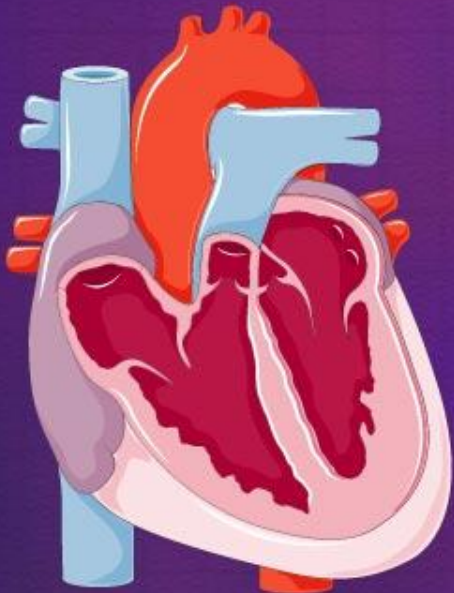


Neonatal Critical Congenital Heart Disease screening

Sophia Tsakiri, MD



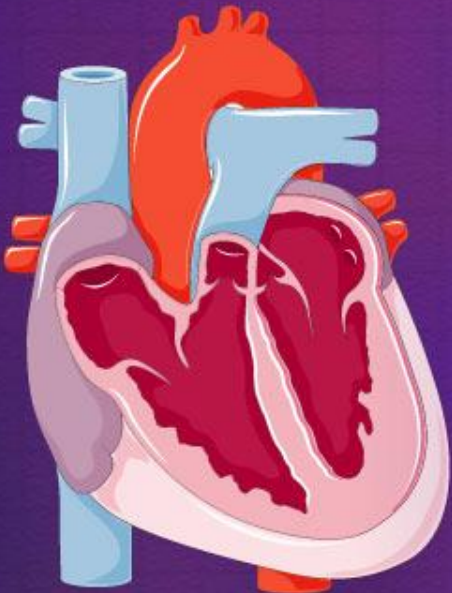
 **UTHealth**[®]
The University of Texas
Health Science Center at Houston

McGovern
Medical School

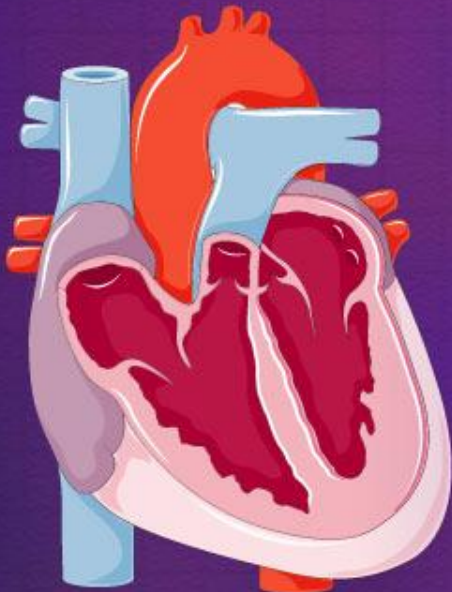
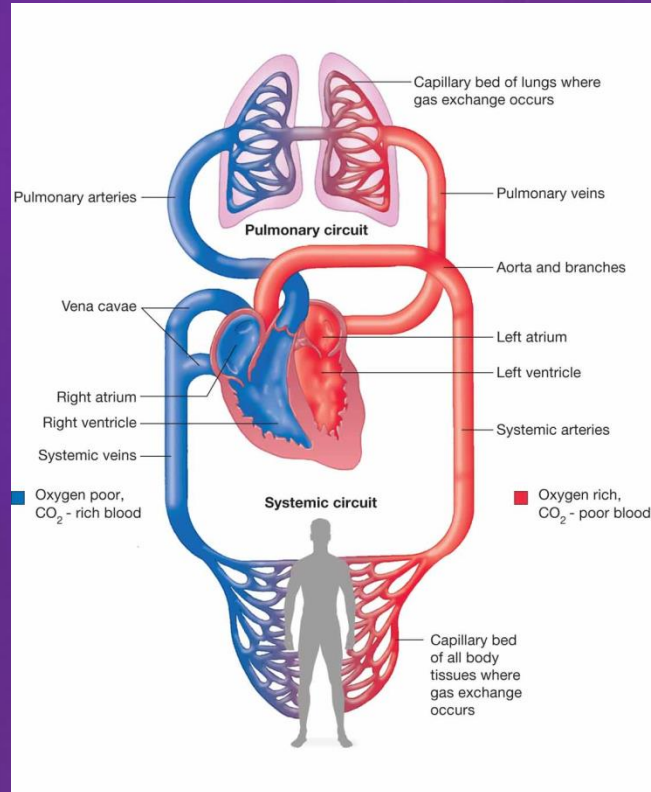
HARRISHEALTH
SYSTEM

Objectives

- Review of the fetal and neonatal circulation
- Overview of critical congenital heart diseases [CCHD]
- Review of CCHD outcomes
- Screening for CCHD
- Screening for CCHD with pulse oximetry

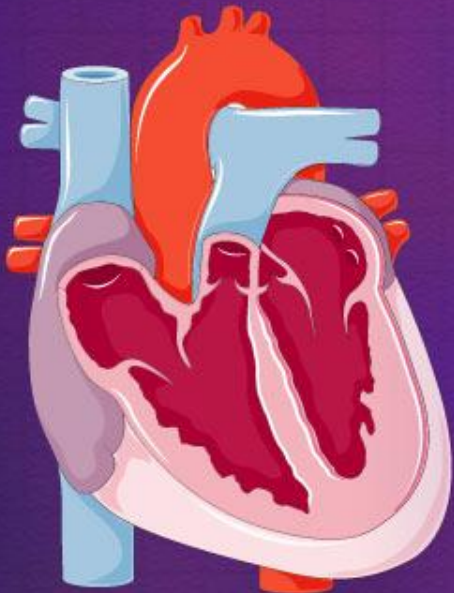
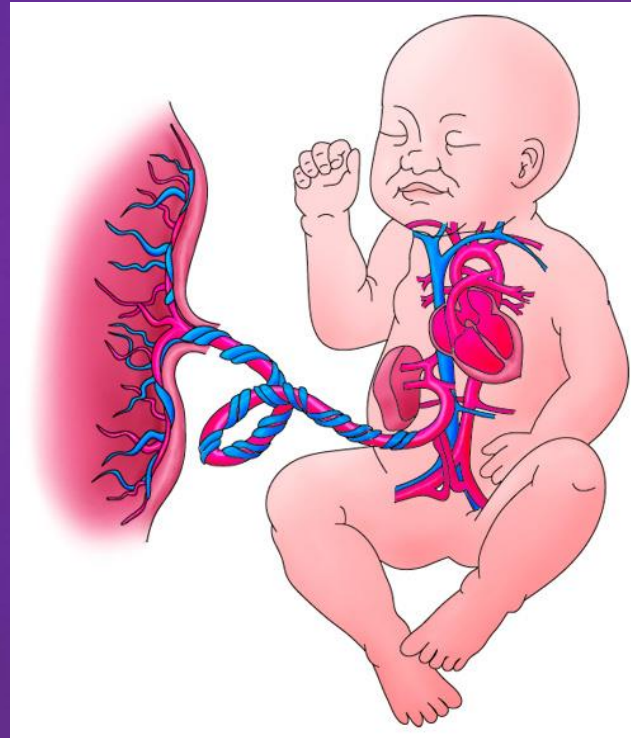


Cardiovascular system



One-way direction of blood flow

Fetal circulation

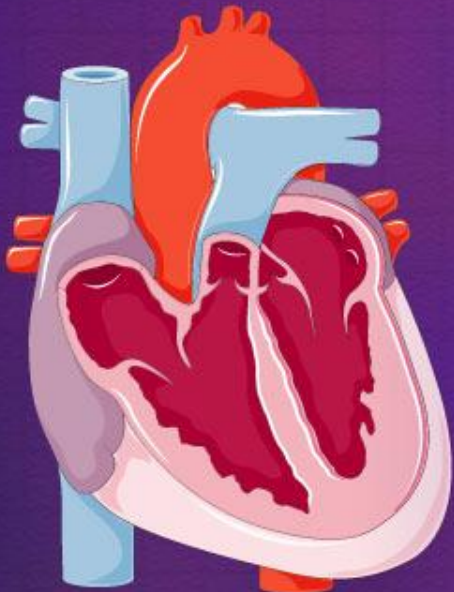
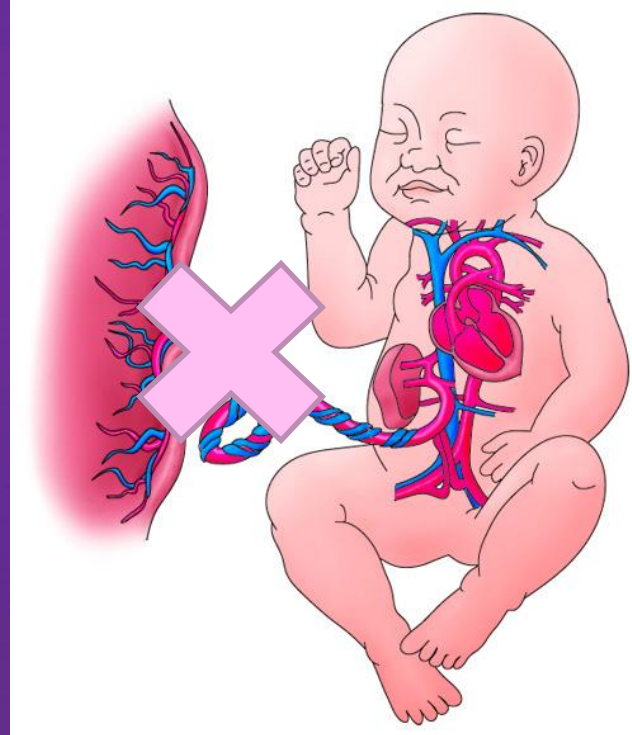


