/L
Glucose ↑	117 mg/dl 6.5 mmol/L	60-110 mg/dl 3.3-6.1 mmol/L

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Initial Assessment

depressed juvenile K9

mild dehydration

mild azotemia

So….what do you do?

Your Options…….

1. Give the patient conservative therapy including SQ fluids & send it home?

2. Hospitalize the patient & administer IV fluids?

3. Check the Acid/Base status to see how sick the patient really is?

Acid-Base Review

- Why is it needed?
- Henderson-Hasselbalch
- The 4 classic acid-base disturbances

Why do we become concerned with pH?

Maintaining proper pH is vitally important…

Just as important as electrolytes!!!

- Intracellular processes (enzymes) work optimally within narrow pH
- Proper electrolyte balance between cells & body fluids
- Oxygen delivery to tissues (O_2-Hb affinity)
- Myocardial contractility & hence blood pressure is decreased with low pH
  - Arrhythmias may result (VPC's)

pH and Acid-Base

pH

- Measure of hydrogen ions in solution
- A measure of the acidity or alkalinity of the solution

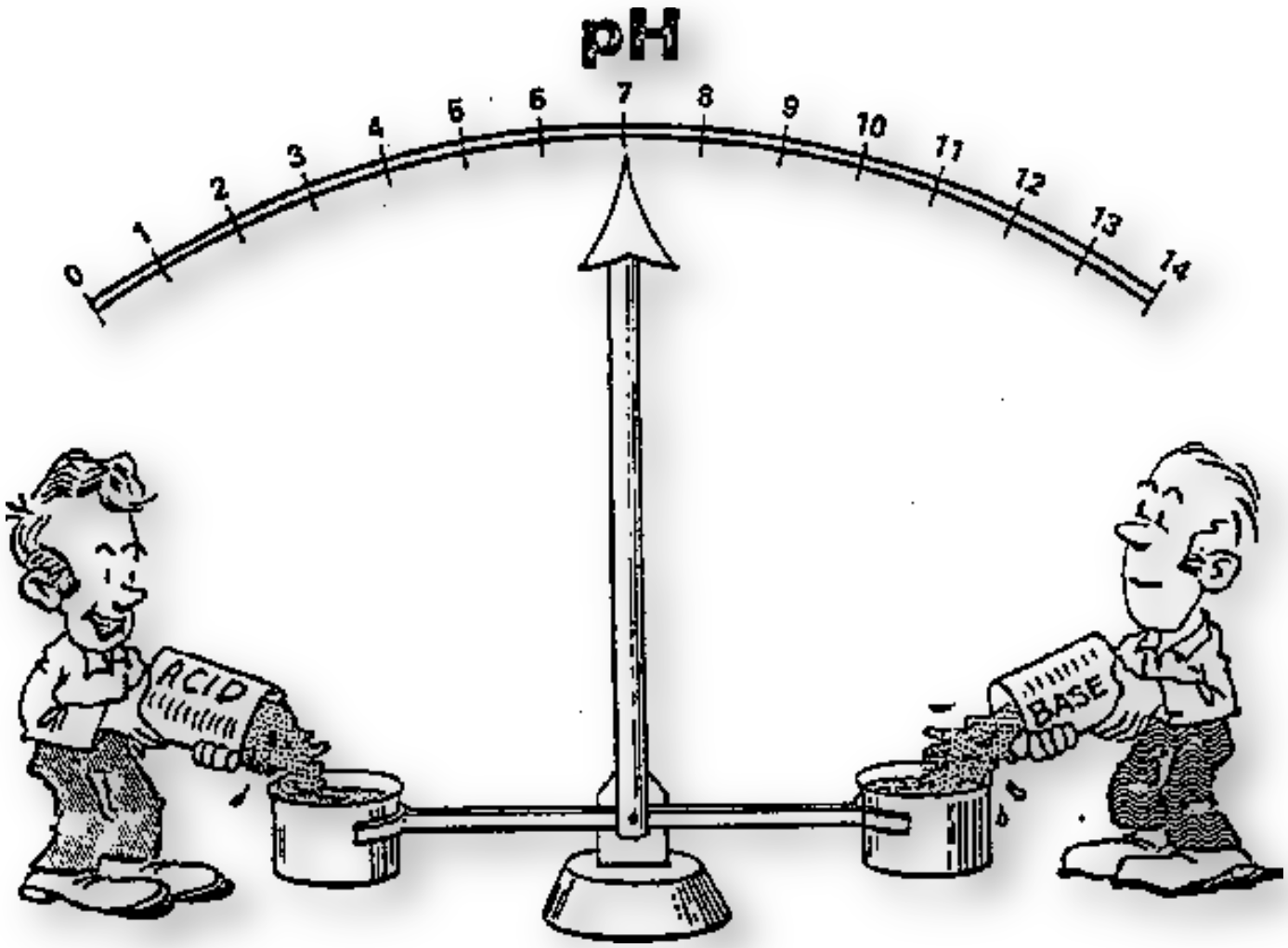
Acid

- Can donate a hydrogen (H+) ion to a base
- When dissolved in water (blood is mostly water) will create a pH < 7

