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IN THIS ISSUE

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Neonatology Today (NT) is a monthly newsletter for BC/BE neonatologists and perinatologists that provides timely news and information regarding the care of newborns and the diagnosis and treatment of premature and/or sick infants.

Upcoming Meetings
(see website for additional meetings)

Evidence-based Neonatology
June 1, 2011; Stockholm, Sweden
http://ebneo.org/wp/index.php/programme

NEO Forum 2011
June 10, 2011; Fiddlers Elbow Country Club, Bedminster. NJ USA
http://mananewborn.com/neoforum2011/

AAP District VIII Section on Perinatal Pediatrics 35th Annual Evidence-based NeonatologyConference
July 14-17, 2011; Portland, OR USA
http://www.d8neonatalconference.org/

Recruitment Ads: Page 2

Tetralogy of Fallot in the Neonate

By Srilatha Alapati, MD and P. Syamasundar Rao, MD

Introduction

In the previous issues of *Neonatology Today*, we discussed general topics of congenital heart disease in the neonate,[1-5] but began addressing individual cardiac lesions[6] recently. In this issue, Tetralogy of Fallot will be discussed.

TETRALOGY OF FALLOT

Tetralogy of Fallot (TOF) is the most common cyanotic congenital heart defect (CHD) beyond one year of age and constitutes 10% of all CHD;[7] however, transposition of the great arteries remains the most common cyanotic heart defect in the neonate.[6, 7] A little more than 100 years ago, Fallot[8] defined this entity as a constellation of four abnormalities:

1. ventricular septal defect (VSD),
2. pulmonary stenosis (PS),
3. right ventricular hypertrophy and
4. dextroposition of the aorta (Figure 1).

The VSD is always large and non-restrictive and is located in the membranous septum in the subaortic region. Pulmonary stenosis is variable in severity and site of obstruction. The right ventricular outflow obstruction may be mild resulting in initial left-to-right shunt at the ventricular level or it may be severe causing severe cyanosis even in the neonatal period. The obstruction may be infundibular, valvar or supravalvar in nature or may involve branch pulmonary arteries. The stenotic lesion may be at a single site or may involve multiple sites. Infundibular obstruction is the most common obstruction in TOF and is due to anterior and superior deviation of infundibular (conal) septum. The valvar stenosis may be due to valve leaflet fusion and/or due to valve ring hypoplasia. Right ventricular hypertrophy of severe degree is present in all cases. Dextroposition or over-riding of aorta over the ventricular septum is variable in degree.

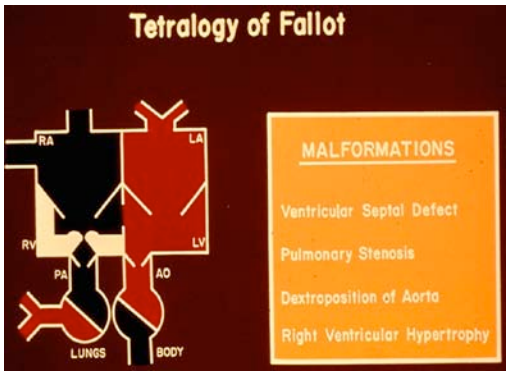

Figure 1. Box diagram illustrating component lesions seen in Tetralogy of Fallot: 1. ventricular septal defect, 2. pulmonary stenosis, 3. dextroposition of the aorta and 4. right ventricular hypertrophy. Ao, aorta; LA, left atrium; LV, left ventricle; PA, pulmonary artery; RA, right atrium; RV, right ventricle.

"Tetralogy of Fallot (TOF) is the most common cyanotic congenital heart defect (CHD) beyond one year of age and constitutes 10% of all CHD;[7] however, transposition of the great arteries remains the most common cyanotic heart defect in the neonate.[6, 7]"

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The aorta is large, and is thought to be so due to a developmental anomaly rather than the result of physiologic abnormality of TOF. Right aortic arch is present in 25% of TOF cases. Atrial septal defect may be present in 15% of patients with TOF, in which case it may be called Pentology of Fallot.

TOF is associated with a number of syndrome complexes and these include, CATCH-22, CHARGE, Down's, fetal alcohol, Goldenhar's, Pierre-Robin, TAR (Thrombocytopenia absent radius), VATER/VACTERAL, and velocardiofacial syndromes and anomalies of other organ systems such as imperforate anus, hydrocephalus, tracheo-esophageal fistula and omphalocele, and as such may have therapeutic implications.