Placenta: gas and nutrient exchange

Parallel pulmonary and systemic circulations

Fetal shunts: atrial, ductal, hepatic

Neonatal circulation



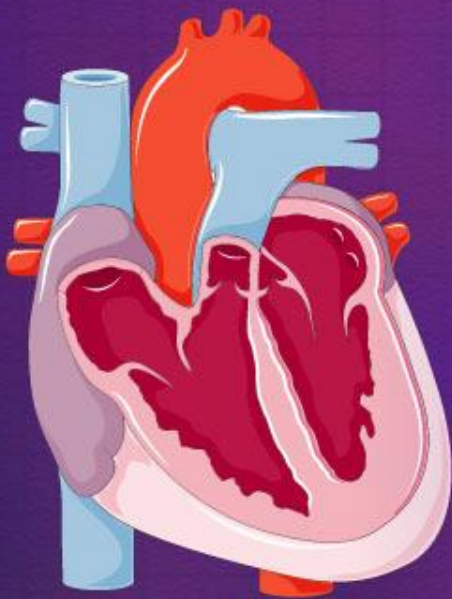
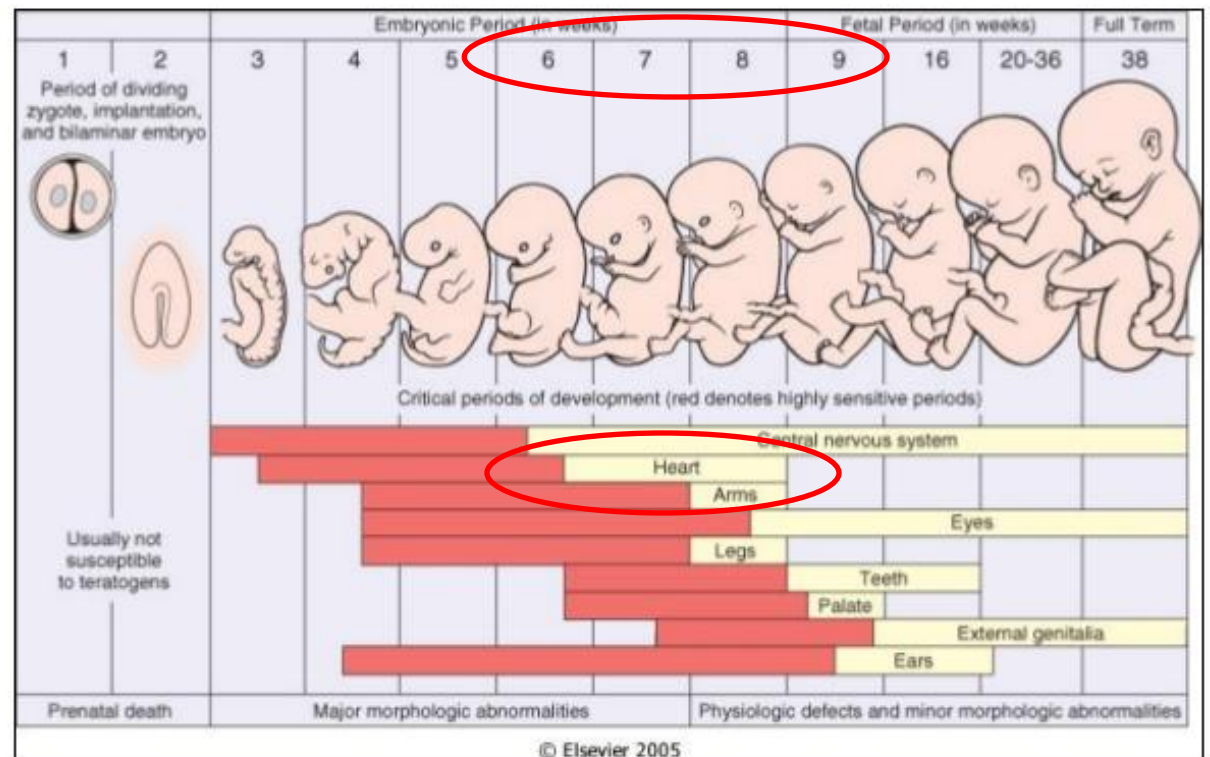
Removal of the placenta

Closure of fetal shunts: atrial, ductal, hepatic

Establishment of one-way direction of blood flow

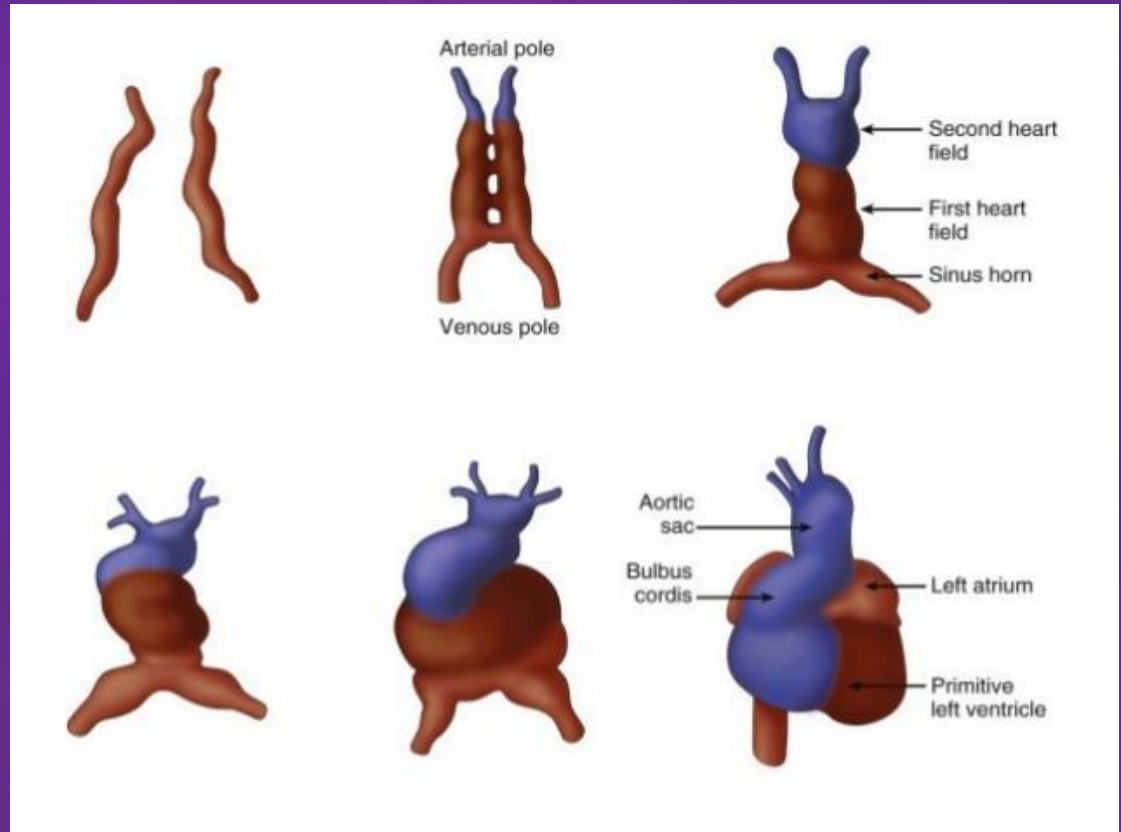
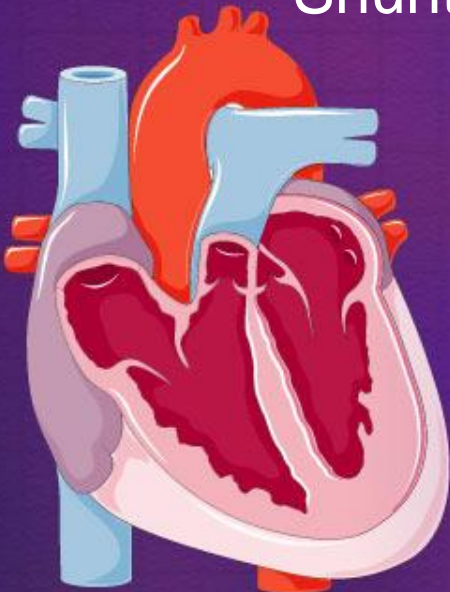
Cardiac embryology

Critical periods of development for various organ systems and the resultant malformations



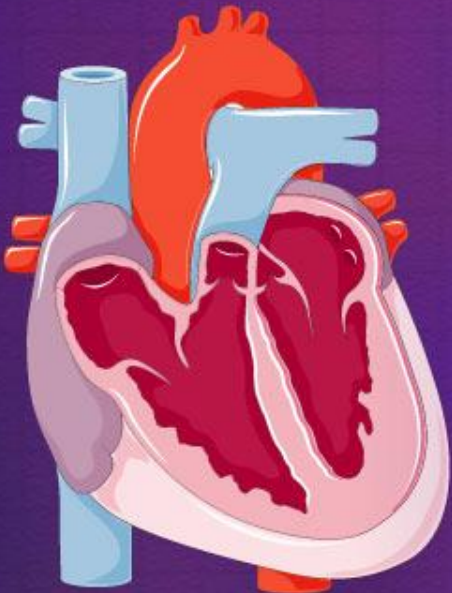
Cardiac embryology

- Fusion
- Bending
- Rotation
- Looping
- Partitioning
- Shunts



Risk for Congenital Heart Disease (CHD)

- 8 out of 1000 babies have CHD
- Most are mild
- 2/1000 are critical
- Higher risk for CHD, if a family member w/ CHD
- Recurrence risk in the family 2-15%
- More than 2 million Americans with CHD
- ~5,000 infants born each year with CHD in US
- Leading cause of death in 1st year of life



Causes of CHD

- **Unknown**
- Genetic syndrome: eg. Trisomy 21, 18, 13
- Single gene defects
- Maternal illness: Diabetes, SLE, obesity, PKU
- Environmental exposure:

Infections: Rubella

Enterovirus

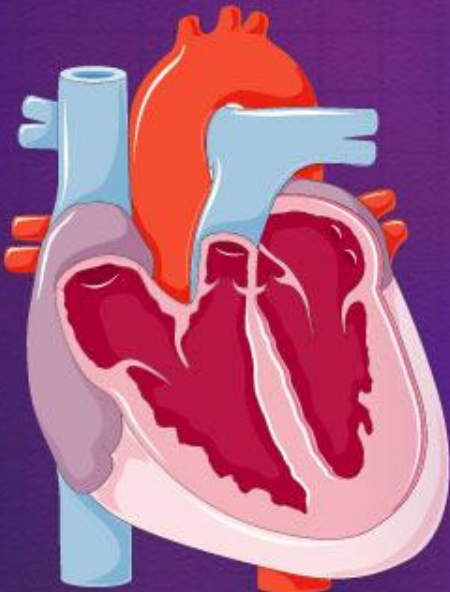
Alcohol

Drugs: Thalidomide

Anti-acne meds

Valproic acid

Lithium



Congenital heart disease

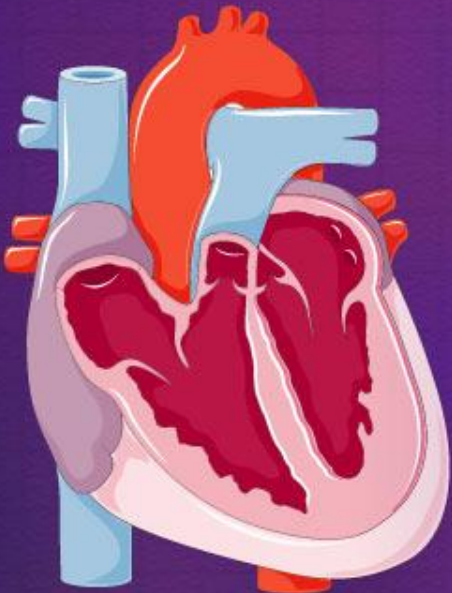
A heart abnormality that is present from birth

