Cardiac Disorders of the Newborn

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Objectives

- Review cardiac conditions encountered in the newborn period
- Describe the clinical manifestations of these conditions
- Discuss implications to respiratory management of selected congenital cardiac disorders
- Disclaimer: speaker is not a cardiologist....
Embryologic Development of the Heart

- The heart is the first organ to form and function during embryogenesis.
- Improper formation of the heart leads to congenital heart defects, which are the most common form of human birth defects (~1/100).
- Heart formation requires delicate spatial and biochemical interactions among various cell types.

Congenital Cardiovascular Malformations

- Overall incidence of these malformations is 0.4-1% among live-born infants.
- For most structural cardiovascular malformations, the genetic and biochemical basis for the developmental error is largely unknown.
- At least 25% of patients with a congenital heart defect have one or more extracardiac malformations.
Cardiovascular malformations in 40-50%.
Most common abnormalities:
- Common atrioventricular canal
- Ventricular septal defect
- Tetralogy of Fallot
- Patent ductus arteriosus
Advanced maternal age
Increased nuchal thickening

47% of children w/ common AV canal defects have Down Syndrome
Majority w/ Down syndrome and AV canal have easily heard murmur
Presentation:
- CHF
- Failure to grow adequately
The most common clinical presentations for congenital heart disease in the newborn are:

- Congestive Heart Failure
- Hypoxemia

Congestive Heart Failure

- Pump Failure
  - Inadequate Inflow
    - Pericardial disease
    - Restrictive cardiomyopathy
    - Mitral stenosis
    - Pulmonary venous obstruction
  - Inadequate Outflow
    - Dilated cardiomyopathy
    - Systemic outflow obstruction

Heart Failure may occur with/without myocardial failure, which refers to contractile dysfunction.
Heart Failure in Structurally Normal Hearts

- Prenatal
  - Anemia
  - Arrhythmia
  - A-V fistula
  - Cardiomyopathy
  - Twin-twin transfusion

Heart Failure in Structurally Normal Hearts

- Neonate and Infants
  - Anemia
  - Arrhythmia
  - A-V fistula
  - Dilated cardiomyopathy
  - Endocrinopathies
  - Hypoglycemia
  - Hypothyroidism
  - Hypoxic ischemic injury
  - Hypertension
  - Infection/sepsis
  - Kawasaki syndrome
Heart Failure in Structurally Normal Hearts

- **Childhood**
  - Acquired valve disorders
  - Anemia
  - Arrhythmia
  - Dilated cardiomyopathy
  - Hypertension
  - Renal failure
  - Restrictive cardiomyopathy

Heart Failure in those with Congenital Heart Disease

- **Prenatal**
  - Atrioventricular valve regurgitation
  - Mitral stenosis w/ intact atrial septum
Heart Failure in those with Congenital Heart Disease

- Neonates and Infants
  - Systemic outflow obstruction
  - Aortic valve stenosis
  - Coarctation of the aorta
  - Subaortic stenosis
  - Truncal valve stenosis
  - Systemic inflow obstruction
  - Cor triatriatum
  - Mitral stenosis
  - Pulmonary venous stenosis
  - Systemic ventricular volume overload

Cor Triatriatum

- Membrane in Left Atrium from failure to reabsorb common pulmonary vein
- Membrane obstructs pulmonary venous return
- Results in pulmonary hypertension and overload of right ventricle
High incidence of associated intracardiac lesions

If intracardiac lesion results in decreased flow to ascending aorta—e.g., VSD, mitral or subaortic obstruction—this results in hypoplasia of the transverse arch and aortic isthmic area

Familial recurrence in some

Association w/ syndromes—Turners

Intracranial aneurysm (10% of adults w/ coarctation)

Tissue from the neural crest and branchial arch mesenchyme contribute to the formation and septation of the outflow tract of the heart

Hypoplasia or aplasia of the thymus and parathyroid gland (pharyngeal pouches III and IV)

