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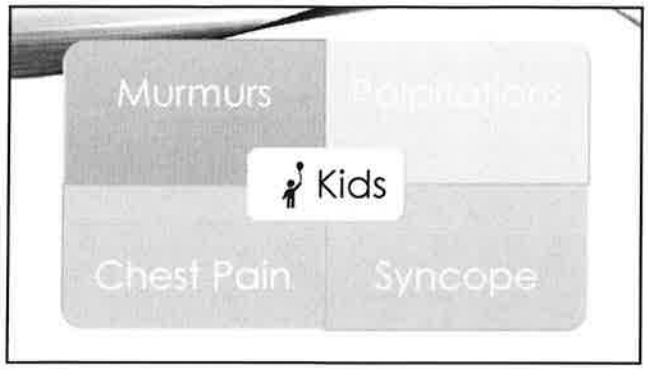
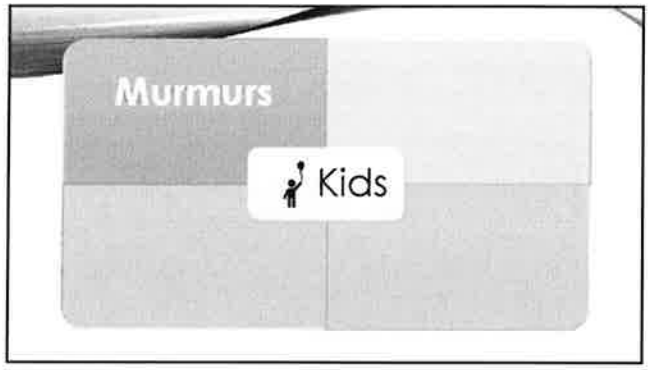
EVALUATION OF CARDIAC CONDITIONS IN CHILDREN:

WHEN TO WATCH, WHEN TO REFER

I have no financial disclosures.

- Summarize murmurs, palpitations, syncope, and chest pain in children.
- Distinguish cardiac from noncardiac causes of these conditions.
- Recognize significant physical exam findings and patient history information.
- Identify conditions that warrant referral to pediatric cardiology.





MURMURS

- Approximately 80% of children ages 3-4 may have a murmur
- 61% of murmurs referred to specialist are innocent (no cardiac pathology)
- Less than 1% of all murmurs result from congenital heart disease
- Most common reason for referral to pediatric cardiologist

CASE SCENARIO: ANDREW

At the one year check-up of a patient you have followed since birth, you detect a 2/6 systolic murmur at the LLSB that you had not previously detected before.

The blood pressure and pulses are normal.

CASE SCENARIO: ANDREW

He has gained weight and has grown well.

How do you decide if this is innocent, and what do you tell the parents?

WHAT IS A MURMUR?

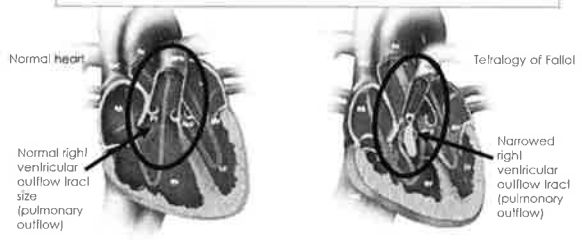
- Sounds produced by vibrations caused by turbulent blood flow through the heart
- Can also be caused by normal blood flow through normal structures (innocent)
- Can be intensified by anything that decreases cardiac output
  - Anemia
  - Fever

MURMURS

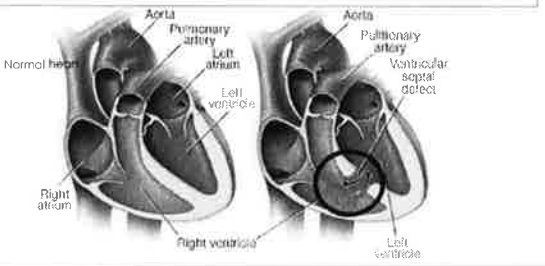
Systolic murmurs have only a few possible causes:

- Blood flow across an outflow tract (pulmonary or aorta)
- VSD (ventricular septal defect)
- Atrioventricular valve regurgitation (AVV)
- Patent ductus arteriosus (PDA)
- Benign (innocent)