Structural defects

- Hypoplasia
- Obstruction
- Septal defects
- Complex anatomy

Functional defects

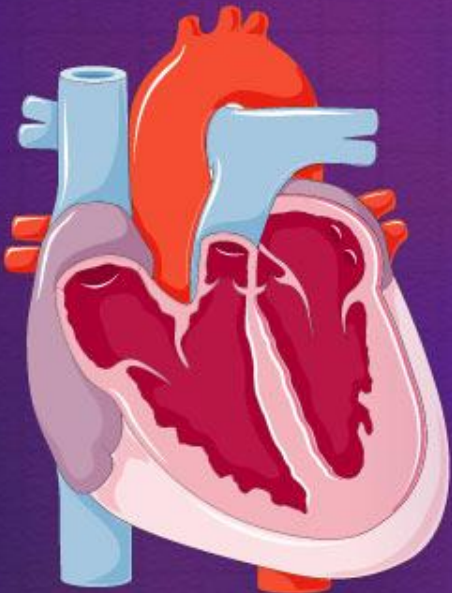
- Infections
- Metabolic cardiomyopathy
- Arrhythmias



Critical Congenital Heart Disease (CCHD)

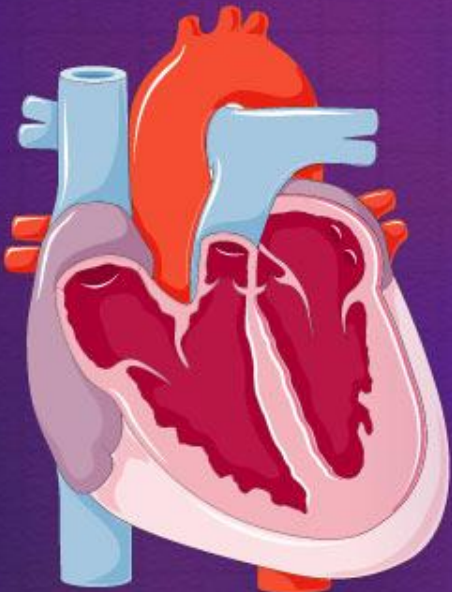
An abnormality in the structure or function of the heart

- that exists at birth,
- causes severe life-threatening symptoms,
- and requires medical intervention within the first few hours, days or months of life



CCHD pathology

- **Hypoplasia:** Hypoplastic left ventricle
Single ventricle
- **Obstruction:** Pulmonary atresia with intact septum
Tricuspid atresia
Pulmonary stenosis
Aortic arch atresia, hypoplasia or interruption
Coarctation of Aorta
- **Septal defects:** Atrial septal defect
Ventricular septal defect
Atrioventricular septal defect
- **Complex anatomy:** Tetralogy of Fallot
Total Anomalous Pulmonary Venous Return
Transposition of great arteries
Truncus arteriosus communis
Double outlet right ventricle
Ebstein's anomaly



CCHD pathophysiology

Ductal-dependent systemic circulation:

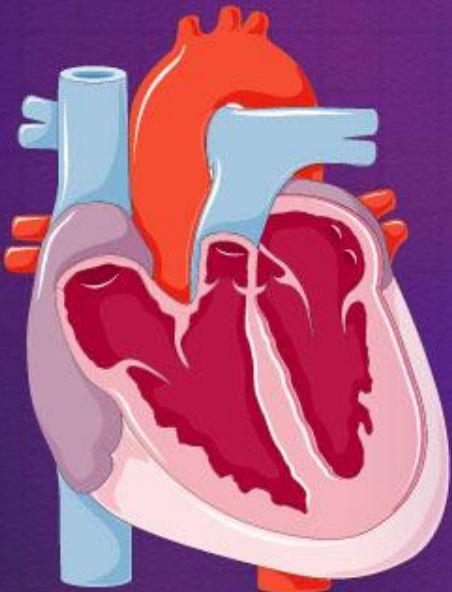
- eg. HLHS, CoA, interrupted Ao arch
- Shock, if the ductus closes

Ductal-dependent pulmonary circulation:

- eg. Pulmonary atresia, TOF
- Severe hypoxia, if the ductus closes

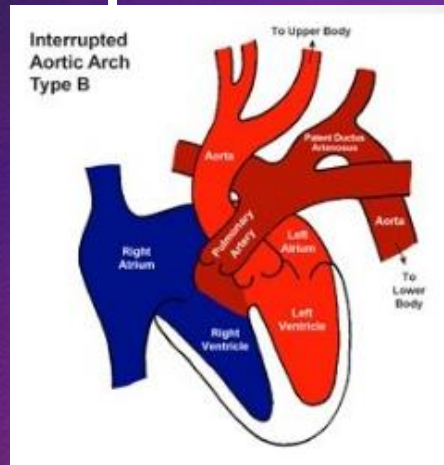
Complex pathophysiology

- eg. TAPVR, truncus, TGA
- Combination of cardio-respiratory insufficiency, if the ductus closes

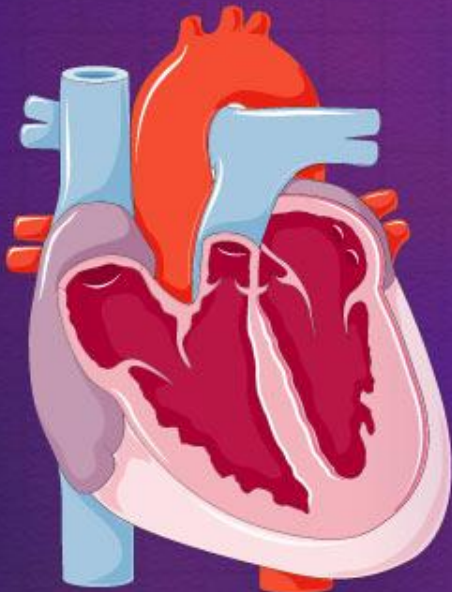
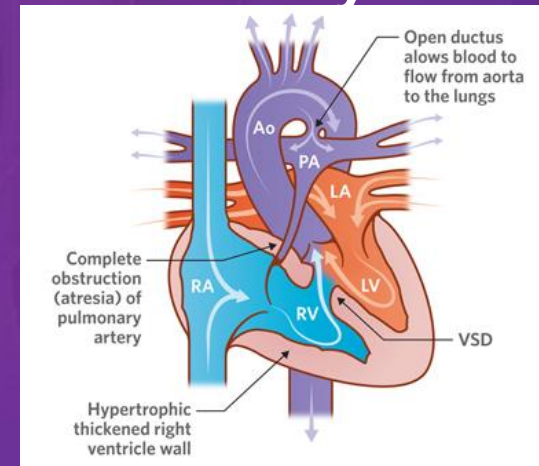


CCHD pathophysiology

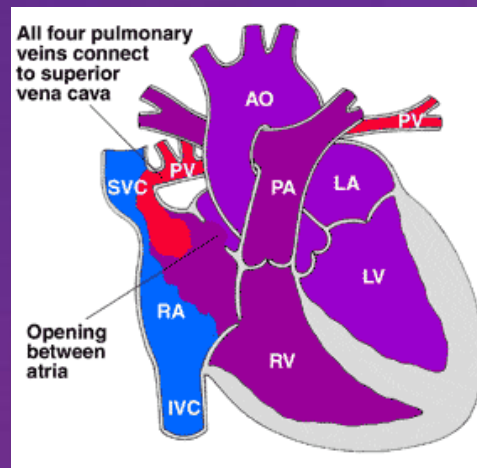
Interrupted aortic arch



Pulmonary atresia

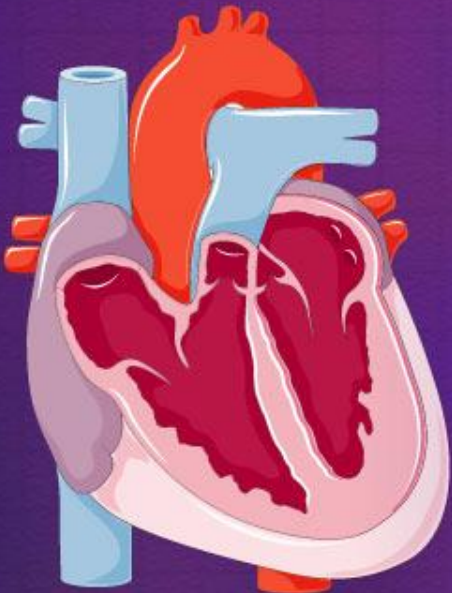


TAPVR



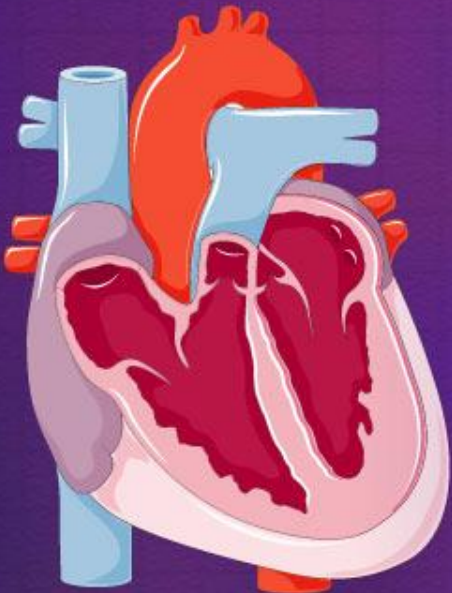
Presentation of CHD

- CCHD patients can look **healthy** at birth
- Within hours or days after birth they can have serious complications and even die
- Some patients will be asymptomatic for months or years



Symptoms of CHD

- Cyanosis or mild hypoxia
- Low blood pressure
- Breathing difficulty or tachypnea at rest
- Feeding difficulty
- Poor growth
- Sleepiness or irritability
- Sweating
- Murmur on exam
- **Sudden death**: 1/3 of first year cardiac deaths