PATHOPHYSIOLOGY

Because the VSD is large, the systolic pressures in both ventricles are equal and for practical purposes both ventricles act as one functional chamber. The quantity of blood flow into the systemic and pulmonary circuits depends upon their respective resistances. The level of systemic vascular resistance and the resistance offered by the right ventricular outflow tract stenosis determine the flows. The more severe the PS, the less is the pulmonary flow. In the average case of Tetralogy of Fallot, the resistance offered by PS is more than that of the systemic vascular tone with consequent right-to-left shunt across the VSD (Figure 2). The resultant cyanosis and hypoxemia stimulate bone marrow (via kidney and erythropoietin) and produce polycythemia.[9] While the polycythemia is helpful in increasing the oxygen carrying capacity, it becomes counterproductive when the hematocrit is excessive (> 60 to 70%).

CLASSIFICATION

There are several variants of TOF with differences in presentation in the neonatal period. Management of these babies differs from one variant to another. Based on these considerations, we prefer to classify neonatal TOF as follows: Type I, Conventional TOF; Type II, TOF with pulmonary atresia; Type III, TOF with multiple aorto-pulmonary collateral arteries (MAPCAs); and Type IV, TOF with absent Pulmonary Valve Syndrome. Each of these entities will be discussed separately.

TYPE I. CONVENTIONAL TOF

Symptoms

The degree severity of PS determines the clinical presentation. When PS is mild, symptoms may not be present until late childhood, while with severe PS, the presentation may be in the neonatal period. Typically the baby may be pink (not cyanotic) as a neonate and develops cyanosis between 2 to 6 months of age. Most usual modes of presentation are asymptomatic murmur discovered on routine auscultation, bluish color (cyanosis) observed by the parent, nurse or primary physician and hypercyanotic spells (not common in the neonate). Since the hypercyanotic spells are uncommon in the neonate, they will not be described here, but the reader is referred to elsewhere[9-12] for further treatment of this subject.

Physical Examination

Central cyanosis is observed in most cases of' Tetralogy of Fallot. However, it should be noted that mild arterial desaturation may not cause clinically detectable cyanosis. Clubbing of fingers and toes is observed beyond the first few months of life. Prominent right ventricular impulse or heave may be present. A systolic thrill may be present at the left upper sternal border. The first heart sound may be normal or slightly increased. The second heart sound is single without an audible pulmonary component. A grade III-IV, long, ejection, systolic murmur, caused by blood flow through the right ventricular outflow tract, is usually heard at the left upper sternal border. In contrast to PS with intact ventricular septum, the murmur of tetralogy becomes shorter and less intense with increasing severity of PS. During hypercyanotic spell the murmur disappears or becomes very soft. A holosystolic murmur of VSD may be heard at the left lower sternal border in some babies, especially in less severe and acyanotic forms of TOF. Early diastolic murmurs do not occur with TOF; the exception is TOF with absent pulmonary valve. Continuous murmur of associated patent ductus arteriosus (PDA) is rarely heard. There are usually no signs of congestive heart failure.

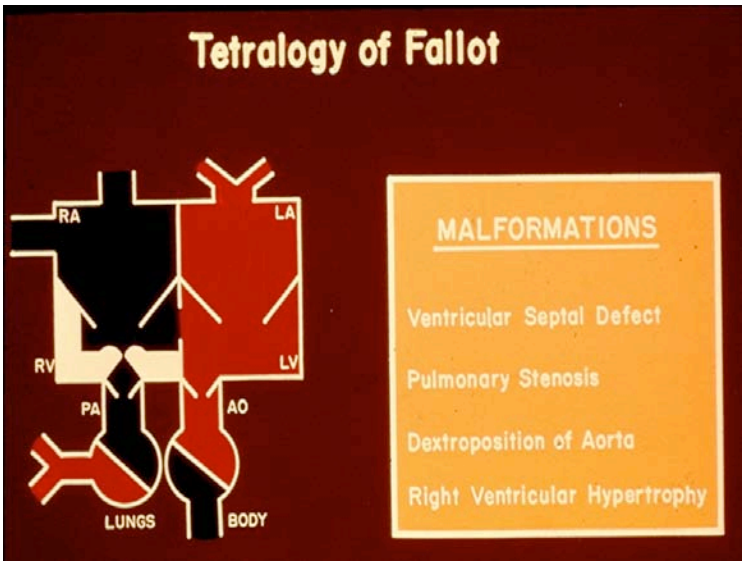

Figure 2. Box diagram illustrating right-to-left shunt at ventricular level because of high resistance offered by pulmonary stenosis. Abbreviations are same as in Figure 1.

