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Truncus Arteriosus in the Neonate

By P. Syamasundar Rao, MD and Duraisamy Balaguru, MD

Introduction

The most common cyanotic congenital heart defects (CHDs), the so-called "5Ts" are listed in Table I. In the previous issues of *Neonatology Today*, we addressed four of these CHDs, namely, Transposition of the Great Arteries,[1] Tetralogy of Fallot,[2] Tricuspid Atresia[3] and Total Anomalous Pulmonary Venous Connection.[4] In this issue of *Neonatology Today* we will discuss Persistent Truncus Arteriosus, in short, Truncus Arteriosus.

Table I.
Transposition of the Great Arteries
Tetralogy of Fallot
Tricuspid Atresia
Total Anomalous Pulmonary Venous Connection
Truncus Arteriosus

Truncus Arteriosus

Truncus Arteriosus is a rare cyanotic CHD accounting for less than 1% of all CHDs,[5] although a higher incidence (2.8%) is reported in autopsy series.[6] Truncus Arteriosus is characterized by a single arterial vessel (truncus) originating from the heart which gives rise to the aorta, pulmonary artery and coronary arteries.[7] Pulmonary arteries originate from the truncus and their origin and distribution form the basis for classification and will be reviewed later. The truncus is most commonly associated with a large Ventricular Septal Defect (VSD) in the conal septum. The truncal valve is usually tricuspid (69%), but may be quadracuspid (22%) or bicuspid (9%) and rarely unicuspid or pentacuspid.[8] Truncal valve regurgitation or stenosis may be present, though not frequent. Right aortic arch is frequently (nearly 40%) seen with Truncus Arteriosus. Interrupted aortic arch may be present in 10% of cases. There is a high degree of association with DiGeorge Syndrome with 22q11 micro deletion, identified using Fluorescent in Situ Hybridization (FISH) technique; approximately one-third of truncus patients have such a genetic abnormality.[9,10]

Embryology

In the early embryonic period, Truncus Arteriosus is a segment of the cardiac tube connecting the ventricle with aortic arches. During further development, anterior and posterior cushions emerge within the walls of the Truncus Arteriosus which form a "spiral septum." The spiral septum divides the Truncus Arteriosus into the aorta and main pulmonary artery. If the spiral septum fails to develop, postnatal Truncus Arteriosus ensues. Indeed, the full description of this entity is Persistent Truncus Arteriosus. The causes of this developmental abnormality are not known, but various theories have been proposed which include: abnormal flow pattern during the bilocular stage of the cardiac tube, abnormal migration of cardiac neural crest cells into the primitive truncus[11] and mutation of PAX3 gene[12] which is thought to be expressed in the cardiac neural crest cells.

Classification

A number of classifications have been proposed,[13-17] but the classification put forward by Collett and Edwards[13] is most commonly used by clinicians, including the authors of this review.[5] Collett and Edwards[13] classified the Truncus Ar-

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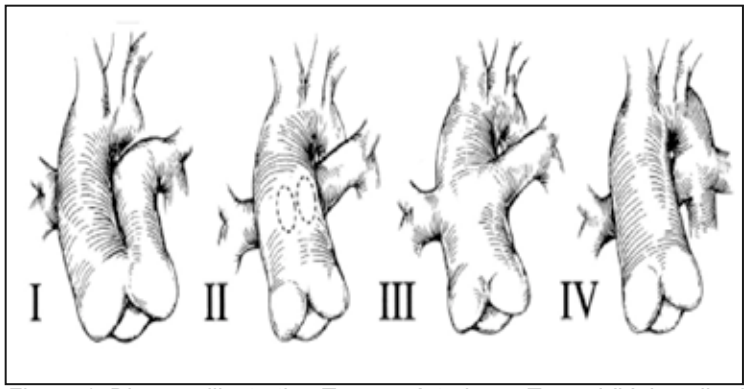

Figure 1. Diagram illustrating Truncus Arteriosus Types I-IV described by Collett & Edwards.[13] See the text for complete description.

teriosus based on the origin and distribution of the pulmonary arteries (Figure 1): Type I – Main pulmonary artery (PA) is present and arises from the posterior and left region of the truncus, just above the semilunar valve; this is a short vascular segment and immediately divides into right and left PAs. Embryologically, it is deemed to be due to partially formed spiral septum with consequent partial separation of aorta and main PA. This is the most common type and is seen in 48-68% of cases. Type II – There is no main PA; the branch PAs arise from the back portion of the truncus, usually very close to each other. Prevalence of Type II is lower than Type I and is seen in 29-48% cases. Type III – Again, there is no main PA, and both branch PAs arise from either side of the truncus, separate from each other. Type III is least common and is seen in 6-10% of cases. Type IV – In this type there is also no main PA, but the branch PAs come off of the descending aorta or other parts of aorta. At the present time, this entity is not considered to be a variety of Truncus Arteriosus. It has been called pseudotruncus,[18] and may be a variant of pulmonary atresia with VSD.[2,5,18]

Pathophysiology

Because of the mixing of systemic and pulmonary venous returns at the level of VSD, truncal valve and proximal Truncus Arteriosus, systemic arterial desaturation is present in all babies with truncus. Because of high pulmonary vascular resistance at birth, the pulmonary blood flow may not be excessive and the neonate is not usually symptomatic. They are only mildly cyanotic with oxygen saturation in the low 80's. As the pulmonary vascular resistance (PVR) falls in the natural course of development, the pulmonary blood flow increases causing left heart volume overload. The oxygen saturations may increase into the low 90's. Rapid or anomalous fall in PVR causes excessive pulmonary blood flow, increased left-heart volume overload and congestive heart failure. These features are exacerbated in the presence of truncal valve regurgitation. If the pulmonary arteries are stenotic or hypoplastic (in rare cases of Type II and II anatomy), the pulmonary blood flow may be decreased.

If the infants with increased pulmonary blood flow are not treated within the first six months of life, PVR may increase and Pulmonary Vascular Obstructive Disease is likely to develop.[19]

Clinical Features

With increasing use of prenatal ultrasound, some of the babies may be identified prior to birth.[20] Most babies are asymptomatic at birth, but may

"Truncus Arteriosus is a rare cyanotic CHD accounting for less than 1% of all CHDS,[5] although a higher incidence (2.8%) is reported in autopsy series.[6]"

be detected because of a murmur, abnormal heart sounds or cyanosis. Within days and weeks of birth, as the PVR drops, the pulmonary blood flow increases and when it is excessive, the babies develop signs of congestive heart failure, namely: tachypnea, tachycardia, excessive sweating, irritability, poor feeding and poor weight gain. These symptoms may appear earlier if there is associated truncal valve insufficiency.

Babies with interrupted aortic arch may present precipitously when the ductus arteriosus closes. Clinical manifestations include circulatory collapse, metabolic acidosis, respiratory distress and cyanosis. Absent femoral pulses may be present.

Mild cyanosis may be present in the first few days of life because of high pulmonary vascular resistance at birth, but improves with time as the PVR decreases. In rare cases with ostial stenosis or hypoplasia of branch PAs, the cyanosis persists and may even become severe.

Abnormal facies, described as "conotruncal facies"[21] may be seen in some babies.