BLOOD FLOW ACROSS AN OUTFLOW TRACT
EXAMPLE: TETRALOGY OF FALLOT

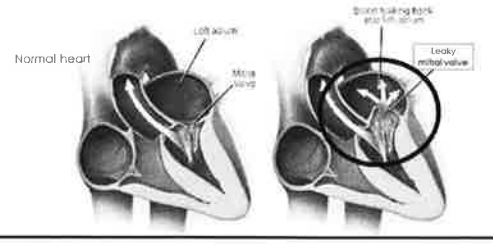


SEPTAL DEFECTS
EXAMPLE: VENTRICULAR SEPTAL DEFECT

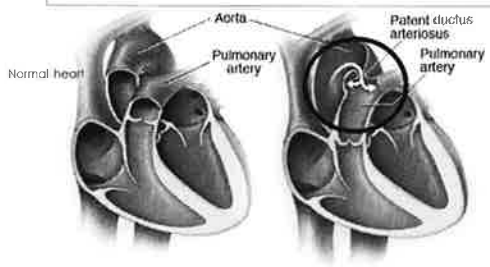


ATRIOVENTRICULAR VALVE REGURGITATION

EXAMPLE: MITRAL REGURGITATION



PATENT DUCTUS ARTERIOSUS



DESCRIBING MURMURS

Grades

- 1-6
- 1 is barely audible
- 3 is loud but no thrill
- 4 is loud and has palpable thrill
- 6 is audible without stethoscope
- **3 or above considered pathologic**

Timing

- Can occur early, middle, late in systole
- **Holosystolic**

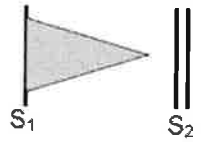
Quality

- **Harsh**

DESCRIBING MURMURS

Timing

1. Systolic ejection murmurs
2. Holosystolic murmur
3. Decrescendo systolic murmur



Decrescendo murmur

AUSCULTATION

First Heart Sound – S1

- Left lower sternal border
- Caused by closure of mitral and tricuspid valves
- Normally a single sound

☐ **Clicks**

AUSCULTATION

Second Heart Sound – S2

- Left upper sternal border
- Closure of aortic and pulmonic valves
- Split S2 - should split into 2 components with inspiration
  - A2 – closure of aortic valve
  - P2 – closure of pulmonic valve
  - Occurs because inspiration brings more blood into the right ventricle, RV ejection is prolonged and pulmonary valve closes later

☐ **Loud, single S2**

PALPATION

- **Active Precordium**
  Can be pathologic or benign
- **Discrepant Brachial and Femoral Pulses**
  Compare right brachial and femoral
- **Thrill**

MURMURS - HISTORY

Family History
- **Sudden cardiac death at young age (suspicious accidents, drownings)**
- **Congenital heart disease**

Prenatal/Maternal History
- **Advanced maternal age**
- **Diabetes mellitus**
- **Exposure to teratogens or alcohol during pregnancy**
- **Maternal infection (e.g. Rubella)**

HISTORY

Infants
- **Poor weight gain**
- **Poor or brief feedings**
- **Diaphoresis with feeding**
- **Tachypnea or increased work of breathing**
- **Color changes**
- **Chromosomal abnormalities/congenital anomalies**

HISTORY

Older children

- ☐ **Chest pain**
- ☐ **Syncope**
- ☐ **Exercise intolerance**
- ☐ **Rheumatic fever**

HISTORY - **SAFER** APPROACH TO PEDIATRIC MURMURS

Syndromic features
Age
Family History
Evaluation of feeding and growth
Rheumatic fever

BENIGN, "INNOCENT" MURMURS

- "Still's murmur"
  - Brief, vibratory quality, grade 1-3, low-pitched
  - Best heard with bell of stethoscope @ LLSB
  - Typical age 2-6, but not exclusively
  - Loudest in supine, diminishes in intensity with sitting or standing
- Pulmonary flow murmur
  - Loudest with inspiration and supine, diminishes with standing and Valsalva
- Supraclavicular flow murmur
  - Loud in supine, diminishes with neck hyperextension
- Venous hum
  - Disappears with head "looking down" position

BENIGN, "INNOCENT" MURMURS

Considered benign if 4 criteria met:

I. Absence of abnormal physical exam findings
II. Negative review of systems
III. Negative history and family history
IV. Auscultation findings consistent with innocent murmur

BACK TO ANDREW...