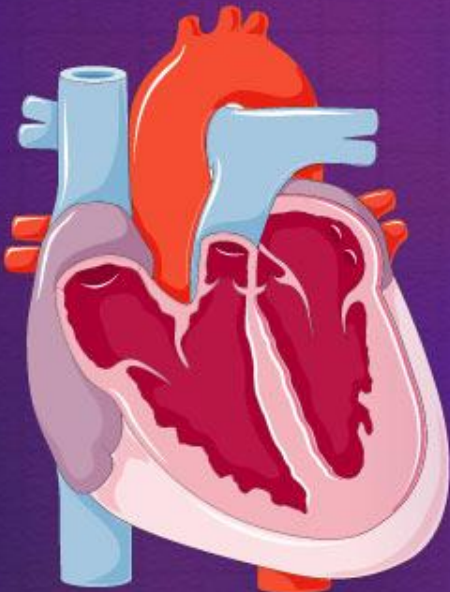


Outcomes of CHD

85% of children diagnosed with CHD will survive into adulthood

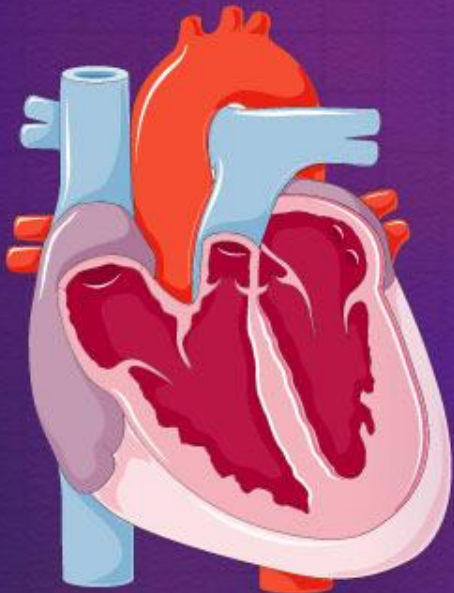
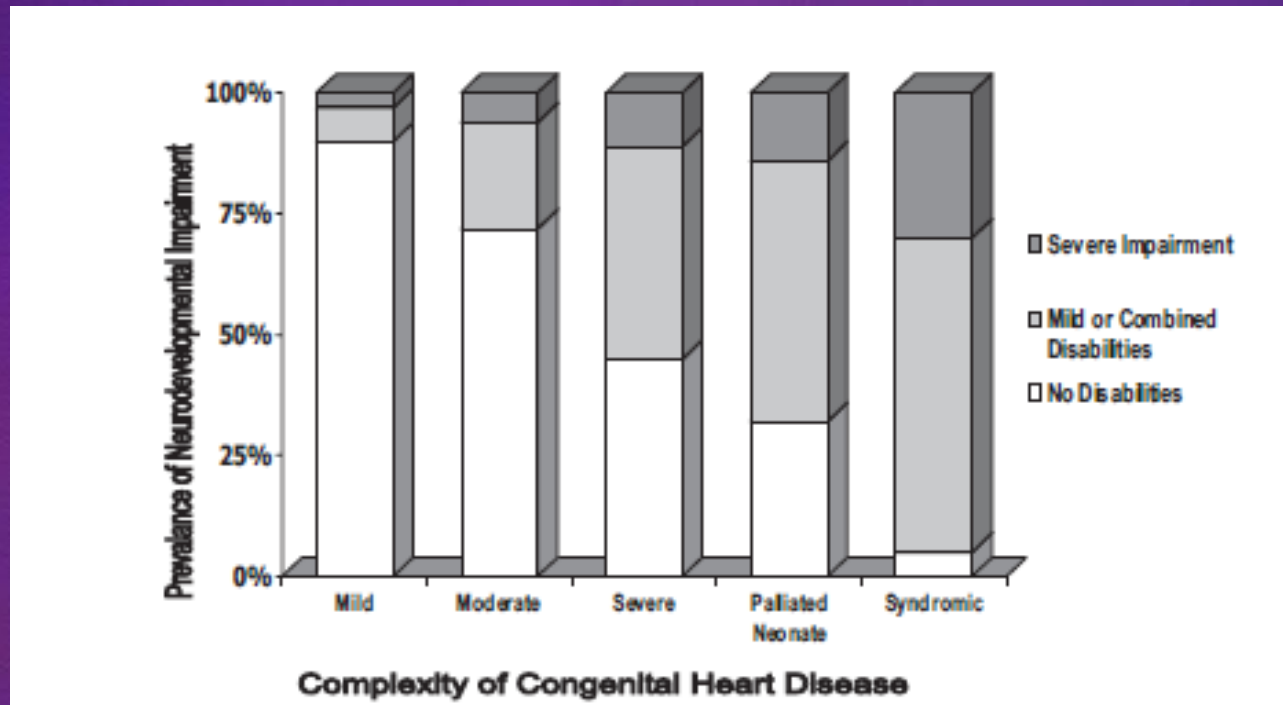
Survival rates vary by disease complexity:

CHD complexity	CHD examples	Long-term survival [>20 years]
Simple	ASD, VSD, valve d/o	95%
Moderate	CoA, AVC, TOF	90%
Great	Truncus, TGA, single ventricle	80%
Specific complex disorders	HLHS	60-70%



Neurodevelopmental delay in CHD

The prevalence and severity of NDD increases with the complexity of CHD



NDD in the areas of intelligence, language, attention, motor skills, visual processing, executive function and psychosocial adjustment

Determinants of outcome of fetal cardiac disease

Late detection or lack of diagnosis



Closure of the ductus arteriosus and physiologic increase of the pulmonary vascular resistance



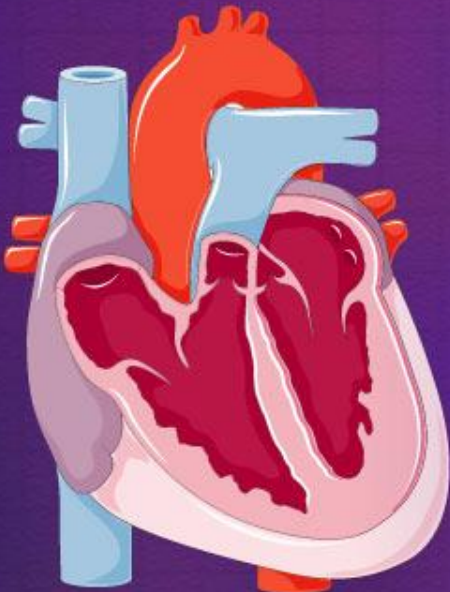
Cardiogenic shock, multiorgan failure and hypoxic ischemic brain injury



Morbidity

Neurodevelopmental delay

Death



Improved outcome of fetal cardiac disease

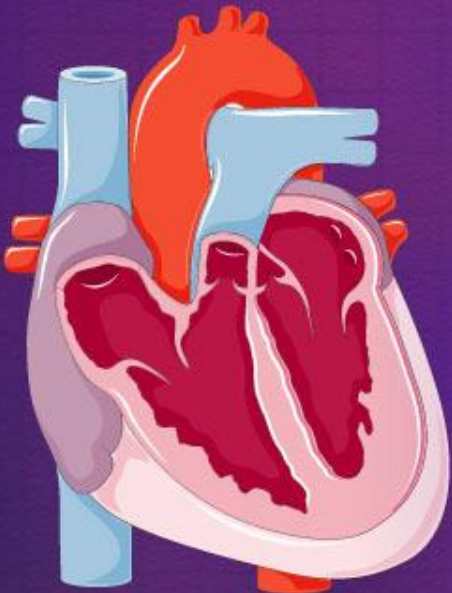
Early detection and risk stratification

Delivery at an appropriate birthing center

Early disease-specific treatment

Multidisciplinary medical care

Social support



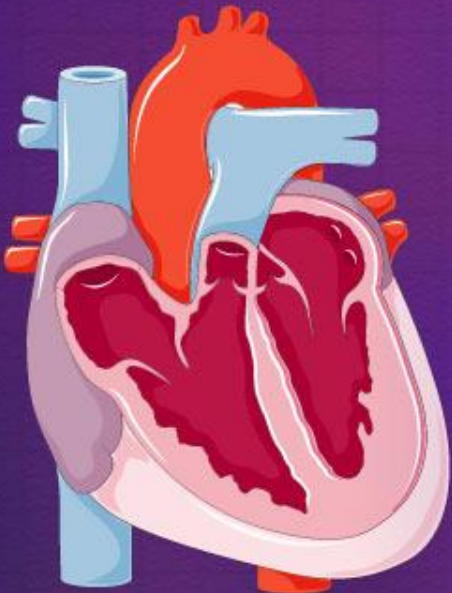
Donofrio MT et al. J Am Soc Echocardiogr 2015; 28(11): 1339-1349

Donofrio MT et al. Circulation 2014; 129: 2183-2242

Marino BS et al. Circulation 2012; 126: 1143-1172

Critical CHD screening

- CCHD screening of the fetus
- CCHD screening of the high risk fetus
- CCHD screening of the ill newborn
- CCHD screening of the well newborn



Fetal echocardiography

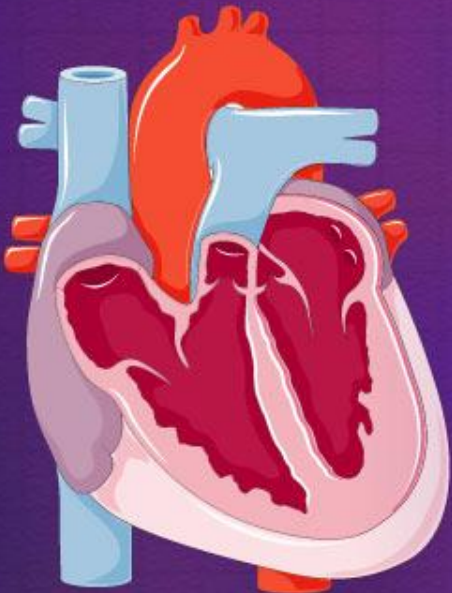
Specificity nearly 100%

Fetal CHD diagnosis is usually accurate

Sensitivity of the basic ECHO views 49%

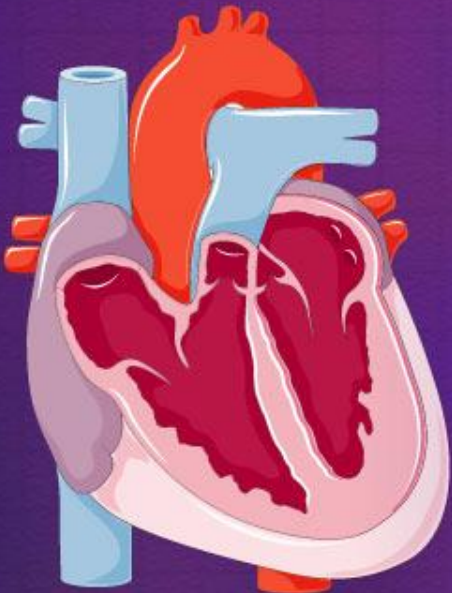
Sensitivity of the advanced ECHO protocols and of the 3rd trimester screening can be up to 85%