Physical examination shortly after birth may be benign with slight right ventricular prominence. As the PVR falls, hyperdynamic precordium with increased right and left ventricular impulses may be observed. Thrills are not usually present. Both the brachial and femoral pulses are increased (sometimes bounding) due to diastolic flow from the aorta into the PAs. However, if the pulmonary blood flow is normal or diminished due to anatomic pulmonary artery stenosis, hyperdynamic precordium is not present. Hepatomegaly may be seen in babies with congestive heart failure.

On auscultation, the first heart sound is of normal intensity or loud and the second heart sound is single. A loud third heart sound may be heard at the apex. An ejection systolic click may be heard at the apex either due to truncal valve abnormalities or dilated truncus. Ejection systolic murmur may be heard at the left upper sternal border which may be either due to increased pulmonary blood flow through non-stenotic branch PAs or due to truncal valve stenosis. When there is severe pulmonary artery stenosis, the systolic murmur may be more prominent and may become continuous. High frequency, early diastolic decrescendo murmur may be heard in the presence of truncal valve regurgitation. A mid-diastolic flow rumble may be heard in babies with markedly increased pulmonary blood flow; this is due to increased flow across the mitral valve. In extremely rare cases with restrictive VSD, holosystolic murmur may be heard at the left lower sternal border.

Noninvasive Studies

Electrocardiogram (ECG). The ECG shows either a normal or right axis with the usual neonatal right ventricular preponderance in the early neonatal period. As the pulmonary blood flow increases, the left ventricle

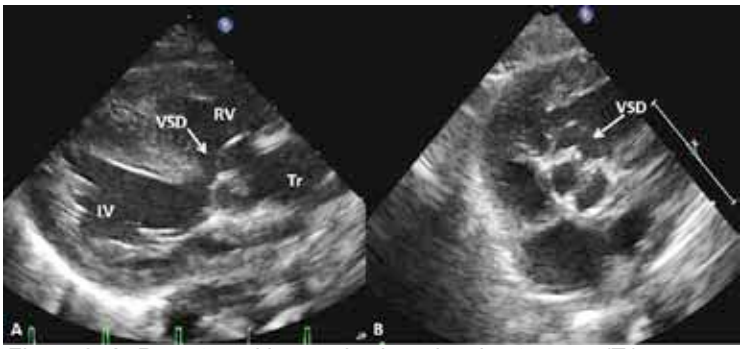

Figure 2. A. Parasternal long axis view showing truncus (Tr) overriding the ventricular septum and ventricular septal defect (VSD) (arrow). B. Parasternal short (B) axis view demonstrates the VSD in the conal septum. LV, left ventricle; RV, right ventricle.

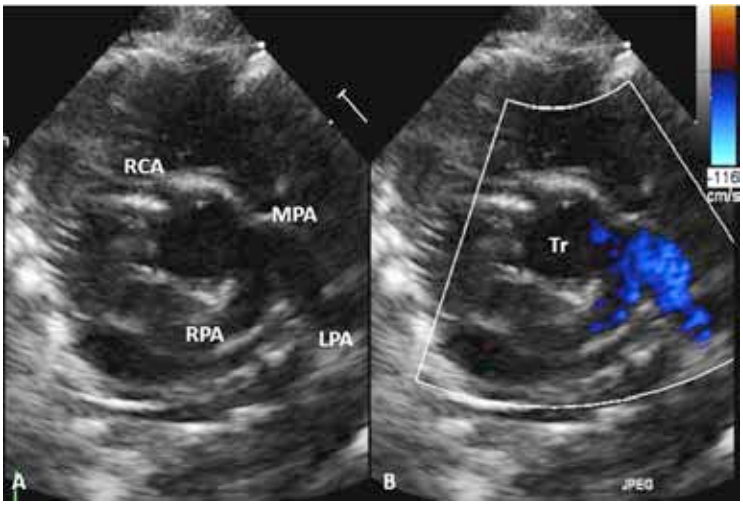

Figure 3. Parasternal short-axis views in 2D (A) and color Doppler (B) showing origin of main pulmonary artery from the truncus (Tr). The main pulmonary artery (MPA) is short and bifurcates into right (RPA) and left (LPA) pulmonary arteries. In B, color Doppler imaging shows non-turbulent flow in both pulmonary arteries. RCA, right coronary artery.

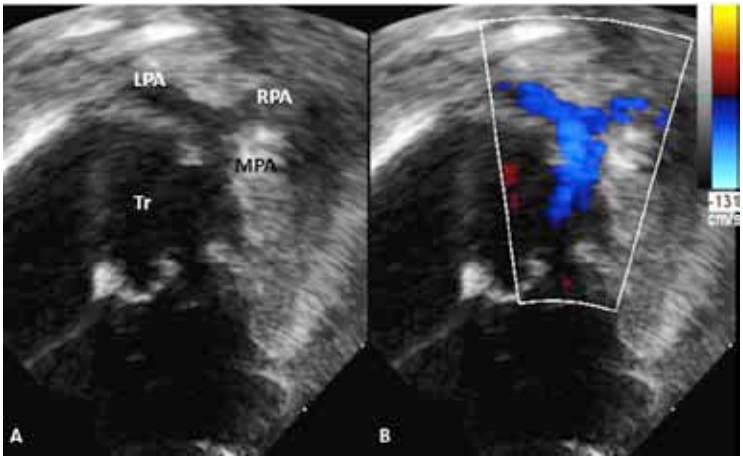

Figure 4. Apical 4-chamber views [2D (A) and color Doppler (B)] with anterior tilt of the transducer demonstrate main pulmonary artery (MPA) originating from the left side of the truncus (Tr) which bifurcates into right (RPA) and left (LPA) pulmonary arteries.

enlarges giving a pattern of biventricular hypertrophy. Left atrial enlargement also occurs. Babies with decreased pulmonary blood flow may exhibit only right ventricular hypertrophy. It is important to note that there is no particular ECG pattern that is diagnostic of truncus arteriosus.[22]

Chest X-ray. Early in the neonatal period, the heart size may be normal or slightly enlarged with normal pulmonary vascular markings. With time (as PVR drops) cardiomegaly will ensue along with increased pulmonary vascular markings. Right aortic arch may be present in more than one-third of the patients. A mildly cyanotic baby with increased pulmonary vascular markings and right aortic arch is virtually diagnostic of truncus arteriosus.

Echocardiogram. Echocardiography is extremely useful in confirming the diagnosis and in providing the necessary information for surgical planning. Echo-Doppler features (Figures 2-4) include origin of only one great artery (truncus) from the ventricles, conal septal VSD, truncal valve overriding the ventricular septum, and origin of the pulmonary arteries from the truncus.[5] Detailed definition of pulmonary arteries, categorizing the type of truncus (Types I, II or III) based on the origin and distribution of the pulmonary arteries and detection of other associated anomalies such as interrupted aortic arch, anomalies of the origin of aortic arch branches, abnormalities of coronary artery origins, persistent left superior vena cava, additional VSDs and Patent Ductus Arteriosus (PDA) may also be accomplished by echo studies. Presence of truncal valve stenosis or regurgitation and branch pulmonary artery stenosis may also be detected by Doppler examination of these structures. Truncus Arteriosus should be differentiated from pulmonary atresia with VSD and aortopulmonary window.[23]

Magnetic resonance imaging (MRI). These studies may be used if the anatomy of the Truncus Arteriosus cannot be determined with certainty by echo-Doppler studies. Suspicion of associated interrupted aortic arch and inability to confirm by echocardiogram may be an indication for MRI.

