Pediatric Pharmacology

Medications for Children Podiatry Edition

Hannah Park, DPM, FACFAS, FACPM
| Foot and Ankle Institute, Rush Oak Park Hospital, Chicago, IL

BALANCE
HEALTH

Conflict of Interest Disclosure

I, Hannah Park, has no financial relationship with companies and/or products which could affect the objectivity of this lecture.

The content of this presentation reflects the opinions of the speaker alone and any products or services mentioned are not endorsed by Balance Health.

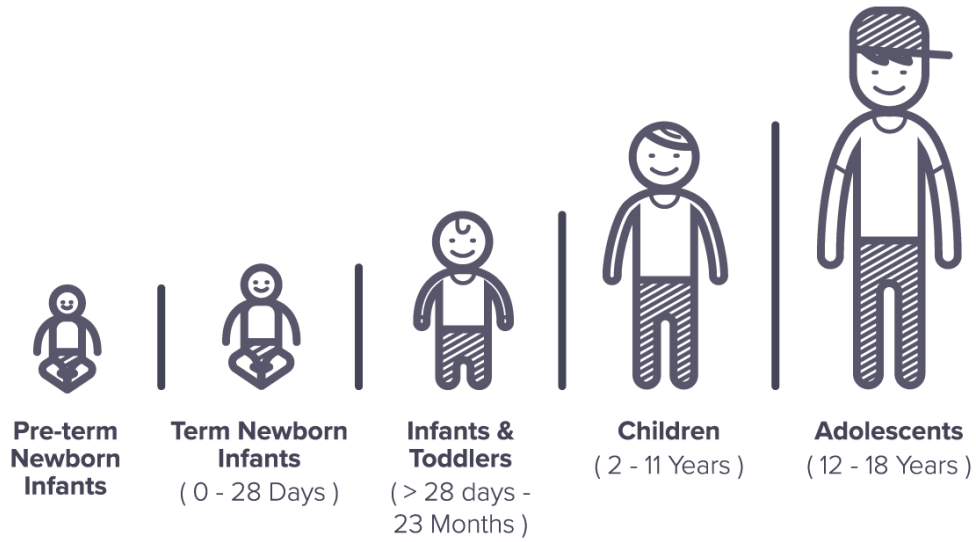
BALANCE
HEALTH

Objectives

- To understand pediatric pharmacology
  - Differences in Children in the Absorption and Excretion of Drugs

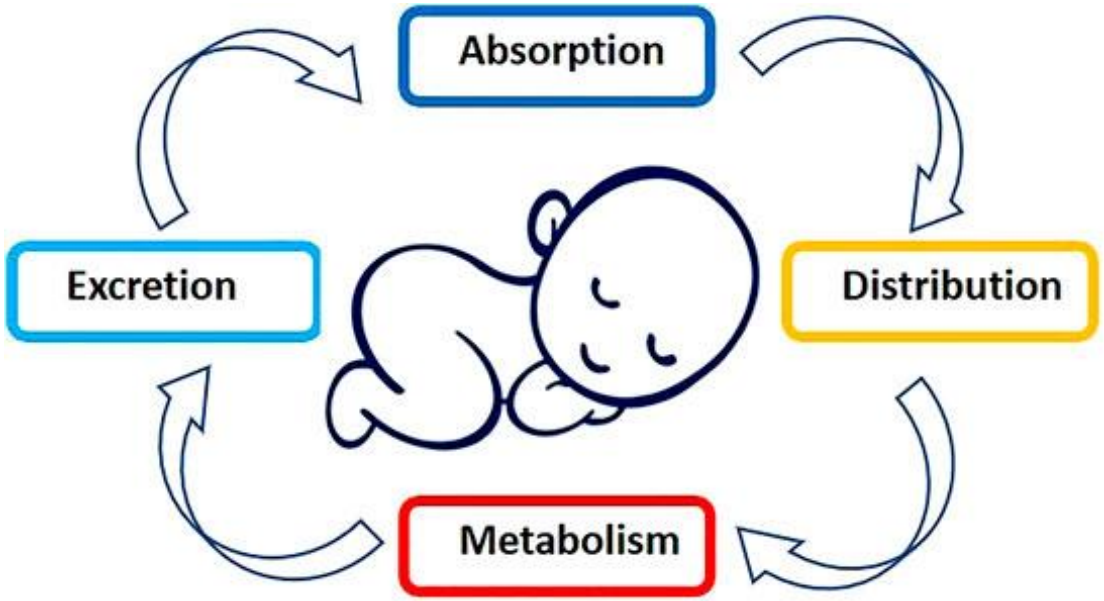
- To understand safe, effective, age-appropriate drug therapy in a podiatric setting