2/6 systolic murmur
Normal BP and perfusion
Thriving well
Negative history and review of systems

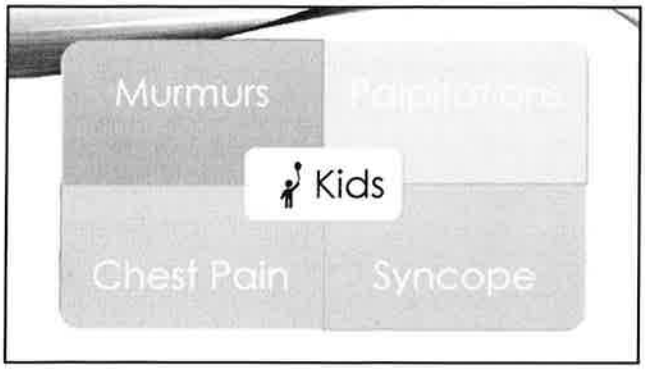
Louder in supine position, diminishes upon standing

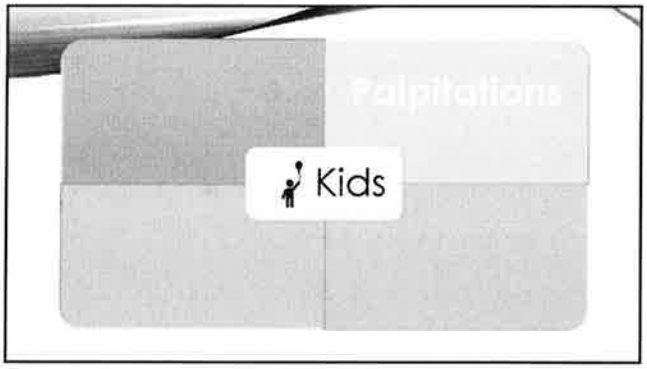
What is your diagnosis?

Innocent murmur of childhood

MURMURS THAT WARRANT REFERRAL

- **Presence of first-degree relative with sudden cardiac death at young age or congenital heart disease**
- **Cyanotic patients or impaired perfusion**
- **Neonates with symptoms**
- **Harsh murmurs, > grade 3**
- **Trisomy 21/malformation syndromes**
- **Failed neonatal screen**





PALPITATIONS

- Subjective feeling of abnormal heartbeat or "racing"
- Most causes are benign
- Although cardiac dysrhythmias are frequently the underlying etiology of palpitations in adults, same is not true for children
- Incidence of dysrhythmias is 0.5 per 1,000 pediatric ED visit (50% of those are sinus tachycardia)

HISTORY

HPI
- Parental report of "fussiness" in infants
- Young child: "heart is pounding" or "beeping" or c/o chest pain

Onset and duration of symptoms
- **Rapid, sudden resolution**

Associated symptoms
- Dizziness, syncope, shortness of breath, chest pain
- Fever or gastrointestinal illness

PALPITATIONS - HISTORY

Family History
- **Sudden cardiac death at young age (suspicious accidents)**

Dietary & Social History
- Evaluate for food/substances that can explain palpitations
  - Caffeine
  - Dietary supplements
  - Illicit drugs (cocaine, amphetamines)

PHYSICAL EXAM

- **Murmur or other abnormal heart sounds**
- **Hepatomegaly**
- **Wheezing**
- **Jugular vein distension**
- **Peripheral edema**
- **Deafness**

CARDIAC CAUSES OF PALPITATIONS

- Sinus tachycardia
- Tachydysrhythmias
  - SVT
  - PVC/PAC
  - A-flutter
  - A-fib
  - V-tach
- Repaired congenital heart disease
- Bradycardia
  - AV block
  - Sinus pauses
- Cardiomyopathies
- Myocarditis
- Mitral valve prolapse

NON-CARDIAC CAUSES OF PALPITATIONS

- Electrolyte imbalances
- Asthma
- Hyperthyroidism
- Anxiety/Panic attacks
- Stress
- Fever
- Medications/Drugs
- Dietary Substances

PALPITATIONS

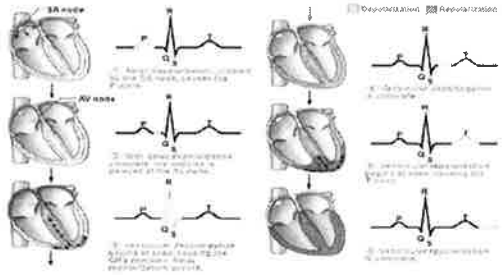
Real question:

Are symptoms caused by arrhythmia or normal (sinus) rhythm?