Other Laboratory Studies. Blood gases are useful in indicating the extent of hypoxemia and ventilatory status. Serum glucose, calcium, hemoglobin and hematocrit values are helpful in the overall appraisal, same as that utilized for other cyanotic CHD in the neonate.[1-4]

Catheterization & Angiography

Cardiac catheterization with selective cineangiography is rarely needed in neonates and infants because echo-Doppler studies (plus rarely, MRI) usually provide the information essential for surgical planning.

Differential Diagnosis

Differential diagnosis of cyanotic infants who are in heart failure, but with only mild cyanosis includes: transposition of great arteries with VSD, double outlet right ventricle, Tricuspid Atresia with large VSD (with or without transposition of great arteries), single ventricle without pulmonary stenosis and Total Anomalous Pulmonary Venous Return (TAPVR). Left axis deviation and LV dominance in the ECG is suggestive of Tricuspid Atresia. Low voltage to the left (R waves in V5 and V6) and posterior (S waves in V1 and V2) in the ECG may indicate TAPVR. Absent pulmonary artery segment in the chest X-ray is a common feature for both Truncus Arteriosus and transposition of great arteries. However, in Type I Truncus Arteriosus, a normal-appearing pulmonary artery segment may be seen. Right aortic arch is suggestive of Truncus Arteriosus. Nonetheless, echocardiographic features are distinctive for each of the above mentioned entities.

Management

The treatment of choice for Truncus Arteriosus is total surgical correction[24,25] and will be discussed hereunder. Recent trend is to perform this surgery in the neonatal period around the age of 10 days.[26,27] The

infant should be managed to ensure good clinical and metabolic state before going to surgery.

General Measures. Initial management of Truncus Arteriosus is akin to that used in other cyanotic neonates.[1-4] The baby's temperature should be monitored and a neutral thermal environment preserved. Ambient oxygen is not usually necessary and should be administered only if the baby is hypoxemic. Similar to other cyanotic CHD patients, oxygen does not increase O_2 saturation because of fixed intra-cardiac right-to-left shunting and indeed may be harmful in that it may induce more rapid pulmonary arteriolar relaxation, causing earlier heart failure. Metabolic acidosis (pH < 7.25) should be corrected with sodium bicarbonate (usually 1-2 mEq/kg diluted half and half with 5% or 10% dextrose solution). If respiratory acidosis is present, suctioning, intubation and assisted ventilation should be provided as deemed necessary. Hypoglycemia can be a significant problem and if hypoglycemia (<30 mg/100ml) is present, 15% to 20% dextrose solution should be infused. Serum calcium levels should also be watched for and if hypocalcemia is noticed, it should be addressed. This is particularly important in babies with DiGeorge Syndrome.

Specific Measures. These depend upon the status of pulmonary blood flow, presence of significant truncal valve insufficiency and the existence of associated interrupted aortic arch. With increasing age, the pulmonary blood flow increases and congestive heart failure sets in. Diuretics, Digoxin and afterload reducing agents such as Captopril, should be used in adequate doses. A high calorie diet may be necessary in infants with signs of increased pulmonary blood flow and congestive heart failure. Neonates who are slightly cyanotic and have no features of increased pulmonary blood flow, may not need active therapy. However, close follow-up is required while waiting for surgery. In the presence of truncal valve insufficiency use of afterload reducing agents is the main treatment strategy and early surgery may be required. If interrupted aortic arch is present, Prostaglandin E_1 (PGE_1) administration should immediately be instituted and early surgery becomes necessary.

Surgery. Initial palliative pulmonary artery banding followed later by total correction is no longer used. Complete surgical repair in the neonatal period, as indicated above, is the current approach. This will also avoid the development of pulmonary vascular obstructive disease, which was a major problem in earlier surgical series when operations were performed late. Surgery (Figure 5) involves closure of the VSD, separation of the pulmonary arteries from the truncus and anastomosing them to the right ventricle via a valved conduit (usually aortic homograft) and closing the defect in the truncus. The truncal valve does not usually require surgical intervention, but if significant truncal valve stenosis or regurgitation is present, it should be surgically addressed at the time of surgical repair. Similarly, interrupted aortic arch should be repaired at the same time.

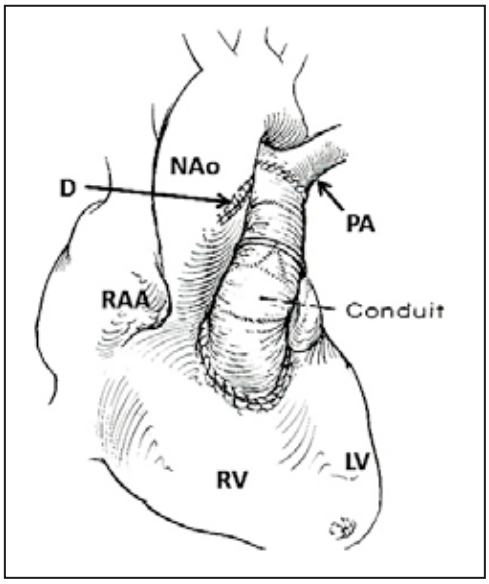

Figure 5. Schematic diagram of surgical repair of Truncus Arteriosus which consists of separation of pulmonary arteries (PA) from the truncus and connecting the pulmonary arteries to the right ventricle (RV) via a valved conduit (usually an aortic homograft) and closure of the ventricular septal defect (not shown) and defect (D) in the neoaorta (NAo) created by disconnecting the PA. LV, left ventricle; RAA, right atrial appendage.

Surgical Outcomes

Mortality for Truncus Arteriosus repair is approximately 10%, as reported in a recent review of 572 corrective operations performed (between 2000 and 2009 in 63 centers) at a median age of 12 days.[28] The surgery of Truncus Arteriosus along with repair of truncal valve or interrupted aortic arch has much higher (12.5% to 60%) mortality.[28,29] Studies of long-term outcome after surgery reveal the need for catheter interventions and repeat surgery to replace the conduits or repair of truncal valve in the majority of the patients[5,29-31] and will not be reviewed in this review of Truncus Arteriosus in the neonate.

Summary and Conclusions

Truncus Arteriosus is an uncommon cyanotic heart defect with a prevalence of less than 1% of all CHDs and is characterized by a single blood vessel (truncus) originating from the heart which in turn gives rise to the aorta, pulmonary artery and coronary arteries and is usually associated with a large VSD in the conal ventricular septum. This anomaly is generally classified (Collett and Edwards) based on the origin and distribution pulmonary arteries from the truncus, namely Types I, II, III and IV. These babies are usually asymptomatic at birth and may be detected because of a cardiac murmur or cyanosis. As the PVR decreases, the pulmonary blood flow increases and the babies may show signs of congestive heart failure. Clinical findings include mild cyanosis, a single second heart sound, an ejection systolic click and an ejection systolic murmur at the left upper sternal border. If there is associated severe truncal valve regurgitation, interrupted aortic arch or anomalous and rapid fall in PVR, the presentation is earlier and the symptomatology more severe. ECG is either normal or shows biventricular hypertrophy. Chest X-ray shows cardiomegaly and increased pulmonary vascular markings, and associated right aortic arch is virtually diagnostic of truncus. Echocardiographic studies are useful in confirming the diagnosis and in the definition of pulmonary artery anatomy and of the associated defects. Medical management depends on the status of pulmonary blood flow and the presence of associated truncal valve insufficiency and/or interrupted aortic arch; the condition should be addressed with anti-congestive measures, afterload reducing agents and intravenous administration of PGE_1 to open the ductus, respectively. Total surgical correction around the age of two weeks is recommended, although the need for re-intervention later in life is frequent.