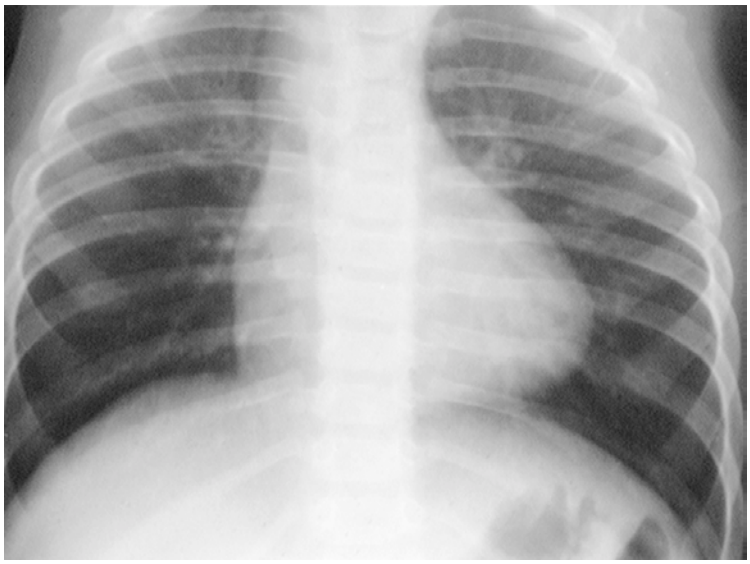

Figure 3. Chest X-ray showing uplifted apex giving the appearance of boot shaped heart and right aortic arch.

Noninvasive Evaluation

Chest x-ray shows normal to minimally increased size of the heart. An uplifted apex, thought to indicate right ventricular hypertrophy may be seen and is described by some as "boot-shaped" heart. Concavity in the region of pulmonary conus, reflecting hypoplasia of the pulmonary outflow tract may be present. Pulmonary vascular markings are usually diminished. A right sided aortic arch may be present (Figure 3). While a

right aortic arch is expected to be present in 25% of TOF patients, the presence of a right aortic arch along with concave pulmonary conus and decreased pulmonary vascular markings in a chest roentgenogram makes the diagnosis of TOF virtually certain.

Electrocardiogram shows signs of right ventricular hypertrophy (Figure 4). Right atrial enlargement is less commonly seen.

Echocardiogram is helpful in confirming the diagnosis. Enlargement of the right ventricle, large VSD, aortic over-ride (Figure 5) and right ventricular outflow tract obstruction can be demonstrated. Shunting across the VSD (Figure 6) and increased Doppler flow velocity across the right ventricular outflow tract (Figure 7) can be shown. Size of the main and proximal branch pulmonary arteries can be evaluated although the distal pulmonary arteries cannot easily be imaged by echocardiogram.

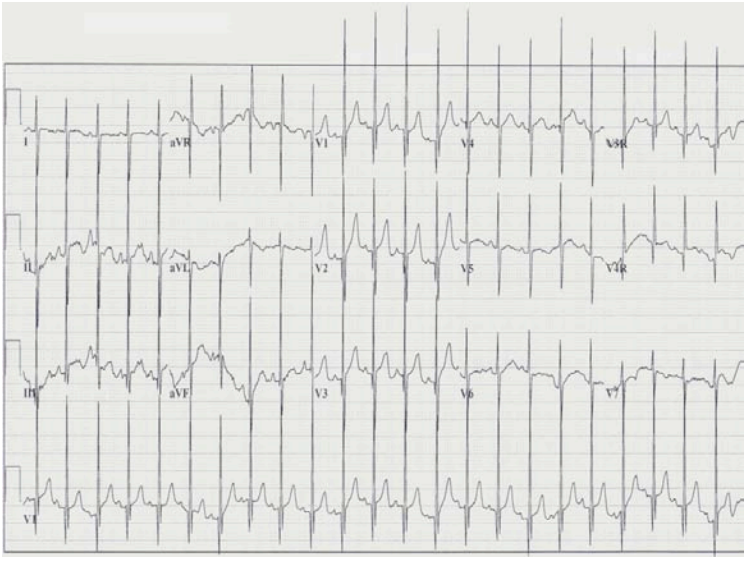

Figure 4. ECG in a neonate showing right axis deviation and right atrial enlargement and right ventricular hypertrophy.