Pediatric Patient Groups



- Neonate: 0-28 days
- Infant: 1-12 months
- Toddler: 1-3 years
- Preschool 3-5 years
- School age: 6-12 years
- Adolescent: 13-18 years

Pediatric Dosing based Pharmacokinetics (ADME)



- Increased gastric pH and reduced gastrointestinal entering time (oral/enteral)
- Higher density of skeletal-muscle capillaries (i.m.)
- Thinner stratum corneum and higher hydration of epidemidis (topical)

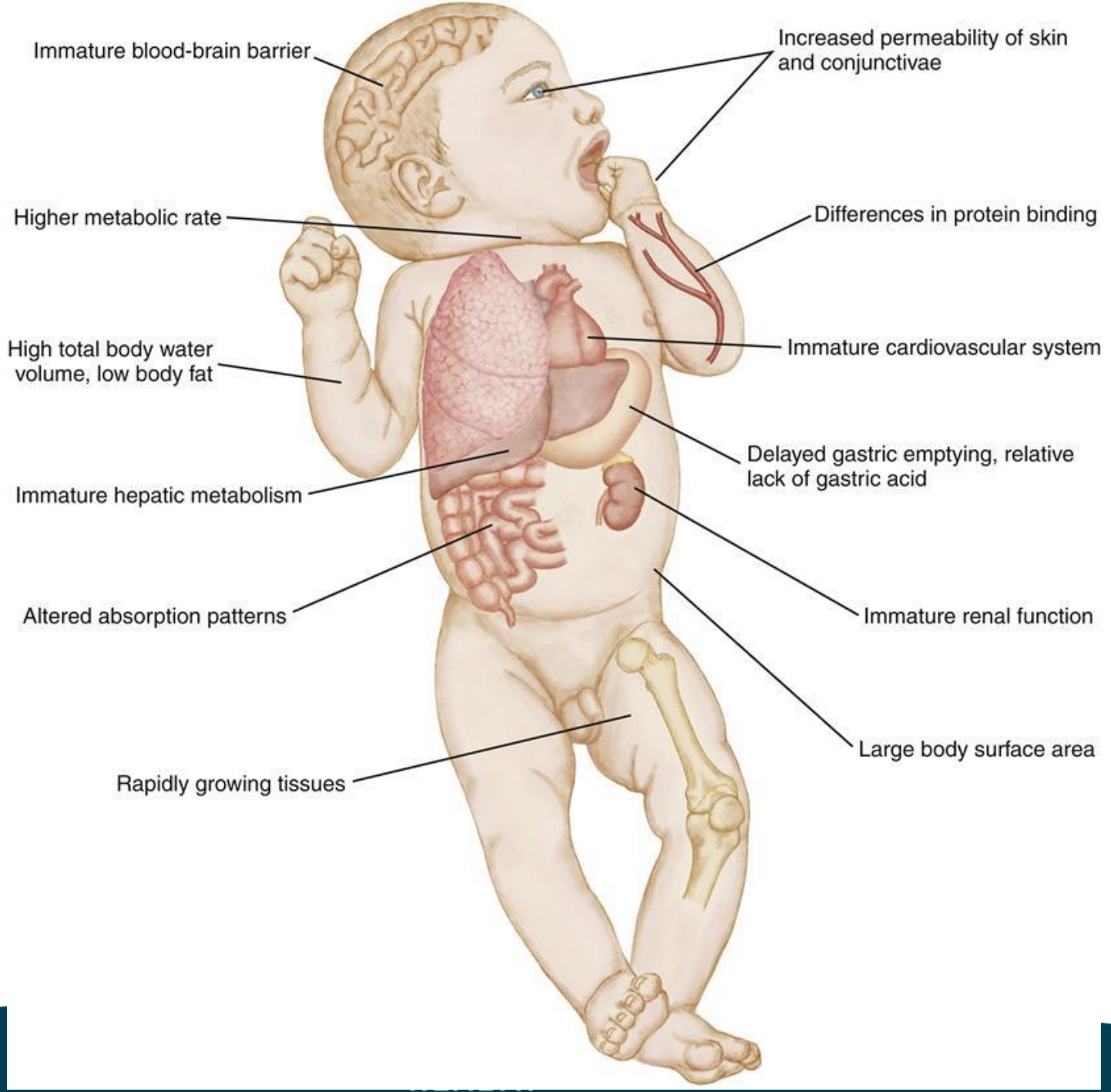
- Reduced hepatic drug-metabolizing enzyme activity
- Immaturity of intestinal drug-metabolizing enzymes and efflux transporters
- Reduced hepatic blood flow