"Total surgical correction around the age of two weeks is recommended, although the need for re-intervention later in life is frequent."

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NEONATOLOGY TODAY

News and Information for BC/BE Neonatologists and Perinatologists

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Ophthalmic Trends in Neonatal Imaging: How Retinopathy of Prematurity Screenings Have Exposed the Need for Universal Neonatal Ocular Imaging

By Darius M. Moshfeghi, MD

The latest trends in neonatal imaging began with screening for Retinopathy of Prematurity (ROP) and have exposed a greater need for universal neonatal imaging. Infants born at 30 weeks or earlier gestational age or who weigh less than 1500 g at birth are required to be screened for ROP. They are identified by a Neonatal Intensive Care Unit (NICU) and screened to determine if their retinas are not fully developed. The intention of ROP screening is to intervene while the disease is in its earlier stages, as blindness from ROP is preventable in up to 99% of babies receiving treatment.[1]

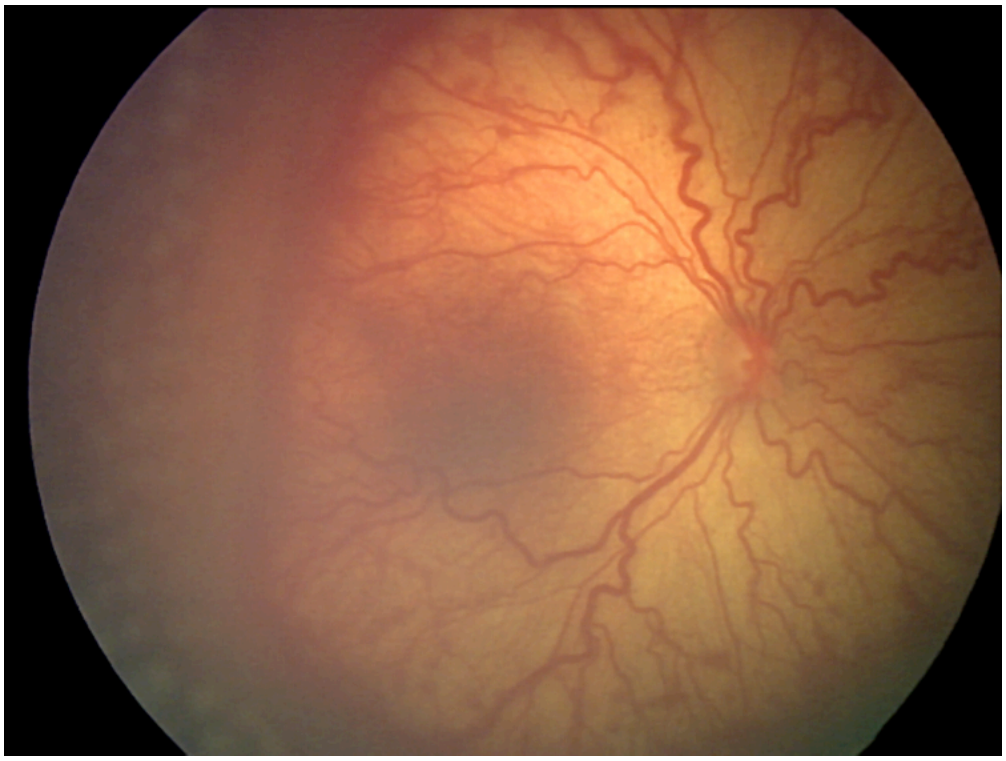

Image of Retinopathy of Prematurity.

The SUNDROP Program

The Stanford University Network for the Diagnosis of Retinopathy of Prematurity (SUNDROP) program at the Lucile Packard Children's Hospital (LPCH) is a hub-and-spoke, store-and-forward telemedicine screening program. The central hub is the reading center at Stanford University and the spokes are six individual NICUs. Each NICU has a RetCam (Clarity Medical System), which is used by nurses to screen preterm infants for ROP. The nurse looks for all referral-warranted and treatment-warranted disease. To date, the SUNDROP program has achieved 100% capture of more than 500 premature infants in 7 years. Screening sensitivity was in excess of 99%.[2]

The NEST Program

My colleagues and I at LPCH at Stanford University are now at the start of the Newborn Eye Screen Testing (NEST) program. There are approximately 4,500 live births a year at the LPCH. We plan to screen every infant within 72 hours of birth to evaluate for the presence of pathology and then make appropriate referrals to pediatric ophthalmologists or retinal specialists. Our goal is to determine if we can intervene and prevent vision loss by identifying disease. We know from studies conducted in Brazil, China, and Spain that nearly 12,000 infant screenings have been recorded to date at the overall incidence rate of 20%.[3] Most of that percentage is made up of retinal hemorrhages from birth trauma, and those go away spontaneously. However, about 2% of the hemorrhages have been affecting the center of the vision of the macula and may be responsible for long-term damage. The data reveals a fairly consistent 0.5% to 2.5% rate of other severe pathology in the eye, such as: cataract, vitreous hemorrhage, congenital glaucoma, coloboma, hamartoma, retinoblastoma, and nerve anomalies. We intend to offer screening to parents of every infant and anticipate at least a 25% participation rate.

Ancillary Screening Needs

As a result of the SUNDROP and NEST programs, we are often asked to use our screening tools to evaluate infants for neonatal eye sepsis causing endophthalmitis, known ocular abnormalities that might have incontinentia pigmenti, or other diseases that are common in the premature population. Sometimes we will screen a term baby if he or she has an eye infection or optic nerve abnormality, such as suspected cataract or glaucoma. In the emergency room,

"To date, the SUNDROP program has achieved 100% capture of more than 500 premature infants in 7 years. Screening sensitivity was in excess of 99%.[2]"

RetCam3 Review Station

infants are scanned to evaluate accidental trauma, such as Shaken Baby Syndrome.

There is a vexing problem of amblyopia in the United States, which is at a 2% to 5% rate depending on population and socioeconomic status. There have been a number of small studies in the United States where 25 to 50 consecutive infants have been examined for the incidence of retinal hemorrhages.[4] The incident rates have been between 20% and 40%, but the infants' hemorrhages resolved spontaneously. However, now that there has been a study screening up to 12,000 infants and the data reveals pathology 2% of patients, there is a whole different order of magnitude. A large population of infants had never been analyzed before, and now that we have a screening tool, we can not only screen infants for vision problems, but we can intervene and change the course of the disease. We can also determine if our interventions have any negative, neutral, or positive outcomes.

Conclusion

Neonatal ocular screenings are like screening for any other demographic. If we don't look for the pathology, we are not going to find it. And if we cannot find the pathology, we cannot treat it. Identifying ocular pathology in newborn infants may lead to early detection and treatment of eye diseases, the preservation of vision, and the prevention of blindness.

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Utilize additional therapies to maximize oxygen delivery with validated ventilation systems.

Reference: 1. Data on file. Hampton, NJ: Ikaria, Inc; 2013.

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Utilize additional therapies to maximize oxygen delivery with validated ventilation systems. In patients with collapsed alveoli, additional therapies might include surfactant and high-frequency oscillatory ventilation.

The safety and effectiveness of INOmax have been established in a population receiving other therapies for hypoxic respiratory failure, including vasodilators, intravenous fluids, bicarbonate therapy, and mechanical ventilation. Different dose regimens for nitric oxide were used in the clinical studies.