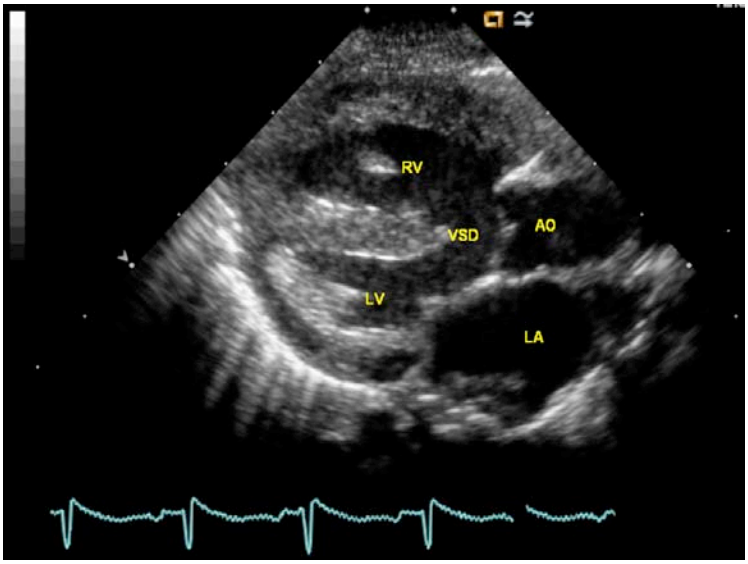

Figure 5. Selected video frame of a 2-dimensional echocardiogram demonstrating a large ventricular septal defect (VSD) with an overriding aorta (Ao). The right ventricle (RV) is enlarged and hypertrophied. LA, left atrium; LV, left ventricle.

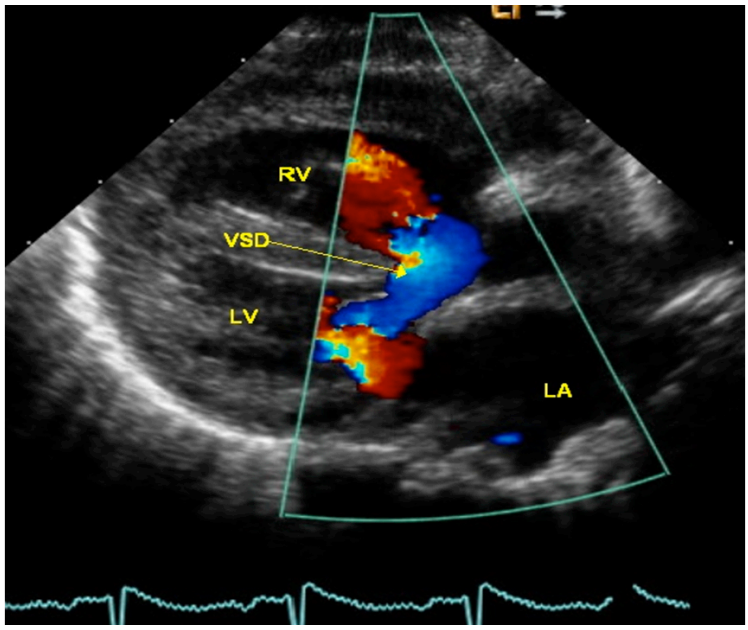

Figure 6. Color Doppler flow mapping of a similar echo frame as in Fgure 5 demonstrating right to left shunt across the ventricular septal defect (VSD) - in blue flow. Other abbreviations are same as in Figure 5.