Diagnostic tools

- EKG
- Holter
- Event monitors

NORMAL ACTIVATION SEQUENCE



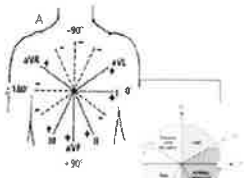
RHYTHM ANALYSIS

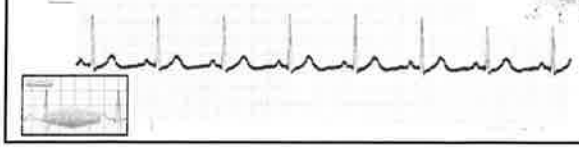
How are the P and QRS related?

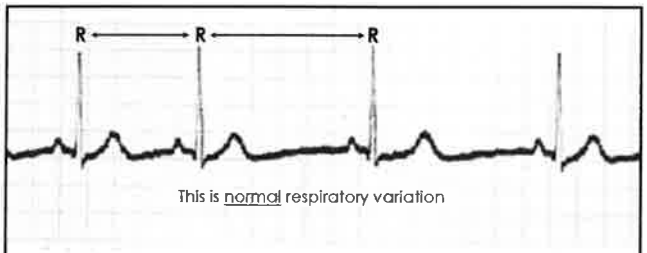
Who leads?
Who follows?

NORMAL (SINUS) RHYTHM

- P wave precedes every QRS
- QRS complex follows every P
- Normal P wave axis
  (0-90° or upright in leads I and aVF)



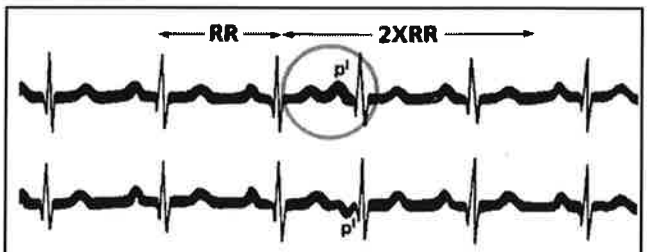




This is normal respiratory variation

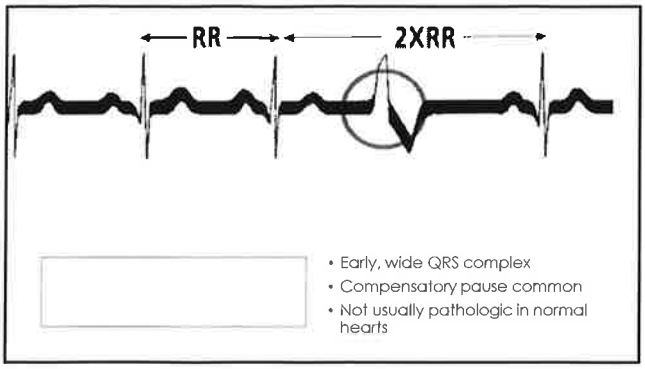
SINUS ARRHYTHMIA

- P wave precedes every QRS
- QRS complex follows every P
- Normal P wave axis
- Rate varies



ATRIAL ECTOPY (PAC)

- Early, abnormal P waves
- Narrow QRS complex
- Not usually pathologic in normal hearts



- Early, wide QRS complex
- Compensatory pause common
- Not usually pathologic in normal hearts

SUPRAVENTRICULAR TACHYCARDIA (SVT)

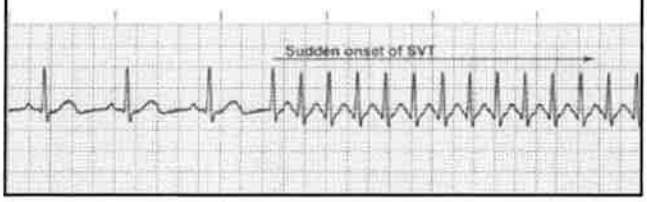
- Most common pediatric tachyarrhythmia
- Incidence as high as 1 in 250
- 50% of pediatric cases occur in infancy
- Most patients have structurally normal hearts

Rate

- **Infant: 220-300bpm**
- **Small children: >220bpm**
- **Older children: >180bpm**

SVT

- Usually narrow complex
- P waves are abnormal (if recognizable)