Base

- Can accept a H+ ion
- When dissolved in water will create a pH >7

Acid and Base
pH (7.35-7.45)



Physiologic Acid-Base Regulation

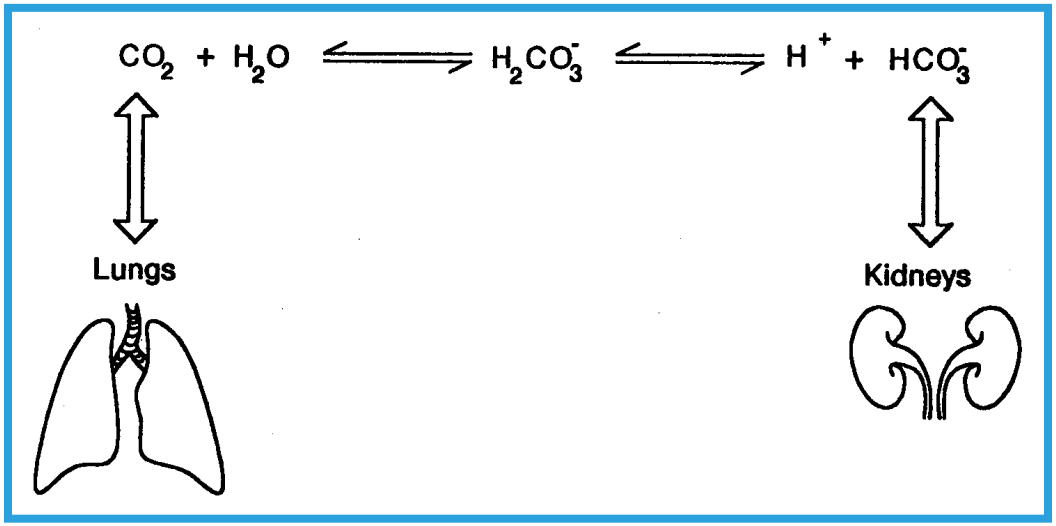
Henderson-Hasselbalch

$$pH = 6.1 + \log \frac{[HCO_3]}{[H2CO_3]} \Rightarrow pH = 6.1 + \log \frac{[HCO_3]}{[0.03\ XPCO_2]}$$

$$pH \approx \frac{[HCO_3]}{[PCO_2]} \approx \frac{[Base]}{[Acid]}$$

Physiologic Acid-Base Regulation

- **Kidneys (metabolic)**
  - HCO_3
  - Slow response (days)
- **Lungs (respiratory)**
  - CO_2
  - Quick response (minutes to hours)



Compensation is an active physiologic process and overcompensation does not occur

What do you need to know regarding acid-base?

Is the pH of my patient abnormal?

- Low pH (<7.35) ➡ **Acidotic**
- High pH (>7.45) ➡ **Alkalotic**

What is the cause of the abnormality?

- Respiratory (Heart/Lung) pCO2 ↑↓
- Metabolic (Mostly Kidney or Gastrointestinal) HCO3 ↑↓
- Mixed

Interpretation Simplified

$$pH \approx \frac{HCO_3}{PCO_2} \approx \frac{Base}{Acid} \approx \frac{[Kidney]}{[Lungs]}$$

1°Acidemia

- ↓ HCO_3 = Metabolic Acidosis
- ↑ PCO_2 = Respiratory Acidosis

1°Alkalemia

- ↑ HCO_3 = Metabolic Alkalosis
- ↓ PCO_2 = Respiratory Alkalosis

What else do you need to know?

- How severe is the abnormality?
- Do I need to treat the abnormality?
- How do I treat the abnormality?
- Is there compensation?
  - The body's way to help bring pH back to normal

$$pH \approx \frac{[HCO_3]}{[PCO_2]}$$

Anion Gap

Anion gap: amount of unmeasured anions in blood

$(Na + K + UC) = (Cl + HCO3 + UA)$

$AG = UA - UC$

Used to further describe metabolic acidosis and help determine the cause.

Increased Anion Gap	Decreased Anion Gap
Uremic acids	Uncommon
Lactic acid	Hypoalbuminemia
Ketoacids	Hemodilution
Toxins	

Base Excess or Base Deficit

The amount of acid or base needed to return the pH to 7.40

Used in treatment of acidosis = amount of base to administer

BE < -5 is a Base Deficit Acidosis

BE > 5 is a Base Excess Alkalosis

Sodium bicarbonate therapy

When?