- Increased lean mass versus fat mass per kg body weight
- Lower concentrations of drug-binding proteins (α1-acid glycoprotein and albumin)
- Higher plasma concentrations of bilirubin
- Altered blood flow, tissue perfusion, membrane permeability and cardiac output

- Reduced glomerular filtration rate
- Reduced tubular secretion
- Reduced tubular reabsorption

Absorption of Drugs in Pediatric Patients

Increase absorption, decrease metabolism, and excretion.



The Goal: Safety!

- Increased sensitivity to adverse effects
- Risk of toxicity due to immature organ systems

BALANCE HEALTH

KIDs (Key Potentially Inappropriate Drugs in Pediatrics) List Harmful Drugs.

JPPT | 2025 KIDs List

Pediatric Pharmacy Association 2025 KIDs List of Key Potentially Inappropriate Drugs in Pediatrics

Christopher McPherson, PharmD; Rachel S. Meyers, PharmD; Jennifer Thackray, PharmD; Danielle L. Stutzman, PharmD; Kimberly P. Mills, PharmD; Sana J. Said, PharmD; Karisma Patel, PharmD; Robert C. Hellinga, PharmD; Amy L. Potts, PharmD, MMHC; Lisa Lubsch, PharmD; Kelly L. Matson, PharmD; and David S. Hoff, PharmD

Table 1. Key Potentially Inappropriate Drugs in Pediatrics (KIDs) List: Second Edition *(cont.)*

Drug (Systemic Administration Unless Otherwise Noted)	Risk/Rationale	Recommendation	Strength of Recommendation	Quality of Evidence

www.jppt.org

Potential Inappropriate Drugs in Pediatrics : Codeine & Tramadol

Table 1. Key Potentially Inappropriate Drugs in Pediatrics (KIDs) List: Second Edition *(cont.)*

Drug (Systemic Administration Unless Otherwise Noted)	Risk/Rationale	Recommendation	Strength of Recommendation	Quality of Evidence
Opioids				
Codeine[126–130]	Respiratory failure, death	Avoid in younger than 12 yr Avoid in 12–18 yr of age after surgery to remove tonsils and/or adenoids Caution in 12–18 yr of age Recommend pharmacogenetic testing	Strong	High
Tramadol[129,130,134]	Respiratory failure, death	Avoid in younger than 12 yr Avoid in 12–18 yr of age after surgery to remove tonsils and/or adenoids Caution in 12–18 yr of age Recommend pharmacogenetic testing	Weak	Low

Potential Inappropriate Drugs in Pediatrics (2nd ed): Tetracycline & Verapamil

Table 1. Key Potentially Inappropriate Drugs in Pediatrics (KIDs) List: Second Edition *(cont.)*

Drug (Systemic Administration Unless Otherwise Noted)	Risk/Rationale	Recommendation	Strength of Recommendation	Quality of Evidence
Tetracyclines[33,146–150] Demeclocycline Eravacycline Minocycline Omadacycline Sarecycline Tetracycline Tigecycline	Tooth discoloration	Caution in younger than 8 yr	Strong	High (demeclocycline, tetracycline) Low (minocycline, sarecycline, tigecycline) Very low (eravacycline, omadacycline)
	Enamel hypoplasia (tetracycline)	Caution in younger than 8 yr	Strong	High
	Retardation of skeletal development and bone growth (tetracycline)	Caution in younger than 1 mo	Strong	Moderate
Verapamil[157–159]	Cardiovascular collapse	Caution in younger than 1 yr	Weak	Low