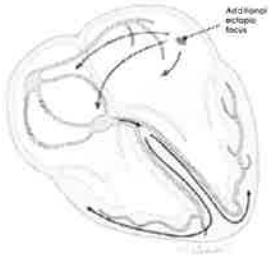
SVT - PRESENTATION

Infants
- **Irritable, fussy, or feeding poorly**
- **CHF (diaphoresis, pallor, resp distress) if episode has been untreated x several hours**
- **History of not behaving per usual x 1-2 days**

Children
- **Palpitations, racing, neck pounding, short of breath, dizzy**
- CHF is rare

SVT - MECHANISM

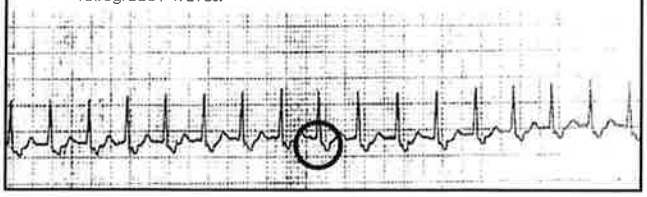
1. **AV Nodal Reentrant Tachycardia** (AVRNT)
   - Re-entry occurs within AV node
   - No accessory pathway
   - Most common SVT in adults
2. **AV Reentrant Tachycardia** (AVRT)
   - Re-entry uses accessory pathway
   - Most common SVT in children
   - WPW is one type
3. **Atrial tachycardia**
   - Additional ectopic focus (not SA node)



PATIENT SCENARIO: DYLAN

Dylan is a 14-year old male who presents to the ED complaining of palpitations and dizziness. He has no past medical history of note.

A 12 lead ECG demonstrates a narrow-complex tachycardia with retrograde P waves:



SVT - TREATMENT

Cardioversion

- Synchronized cardioversion if unstable
- Adenosine if stable

SVT - TREATMENT

Prevention with drugs

- digoxin, propranolol, flecainide, amiodarone

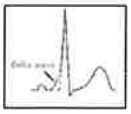
Radiofrequency ablation

- >90% success rate

WOLFF-PARKINSON-WHITE SYNDROME

Dylan is hemodynamically stable and receives a dose of IV adenosine. He reverts to normal sinus rhythm. The 12-lead EKG shows this:

- **Shortened PR interval**
- **Delta waves**
- **Prolonged QRS**



WOLFF-PARKINSON-WHITE SYNDROME

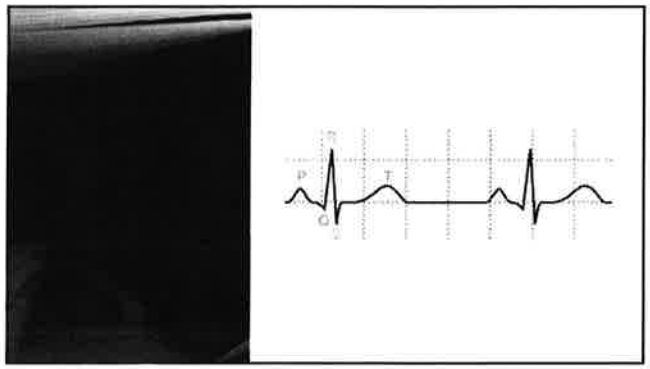
Dylan is referred to a pediatric cardiologist.

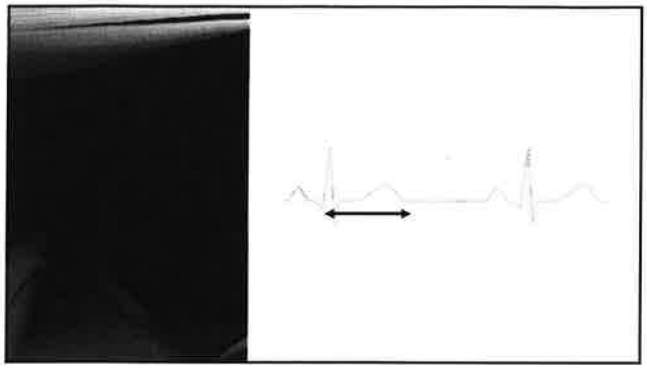
In the cath lab, he is found to have an accessory pathway with both antegrade and retrograde properties and undergoes successful radiofrequency ablation.