- pH ≤ 7.1 *if respiratory function normal (impacts myocardial contractility)

What?

- mEq $NaHCO_3$ = (Normal – measured HCO_3 x 0.3 x kg)

How?

- ½ dose slow IV (20 min), remainder at maintenance IVF rate if needed

Goal of therapy: Increase the pH just enough to get out of the danger zone (i.e. pH 7.2), NOT to return the pH to normal

8.4% $NaHCO_3$= 1mEq/ml

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Calcium: Ca

An electrolyte important for bone formation, skeletal muscle and heart muscle tone, nerve and muscle activity, biochemical processes in the cells, and coagulation.

Hypocalcemia	Hypercalcemia
Kidney failure	Kidney failure
Milk fever/ Eclampsia	Cancer
Hypoparathyroidism	Hyperparathyroidism
Pancreatitis, PLE, ethylene glycol poisoning	Toxicity – grapes/plants/ rodenticide

Ionized Ca : iCa

iCa: active form of body calcium (50% of Ca in body ionized) and is the most important indicator of calcium levels.

Signs of Low iCa Dogs < 1.12; Cats < 1.20 mmol/L	Signs of High iCa Dogs > 1.40; Cats > 1.32 mmol/L
Restless, panting, lethargy	Weakness, coma
PU/PD, anorexia,	PU/PD, anorexia, constipation
Tachycardia	Bradycardia, heart block
Tremors, seizures, stiff gait	Ataxia, muscle twitching, seizures

Alkalosis ↓ iCa

Acidosis ↑ iCa

Lactate

Lactate assesses

- systemic perfusion
- 0_2 delivery & consumption

Lactate elevates with peripheral tissue hypoperfusion in various conditions	
Sustained heavy exercise	DKA
Asthma	Sepsis
Anemia	Organ failure (liver/kidney)
Trauma	GDV

High levels pre and post treatment can indicate a poor prognosis (poor tissue perfusion)

**References at end

Back to our case…

Puppy with dietary indiscretion

- depressed
- mild dehydration
- increased amylase
- mild azotemia

Check the acid-base status!

Acute Vomiting and Diarrhea

Test	Value	Range
pH	**7.30 (L)**	7.35-7.45
pCO_2	**33 (L)**	35-38
HCO_3	**12 (L)**	15-23
TCO_2	**16 (L)**	17-25
AG	15	8-25
BE	-5	-5 to +5