BALANCE HEALTH

Potential Inappropriate Drugs in Pediatrics (2nd ed): Aspirin & Salicylic Acid

Table 1. Key Potentially Inappropriate Drugs in Pediatrics (KIDs) List: Second Edition *(cont.)*

Drug (Systemic Administration Unless Otherwise Noted)	Risk/Rationale	Recommendation	Strength of Recommendation	Quality of Evidence
Salicylates[139,140] Aspirin Bismuth Subsalicylate Salicylic Acid (topical) Salsalate	Reye syndrome	Caution in 18 yr of age and younger with suspicion of viral illness (influenza and varicella)	Weak	Very low

THE KIDS LIST

KEY POTENTIALLY INAPPROPRIATE DRUGS IN PEDIATRICS

Infographic BY: KELSEY BENTLEY *AUHCOP P3 STUDENT*

What is it?

A detailed list of medications that have been studied and found to be harmful in the pediatric population. The KIDs List organizes medications into drugs that should be "avoided" or "used with caution" in all or a subset of the pediatric population. The list consists of 67 drugs, 39 being in the "avoid" category and 23 in the "use with caution" category.

Why is it Needed?

Growth and development in pediatrics from birth to the adolescent years is a dynamic process. Pediatric patients are at a higher risk of ADRs as significant maturational changes in both body composition and organ function occur. This changes the pharmacologic response of drugs in pediatrics and requires a unique understanding of physiologic characteristics at different ages and the direct changes in pharmacokinetics of drugs.

Defining Categories

Low Birth Weight: <1500g
Neonate: < 1 month
Infant: < 24 months
Children: < 18 years

Avoid: strong recommendation or life-threatening/altering ADRs

Caution: lacks strong recommendation or benefits may outweigh the risks

Antibiotics

Nitrofurantoin
Risk: hemolytic anemia
Recommendation: Avoid in neonates

Macrolides:
Azithromycin and Erythromycin
Risk: hypertrophic pyloric stenosis
Recommendation: Avoid in neonates unless treating B. pertussis, C. trachomatis, ureaplasma

Dicloxacillin and Ceftriaxone
Risk: Kernicterus
Recommendation: Caution in neonates

Chloramphenicol
Risk: gray baby syndrome
Recommendation: Avoid in neonates *serum monitoring*

Tetracyclines:
Demeclocycline and Tetracycline
Risk: tooth discoloration, enamel hypoplasia, slowing of skeletal and bone growth
Recommendation: Caution in < 8 years

Daptomycin
Risk: Neuromuscular and skeletal and events
Recommendation: Caution in infants

Dopamine Antagonists

Drugs
Chlorpromazine, Fluphenazine, Haloperidol, Metoclopramide, Perphenazine, Pimozide, Prochlorperazine, Promethazine, Trifluperazine, Trimethobenzamide

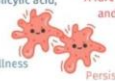
Risk:
Acute dystonia (dyskinesia): increased risk of respiratory depression, extravasation, and death with IV use

Recommendation:
Avoid in infants
Caution in children

Salicylates

Drugs
Aspirin, Bismuth subsalicylate, Choline magnesium trisalicylate, Magnesium salicylate, Methenamine, sodium phosphate monobasic, phenyl salicylate, methylene blue, hyoscyamine, Methyl salicylate (topical), Salicylic acid, Salsalate

Recommendation:
Caution in children with suspicion of viral illness (influenza and varicella)



Risk: Reye's Syndrome

What?
A rare condition that causes the brain to swell and the loss of liver function after a viral illness or infection

Symptoms?
Persistent or recurrent vomiting, Listlessness, Personality changes, Disorientation or confusion