Fetal ECHO may miss up to 50% of CHD



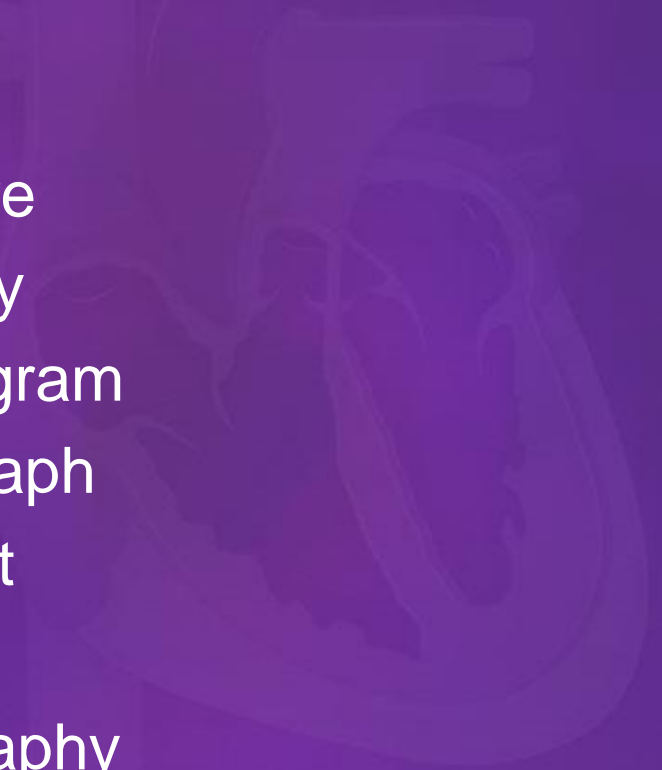
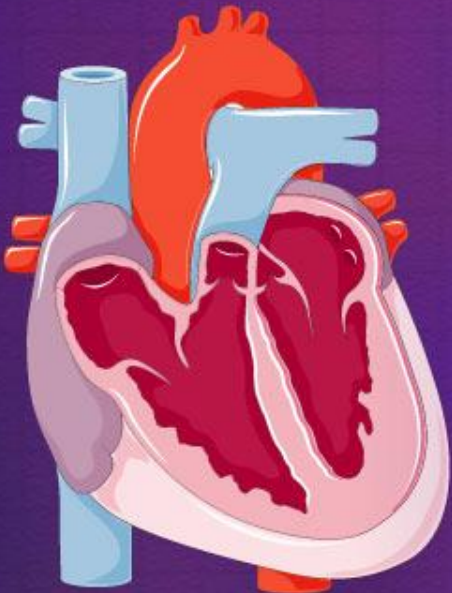
Fetuses at high risk for CHD

- Maternal diabetes mellitus
- Phenylketonuria
- Family history of CHD
- Maternal infections
- Maternal Lupus and Connective tissue d/o
- Teratogen exposure
- Assisted reproductive technology
- Known or suspected chromosomal abnormality
- Monochorionic twins
- Hydrops fetalis
- Arrhythmias



Work up and diagnosis of CCHD in the ill neonate

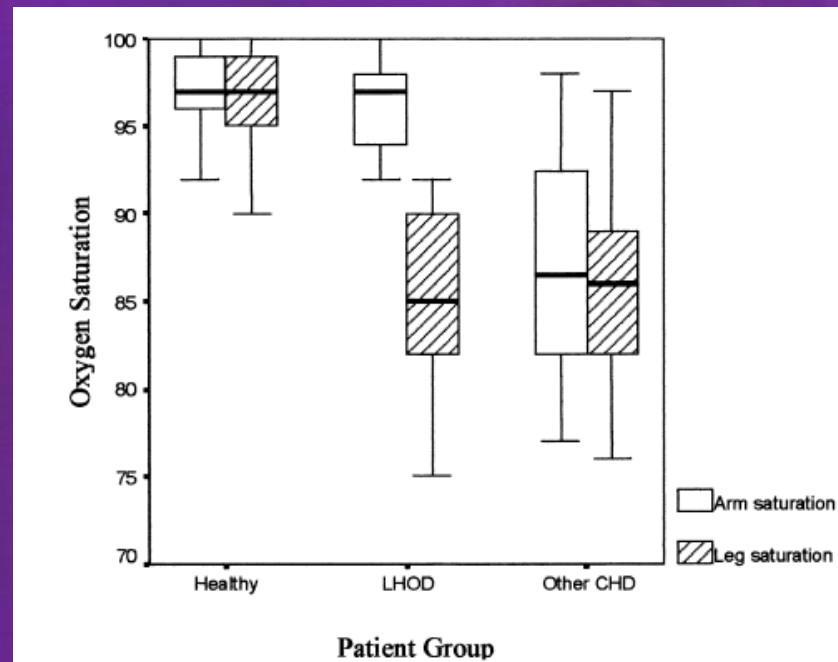
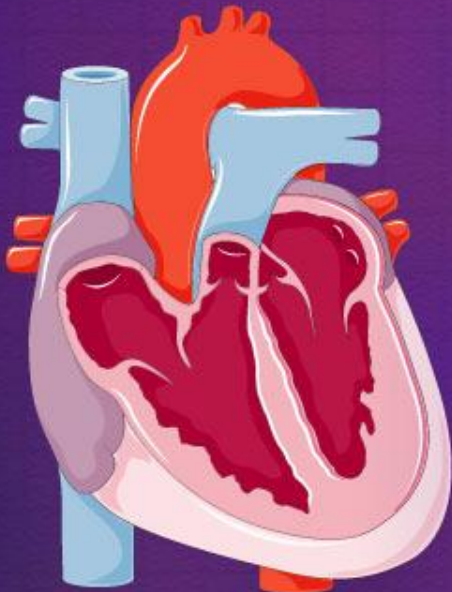
- Clinical exam
- Blood pressure
- Pulse oximetry
- Electrocardiogram
- Chest radiograph
- Hyperoxia test
- Echocardiography
- Cardiac catheterization
- Genetic and other testing



CCHD screening: the evidence

Case-control study of pulse oximetry measurements

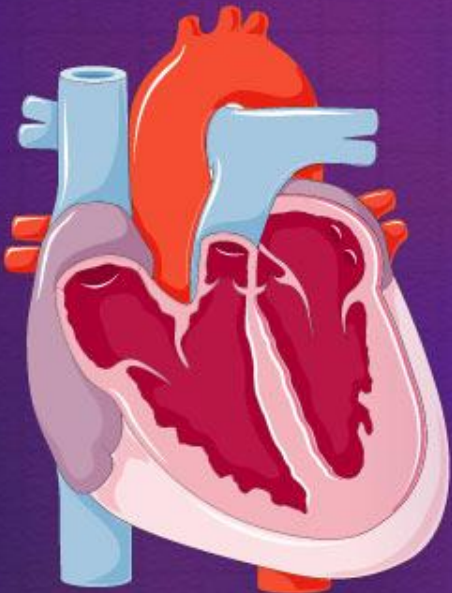
- 2,876 healthy newborns
- 32 newborns with CHD



CCHD screening: the evidence

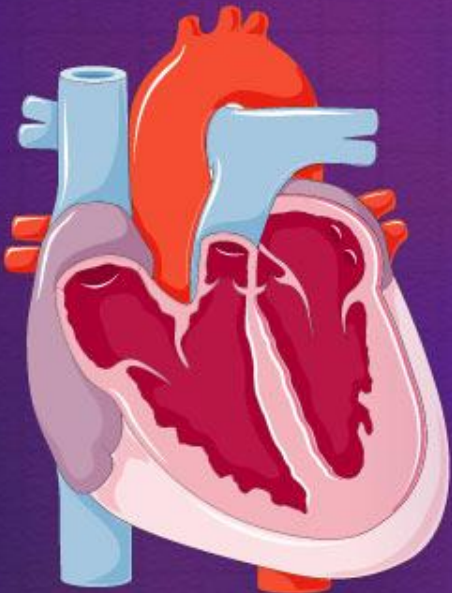
Meta-analysis of pulse oximetry screening for CCHD in asymptomatic newborns:

- 13 studies included
(12 cohort & 1 case-control studies)
- 229,421 newborns
- Sensitivity 76.5%
- Specificity 99.9%
- False positive rate 0.14%
- The false positive rate was lower, if the screen was conducted at >24hours of life



Pulse oximetry screening

- Easy
- Rapid
- Non-invasive
- Indirect measure of blood oxygen saturation
- Targets the primary CCHD
- May detect the secondary CCHD

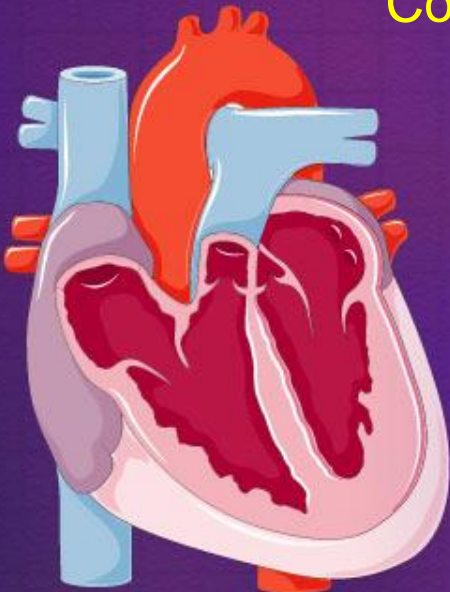


Primary screening targets

Hypoplasia: Hypoplastic left ventricle

Obstruction: Pulmonary atresia with intact septum
Tricuspid atresia

Complex: Tetralogy of Fallot
Total Anomalous Pulmonary Venous Return
Transposition of great arteries
Truncus arteriosus communis



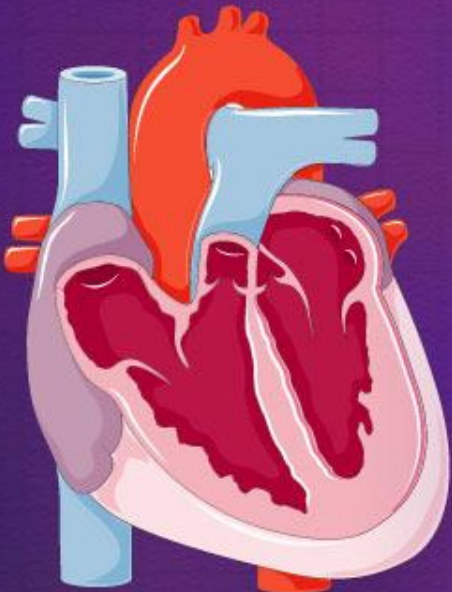
Secondary screening targets

Hypoplasia: Single ventricle defect

Obstruction: Pulmonary stenosis/atresia
Aortic arch atresia/hypoplasia
Interrupted aortic arch
Coarctation of Aorta

Septal defects: Atrial septal defect
Ventricular septal defect
Atrioventricular septal defect

Complex: Double outlet right ventricle
Ebstein's anomaly



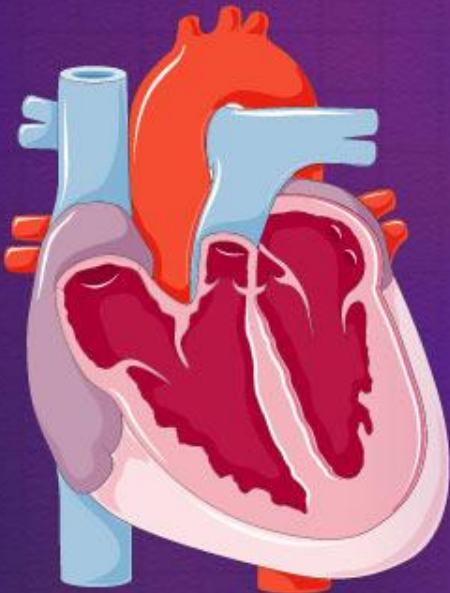
Cost-effectiveness of CCHD screening

Texas Pulse Oximetry Project:

- The CCHD screening is cost-effective, with a cost estimated at **\$3-6** per asymptomatic newborn screened

Peterson 2014:

- The average cost of screening per newborn was **\$13.50** in the US [\$6.68 cost of labor+ \$6.83 in equipment]
- The incremental cost for detecting one of 1,189 estimated newly diagnosed newborns with CCHD per year was **\$20,862**
- The favorable cost-effectiveness estimate of averting up to 20 infant deaths per year was **\$42,385** per life-year gained



Pulse oximetry screening

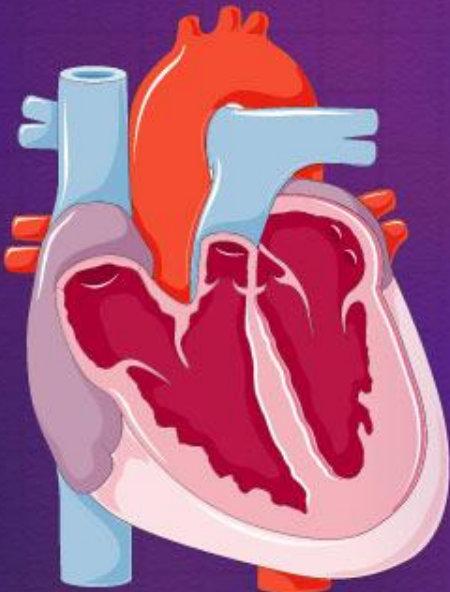
Oakley 2015:

- 6329 babies had post-ductal pulse-oximetry
- 14 had abnormal screen
 - 7/14 had CCHD
 - 3/14 had non-critical CHD
 - 4 had undiagnosed respiratory illness or sepsis

Jawin 2015:

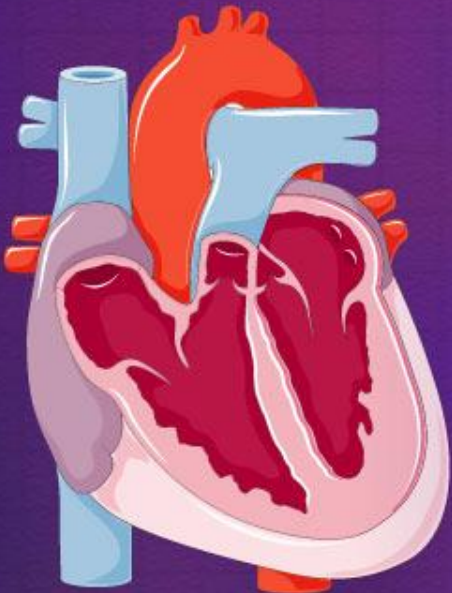
- 5247 babies had post-ductal pulse-oximetry
- 15 had abnormal screen
 - 2/15 had CCHD
 - 2/15 had sepsis
 - 11/15 had undiagnosed respiratory illness

All babies with low saturations had identifiable pathology



Screening recommendations

- US Health and Human Services Secretary's Advisory Committee on Heritable Disorders in Newborns and Children recommended in 2010 that CCHD screening be added to newborn screening panel
- The recommendation was endorsed in 2011 by the Secretary of Health Kathleen Sibelius



ALL STATES SHOULD SCREEN NEWBORNS FOR CRITICAL CONGENITAL HEART DISEASE (CCHD)



Delayed diagnosis of CCHD can lead to infant death

18/10,000 babies are born with CCHD



CCHD can cause impaired speech and motor function

CCHD is a group of 7 abnormalities.

Babies should be screened 24 hours after birth but before they leave the hospital.

\$6.00



AVERAGE COST PER SCREEN

31 STATES



REQUIRE NEWBORN SCREENING FOR CCHD

5 MINUTES



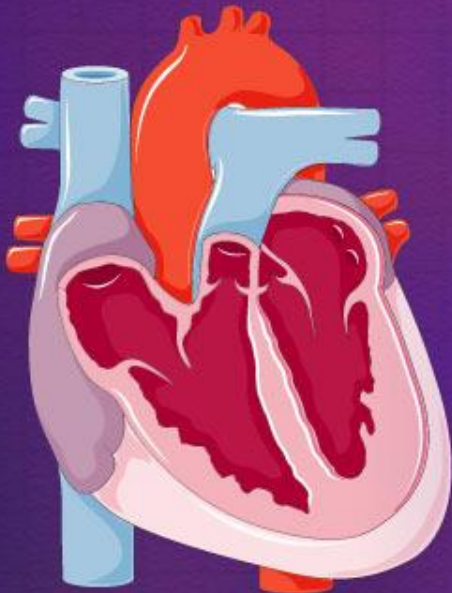
SCREENING IS QUICK AND PAINLESS

CCHD can be added to state newborn screening requirements by legislation, regulation, or adoption as a standard of practice.

American Academy of Pediatrics
DEDICATED TO THE HEALTH OF ALL CHILDREN™

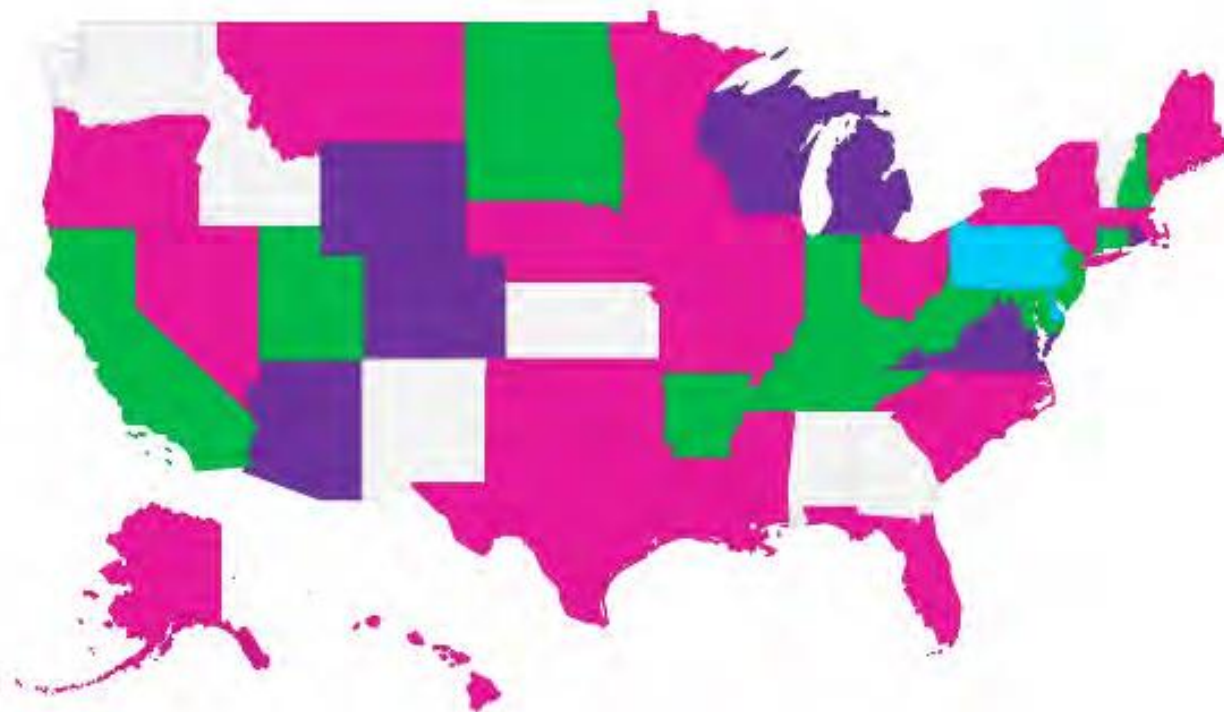


1.800.433.9016, x7799 | stgov@aap.org



Newborn CCHD Screening Progress

Click on a state for additional details.

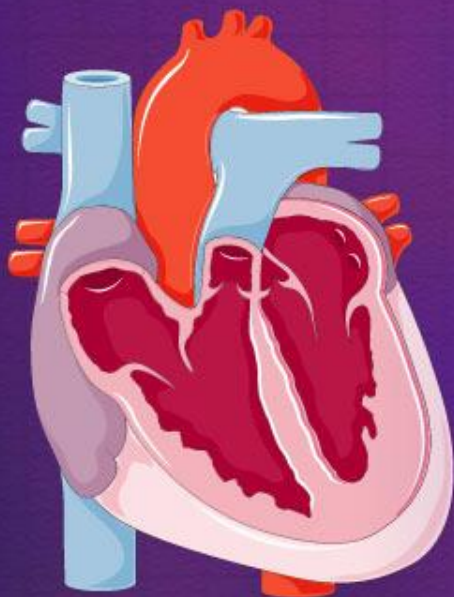


Legislation Introduced

Legislation Enacted

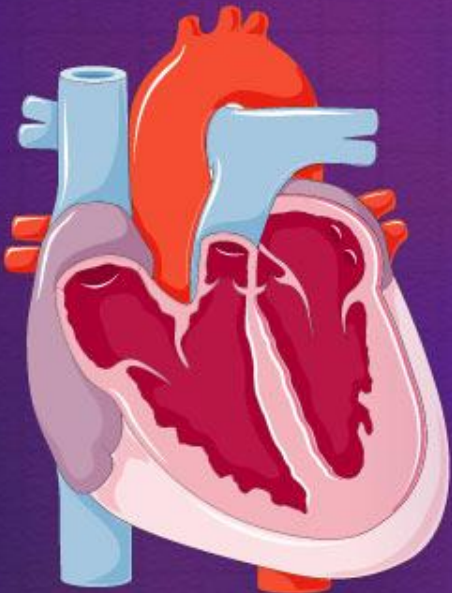
Regulatory Addition to NBS Panel

Multi-Center Screening or Pilot Project



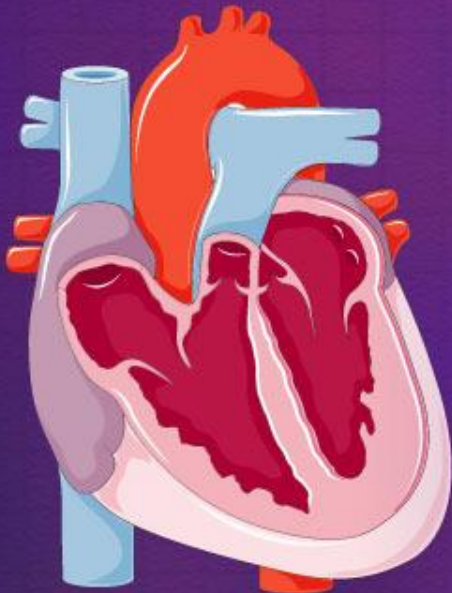
Critical CHD screening in Texas

- House Bill 740, 2013 added CCHD to the required Texas newborn screening panel
- The Texas Department of State Health Services developed the Texas Administrative Code rules for CCHD [Title 25, Chapter 37]
- Screening for CCHD of all newborns at a birthing facility, before they become symptomatic, is mandatory in Texas since **September 1st, 2014**



“CCHD toolkit”