$$\downarrow pH \approx \frac{\downarrow [HCO_3]}{\downarrow [PCO_2]}$$

pH = Acidemia

HCO_3 = Metabolic Acidosis

pCO_2 = Respiratory compensation

Treatment

Hospitalization

Further diagnostics

- Fecal
- Abdominal radiographs/Ultrasound

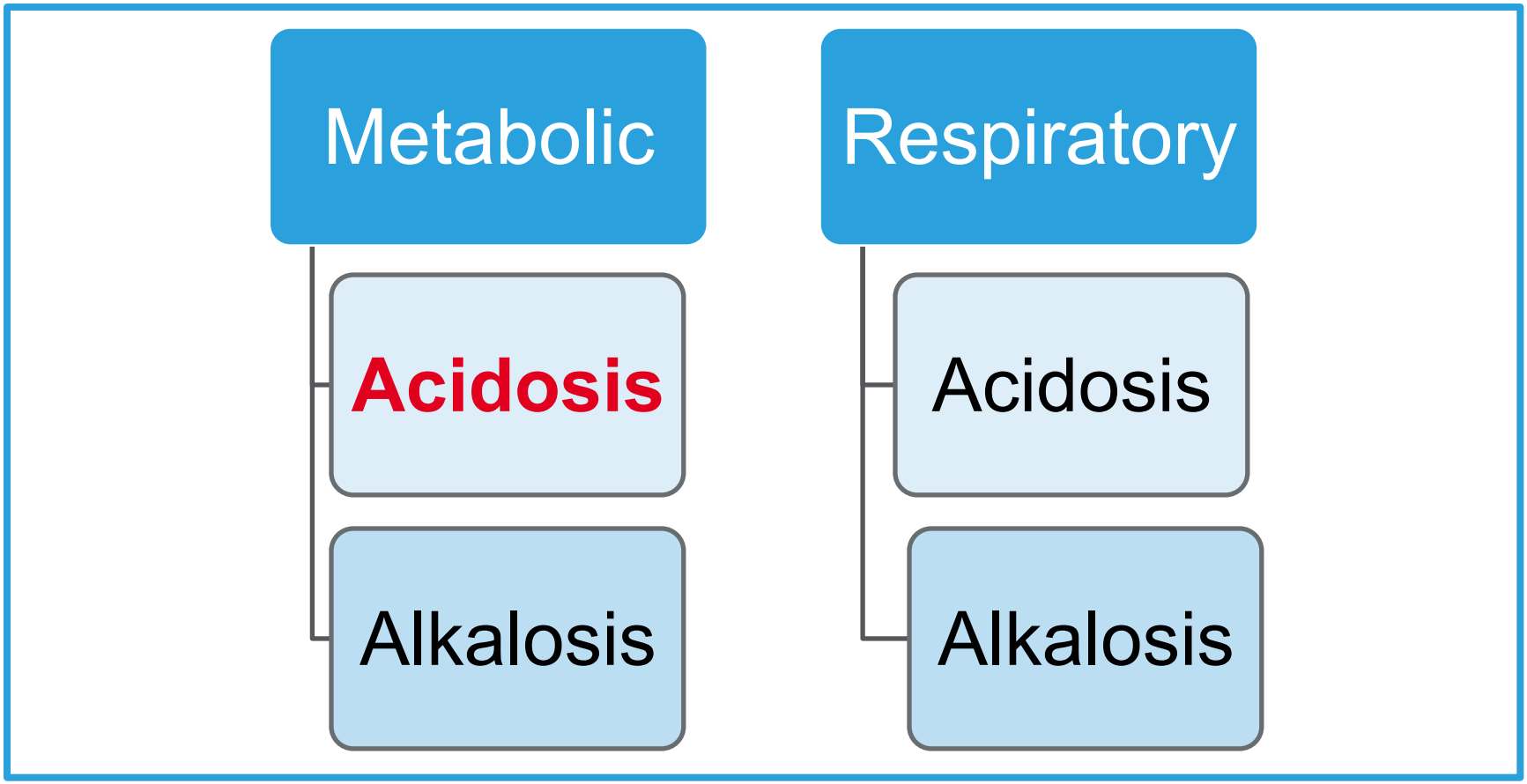
Fluids: LRS, Normosol, or Plasmalyte

Alkalinizing solution is key

Monitor acid-base and electrolytes

Outcome: IV fluids for 3 days & went home

Classic Acid-Base Disturbances



+/- compensation

Metabolic Acidosis

$\downarrow pH \approx \downarrow \frac{[HCO_3]}{[PCO_2]}$

Causes:

Vomiting

- Loss of duodenal & pancreatic secretions ($NaHCO_3$)

Diarrhea

- Loss of Bicarbonate ($NaHCO_3$)

Renal Failure/Insufficiency

- Loss of Bicarbonate ($NaHCO_3$)
- Hydrogen (H+) retention
- Electrolyte abnormalities

Diabetic Ketoacidosis

- Ketones = ↑ acid

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Physical Symptoms of Acidosis

Decrease in normal homeostatic chemical reactions

- Respiratory System:
  - Hyperventilation
- Cardiovascular System
  - Cardiac Arrhythmias
- Gastrointestinal System
  - Nausea, Vomiting, Diarrhea
- Musculoskeletal System
  - Weakness
- General Stability
  - Dehydration & Shock

Case #2

Patient: 9 yr. old. SF German Shepherd

History / Physical exam:

Vomiting on/off 3 weeks & not eating well

Seems to be drinking more than usual

QAR

5% dehydrated

Pale mm

Primary Diagnostics: CBC/Chemistry and radiographs

Case #2

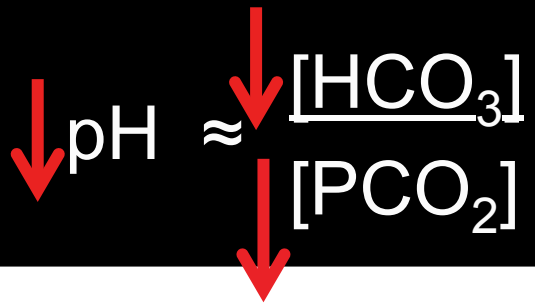
CBC

HGB	10.6 106	12-18 g/dl 120-180g/L
HCT	34	37-55 %

Chemistry

BUN	102 50	7-25 mg/dl 2.5-8.9mmol urea/L
CR	7.5 150	0.3-1.4 mg/dl 27-124umol/L
Phos	8 3	2.9-6.6 mg/dl 0.94-2.13mmol/L
Ca	13 4	8.6-11.8 mg/dl 2.15-2.95 mmol/L
TP	8.6 86	5.4-8.2 g/dl 54-82 g/L

Case #2



Test	Value	Reference Range
pH	7.29	7.35-7.45
pCO_2	32	35-38
HCO_3^-	11	15-23
iCa	1.3	1.12-1.40
Na	136	138-160
K	3.2	3.7-5.8
Cl	110	112-129
AG	35	8-25

pH = Acidemia

HCO_3 = Metabolic acidosis

pCO_2 = Respiratory compensation

AG = Uremic toxins

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Case #2 - Treatment

Address dehydration and electrolyte imbalances

Replacement and Maintenance crystalloid fluids

- **Alkalinizing**
  - Lactated Ringers, Normosol, Plasmalyte

Add Potassium to maintenance fluids.