TOF is one of the most common cardiac defects in velocardiofacial syndrome

Palate abnormalities

Facial dysmorphisms

Neonatal Hypocalcemia

Immune deficit

Speech and learning disabilities
**22q11 Deletion Syndrome:**

Neural Crest Migration Abnormality

- DiGeorge sequence
- Velocardiofacial syndrome
- Conotruncal anomaly face syndrome
- CATCH 22

- Aplasia/Hypoplasia of thymus and parathyroid gland (neural crest cells populate branchial arches)

- Neural crest cells contribute to formation and septation of the outflow tract of the heart
- Interruption of the aortic arch (particularly type B)
- Truncus arteriosus
- Tetralogy of Fallot

**Truncus Arteriosus**

- Associated w/ DiGeorge syndrome and deletion of 22q11
- Septation of the single truncus into aorta and main PA occurs by the end of the 5th week of embryology
- Most patients develop CHF in neonatal period
Tetralogy of Fallot

- Defective embryonic neural crest migration and resulting in abnormal conotruncal development
- Primary problem is underdevelopment of the pulmonary infundibulum, with the other features being secondary
- Cyanotic because of R-to-L shunting at ventricular level, because of RV outflow tract obstruction
- Degree of cyanosis is directly proportional to the severity of the RV outflow obstruction
- Mild outflow obstruction results in 'pink' tet
- Crying increases pulmonary vascular resistance, increases R-to-L shunting and worsens cyanosis
- Squatting increases systemic vascular impedance, limiting shunting and improving cyanosis

Neural Crest Migration has also been implicated in which of the following adult conditions:

- Dementia
- Aortic aneurysm
- Extra digits
- Lack of desire to use ‘cheaters’ in respiratory set-ups
Heart Failure in those with Congenital Heart Disease

- Neonates and Infants (continued)
  - Aortic or mitral regurgitation
  - Aortopulmonary window
  - Atrial septal defect
  - Atrioventricular canal defect
  - Patent ductus arteriosus
  - Single ventricle
  - Totally anomalous pulmonary veins
  - Truncus arteriosus
  - Ventricular septal defect

Heart Failure in those with Congenital Heart Disease

- Children
  - Aortic regurgitation
  - Mitral regurgitation
  - Mitral stenosis
  - Pulmonary vein stenosis
Heart Failure in Hypoplastic Left Heart Syndrome

- Survival requires patency of DA
- Right ventricle supplies both pulmonary and systemic circulations
- Relative flow to pulmonary and systemic circuits depends on relative resistances
- Restrictive ASD raises LA pressure, increases total pulmonary resistance, and limits pulmonary blood flow
- Unrestricted does not limit pulmonary blood flow...CHF

Physiology of Heart Failure: Step 1-Inadequate Tissue Oxygenation

- Aerobic ‘switch’ to anaerobic metabolism
  - Lactate generation
  - Local vasodilation
  - Localized increase blood flow to improve oxygenation
**Physiology of Heart Failure: Step 2-Systemic Responses**

- Local Vasodilation
  - Decrease in peripheral resistance
  - Decrease in systemic BP
  - Sympathetic nervous system activated
  - Rapid response reflexes activated: Goal-to improve BP
    - Tachycardia
    - Stimulation of myocardial contractility
    - Regional vasoconstriction
  - Long-term Restoration of BP: improve pre-load
    - Activate Renin-Angiotensin-Aldosterone system
    - Renal fluid retention
    - Expansion of vascular volume

**What if there is Diminished Ability of the Heart to Respond?**

- When fall in cardiac output and secondary fall in BP are due to diminished cardiac capacity, increasing the preload may increase the circulating volume and filling pressure, without improving tissue oxygenation (pump is already at max capacity)

- **Heart Failure** is a compromise between symptoms associated w/ inadequate cardiac output during euvolemia and the symptoms associated w/ venous congestions during hypervolemia
**Heart Failure Manifests as Respiratory Signs and Symptoms**

Increased interstitial fluid from increased pulmonary venous pressure (e.g., pulmonary edema) causes:

- Tachypnea:
- Nasal flaring
- Intercostal retractions
- Grunting

- Wheezing-may result during compression of airways by distended, hypertensive, pulmonary vessels

**Pulmonary Edema in Lungs of Infants**

The pulmonary vasculature in the lung of infants is fully recruited at rest and is particularly predisposed to the development of pulmonary edema when flow is increased via anatomic L-to-R shunts.
Some basic definitions*

physiologic
L to R shunt =

lungs to lungs shunt

Blood that is returning to the heart from the lungs is recirculated back to the lungs without going out to the rest of the body.