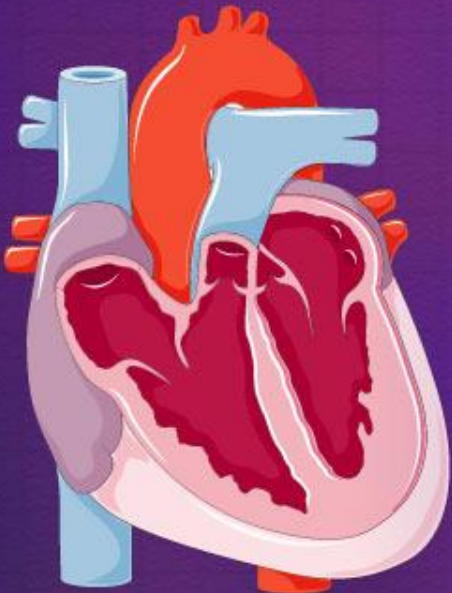
- Developed for the Texas Pulse Oximetry Project from UTHSC San Antonio, Baylor College of Medicine and the Texas DSHS
- Educational effort with a goal to facilitate the implementation of the rules for CCHD screening and of the reporting of documented cases of CCHD



- <https://www.dshs.state.tx.us/newborn/cchdtoolkit/>
- Algorithm for screening
- Documentation
- Sample policy
- CCHD reporting form

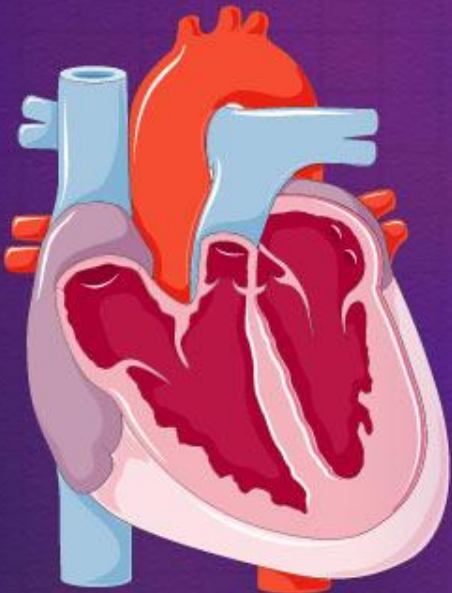
Critical CHD screening in Texas

- Screening for CCHD with pre- and post-ductal pulse oximetry measurements to detect mild hypoxemia
- Interpretation of results, according to the most current published AAP screening algorithm
- The pulse oximeter used for the screening should meet the FDA standards

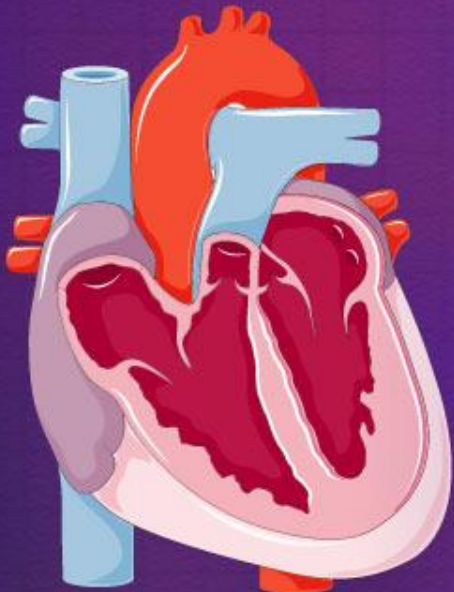


Critical CHD screening in Texas

- Screening for CCHD with pulse oximetry measurements of the right hand and one foot in parallel or one after the other
- Infant should be calm and awake
- Perform before the discharge from the nursery and after 24 hours of age
- If an early discharge is planned, CCHD screening should be done as close to discharge as possible



Pulse oximetry screening for CCHD



Pre-ductal measurement: **right hand**

Post-ductal measurement: **one of the feet**

Critical Congenital Heart Disease Newborn Screening Algorithm

Pulse ox on right hand and foot after 24 hours

$\geq 95\%$ in right hand
or foot and $\leq 3\%$
difference between
right hand and foot

PASS

90% - 94% in
right hand
and foot

or

$> 3\%$ difference
between right
hand and foot

Indeterminate

Repeat screen in 1 hour

Indeterminate

Repeat screen in 1 hour

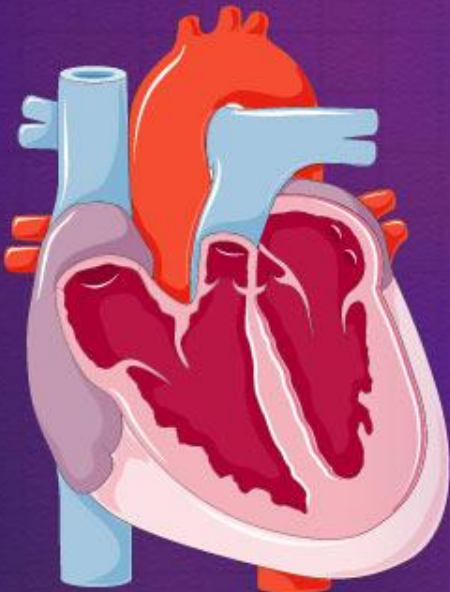
POSITIVE
(FAIL)

$< 90\%$ in right
hand or foot

POSITIVE
(FAIL)

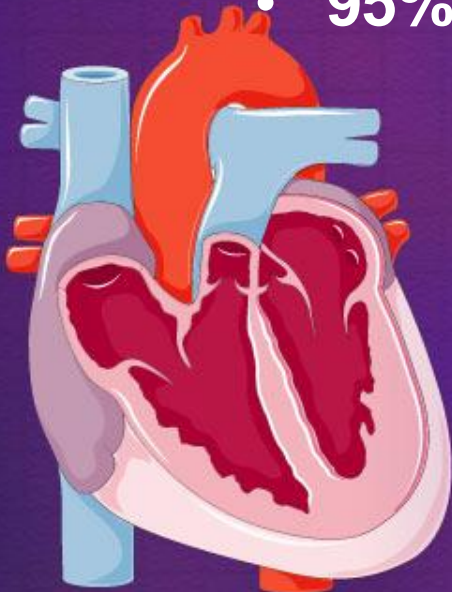
Notify
MD/NNP

Remind parents
that CCHD
newborn screening
may not find all
types of problems
in a baby's heart.

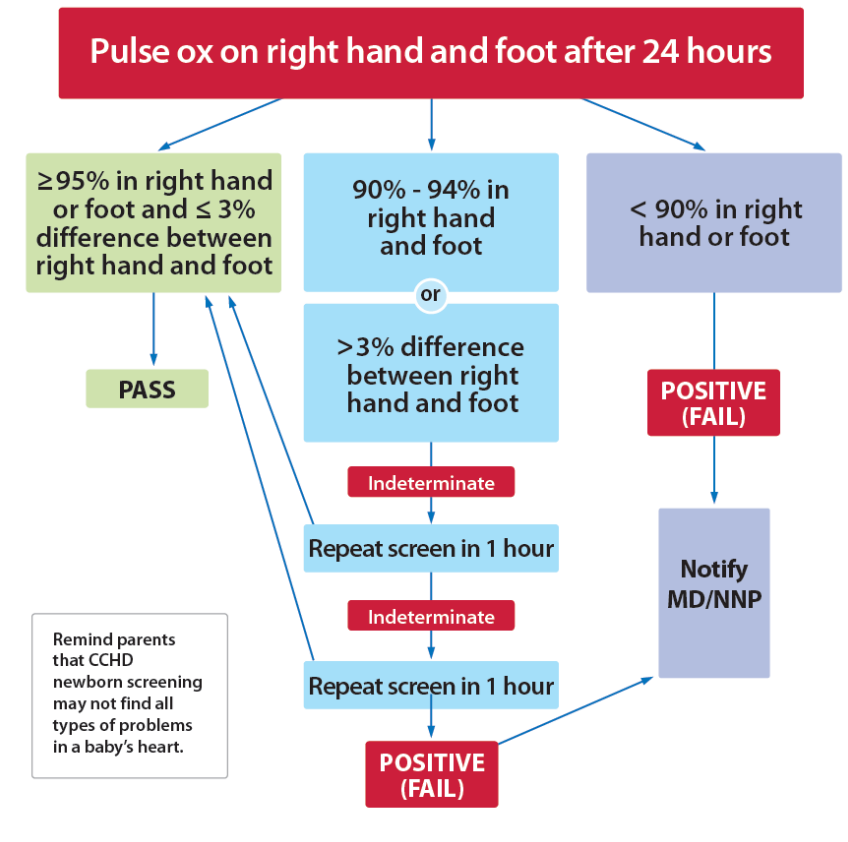


Passing scores

- 100% and 100%
- 100% and 97%
- 99% and 96%
- 98% and 95%
- 97% and 94%
- 96% and 93%
- 95% and 92%



Critical Congenital Heart Disease Newborn Screening Algorithm



Virginia Department of Health Mueller CCHD Screening Table

Green = Negative Screen (PASS)

Yellow = Rescreen in 1 hour

Yellow for 3 consecutive screens = Positive Screen (FAIL)

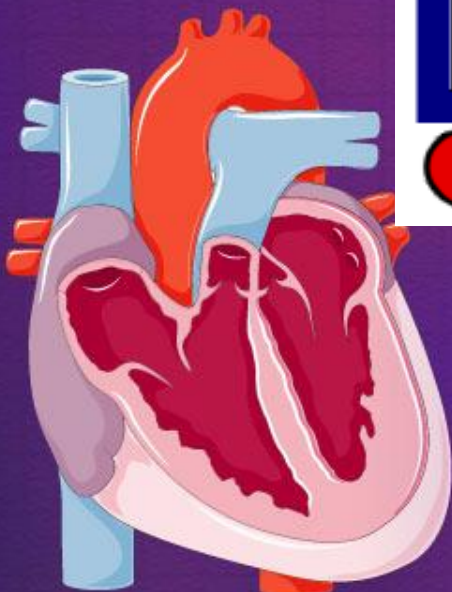
* Red = Automatic Positive Screen (FAIL)

Right Hand	Foot											<90
	100	99	98	97	96	95	94	93	92	91	90	
100	100	99	98	97	96	95	94	93	92	91	90	*
99	100	99	98	97	96	95	94	93	92	91	90	*
98	100	99	98	97	96	95	94	93	92	91	90	*
97	100	99	98	97	96	95	94	93	92	91	90	*
96	100	99	98	97	96	95	94	93	92	91	90	*
95	100	99	98	97	96	95	94	93	92	91	90	*
94	100	99	98	97	96	95	94	93	92	91	90	*
93	100	99	98	97	96	95	94	93	92	91	90	*
92	100	99	98	97	96	95	94	93	92	91	90	*
91	100	99	98	97	96	95	94	93	92	91	90	*
90	100	99	98	97	96	95	94	93	92	91	90	*
<90	*	*	*	*	*	*	*	*	*	*	*	<90

Created by Cynthia Mueller BSN, RN - Anne Arundel Medical Center

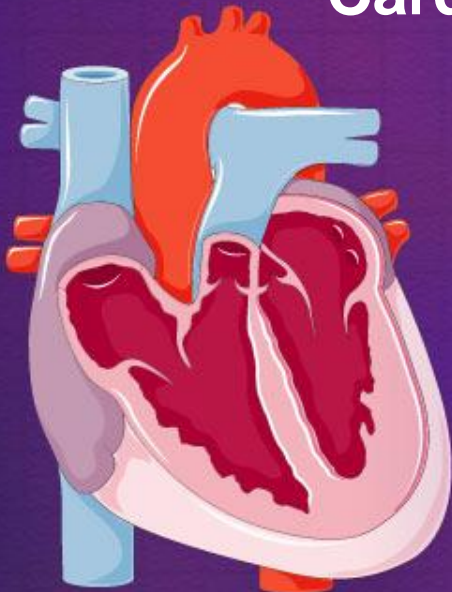


Screen all babies after 24 hours, before discharge.