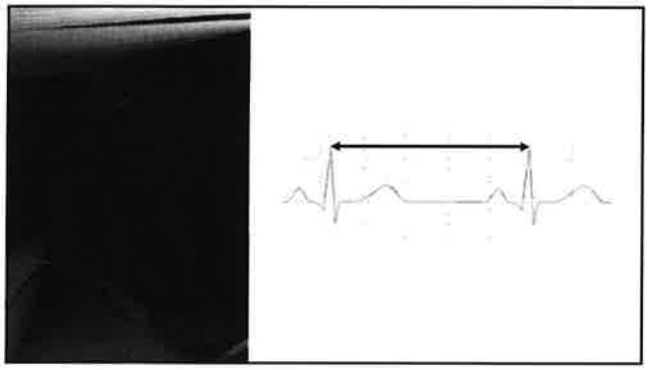
LONG QT SYNDROME

- LQTS predisposes to ventricular tachycardia
- QT varies with rate but not age
  - Rate correction= QTc = QT /√(RR)
  - QTc normally < 450-470msec

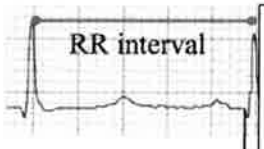
When HR is less than 78 bpm, if the QT interval is less than half of the RR, it is normal







CALCULATING THE CORRECTED QT



Normal QTc before puberty = **< 440 msec.**
After puberty:
Female < 480 msec
Male < 470 msec

Step 1	Step 2	Step 3	Step 4
QT interval = 13 boxes. Multiply by 14 = **0.52 seconds**	RR interval = 25 boxes. Multiply by 14 = **1 seconds**	Calculate the square root of RR Interval $\sqrt{1} = 1$	$\frac{0.52}{1}$ **= 0.52 or 520 msec PROLONGED**

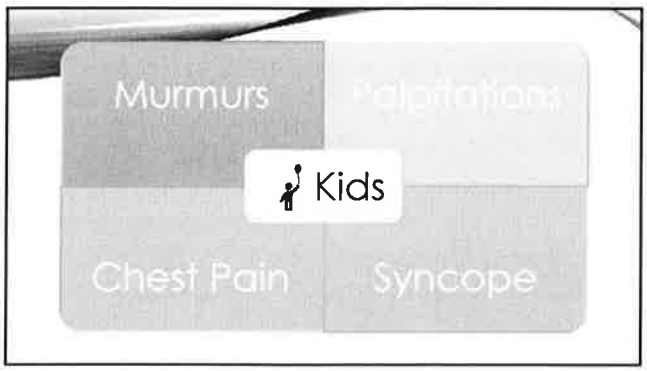
LONG QT SYNDROME

Long QT causes

- Long QT syndrome (Na or K channel mutation) - #1 cause
- Drug effect (Cisapride, Erythromycin, sotalol) - #2 cause
  - crediblemeds.org
- Low Mg^{+}, Low K^{+}, Low Ca^{-}
- CNS injury

PALPITATIONS THAT WARRANT REFERRAL

- **Abnormal EKG**
  - WPW, Long QT, SVT
- **Frequent PAC or PVC**
- **Frequent symptoms suggesting SVT**
  - Paroxysmal resolution
  - HR > 200bpm



CHEST PAIN

- Second to heart murmur for referral to pediatric cardiologist
- One of most common reasons for unscheduled primary care and emergency visits
- Accounts for > 650,000 visits per year in patients 10-21 years
- Cardiac vs. non-cardiac

PATIENT SCENARIO: KRISTEN

12 year old female c/o chest pain x 5 days

- Pain in left upper sternal border
- Sharp and stabbing
- 5/10 in intensity
- Increases with deep breathing
- Lasts 1 minute
- No recent history of fever, cough, exercise intolerance, palpitations, dizziness, or syncope.

PATIENT SCENARIO: KRISTEN

- Exam: no signs of inflammation over sternum or rib cage
- Palpitation: mild-to-moderate tenderness over left 2nd and 3rd costochondral junctions
- Says that pain during physical exam is similar to pain she has experienced x last 5 days (reproducible)
- Cardiovascular and organ system exam normal.

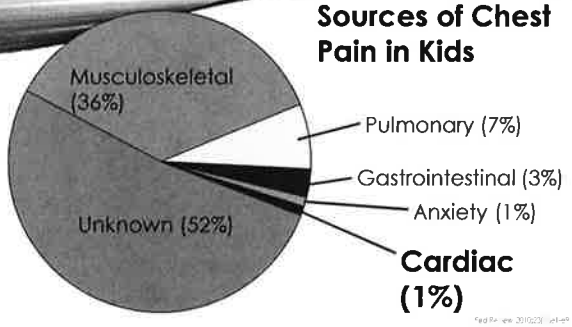
PATIENT SCENARIO: KRISTEN

What is the most likely cause of this child's chest pain?