Pain

Benzocaine
Risk: methemoglobinemia
Avoid in infants for teething or pharyngitis

Lidocaine
Risk: seizures, arrythmias, death
Avoid in infants for teething

Naloxone
Risk: Seizure
Avoid in Neonates for postpartum resuscitation

Codeine and Tramadol
Risk: respiratory depression, death
Avoid in children *unless pharmacogenetic testing is used*

Meperidine
Risk: Respiratory Depression
Avoid in neonates, Caution in children

Other Strong Recommendations

Carbinoxamine: Death
Avoid in Infants

Darunavir: Seizures, Death
Avoid in < 3 years or < 10kg

Dicyclomine: Apnea
Avoid in < 6 months

Diphenoxylate and atropine: Respiratory Depression, Death
Avoid in < 6 years

Hexachlorophene: Neurotoxicity
Avoid in Neonates

Indinavir: Nephrolithiasis and Hyperbilirubinemia
Avoid in Children

Lamotrigine: Skin Reactions
Caution in Children*titrate*

Loperamide: Ileus, Lethargy
Avoid in Infants for acute infectious diarrhea

Midazolam: hemorrhage, leukomalacia, death
Avoid in Very Low Birthwt Infants

Mineral Oil: Lipid pneumonitis
Avoid in Infants

Olanzapine: Metabolic Syndrome
Caution in long-term use

Paregoric: Gasping, Seizures
Avoid in Children

Propofol: infusion syndrome
Avoid doses > 4 mg/kg/hr for > 48 hr

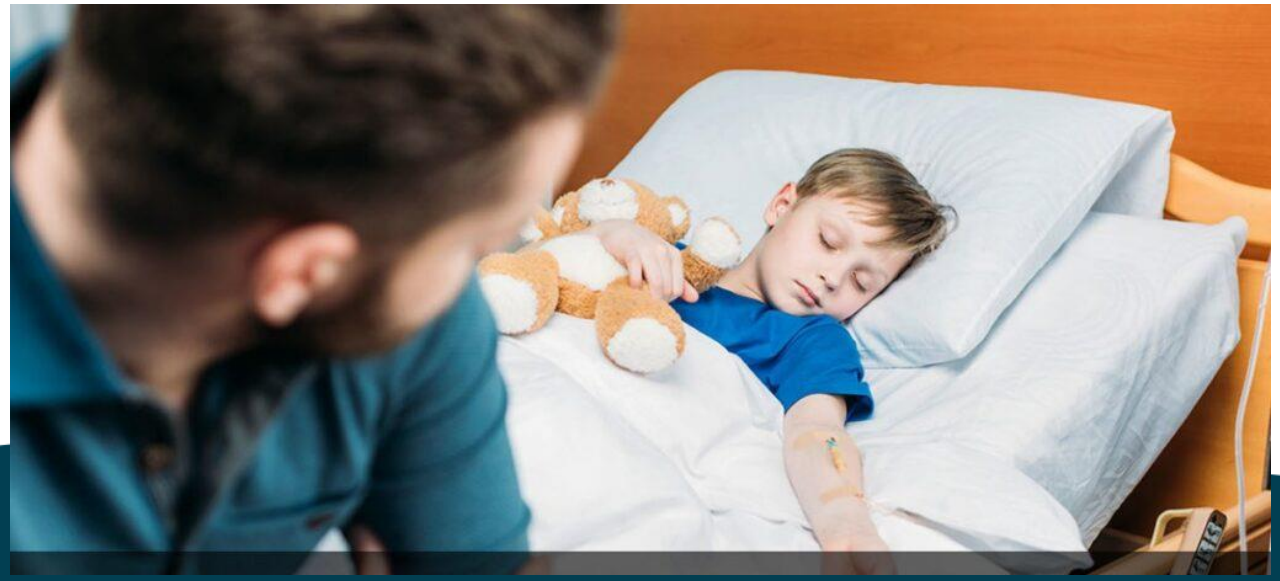
Meyers RS, Thackray J, Matson KL, McPherson C, Lubsch L, Hellinga RC, Hoff DS. Key Potentially Inappropriate Drugs in Pediatrics: The KIDs List. J Pediatr Pharmacol Ther. 2020;25(3):175-191. doi: 10.5863/1551-6776-25.3.175. PMID: 32265601; PMCID: PMC7134587.