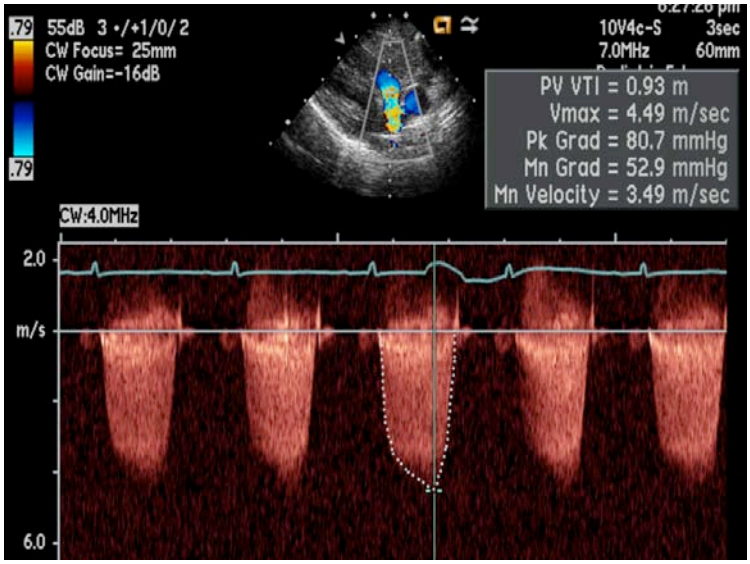

Figure 7. Doppler flow velocity across the right ventricular outflow tract, demonstrating severe obstruction.

Cardiac Catheterization and Angiography.

Catheterization is not routinely required, but may be performed if all the data required for making decision for surgical correction cannot be obtained by non-invasive studies with reasonable certainty.

Oxygen saturation data reveal systemic venous and arterial desaturation, usually proportional to the degree of right ventricular outflow obstruction. There are usually no left-to-right shunts. Pulmonary venous and left atrial saturations are usually normal. The left ventricular and aortic saturations are diminished because of right-to-left shunt across the VSD. Aortic saturation is a better (than left ventricular) indicator of the degree of desaturation because of better mixing distally. The peak systolic pressures in both ventricles are equal because of a large non-

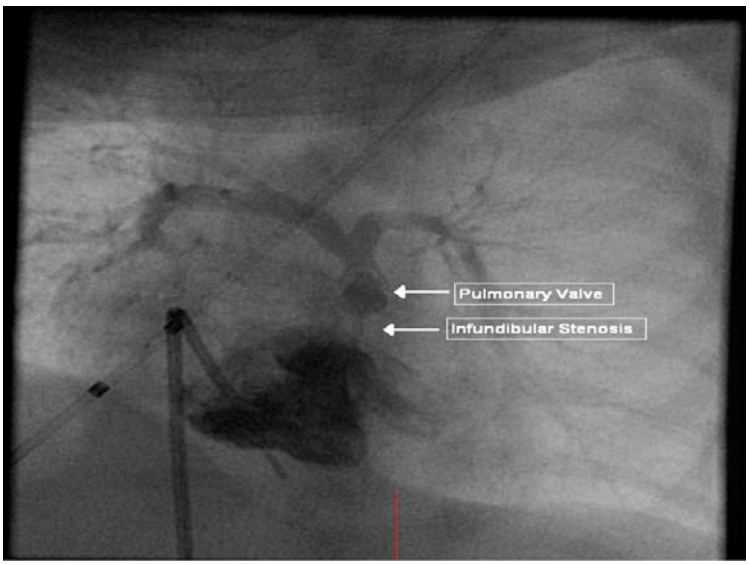

Figure 8. Selective frame from right ventricular cineangiogram in 15 degree LAO and 30 degree cranial projection demonstrating severe infundibular and valvar pulmonary stenosis. The pulmonary artery anatomy is also clearly demonstrated.

restrictive VSD. The top of the right ventricular pressure curve is flat, when compared to that of patients with PS with intact ventricular septum in which it is triangular. The pulmonary arterial pressures are low to normal with demonstrable peak systolic gradients across the pulmonary valve and infundibulum. However, multiple gradients may not be demonstrable in all patients either because of technical (multiple holes in the catheter or rapid withdrawal) or physiologic reasons.[13] Angiographic data should be used to supplement pressure information for assessment of degree and level of right ventricular outflow obstruction. The left ventricular and aortic pressures are normal without any gradient across the aortic valve.

Angiography is an integral part of cardiac catheterization. Selective left ventricular angiography in a left axial oblique view to demonstrate the size and function of the left ventricle and the size and location of the VSD, particularly to exclude muscular VSD, is important. Similarly selective right ventricular angiography to study its architecture, size and function and to evaluate right ventricular outflow obstruction (Figure 8) is useful. Pulmonary arteriogram in a sitting-up view (150 LAO and 350 cranial) to visualize the size of the main and branch pulmonary arteries and to exclude branch pulmonary artery stenosis should be obtained. Aortic root angiography is also necessary to visualize coronary artery anatomy, especially to exclude coronary arteries crossing the right ventricular infundibulum. Origin of the left anterior descending coronary artery from the right coronary artery occurs in a significant number of cases of TOF and should be excluded, if need be, by selective coronary angiography.