Monitor for PaO_2, methemoglobin, and inspired NO_2 during INOmax administration.

CONTRAINDICATIONS
INOmax is contraindicated in the treatment of neonates known to be dependent on right-to-left shunting of blood.

WARNINGS AND PRECAUTIONS

Rebound Pulmonary Hypertension Syndrome following Abrupt Discontinuation
Wean from INOmax. Abrupt discontinuation of INOmax may lead to worsening oxygenation and increasing pulmonary artery pressure, i.e., Rebound Pulmonary Hypertension Syndrome. Signs and symptoms of Rebound Pulmonary Hypertension Syndrome include hypoxemia, systemic hypotension, bradycardia, and decreased cardiac output. If Rebound Pulmonary Hypertension occurs, reinstate INOmax therapy immediately.

Hypoxemia from Methemoglobinemia
Nitric oxide combines with hemoglobin to form methemoglobin, which does not transport oxygen. Methemoglobin levels increase with the dose of INOmax; it can take 8 hours or more before steady-state methemoglobin levels are attained. Monitor methemoglobin and adjust the dose of INOmax to optimize oxygenation.

If methemoglobin levels do not resolve with decrease in dose or discontinuation of INOmax, additional therapy may be warranted to treat methemoglobinemia.

Airway Injury from Nitrogen Dioxide
Nitrogen dioxide (NO_2) forms in gas mixtures containing NO and O_2. Nitrogen dioxide may cause airway inflammation and damage to lung tissues. If the concentration of NO_2 in the breathing circuit exceeds 0.5 ppm, decrease the dose of INOmax.

If there is an unexpected change in NO_2 concentration, when measured in the breathing circuit, then the delivery system should be assessed in accordance with the Nitric Oxide Delivery System O&M Manual troubleshooting section, and the NO_2 analyzer should be recalibrated. The dose of INOmax and/or FiO_2 should be adjusted as appropriate.

Heart Failure
Patients with left ventricular dysfunction treated with INOmax may experience pulmonary edema, increased pulmonary capillary wedge pressure, worsening of left ventricular dysfunction, systemic hypotension, bradycardia and cardiac arrest. Discontinue INOmax while providing symptomatic care.

ADVERSE REACTIONS
Because clinical trials are conducted under widely varying conditions, adverse reaction rates observed in the clinical trials of a drug cannot be directly compared to rates in the clinical trials of another drug and may not reflect the rates observed in practice. The adverse reaction information from the clinical studies does, however, provide a basis for identifying the adverse events that appear to be related to drug use and for approximating rates.

Controlled studies have included 325 patients on INOmax doses of 5 to 80 ppm and 251 patients on placebo. Total mortality in the pooled trials was 11% on placebo and 9% on INOmax, a result adequate to exclude INOmax mortality being more than 40% worse than placebo.

In both the NINOS and CINRGI studies, the duration of hospitalization was similar in INOmax and placebo-treated groups.

From all controlled studies, at least 6 months of follow-up is available for 278 patients who received INOmax and 212 patients who received placebo. Among these patients, there was no evidence of an adverse effect of treatment on the need for rehospitalization, special medical services, pulmonary disease, or neurological sequelae.

In the NINOS study, treatment groups were similar with respect to the incidence and severity of intracranial hemorrhage, Grade IV hemorrhage, periventricular leukomalacia, cerebral infarction, seizures requiring anticonvulsant therapy, pulmonary hemorrhage, or gastrointestinal hemorrhage.

In CINRGI, the only adverse reaction (>2% higher incidence on INOmax than on placebo) was hypotension (14% vs. 11%).

Based upon post-marketing experience, accidental exposure to nitric oxide for inhalation in hospital staff has been associated with chest discomfort, dizziness, dry throat, dyspnea, and headache.

OVERDOSAGE
Overdosage with INOmax will be manifest by elevations in methemoglobin and pulmonary toxicities associated with inspired NO_2. Elevated NO_2 may cause acute lung injury. Elevations in methemoglobin reduce the oxygen delivery capacity of the circulation. In clinical studies, NO_2 levels >3 ppm or methemoglobin levels >7% were treated by reducing the dose of, or discontinuing, INOmax.

Methemoglobinemia that does not resolve after reduction or discontinuation of therapy can be treated with intravenous vitamin C, intravenous methylene blue, or blood transfusion, based upon the clinical situation.

DRUG INTERACTIONS
No formal drug-interaction studies have been performed, and a clinically significant interaction with other medications used in the treatment of hypoxic respiratory failure cannot be excluded based on the available data. INOmax has been administered with dopamine, dobutamine, steroids, surfactant, and high-frequency ventilation. Although there are no study data to evaluate the possibility, nitric oxide donor compounds, including sodium nitroprusside and nitroglycerin, may have an additive effect with INOmax on the risk of developing methemoglobinemia. An association between prilocaine and an increased risk of methemoglobinemia, particularly in infants, has specifically been described in a literature case report. This risk is present whether the drugs are administered as oral, parenteral, or topical formulations.

 IMK111-01540 April 2013

Necrotizing Enterocolitis of Newborn and the Coding Capture

By Julie-Leah J. Harding, CPC, RMC, PCA, CCP, SCP-ED, CDIS

A gastrointestinal disease that mostly affects premature infants, Necrotizing enterocolitis (NEC) involves infection and inflammation that causes destruction of/or part of the intestine. NEC is the most common gastrointestinal disorder for hospitalized premature infants. NEC usually occurs within the first two weeks after birth.

Understanding Necrotizing Enterocolitis (NEC):

- **Necrotizing** means the death of tissue,
- **Entero** means the small intestine,
- **Colo** means the large intestine, and
- -**Itis** means inflammation.

Symptoms of NEC are: Abdominal distention, constipation, dark or bloody stools, feeding difficulties, unstable body temperature, vomiting and less active. NEC is more common in infants weighing less than 1,500 grams.

Provider documentation drives the code assignment when reporting Necrotizing Enterocolitis (NEC). NEC is defined by stages.

- **Stage One**: Necrotizing enterocolitis without pneumatosis, without perforation
- **Stage Two:** Necrotizing enterocolitis with pneumatosis, without perforation
- **Stage Three:** Necrotizing enterocolitis with perforation or Necrotizing enterocolitis with pneumatosis and perforation.
- **Unspecified Stage:** Necrotizing enterocolitis in newborn.

Navigating ICD-9 and ICD-10 to report NEC:

- ICD-9 777.51, Stage One; 777.52, Stage Two; 777.53, Stage Three; 777.50, Unspecified Stage.
- ICD-10-CM P77.1, Stage One; P77.2, Stage Two; P77.3, Stage Three; P77.9, Unspecified Stage.
- SNOMED CT 206525008.

Note:

- ✓ If enterocolitis is captured as pseudomembranous in a newborn, it will be reported in ICD-10 as A04.7 Enterocolitis due to Clostridium difficile, Foodborne intoxication by Clostridium difficile, Pseudomembraneous colitis.
- ✓ If NEC is captured as due to Clostridium difficile, it will be reported in ICD-10 as A04.7; if you refer to the ICD-10-CM index, See Enterocolitis, to Necrotizing, to due to Clostridium difficile.
- ✓ K55 Vascular disorders of intestine within ICD-10-CM excludes necrotizing enterocolitis of newborn (P77.-)
- ✓ P37 Other congenital infectious and parasitic diseases within ICD-10-CM excludes necrotizing enterocolitis of newborn (P77.-).