What will you recommend for her?

Does she need referral to a pediatric cardiologist?

Sources of Chest Pain in Kids



NONCARDIAC SOURCES OF CHEST PAIN

Musculoskeletal
- Costochondritis/costosternal syndrome
- Tietze syndrome
- Nonspecific or idiopathic chest-wall pain
- Slipping rib syndrome
- Trauma and muscle strain–overuse injury
- Xiphoid pain (xiphoidalgia)
- Sickle cell vaso-occlusive crisis

Pulmonary or Airway-related
- Bronchial asthma
- Exercise-induced or cough variant asthma
- Bronchitis
- Pleurisy
- Pneumonia
- Pneumothorax
- Pulmonary embolism
- Acute chest syndrome

Gastrointestinal
- Gastroesophageal reflux disease
- Esophageal spasm
- Peptic ulcer disease
- Drug-induced esophagitis/gastritis
- Cholecystitis

Miscellaneous
- Panic disorder
- Hyperventilation
- Breast-related conditions
- Herpes zoster
- Spinal cord or nerve root compression

CARDIAC SOURCES OF CHEST PAIN

Inflammatory: Pericarditis, Myocarditis
- Infective: viruses, bacteria
- Noninfective: SLE, Crohn disease, postpericardiotomy syndrome

Increased Myocardial Demand or Decreased Supply
- Cardiomyopathy: dilated or hypertrophic
- LVOT obstruction: aortic stenosis, subaortic stenosis, supravalvar aortic stenosis
- Arrhythmias

Coronary Artery Abnormalities
- Congenital: ALCAPA, ALCA from right coronary sinus, coronary fistula
- Acquired: Kawasaki disease, postsurgical (after arterial switch operation, after Ross procedure), posttransplant coronary vasculopathy, familial hypercholesterolemia

Miscellaneous
- Aortic dissection
- Rupture of aortic aneurysm
- Pulmonary hypertension
- Mitral valve prolapse
- Atrial myxomas
- Cardiac airway/stent complications

Drugs
- Cocaine
- Sympathomimetic overdose

HISTORY

Description
- duration
- onset
- location
- quality
- severity
- radiation
- precipitating factors (exertion)
- mitigating factors

Past Medical History
- Asthma
- Sickle cell disease
- Kawasaki disease
- Cardiac disease
- Hypercholesteremia

Surgical History
- Chest surgery
- Abdominal surgery

HISTORY

Family history

- ☐ **Sudden cardiac death in young person**
- ☐ **Suspicious events**
- ☐ **Arrhythmias**
- ☐ **Cardiomyopathies**
- ☐ **Hypercholesteremia**

History of trauma

- ☐ **Drug abuse**
- ☐ **Psychological stress**

Genetic disorders

- ☐ **Marfan**
- ☐ **Turner**
- ☐ **Ehlers-Danlos**

PHYSICAL EXAM

- ☐ **Dysmorphic features**
- ☐ **Hyperdynamic precordium**
- ☐ **Irregular heart beats**

- Peripheral pulses
- Chest inspection
- Reproducible chest pain

- ☐ **Distant heart sounds**
- ☐ **Abnormal loud second heart sound**
- ☐ **Systolic clicks**
- ☐ **Murmurs**
- ☐ **Gallops**
- ☐ **Absent femoral pulses**

EVALUATION OF CHEST PAIN IN KIDS

Chest X-ray

- ☐ **Cardiomegaly**
- Bony lesions
- Airways
- Lung parenchymal disease
- Pleural lesions

ECG

- Rate
- Rhythm
- Signs of ischemia, pericarditis, chamber hypertrophy

TREATMENT OF NONCARDIAC CHEST PAIN

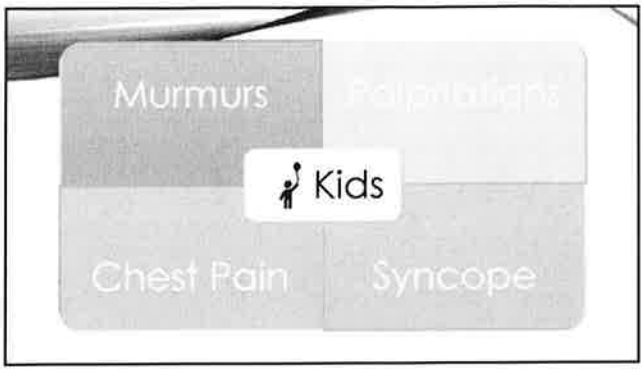
- Reassurance and education
- Rest
- Analgesia