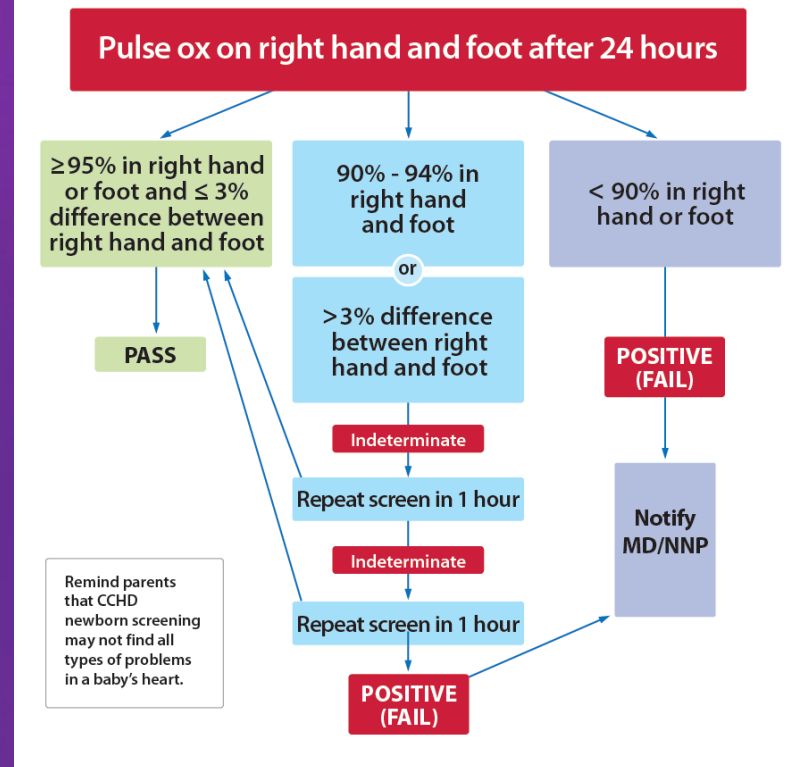


The next steps for a failed screen

- Pulmonary evaluation
- Infectious etiology evaluation
- ECHO
- Referral to a Pediatric Cardiologist



Critical Congenital Heart Disease Newborn Screening Algorithm



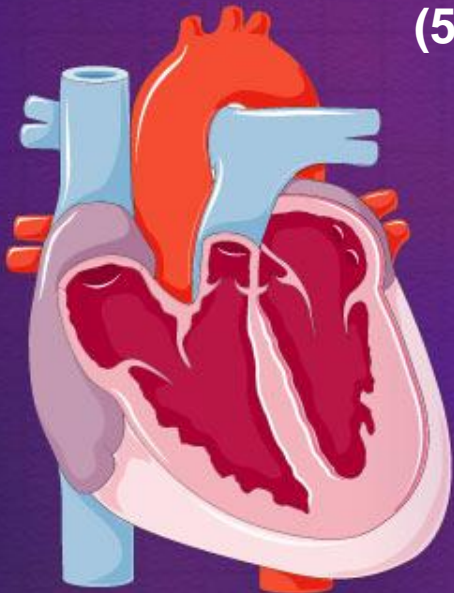
Reporting of confirmed CCHD cases

All confirmed cases of CCHD need to be reported to the DSHS via the CCHD Reporting Form

CCHD Program

Mail: DSHS Newborn Screening Genetics Branch
 PO Box 149347, MC 1918
 Austin, Texas 78714-9347

Fax: CCHD Program
 (512) 776-7593



TEXAS
 Department of State Health Services

Critical Congenital Heart Disease Reporting Form

Chapter 37, Subchapter E, Newborn Screening for Critical Congenital Heart Disease of the Texas Administrative Code requires a physician, health care practitioner, health authority, birthing facility, or other individual who has information of a confirmed case of a disorder for which a screening test is required, to report the confirmed cases to the department.

Instructions:

1. Complete form for all confirmed CCHD cases
2. Print form
3. Manually sign form
4. Fax signed form to 512-776-7593 Attention: CCHD Program

Facility Name: _____ Facility Location (City): _____
 Medical Record #: _____ Mother Texas Resident: Yes No
 Facility Type: Hospital Children's Hospital Birthing Center Home Birth
 Baby's Name: First _____ Last _____ Date of Birth: _____
 Baby's Ethnicity: White African American Hispanic Asian Native American Other _____
 Patient Age (in hours at time of screening): _____ Sex: M F Unknown
 Mother's Name: First _____ Last _____
 Mother's Maiden Name: _____ Mother's Date of Birth: _____

Diagnosis First report on this baby Update to a previously reported case

Primary Target Condition	Secondary Target Condition
<input type="checkbox"/> 1 hypoplastic left heart syndrome	<input type="checkbox"/> 9 coarctation of the aorta
<input type="checkbox"/> 2 pulmonary atresia with intact septum	<input type="checkbox"/> 10 double outlet right ventricle
<input type="checkbox"/> 3 tetralogy of fallot	<input type="checkbox"/> 11 Ebstein anomaly
<input type="checkbox"/> 4 total anomalous pulmonary venous return	<input type="checkbox"/> 12 interrupted aortic arch
<input type="checkbox"/> 5 transposition of the great arteries	<input type="checkbox"/> 13 single ventricle
<input type="checkbox"/> 6 tricuspid atresia	<input type="checkbox"/> 14 unspecified secondary
<input type="checkbox"/> 7 truncus arteriosus	
<input type="checkbox"/> 8 unspecified primary	

Comments:

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Diagnosis Timeframe (choose only one).

Prenatal diagnosis
 If prenatally diagnosed, did prenatal and post-natal diagnosis match? Yes No
 If no what was the prenatal diagnosis? _____

Post-natal diagnosis prior to pulse oximeter screening

Post-natal diagnosis with pulse oximeter screening

Post-natal diagnosis after a normal pulse oximeter screening

Was post-natal echocardiogram performed? Yes No

Delivery Outcome: Live Birth Non-live birth

Treatment Provided: Cardiac surgery Medical management Supportive care

Baby Status: Baby Living Baby Expired

Infant was transported: Yes No
 If yes indicate for what purpose(s)
 Evaluation
 Treatment

Infant has:
 Isolated heart disease
 Multiple anomalies
 Syndrome/chromosomal anomaly diagnosed

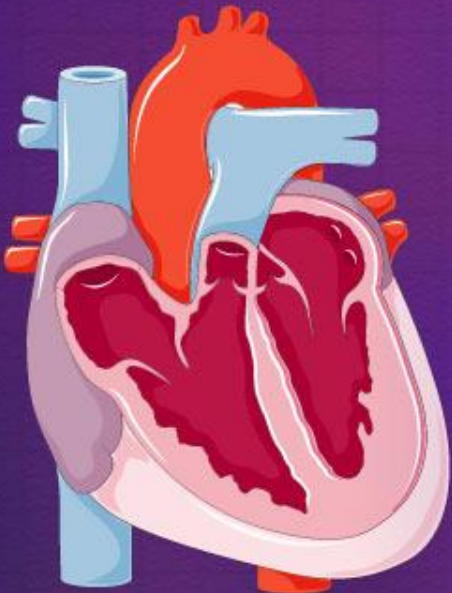
Printed name of person completing report _____ Title _____
 Signature of person completing report _____ Date sent _____

Fax signed form to 512-776-7593 Attention: CCHD Screening

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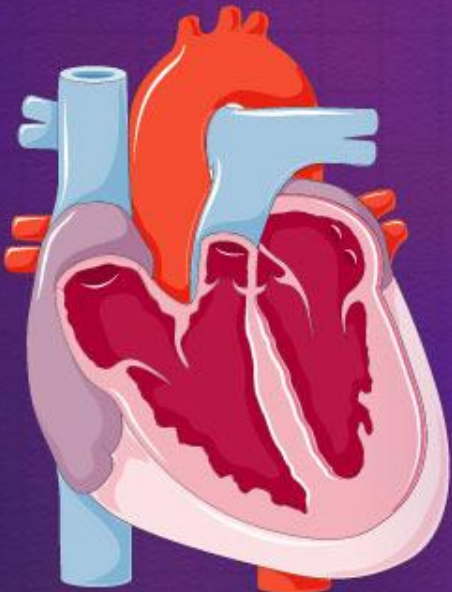
Exemption from CCHD screen

- Parent **declines** screening
- Previously **diagnosed** newborn with CCHD
- Newborn has had a post-natal **ECHO**
- Newborn was **discharged** from birthing facility by 10 hours of life with referral to another birthing center, physician or healthcare provider
- Newborn was **transferred** to another facility before the screening

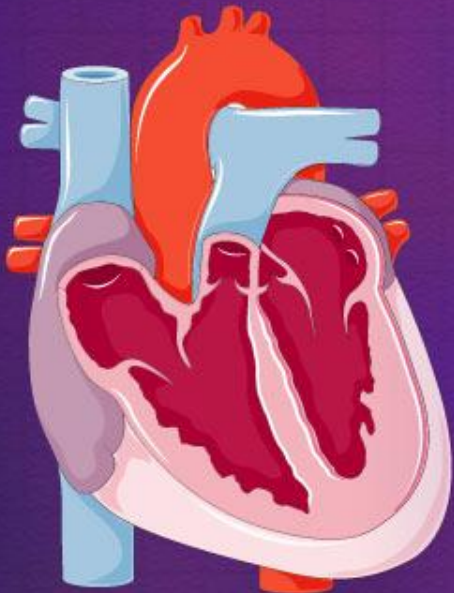


Medical, Social & Financial impact of CHD

- CHD is a “lifelong” condition: even patients with “repaired” CHD, will need lifelong highly specialized care
- Associated conditions:
 - Congestive heart failure
 - Pulmonary hypertension
 - Arrhythmias
 - Endocarditis
 - Developmental delay
- Prolonged & repeated hospitalizations
- Long follow up and treatment
- Extensive financial resources
- Emotional and financial strain for the family



**Screening and timely diagnosis
of CCHD means decreased
morbidity and mortality**





Thank you!