Do not forget to report the pre-term newborn's birth weight and gestational age if the documentation supports it:

ICD-9-CM 764.0-, Light for dates, Small for dates.
764.9-, Fetal growth retardation (IUGR).
765.0-, Extreme immaturity of infant.
765.1-, Other preterm infants; usually implies the birth weight of 1000-2400 grams.

A secondary code is required:

- Weeks of gestation.
- 765.2- from unspecified to less than 24 weeks up to 37 or more weeks completed.

The above codes all require a 5th digit – refer to your ICD-9 manuals to define the appropriate 5th and required digit.

ICD-10-CM P05.0-, Newborn light for gestational age.
P05.1-, Newborn small for gestational age.
P05.9 (no 5th digit required) Newborn affected by slow intrauterine growth.
P07.0-, Extremely low birth weight newborn.
P07.1-, Other low birth weight newborn.

A secondary code is required:

- Weeks of gestation.
- P07.2-, Extreme immaturity of newborn (less than 28 completed weeks).
- P07.3-, Other preterm newborn (28 completed weeks or more but less than 37 completed weeks).

Remember that documentation is the key to accurate coding assignment. If the documentation is not specific, this is a great opportunity for clinical documentation improvement.

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Review of the iPad and iPhone App, "My Preemie"

By Alan R. Spitzer, MD

Homepage of MyPreemie app, on an iPad.

As every practicing neonatologist knows, the NICU experience is often an overwhelming one for families. Families rarely plan for a premature infant birth, and the rapidity with which the situation commonly arises often leaves families somewhat adrift and rudderless as they attempt to negotiate this terrifying event. By the time that they begin to fully understand their circumstances, several days have gone by and they find themselves encumbered not only by concern about their newborn infant, but also overloaded by issues and acronyms in the NICU environment that they have never heard before. Even the most educated of parents have a difficult time coping with this new world, and they are sometimes the ones least likely to ask questions for fear of embarrassing themselves by sounding uninformed.

The new app, *My Preemie*, from Palasoftware, attempts to address these issues in a very effective and thoughtful way. Much of the content for the app has been based on the book, *Preemies—the Essential Guide for Parents of Premature Babies* 2nd edition (Gallery Books, New York, 2010), by Dana Wechsler Linden, Emma Trenti Paroli, and Mia Wechsler Doron, which is an exceptional resource itself. *My Preemie*, however, in a very simple and elegant fashion, provides a superb starting point for the family that now finds itself captive in the NICU. The app is highly intuitive and easily navigated, a distinct plus for parents whose existence is already more complicated than they had ever bargained for. *My Preemie* opens to a page on which much of the baby's basic demographic data can be entered (e.g., birth weight, gestational age, first photo, etc.), after which it acts as an ongoing diary in which growth data, changes in the infant's clinical condition, new events (both good and bad), additional photos of the infant, and a variety of other information can be entered on a daily basis. Mother and father (or grandparents) can make daily observations separately, which then can later be combined. In addition, parents can record their feelings on a particular day, an aspect of the app that may be very helpful in allowing a parent to recognize that it is acceptable to feel bad at times about the situation of having a baby in the NICU. The app also contains a mini-textbook for the NICU: NICU terminology is well-covered in easily understood language, the problems that most preemies are likely to encounter are clearly explained, and some thoughtful questions are provided that would seem to be quite helpful for anyone unsure of what might be an important consideration at various points during the hospital stay. For parents who wish to read more detailed information, online resources are provided that are easily accessed and have been carefully selected for the quality of information provided, such as outcome data from the NICHD Neonatal Network.

"I would strongly urge neonatologists and neonatal nurse practitioners to suggest 'My Preemie' to any family looking for a great smartphone/tablet app to help them navigate the turbulent waters of the NICU experience."

My Preemie therefore, seems to be an exceptional resource for parents who both want to chart their premature neonate's progress through the NICU hospitalization while having ready access to a wealth of excellent information. There is little question that this app, for a very modest cost, will prove invaluable for any family with smartphone or tablet access and a baby in the NICU. It should help enormously in allaying NICU anxiety, while providing a wonderful diary that families can one day look back upon and recall what they experienced during their child's NICU days.

I have a couple of minor criticisms of the app that could be easily remedied in upgrades. First, while the parent is provided a section to help track the nurses caring for the infant, there does not appear to be a similar section to list physician names and roles, often more confusing than nursing staffing, especially in the academic center with fellows, residents, students, etc. Depending on the way that care is provided, physician responsibility in the NICU may be unclear to many families and documenting who is in charge that day would be helpful. Another minor concern about the app (sorry to be a bit sexist here) is that it is very much maternally oriented in its appearance and feel, and I wonder if fathers will be entirely comfortable using it. The developers might wish to consider a somewhat different entry format for fathers in future editions of the app.

Aside from these relatively trivial points, I have nothing but positive impressions of this app. I would strongly urge neonatologists and neonatal nurse practitioners to suggest *My Preemie* to any family looking for a great smartphone/tablet app to help them navigate the turbulent waters of the NICU experience. It is truly well done and the authors and developers deserve a lot of credit for putting out such a useful, high quality product.

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Preview or download this app for your iPad or iPhone on iTunes:

https://itunes.apple.com/app/mypreemie/id620128292

Medical News, Products & Information

Doctor Calls for Investigation into Possible Lack of Informed Consent in Premature Baby Studies

Concerns over ethics of trial may have global implications

Dr Sidney Wolfe, founder and senior adviser to the Health Research Group at Public Citizen, says it is surprising that the adequacy of consent forms for nearly identical studies in the UK, Australia, New Zealand, Canada, and other countries with similar regulation of human research, has apparently not yet been examined.

He argues that there may well be "serious problems" with such risk disclosure that must be addressed.

The study, called SUPPORT, was funded by the US National Institutes of Health and took place at many universities across the US between 2005 and 2009. A total of 1,316 extremely premature infants were randomly maintained at either higher (91-95%) or lower (85-89%) ranges of oxygen saturation.

The main aim of the study was to see whether the infants were more likely to die or suffer eye damage and blindness at the different oxygen ranges.

Wolfe says that parents were not adequately informed about the risks or true nature and purpose of the research, but others have staunchly defended this lack of informed consent.

He argues that information on risks and possible outcomes was missing from the consent forms, and that the forms "failed to distinguish the important differences between these clearly experimental procedures for managing the oxygen therapy and the usual individualized standard of care the babies would have received had they not been enrolled in the study."

Worse, he adds, "many of the consent forms falsely stated that because all of the treatments proposed in this study are 'standard of care' there would be no expected increase in risk to the infants."

Others, however, defend the lack of appropriate informed consent. In a recent *BMJ* editorial, eminent neonatologist Neena Modi implicitly argued that withholding some risk information would "reduce the burden of decision making at difficult and stressful times" and "would also reduce the risk of 'injurious misconception,' where participation is inappropriately rejected because of an exaggerated and disproportionate perception of risk."

But Wolfe suggests that the underlying principle behind these arguments "is that it is necessary, via inadequately informed consent, to blur the line between research and standard of care to facilitate more consent and participation."

This, he concludes, "appears to be exactly what occurred when consent was obtained for the SUPPORT study subjects."