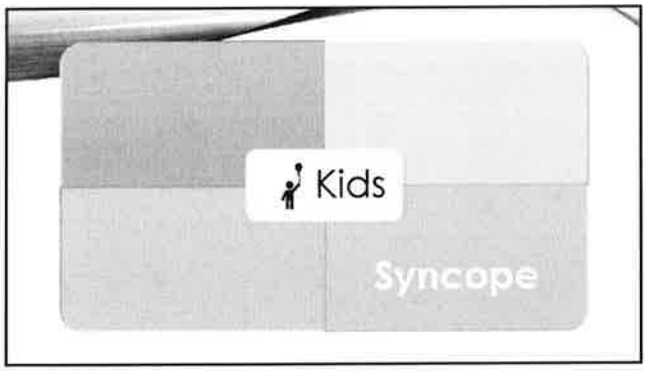
PATIENT SCENARIO: KRISTEN

What is the most likely cause of this child's chest pain?
Costochondritis, characterized by reproducible tenderness on palpation of the chest
What will you recommend for her?
Reassurance that condition is self-limiting, warm compress, NSAIDs if severe pain
Does she need referral to a pediatric cardiologist?
No

CHEST PAIN THAT WARRANTS REFERRAL

- ☐ Exertional chest pain
- ☐ Abnormal cardiac findings
- ☐ Chest pain with palpitations
- ☐ ECG abnormalities
- ☐ Significant family history of arrhythmias, sudden death, or genetic disorders
- ☐ History of cardiac surgery or interventions
- ☐ History of Kawasaki disease
- ☐ First-degree relatives with hypercholesteremia





SYNCOPE

- Transient loss of consciousness and inability to maintain posture due to transient global cerebral hypoperfusion
- Rapid onset, short duration, spontaneous complete recovery
- 15% of children will have syncope by age 18
- Girls more common than boys, peak incidence age 15-19

CLASSIFICATIONS OF SYNCOPE IN CHILDREN

Classes	Underlying Diseases
Neurally-mediated (78%)	Vasovagal syncope
	Postural tachycardia syndrome (POTS)
	Orthostatic hypotension
	Situational syncope
	Carotid sinus syndrome
Cardiac Syncope (2%)	**Arrhythmia**
	Structural cardiac or cardiomyopathy
Unexplained (20%)	

HISTORY

Event History

- **Onset of symptoms in infancy or early childhood**
- **Occurring *during* exercise**
  - *Not to be confused with post-exertional syncope*
- **Palpitations or chest pain before or during syncopal episode**
- **Bladder/bowel incontinence**
- **Degree of amnesia**
  - *Longer period of amnesia correlates to higher risk of cardiac etiology*

HISTORY

Family History

- **Hypertrophic cardiomyopathy**
- **Pacemaker/Implanted cardioverter defibrillator**
- **Channelopathies (Long QT, Brugada Syndrome)**
- **Sudden cardiac death/suspicious events**

PHYSICAL EXAM

- Normal exam in most cases
- **Murmur**
- **Evidence of heart failure**

EKG

- **Ventricular hypertrophy**
- **Ventricular pre-excitation**
- **Long QT interval**
- **Abnormal T waves**
- **Heart block**
- May be normal

SYNCOPE THAT WARRANTS REFERRAL

- **Concerning history related to event**
- **Abnormal EKG**
- **Chest Pain or palpitations before or during syncope**
- **Occurring during exercise**
- **Concerning family history (early sudden death, hypertrophic cardiomyopathy, Long QT)**
- **Suspected or identified cardiac disease**

- Use of thorough patient history and physical exam are crucial to determining the causes and severity of murmurs, palpitations, chest pain, and syncope.
- Any cardiac complaint in the setting of a first-degree relative with sudden cardiac death warrants further evaluation.
- Any neonate presenting with cardiac concerns should be considered an emergency.
- When in doubt, refer.

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Thank you!