Monitor acid-base, electrolytes

Outcome:

Continues to have kidney disease but went home eating and hydrated.

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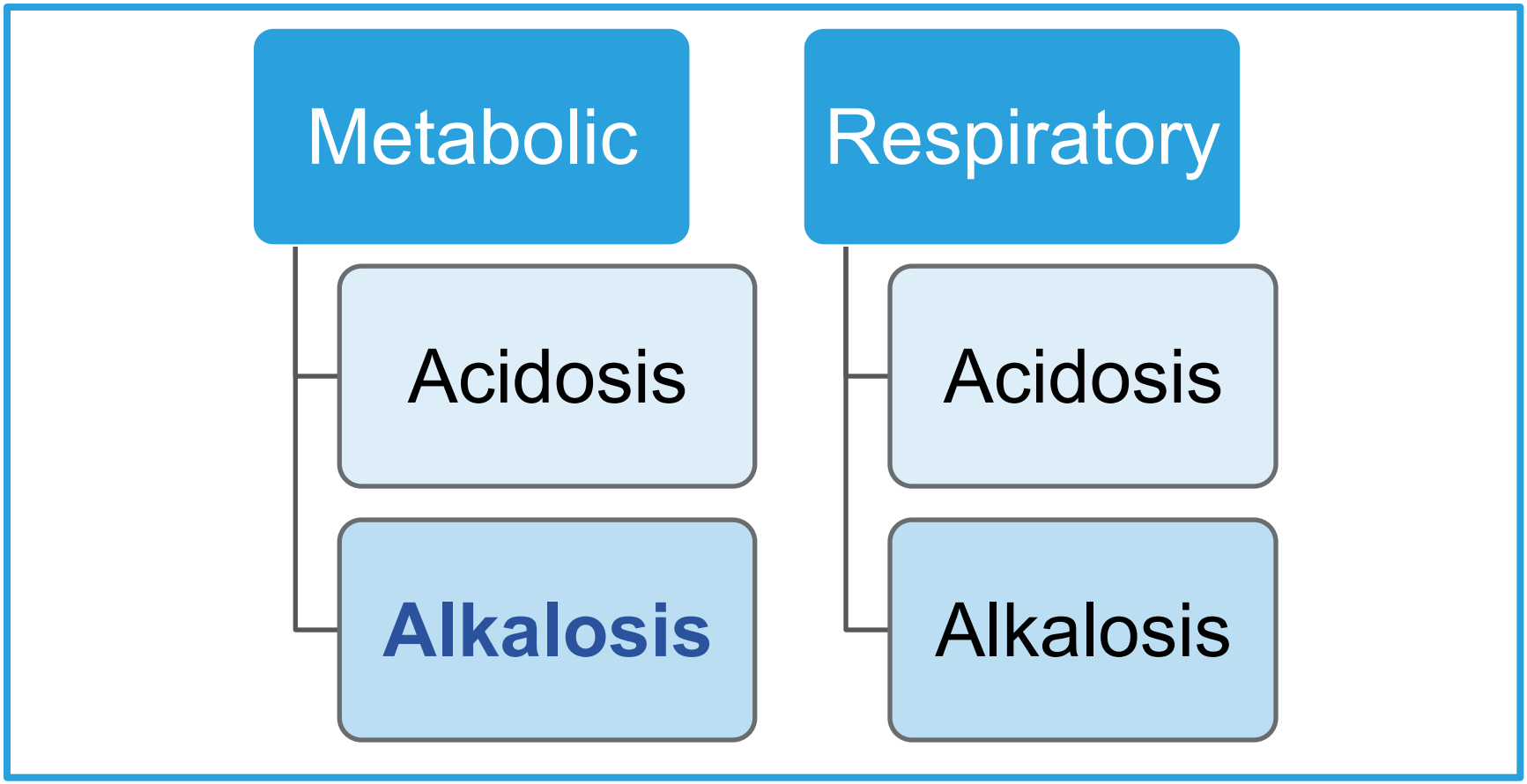
Classic Acid-Base Disturbances



+/- compensation

Metabolic Alkalosis ↑pH ≈ ↑$\frac{[HCO_3]}{[PCO_2]}$

Causes

- Loss of Acid
  - Vomiting (HCl)
    - » GI obstruction (pyloric)
  - Medications (i.e. furosemide)

Case #4

Patient: 5 yr. old. CM Westie

History / Physical exam:

Vomiting for 3 weeks & not eating well

QAR

5% dehydrated

Pale mm

Primary Diagnostics:

CBC/Chemistry

Case #4

CBC - WNL

Chemistry

BUN	**38** **13**	7-25 mg/dl 2.5-8.9 mmol urea/L
Ca	**13.0** **4**	8.6-11.8 mg/dl 2.15-2.95 mmol/L
TP	**8.6** **86**	5.4-8.2 g/dl 54-82 g/L

Case #4

$\uparrow pH \approx \frac{\uparrow [HCO_3]}{\uparrow [PCO_2]}$

Test	Value		Reference Range
pH	7.56	H	7.23-7.45
pCO_2	42	H	35-38
HCO_3^-	39	H	15-23
TCO_2	26	H	17-25
Na	133	L	139-150
K	2.5	L	3.4-4.9
Cl	85	L	106-127
iCa	1.25	N	1.12-1.40

pH = Alkalemia

HCO_3 = Metabolic Alkalosis

pCO_2 = Respiratory compensation

Why isn't respiratory compensation more effective?

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Case #4 - Treatment

Identify and correct cause of vomiting (if possible)

- Further diagnostics – radiographs, ultrasound

Replace electrolyte deficiencies with **acidifying** solution

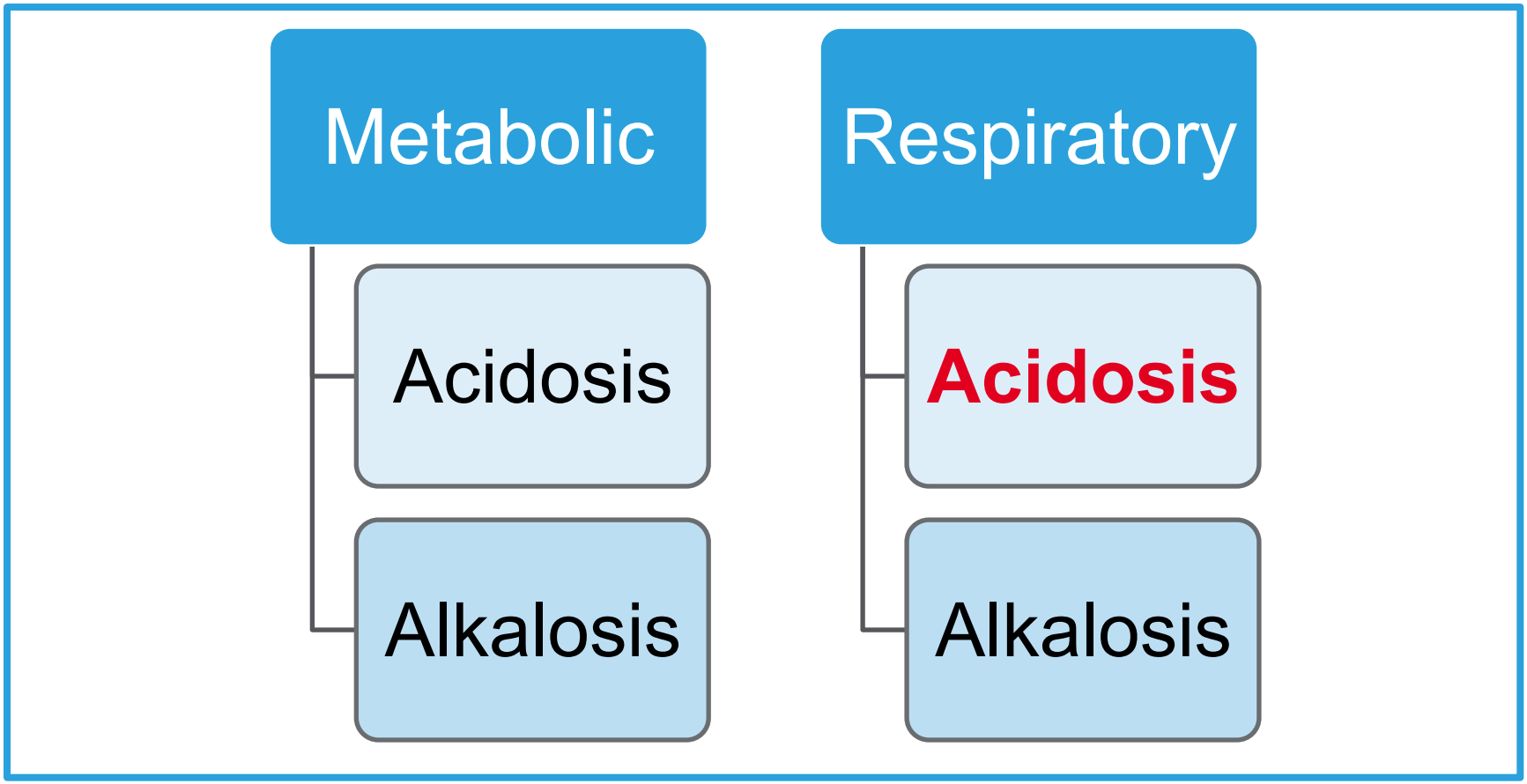