Management

The initial management of TOF and other cyanotic neonates is similar. Monitoring the infant's temperature. and maintaning of neutral thermal environment is extremely important. In hypoxemic infants, ambient oxygen should be administered. In cyanotic CHD patients, no more than 0.4 FIO_2 is necessary. Metabolic acidosis (pH < 7.25), if any, should be corrected with sodium bicarbonate (usually 1-2 mEq/kg diluted half and half with 5% or 10% dextrose solution) immediately. Respiratory acidosis should be cared for by appropriate suctioning, intubation and assisted ventilation. Hypoglycemia may be a significant problem; therefore, the infant's serum glucose should be monitored and the neonates should routinely receive 10% dextrose in water intravenously. If hypoglycemia (<30 mg/100ml) occurs, 15% to 20% dextrose solution should be administered. Similarly hypocalcemia should be monitored for and treated, if found.

Cyanotic spells are rare in the neonatal period, but if they do occur, management as described elsewhere[5, 9-12] may be undertaken.

The goal of management of TOF patients is to allow total surgical correction with minimal mortality and morbidity. The majority of conventional TOF patients are either acyanotic or minimally cyanotic in the neonatal period and do not require surgical intervention. Periodic clinical follow-up and elective surgical repair between the ages of 6 to 12 months may be undertaken. Total surgical correction to include closure of VSD so as to direct left ventricular output into the aorta and resection of the infundibulum and/or relief of pulmonary valvar obstruction can be performed at almost any age. Sometimes total corrective procedures are not feasible with "respectable" mortalit,y either because of pulmonary arterial (and/or annular) hypoplasia, "smallish" left ventricle, and/or anomalous course of a major coronary artery in the right ventricular infundibulum. Size and age of the patients also enter into such decision making. If it is deemed that a given patient is not suitable for total surgical correction, palliative surgery may be utilized to augment pulmonary blood flow and to allow the patients to grow into an age, size and anatomy that are more likely suitable for complete correction. Classic or modified Blalock-Taussig shunt[14,15] are options; most surgeons prefer modified Blalock-Taussig shunt using an interposition Gore-Tex graft between right or left subclavian arteries to the ipsilateral pulmonary artery (Figure 9).

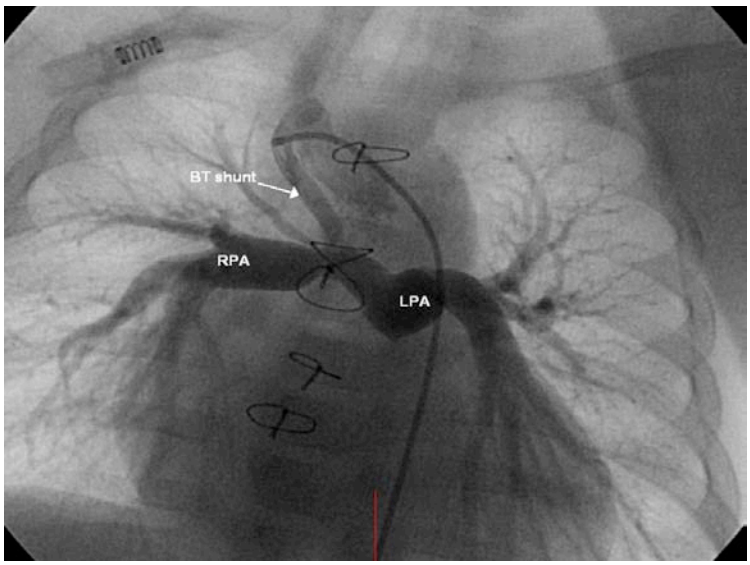

Figure 9. Selected frame from Gore-Tex graft (BT shunt) cineangiogram demonstrating a patent shunt with good opacification right (RPA) and left (LPA) pulmonary arteries.

In the patient with predominant obstruction at the pulmonary valve level (rare), we have used balloon pulmonary valvuloplasty[16-19] to increase the pulmonary blood flow. Balloon pulmonary valvuloplasty,[16-19] in addition to augmenting pulmonary blood flow allows for growth and development of the pulmonary arterial system and left ventricle so that a total surgical corrective procedure could be performed at a later time with a greater chance for success.[16-19]

In some patients, the degree of pulmonary outflow tract obstruction may be so severe that augmentation of pulmonary blood flow with initial intravenous infusion of Prostaglandin E_1 (PGE_1) followed by modified Blalock-Taussig shunt may become necessary.