Potential Inappropriate Drugs in Pediatrics

Propofol[135–137]	Propofol-related infusion syndrome	Avoid doses >4 mg/kg/hr for greater than 48 hr in 18 yr of age and younger	Strong	Moderate

- 2017 FDA- Use of GA and sedation in children < 3 years for lengthy periods or multiple surgeries can negatively affect brain development.
- Also, GA & sedation for more than 3 hours can cause widespread changes in nerve cells in the brain.

But surgeries and procedures should not be delayed if medically necessary for pts < 3 years of age.



Topical Pain Management

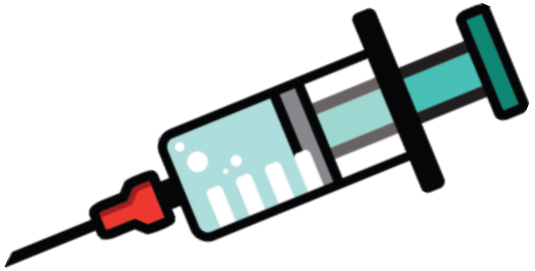
- EMLA cream helps to reduce pain. (Lander 2006; Baxter 2013; Young 1996; Lim 2017) ELMA (lidocaine 2.5% and prilocaine 2.5%) * Effective for one hour*

Age	EMLA Recommendation
Less than 3 months old	1 gram on 10 cm square (1 finger tip)
3-12 months	2 gram on 20 cm square
1-6 years	10 grams on 100 cm square

- Aspercream with Lidocaine 4%
- Avoid Ethyl chloride spray in infants- burn

BALANCE HEALTH

Pain Management
Local Anesthesia Block



Agent	Without Epinephrine	With Epinephrine	Duration	Notes
Lidocaine	5 mg/kg (max 300mg)	7 mg/kg (max 500mg)	30-90 min	▪ 1% soln contains 10 mg/ml ▪ 2% soln contains 20 mg/ml
Bupivicaine	2.5 mg/kg (max 175mg)	3 mg/kg (max 225mg)	6-8 hr	▪ 0.5% soln contains 5 mg/ml ▪ May cause cardiac arrest if injected intravascularly ▪ Do not buffer with bicarbonate

- Aspirate to make sure it's not intravenous.
- Side effects, bupivacaine, especially dose-related: numbness, tingling, drowsiness, blurred vision, ringing of the ears, changes in blood pressure, heart rate, or chest pain. Nausea or vomiting, hives, itching, or swelling.

BALANCE HEALTH

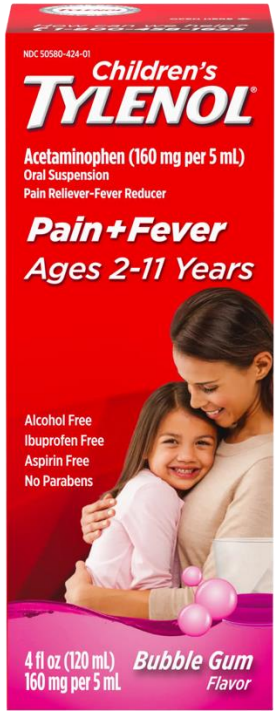
Pain Management: Acetaminophen

(mild to moderate pain, fever)

- Oral/Rectal: 10-15mg/kg every 4-6 hours.
- Adolescents: 325-650 mg every 4-6 hours
- IV: 10-15 mg/kg every 4-6 hours
- Liquid suspension, ,chewable tablet, tablet and suppositories.
- Max of 4,000 mg/day

BALANCE HEALTH

Pain: Acetaminophen: Tylenol, Tempra, Panadol



Weight	Age	Infant Tylenol (Acetaminophen) Oral Suspension 160 mg/5 mL Can be given every 4 hours	Children's Tylenol (Acetaminophen) Oral Suspension 160 mL/5 mL Can be given every 4 hours
		Infant and Children's concentration is ***IDENTICAL* and **can** be used interchangeably **	
6-11lbs	0-3 mos.	1.25 mL	1.25 mL
12-17lbs	4-11 mos.	2.5 mL	2.5 mL
18-23lbs	12-23 mos.	3.75 mL	3.75 mL
24-35lbs	2-3 years	5 mL	5 mL
36-47lbs	4-5 years	____	7.5 mL
48-59lbs	6-8 years	____	10 mL
60-71lbs	9-10 years	____	12.5 mL
72-95lbs	11 years	____	15 mL
> 95lbs	12+ years	____	20 mL