Modern Methods of Abortion Are Not Linked with an Increased Risk of Preterm Birth

The link between previous termination of pregnancy (abortion) and preterm delivery in a subsequent pregnancy has disappeared over the last 20-30 years, according to a study of data from Scotland published in *PLOS Medicine*. The study, led by Gordon Smith from the University of Cambridge, found that abortion was a strong risk factor for subsequent preterm birth in the 1980s, but over the next 20 years, the link progressively weakened and was no longer present among women giving birth from 2000 onwards.

These findings are important as the current recommendations to discuss a possible increased risk of preterm birth if a woman has an abortion were based on studies before 2000. The current analysis indicates that there is no link between abortion and the subsequent risk of preterm birth in modern practice, and so current guidelines may have to be revised.

By using a large dataset from Scotland, the authors found that out of 757,060 live first births (excluding twins) between 1980 and 2008, 56,816 women reported one previous termination, 5,790 women reported two previous terminations, and 822 women reported three or more previous terminations. After adjusting for maternal characteristics, the authors found that there was a strong link between spontaneous preterm birth and previous abortion in 1980-1983, with a >30% increase in the risk of preterm birth with each previous procedure. However, this link progressively weakened, with a 10-20% increase in risk for preterm births in the 1990s, and no link at all from 2000 onwards.

The likely explanation for these findings is changes in methods of abortion. Over the period 1992 to 2008, the authors found that the procedure thought most likely to lead to an increased risk of preterm birth (purely surgical abortion without the use of any drugs) decreased from 31% in 1992 to 0.4% in 2008. Furthermore, the proportion of medical terminations (procedures that avoided the use of surgery altogether) increased from 18% to 68%.

These findings suggest that use of purely surgical termination may have been responsible for the increased risk of spontaneous preterm birth and so, the phasing out of this procedure in Scotland in the 1980s and 1990s may have led to the subsequent disappearance of the established link between previous termination and preterm delivery from 2000 onwards. However, the authors could not directly test whether the two trends were related because they did not have information on the method of previous termination linked to subsequent birth outcome for individual women.

The authors say, "We have shown that previous abortion was a risk factor for preterm birth among nulliparous women in Scotland prior to 2000. However, increased use of medical methods of abortion and of cervical pre-treatment prior to surgical abortion has been paralleled by a disappearance in the association."

The authors add: "We believe that it is plausible that modernising methods of termination of pregnancy worldwide may be an effective long-term strategy to reduce future rates of preterm birth."

This study was funded by the NIHR Cambridge Comprehensive Biomedical Research Centre (Women's Health & Public Health themes) and an MRC PhD fellowship (COW). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Curcumin May Protect Premature Infants' Lungs

Turmeric, a key ingredient in spicy curry dishes, has long been known to have medicinal values. Now new research finds a substance in turmeric, curcumin, may provide lasting protection against potentially deadly lung damage in premature infants.

Premature infants often need the assistance of ventilators and forced oxygen therapy because they're frequently born with inadequate lung function. These therapies can cause the infants to suffer lasting lung damage and even death. Researchers at Los Angeles Biomedical Research Institute at Harbor-UCLA Medical Center (LA BioMed), using disease models, found curcumin provided long-term protection against this damage.

Their study, published online by the *American Journal of Physiology, Lung Cellular and Molecular Physiology*, found curcumin provided protection against Bronchopulmonary Dysplasia (BDP), a condition characterized by scarring and inflammation, and against hyperoxia, in which too much oxygen enters the body through the lungs, for up to 21 days after birth. A previous LA BioMed study found curcumin provided protection for up to seven days after birth.

"This is the first study to find long-term benefits of using curcumin to protect lung function in premature infants," said Virender K. Rehan, MD, the LA BioMed lead researcher who authored the study. "Curcumin is known to have potent antioxidant, anti-inflammatory and anti-microbial properties, making it a promising therapy for premature infants who require oxygen therapy after birth."

BDP is now the most common chronic lung disease of infancy in the US. With more premature babies surviving because of improvements in neonatal care, the cases of BPD have increased. A 2010 study found 67.3% of babies born at 22-25 weeks of gestation developed BPD, compared to 36.6% of infants born at 26-30 weeks of gestation.

To see the study, please visit:
http://ajplung.physiology.org/content/early/2013/06/24/ajplung.00082.2013.abstract

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Agfa HealthCare Launches NX MUSICA2 Platinum and NX MUSICA2 Neonatal for Direct Radiography in North America, Highlighting Neonatal Applications

Agfa HealthCare has announced the North American launch of its NX MUSICA2 Platinum and NX MUSICA2 Neonatal, which take image processing to a new level by rendering excellent bone and soft tissue detail simultaneously in a single exposure. These Agfa HealthCare-exclusive offerings provide enhanced detail across the entire dynamic range of the image for improved contrast, sharpness and density preferred by radiology specialists.

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NX MUSICA2 Platinum provides fine-tuned chest, abdomen and musculoskeletal pre-sets for both adult and pediatric patients. Special image processing defaults can be automatically applied for up to four different pediatric age groups. Designed for these special applications, NX MUSICA2 Platinum fulfills the need of many large health care networks and university medical centers to have dedicated image processing that shows increased emphasis on soft tissue or bony structures depending on the exam type.

NX MUSICA2 Neonatal image processing includes algorithms tuned specifically for the neonatal patient, providing excellent contrast and detail without increasing noise--even on lower dose exams. With MUSICA2 Neonatal and MUSICA2 GenRad (General Radiology), physicians can quickly and easily fine-tune imaging perimeters for the overall patient population as well as their dose sensitive neonatal patients. Installation and set-up is simple; workflow is improved because all MUSICA2 image processing is fully automatic with Digital Radiography (DR) exposures. Technologists, radiologists and clinicians rarely, if ever, need to post-process or window level images to see all pertinent anatomy rendered in a single MUSICA2 image. This image quality and efficiency differentiates the technology, further emphasizing the position of NX MUSICA2 as the market leader for digital image processing.

Providing diagnostic confidence when it matters most

"Agfa HealthCare continues to raise the bar for image quality in radiology with new innovations in image processing. Our most recent advances in technology address the demanding field of pediatric and neonatal imaging with NX MUSICA2 Platinum and NX MUSICA2 Neonatal, giving diagnostic confidence when it matters the most," said Greg Cefalo, US Digital Radiography Business Unit Manager, Agfa HealthCare.

"Especially in the neonatal environment where subtlety of image detail is important, enhanced features help detect minute daily changes to provide physicians with the confidence for urgent clinical decision-making. Agfa HealthCare's image processing algorithm used in NX MUSICA2 Neonatal is finely tuned to the special imaging needs of the neonate," said Cefalo. "For example, neonatal bones have lower subject contrast than adults or older pediatric bones, so NX MUSICA2 Neonatal enhances detail in the low-contrast neonatal bones without adding the additional unwanted noise that traditional image processing creates. These attributes, combined with comprehensive dose management tools, provide excellent image capture technology for radiology's most demanding newborn and premature patients."

NX MUSICA2 Platinum and NX MUSICA2 Neonatal for use with DR now offer Agfa HealthCare's best image processing with its most advanced image capture technology. North American facilities can now help drive dose management, improve clinical capabilities and optimize workflow for better delivery of patient care.

New Initiative Could Help Improve Surgical Outcomes in Children, Study Suggests

Newswise — A group of pediatric surgeons at hospitals around the country have designed a system to collect and analyze data on surgical outcomes in children. The National Surgical Quality Improvement Program (NSQIP) is the first national database able to reliably compare outcomes among different hospitals where children's surgery is performed. The effort could dramatically improve surgical outcomes in children, say the initiative's leaders, who published their findings online August 5, 2013 in the journal, *Pediatrics*.