TYPE II. TOF WITH PULMONARY ATRESIA

The internal cardiac anatomy is similar to that described for conventional TOF. However, the right ventricular outflow tract may be completely obstructed (pulmonary atresia) so that there is no forward flow from the right ventricle into the pulmonary artery, thus ductal-dependent. The atresia may involve the infundibulum, valve and/or main pulmonary artery. Rarely, only valvar atresia may be seen. The branch pulmonary arteries may be normal in size or may be small and hypoplastic. The ductus arteriosus is usually long and tortuous.

Symptoms

Since the pulmonary blood flow is ductal dependent, the infants begin to develop cyanosis as the ductus starts to constrict. This may happen within hours to days after birth. Rarely, cyanosis may not develop until later in life.

Physical Examination

Central cyanosis is usually present and the degree of arterial desaturation depends upon the quantity of pulmonary blood flow. The cardiac impulses are usually normal or a slightly prominent right ventricular impulse may be present. No thrills are usually felt. The first heart sound is normal or loud and heard best at apex. The second hear sound is single. No cardiac murmurs are usually heard. Occasionally, soft 1 to 2/6 continuous murmur of the patent ductus arteriosus may be heard at the left upper sternal border. Signs of heart failure are notably absent.

Noninvasive Evaluation

Chest x-ray shows normal-sized heart with decreased pulmonary vascular markings. Concavity in the pulmonary conus region may be present. Right aortic arch may be present in some patients.

Electrocardiogram may show signs of right ventricular hypertrophy, although it may sometimes be difficult to distinguish from normal neonatal right ventricular preponderance.

Echocardiogram. Internal cardiac anatomy is similar to that seen with conventional TOF. Patency of the ductus arteriosus may be demonstrated. Right ventricular outflow tract obstruction can usually be characterized. Attempts to demonstrate the size of the main and branch pulmonary arteries both by two-dimensional echo and color Doppler flow imaging should be made.

Cardiac Catheterization and Angiography

If the pulmonary artery anatomy can be discerned by echo-Doppler studies, angiography may not be necessary. If they connot be defined with sufficient clarity to undertake an aorto-pulmonary shunt, angiography to demonstrate the pulmonary artery anatomy should be performed.

Management

The initial management of TOF with pulmonary atresia is similar to that described for conventional TOF. Since these patients are ductal dependent, the ductus may be kept open by an infusion of PGE_1; the infusion should be started promptly. The current recommendations are for infusion of PGE_1 at a dose of 0.05 to 0.1 mcg/kg/min intravenously. Although PGE_1 has been used in infants beyond the first month of life, it is most likely to be effective the earlier in life it is begun. It appears that a small ductus can be dilated, but an already closed ductus may be difficult to reopen. Side effects include apnea (10%), elevation of temperature (10%), muscular twitching, and severe flushing. The side effects have not posed substantial management problems; however, the infant should be watched for apnea. Once the O_2 saturations improve, the PGE_1 dose should be weaned down to 0.02 to 0.03 mcg/Kg/min; this is particularly useful in preventing apnea and the need for endotrachial ventilation. The major benefit of prostaglandin use lies in its keeping infants in a reasonable condition while the infant is being transferred to a tertiary care institution. Also, well-planned catheterization and angiography (if necessary), as well as palliative or corrective surgery, can be performed with relative safety because of higher PO_2 and correction of metabolic acidosis. No more than 40% of humidified oxygen is necessary in infants with cyanotic congenital heart disease since they have fixed intracardiac right to left shunt.

Once the diagnosis is established by echo-Doppler and/or cardiac catheterization studies, a permanent way to provide pulmonary blood flow should be considered; this is because the effectiveness of keeping the ductus open with PGE_1 is temporary and the ductal sensitivity to PGE_1 decreases with increasing age. In patients whose cardiac defect could not be corrected in the neonatal period, a Blalock-Taussig shunt[14] is performed; most surgeons perform a modified Blalock-Taussig shunt[15] using an interposition Gore-Tex graft between right or left subclavian arteries to the ipsilateral pulmonary artery. An alternative approach is to keep the ductus open by placing a stent in it.[20-24] Based on our experience and that of others,[20-24] implantation of stent into the ductus is technically demanding, but a feasible procedure. Stenting the ductus arteriosus[25] is an attractive non-surgical option, but because of limited experience, it is not currently a first-line therapeutic option.