BALANCE HEALTH

Pain Management: Ibuprofen

(NSAID mild to moderate pain, inflammation, fever)

- Oral: 5-10 mg/kg every 6-8 hours (max of 40mg/kg/day 2,400 mg/day)
- Adolescents 200-400 mg every 4-6 hours as needed.
- Liquid suspension, chewable tablets, tablets

Pain: Ibuprofen: Motrin or Advil (>6 months)

Weight	Age	Infant Motrin or Advil (Ibuprofen) Concentrated Drops 50 mg/1.25 mL Can be given every 6 hours	Children's Motrin or Advil (Ibuprofen) Oral Suspension 100 mg/5 mL Can be given every 6 hours	Children's Motrin or Advil (Ibuprofen) Chewable 100 mg tablet Can be given every 6 hours
		Infant and Children's concentration are ***DIFFERENT* and are **not** interchangeable**		
6-11lbs	0-5 mos.	**********Not to be given in Infants < 6 months of age**********		
12-17lbs	6-11 mos.	1.25 mL	2.5 mL	_____
18-23lbs	12-23 mos.	1.875 mL	3.75 mL	_____
24-35lbs	2-3 years	____	5 mL	1 tablet
36-47lbs	4-5 years	____	7.5 mL	1.5 tablets
48-59lbs	6-8 years	____	10 mL	2 tablets
60-71lbs	9-10 years	____	12.5 mL	2.5 tablets
72-95lbs	11 years	____	15 mL	3 tablets
>95lbs	12+ years	____	20 mL	4 tablets

BALANCE HEALTH

Pain Management: Norco & Tramadol

- Hydrocodone/Acetaminophen (5/325) (Moderate to severe pain) (Caution Respiratory depression, nausea, constipation)
  - > 18 yrs: hydrocodone 0.1-0.2mg/kg (max 5 mg per dose) combined with acetaminophen every 4-6 hours.
  - Flatfoot reconstruction or Ankle fracture post op (< 5 days worth)

- Tramadol (Caution: risk of seizures and serotonin syndrom
  - > 12 years: 1-2 mg/kg every 4-6 hours as needed (max of 400mg/day)