*ppt. by Greg Gordon, MD.

Some basic definitions*

physiologic
R to L shunt =

body to body shunt

Blood that is returning to the heart from the body is recirculated directly back to the body without going to the lungs to be oxygenated.

*ppt. by Greg Gordon, MD.
Some basic definitions*

**effective pulmonary blood flow** = body to lungs flow

Blood that is returning to the heart from the body that is actually directed to the lungs to be oxygenated.

*ppt. by Greg Gordon, MD.

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**Effects of Pulmonary Edema: Location, Location, Location**

- While fluid filtration occurs in the alveolar capillary, hydrostatic forces in the lung favor fluid accumulation in the extra-alveolar interstitium.
- This interstitium contains airways, so that fluid accumulation may compress these airways leading to airway compression, increased airway resistance and the finding of cardiac asthma and increased airway resistance w/ pulmonary edema.
- Decreased compliance.
  - May occur in the alveolar space and impair surfactant production.
**Treatment for Pulmonary Edema**

- Primarily supportive
- Measures to lower $P_{mv}$ (hydrostatic pressure in the microvasculature):
  - Reduce pulmonary blood flow by decreasing L-to-R shunts or
  - Decrease circulating blood volume
    - Decrease fluid administration
    - Administer diuretics-furosemide most effective, as it results in pulmonary dilation as well as decreased lung water
- Support the respiratory system by providing positive pressure-no decrease in fluid accumulation, but works by improving V/Q mismatching-improves ventilation to the low V/Q compartment in the lung.

**Most Common Presentation of Heart Failure in *Infancy***

- a) Crying like a baby
- b) Headaches
- c) Feeding difficulty
- d) Diarrhea
Cystic Hygroma

The most common clinical presentations for congenital heart disease in the newborn are:

- Congestive Heart Failure
- Hypoxemia
Which Trisomy is this?

- The second most common autosomal chromosomal aberration (1 in 3500 newborns)
- IUGR
- Microcephaly
- Characteristic facies
- Overlapping fingers on hands
- Cardiovascular defects
  - All have VSDs
  - Subpulmonary infundibulum in 98%
  - 93% have polyvalvular disease

Mucopolysaccharidosis

- Hurler’s syndrome
- Deposition of mucopolysaccharides results in:
  - Valvar insufficiency
  - Myocardial dysfunction
  - Sudden death from arrhythmia
  - Diffuse coronary artery disease
Williams Syndrome

- At least half have cardiovascular defects
- Most frequent single defect is supravalvular aortic stenosis, but any of the systemic and pulmonary arteries can be affected
- Abnormalities in elastin production are thought to be responsible for the cardiovascular phenotype-linked to elastin gene on chromosome 7

- Hypocalcemia
- Stellate pattern of the iris
- Short anteverted noses
- Long philtrum
- Prominent lips
- Large, open mouth
- ‘Cocktail’ personality

Holt-Oram

- Radial anomalies and ASD
- Autosomal dominant
- Gene mapped to 12q, encodes a transcription factor TBX5
- 35 mutations described
- All mutations result in null alleles--haploinsufficiency.
**Differential Diagnosis of Excessive Cyanosis (cont’d)**

- Decreased Pulmonary Blood Flow
  - Elevated pulmonary blood flow
  - Pulmonary venous hypertension
  - Restrictive ASD
  - Pulmonary artery distortion
  - Physically small or stenotic systemic to pulmonary artery shunt