- 0.9% NaCl
- Supplemental K^+

Monitor acid-base, electrolytes

Outcome: Gastric mass 

Resectable 

Classic Acid-Base Disturbances



+/- compensation

Respiratory Acidosis

$\downarrow pH \approx \frac{[HCO_3]}{\uparrow [PCO_2]}$

- Anesthesia
- Respiratory disease
  - Infectious (pneumonia)
  - Trauma
  - Neoplasia
  - Decreased tidal volume
    - » GDV
    - » Pneumothorax
  - Brachycephalic Syndrome

Case #5

Patient

- 5 y/o MC bulldog presents for large dermal mass removal

PE

- Excited, panting
- Moderate to severe inspiratory stertor
- Mild mm cyanosis

CBC/Chemistry

- Normal

Case #5

$\downarrow pH \approx \frac{[HCO_3]}{\uparrow [PCO_2]}$

Test	Value	Reference Range
pH	**7.21**	7.35-7.45
pCO_2	**54.5**	35-38
HCO_3^-	20.7	15-23
Lac	0.6	0.6-2.9
TCO_2	24	17-25
BE	-5	-5-0

pH = Acidemia

pCO_2 = Respiratory acidosis

HCO_3 = No compensation

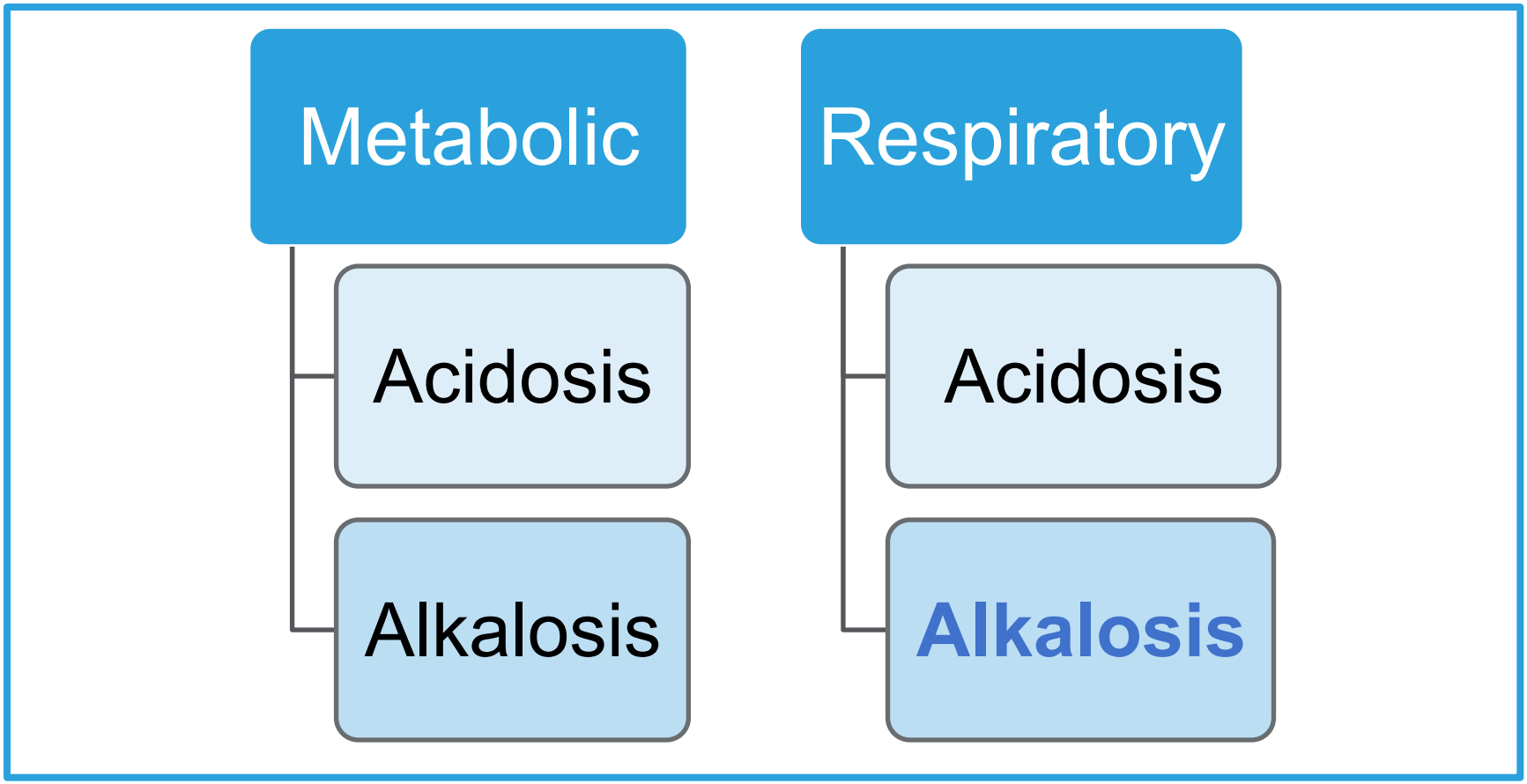
Why is there no metabolic compensation?