The model is based on a similar effort adopted nationwide nearly a decade ago for adult surgery that resulted in reduced mortality and dramatic decreases in post-surgical complications. These efforts, led by the American College of Surgeons (ACS), are being driven, not by a federal mandate, but by a desire to improve patient care, says R. Lawrence Moss, MD, corresponding author of this new study and Surgeon-in-Chief at Nationwide Children's Hospital.

"The real impetus is that people want their patients to do better," said Dr. Moss, who has been involved with the initiative since its inception. "This was a surgeon-directed effort and the ultimate goal is to improve quality of patient care."

The ACS NSQIP-Pediatric began as a pilot in 2008 with four hospitals. The program now has 43 participating institutions that perform children's surgery. The August study is the third published by the group and details how a new statistical model designed specifically for children can be used to reliably discriminate performance among hospitals.

Historically, US hospitals didn't track this kind of information in children or adults, because there was simply no way to collect, analyze and interpret the data in a way that made sense. For example, comparing outcomes of bypass surgery in a cardiac unit at an urban facility performing thousands of the procedures per year to those of an under-staffed rural hospital that rarely does the operation would be comparing apples to oranges, Dr. Moss said. A key component of NSQIP is its ability to accurately adjust outcomes for patient risk factors. This means NSQIP is able to compare hospital performance even when the institutions see different patient populations.

When the ACS implemented its model for measuring surgical outcomes in adult surgery in 2004, it quickly became clear that, while that system would be useful in an adult setting, it couldn't be used by pediatric surgeons. Not only does the adult model include surgeries that aren't performed in children, but the range of post-surgical complications is also different, Dr. Moss said. Adults often suffer complications as a result of diabetes, smoking-related respiratory problems or coronary disease – comorbidities a surgeon wouldn't often see in a pediatric patient. Pediatric patients are more affected by congenital abnormalities and comorbidities specifically related to the diagnosis for which they are having surgery.

Procedures, comorbidities and potential complications are more specific to the pediatric population in the new model. In addition, this new program focuses more on morbidity as a measure of surgical outcomes, rather than mortality, which Dr. Moss said better encompasses the specific nature of pediatric surgery.

Furthermore, creating a "risk-adjusted" model allows pediatric surgeons to avoid the apples-to-oranges comparison, Dr. Moss said. Such elements as surgical case load, complexity of cases, patient demographics and other categories are factored into a highly precise algorithm. The resulting model allows a children's surgical department in a small-town hospital to meaningfully compare its outcomes with a large institution such as Nationwide Children's.

"In the unique world of children's surgery, we can now accurately obtain and share risk-adjusted outcomes in a way that will allow institutions to take actions that are going to improve patient care," said Dr. Moss, who also is the E. Thomas Boles Jr. Professor of Surgery at The Ohio State University College of Medicine.

Participating institutions employ a full-time surgical clinical reviewer who collects data in nearly 100 different categories, ranging from patient demographics to specific post-surgical complications patients experience within 30 days of surgery. Each institution submits its data, then receives a report that shows how they rank in the different categories. These rankings are blind, in that the only institution named in a report is the one receiving the report.

In the *Pediatrics* study, the new model was used to analyze data on 46,281 patients under the age of 18 who underwent surgery at 43 participating institutions in 2011. It's a proof-of-concept that the model works, said Jacqueline M. Saito, MD, MSCI, Assistant Professor of Surgery at Washington University and St. Louis Children's Hospital.

"An important milestone for the program is the ability to analyze hospital performance in multiple outcomes and by surgical specialty," said Dr. Saito, who is the lead author of the study. "Hospitals with below expected performance may use the information yielded from this analysis to improve surgical outcomes locally. Eventually, 'best practice' guidelines will be developed using processes from hospitals with better than expected outcomes."

Now that the model has been tested, the ACS is inviting other institutions to join. The ACS program for adult surgery has hundreds of participating hospitals, and Dr. Moss predicts the pediatric program will also see a surge in participation. To share best practices, those institutions that have the best outcomes will be asked to share details of their programs at the ACS annual meeting.

For more information on the American College of Surgeons National Surgical Quality Improvement Program-Pediatric, visit www.pediatric.acsnsqip.org/.

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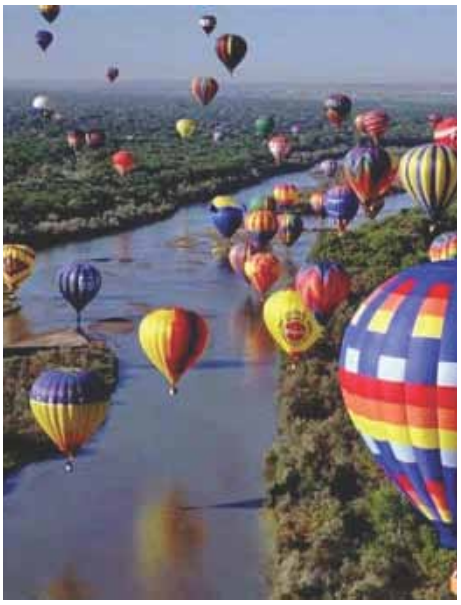

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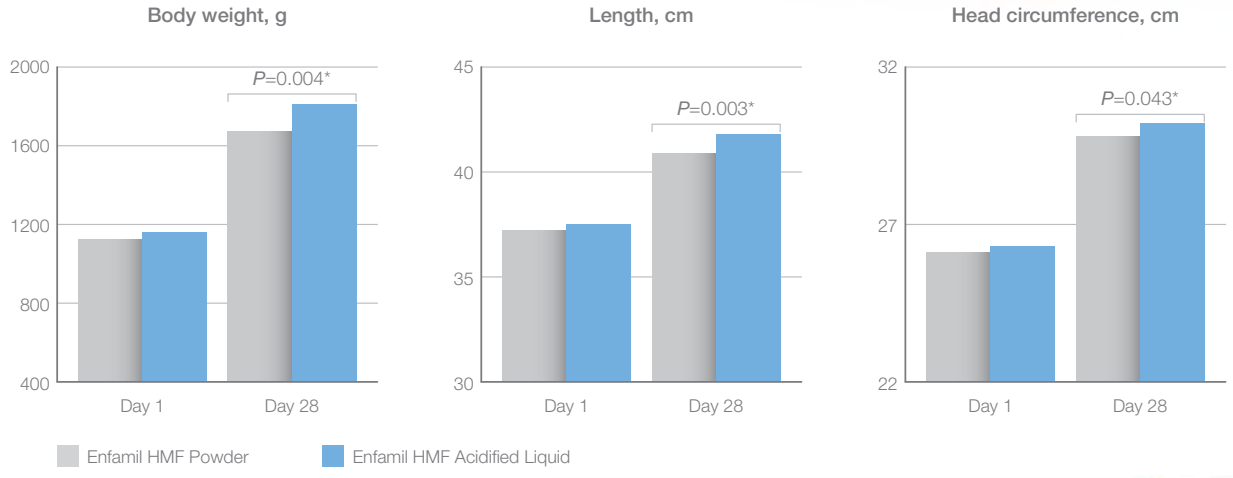

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Reference: 1. Moya F et al. *Pediatrics*. 2012;130:e928-e935.

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