**Respiratory Strategies in CHD**

- In the face of hypoxemia refractory to increased MAP and/or FiO2, think CHD
- Cardiac disorders w/ fixed shunts will be minimally affected by respiratory maneuvers
- iNO should not be used in CHD w/ dependent R-to-L shunts, as this will likely drop pulmonary pressures, reversing to L-to-R flow
- Hypoxic gases may be helpful in CHD to limit the drop in pulmonary vascular resistance normally present in the transition from *in utero* to *ex utero* life
What is the Most Common Cardiac Condition Found in the Neonate?

a) Ventricular Septal Defect
b) Patent Ductus Arteriosus
c) Respiratory Distress Syndrome
d) Tetrology of Fallot
e) Transposition of the Great Vessels

Newborn VSD

Most common lesion
2/3rds close spontaneously

Small VSD
Definite murmur
Will probably close

Large VSD
No murmur
No problems
Home with Mom
CHF symptoms by 4-8 weeks
Delay in closure of the interventricular septum beyond the first 7 weeks of intrauterine life
- Gene mutations result in VSD
- Chromosomal abnormalities
- Environmental factors
- Parent w/ VSD
- More common among premature and LBW infants
- Subpulmonic defect location more common among Asian populations

Functioning of the DA During Fetal Life

- Allows right-to-left shunting around high-pressure pulmonary bed to lower-pressure systemic circulation\(^1\)
- Carries approximately 90% of right ventricular output\(^2\)
- Patency of DA maintained in utero primarily by\(^3\):
  - relatively low fetal PaO\(_2\)
  - high circulating PGs (PGE\(_2\))
- Prostaglandins elevated in utero because\(^3\):
  - large amounts produced by placenta
  - decreased metabolism in fetal lungs (5%-10% of normal flow)

PaO\(_2\) = oxygen tension; PGs = prostaglandins; PGE\(_2\) = prostaglandin E\(_2\)

\(^1\) Schneider DJ, Moore JW. Circulation. 2006;114:1873-1882.
PDA-Clinical Presentation

- Physical Exam and X-ray
  - Cyanosis
  - Tachypnea
  - Tachycardia
  - Hyperdynamic precordium
  - Bounding pulses
  - Systolic murmur
  - Pulmonary edema
  - Increased cardiac silhouette

- Other clinical findings
  - Feeding intolerance
  - Decreased urine output
  - Metabolic acidosis
  - Diastolic 'steal'-oxygen delivery 'abnormality.'
  - Congestive heart failure

When Should Ductal Patency be 'Treated'?

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<th>Medical Rx</th>
<th>Prophylactic</th>
<th>Early Asymptomatic</th>
<th>Late Asymptomatic or Early Symptomatic</th>
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Possible Complication

- ICH
- Pulmonary Hemorrhage
- NEC
- BPD
- ROP

Prophylactic Indomethacin

<12h 3-5days ~1 week >10days

Adapted from Clyman RI, Chome N. J Pediatr 2007;150(3):216-9
Ebstein’s Anomaly

- an abnormality in the tricuspid valve
- two leaflets of the tricuspid valve are displaced downward into the pumping chamber
- These abnormalities cause the tricuspid valve to leak blood back into the right atrium. As a result, the right atrium becomes enlarged.
- If the leak is severe enough, it can lead to congestive heart failure
- The high pressure in the right atrium keeps the PFO open thus allowing deoxygenated blood to be pumped out into the systemic circulation.
- Mild defects may require no specific treatment, only prophylaxis for bacterial endocarditis. Medical treatment is used to help children with congestive heart failure or abnormal heart rhythms.
- Without any treatment, the natural history of Ebstein’s anomaly is gloomy. A 1971 study reported that only 50% of patients survived to 13 years of age.
- Children treated with medicines only have excellent results and few complications.
- Children who have surgery generally do well.

Supportive care in Neonatal period:
- Prostaglandins
- iNO
- Oxygen
- Correction of anemia
- Rhythm problems common
- Marked cyanosis and CHF ominous-the earlier, the more limited the life expectancy
Pulmonary Valve Stenosis

- Normal growth
- Murmur on routine auscultation at birth
- Noonan syndrome - most common lesion is PS due to pulmonary valvular dysplasia
- Leopard syndrome (multiple lentigines syndrome)
- Neurofibromatosis