What does this say about ventilation?

Case #5 - Treatment

- Pre-oxygenate prior to induction & upon recovery
- Delay extubation
- Increased care in the use of drugs to minimize respiratory depression
- Consistent monitoring before, during & after surgery
  - Stable patients while under anesthesia: check acid-base status hourly
  - Unstable patients: check acid-base more often

Classic Acid-Base Disturbances



+/- compensation

Respiratory Alkalosis

- Hyperventilation
  - Stress
  - Pain
  - Fear
  - Iatrogenic (anesthesia)
- Increased Intracranial Pressure
  - Traumatic
  - Neoplastic
- Hypoxia
  - Anemia
  - Primary CNS disease
  - Sepsis

$$\uparrow pH \approx \frac{[HCO_3]}{\downarrow [PCO_2]}$$

Case #6

Patient and History

4 yr old FS Cat

Hit by a car 30 minutes prior to presentation

Had been healthy until that time

PE

Mild hypothermia, moderate tachycardia & dyspnea

Multiple lacerations

Fractured right femur

Next diagnostic steps: Bloodwork and radiographs

Case #6

$\uparrow pH \approx \frac{[HCO_3]}{\downarrow [PCO_2]}$

Test	Value	Reference Range
pH	7.5	7.25-7.4
pCO_2	30.6	33-51
HCO_3^-	22	13-25
Lac	4.0	0.5-2.7

pH = Alkalemia

PCO_2 = Respiratory Alkalosis

HCO_3 = No compensation

Lactate = Increased

What does an increase in lactate mean?

Case #6 -Treatment

- Stabilize patient
  - Analgesia
  - IV fluids
    - Plasmalyte or Normosol
  - O_2 supplementation
  - Fracture stabilization
- Monitor lactate and acid-base levels

- Outcome: Fracture repair and went home

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Case #7 - Advanced

Patient: 2 y.o. CM DSH

History:

Blocked urethra 3 days ago

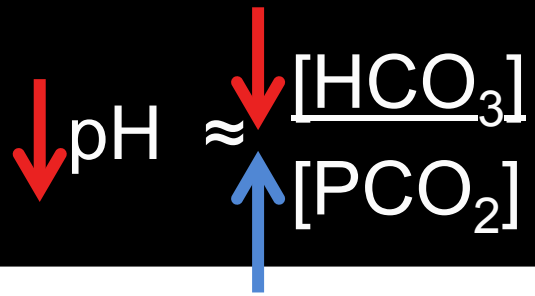
Oliguric

Severely obtunded

Primary Diagnostics:

Acid/ Base analysis and electrolytes

Case #7



Test	Value	Reference Range
pH	7.04	7.25-7.4
pCO_2	52.8	33-51
HCO_3^-	9.9	13-25
Na	132	139-150
K	8.5	2.9-4.2
Cl	108	112-129
AG	38	10-27

pH = Acidemia

HCO_3 = Metabolic acidosis

pCO_2 = Respiratory acidosis

AG = Uremic toxins, lactic acids, ketoacids

Why no respiratory compensation???

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Case #7 - Treatment

Establish urine flow

Maintenance crystalloid fluids

- **Alkalinizing**
  - Lactated Ringers, Normosol, Plasmalyte

Decrease potassium

- Urine flow
- +/- Insulin, calcium gluconate

Monitor acid-base, electrolytes

Outcome:

Full recovery

Emergency & Critical Care Evaluation and Monitoring

Immediate patient-side results in life-threatening situations

- **Acid-base status**
  - pH, HCO_3, pCO_2, AG, BE, TCO_2
- **Oxygen carrying capacity**
  - pO_2, sO_2, Hgb, HCT
- **Electrolytes**
  - Na+, K+, Cl-
- **Other important values**
  - iCa, Glu, BUN, CRE, Lactate

Your portable lab solution

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When Acid-Base/Blood Gas Analysis is Important

- Vomiting & diarrhea
- Renal disease
- Diabetes mellitus
- Respiratory disease
- Cardiac disease
- While under anesthesia

Resources**

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Questions?