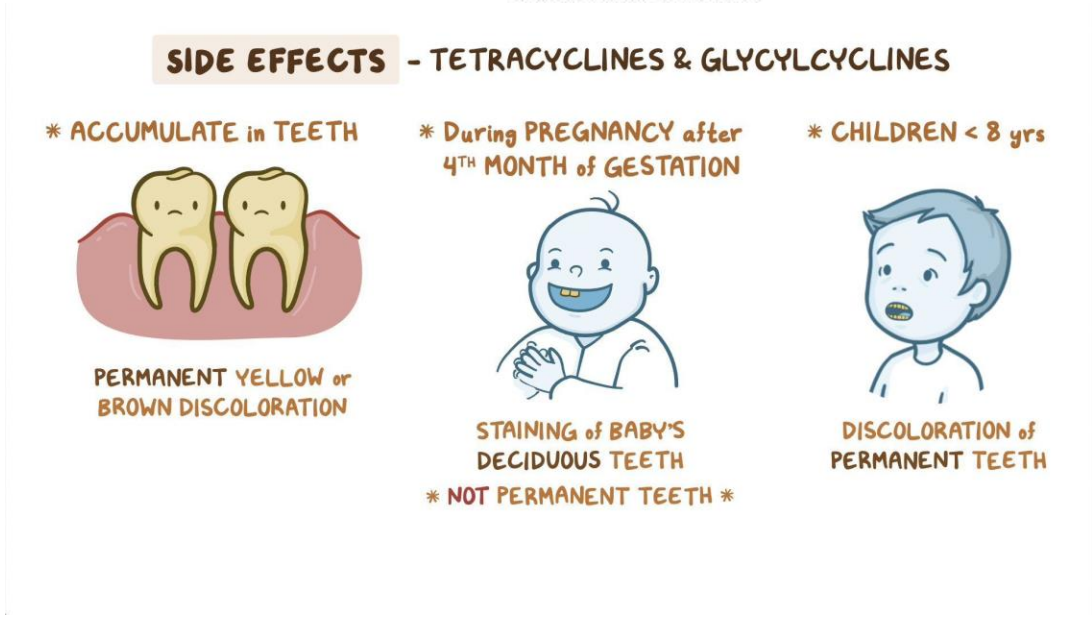
BALANCE HEALTH

Infection Management: Antibiotics

Antibiotic	Dosage	Course	Bacterial Coverage	Commonly used for
Amoxicillin	200-400 mg/kg/day in 4 dosage dosage. Max: 12g/day	7 days	GP: Strep GN: E coil/Kleb	Ear, respiratory strep throat infections
Augmentin (Amoxicillin & Clavulanate)	45 mg/kg/day total day dose is 496.3 or 248.2mg po BID or 5.0 ml of 250mg/5ml BID. Or 3.1 ml of 400mg/5ml BID.	7 days	GP: Strep, MSSA GN: E coil/Kleb Anaerobes	Severe infection
Cephalexin	25mg/kg/day is 275.7 mg or 68 mg po QUID or 2.8 ml of 125 mg/5ml QID or 1 ml of 250mg/5ml QID (25-50mg/kg/da7)	7 days	GP: Strep, MSSA GN: E coil/Kleb	Skin & Soft tissue infection, respiratory
Doxycycline (> 10 years of age)	4.4mg/kg/day divided into 2 doses a day. 100mg BID (45kg and up)		GP: Strep, MSSA, MRSA GN: E coil/Kleb	Open fracture, suspecting bone infection

Antibiotics for Children 101

- Avoid Tetracyclines (< 10 yrs) which can cause tetracycline-calcium orthophosphate complex and cause enamel hypoplasia, discoloration of teeth and dysfunction of bone growth (Reed and Besunder, 1989)
- Avoid Quinolones like cipro which can cause abnormal articular cartilage and reversible arthralgia (Anderson and Goldstein 1987)



Plantar Warts: Salicylic acid

- Most common treatment
- OTC 5%, 10%, 17%, prescriptions 60% and 70%
- Chemical debridement of excess keratin and inducing a local inflammatory response.
- Patch or liquid

Efficacy Rates: 14.3-84%, 5-92% (higher in < 12 years old)

- PRO: Safe, Cheap, self-application
- CONS:
  - Major exfoliator
  - Infection
  - Painful
  - Low efficacy (may take weeks to months)

Plantar Warts: ORAL Cimetidine

Efficacy: 26-87% cure rate

- Pro: Safe of all ages
  - Used on immunocompromised
  - Recalcitrant warts
- CONS: side effects
  - Headache, dizziness, diarrhea, rash, urticaria, alopecia, gynecomastia, breast soreness, arthralgias, and myalgias

- Pediatric patients 25-40mg/kg per day in divided doses
- Adults 20mg/kg daily max of 1600mg Daily

- 4-10 years (by weight)
- 10-14 years of age: 200mg BID
- 14-18 years of age: 200mg TID

Cimetidine (H2 receptor antagonist)

- Not FDA approved for warts, but acid reflux.
- Dr. Seth Orlow and Dr Paller in 1993 first used to simulate the body's immune response and successfully treated multiple resistant warts in 36 children (86%)
- Safe, lone treatment for all age groups, even immunocompromised patients
- Immune system enhancement
- Cimetidine had been previously reported to exhibit immunomodulatory activity by increasing mitogen-induced lymphocyte proliferative and inhibiting suppressor T-cell function at the histamine type 2 receptor site.

Summary

- Pediatric Pharmacology requires understanding age-related changes
- Safe prescribing depends on developmental physiology
- Ongoing research and legislation to improve pediatric drug safety.

BALANCE
HEALTH

THANK YOU!

Hannah Park, DPM, FACFAS

Email: hannahparkdpm@gmail.com

Cell: 630-873-9177

BALANCE
HEALTH