In patients with membranous valvar pulmonary atresia perforation of the valve[26] followed by balloon dilatation, similar to that done for pulmonary atresia with intact ventricular septum[21,26-29] may be attempted.

TYPE III. TOF WITH MULTIPLE AORTO-PULMONARY COLLATERAL ARTERIES

The internal cardiac anatomy is similar to that described for TOF with pulmonary atresia with no forward flow across the pulmonary valve. However, the main pulmonary artery is diminutive or entirely absent, and the branch pulmonary arteries are diminutive with multiple stenoses. There may be discontinuity of the right and left pulmonary arteries and of individual lobar branches. The pulmonary flow is derived solely from multiple aortopulmonary collaterals. These are grossly abnormal vessels that connect the systemic and pulmonary arterial circulations, arising directly from the aorta or its primary or secondary branches, both above and below the diaphragm. They often follow circuitous routes, sometimes crossing the midline, to reach central, lobar, and segmental pulmonary arteries distal to sites of stenosis or discontinuity. The collateral arteries are typically tortuous, variable in caliber, and often stenotic themselves. They clearly appear in association with deficient physiologic pulmonary perfusion and serve a compensatory role, increasing pulmonary blood flow and, hence, systemic arterial oxygenation. Some babies, though less commonly, have pulmonary over circulation. However, the vasculogenic mechanisms that underlie the development of the collateral vessels are as yet unknown.

Symptoms

The degree of cyanosis in these infants is a function of the extent of collateral circulation; that is, they may be very blue if there are few collaterals and they may be relatively pink, rarely to the point of congestive failure, if there are extensive collaterals with very substantial pulmonary blood flow. If the collaterals are very extensive (no cyanosis), Tetralogy of Fallot with major aortopulmonary collaterals may not be recognized in the neonate and may come to attention later than TOF with pulmonary stenosis.

Physical Examination

Central cyanosis may or may not present and the degree of arterial desauration depends upon the extent of collateral circulation. The cardiac impulses are usually normal or a slightly prominent right ventricular impulse may be present. No thrills are usually felt. The first heart sound is normal or loud and heard best at apex. The second heart sound is single. Usually a 2/6 continuous murmur of the collaterals may be audible in the chest and particularly over the back. Signs of heart failure may be present in babies with marked pulmonary over circulation.

Noninvasive Evaluation

Chest x-ray shows variable pulmonary vascular markings in regions with greater or lesser collateral flow. Concavity in the pulmonary conus region may be present. Right aortic arch may be present in some patients.

Electrocardiogram may show signs of right ventricular hypertrophy, although it may sometimes be difficult to distinguish from normal neonatal right ventricular preponderance.

Echocardiogram. Internal cardiac anatomy is similar to that seen with conventional TOF. Pulmonary atresia is recognized by two-dimensional imaging and by Doppler analysis demonstrating absence of right ventricle to pulmonary artery flow. The branch pulmonary arteries are often severely hypoplastic and not detectable on echocardiography. Aortopulmonary collaterals may be detected by continuous flow pattern on color-flow Doppler mapping. Imaging may show the origins of sizable collaterals, but smaller vessels and their distal connections to the pulmonary arteries cannot be completely defined by echocardiogram. Thus, in Tetralogy of Fallot with MAPCAs, echocardiography alone is usually not sufficient to demonstrate key aspects of pulmonary artery anatomy and blood supply, and cardiac catheterization and selective cineangiography is required.

Cardiac Catheterization and Angiography

Cardiac catheterization with cineangiography is needed to delineate all sources of pulmonary blood flow (Figure 10). Key features to be identified include: the size and continuity or discontinuity of the central pulmonary arteries; stenosis or atresia involving lobar and segmental branches; and the origins and courses of all aortopulmonary collaterals and their connections to the true pulmonary arteries. Pulmonary vein wedge injections, in addition to contrast injections in the systemic arteries and collaterals, may be required to visualize all lung segments.

Management

The initial management of TOF with major aortopulmonary collaterals depends on the extent of pulmonary blood flow. If there are inadequate aortopulmonary collaterals, they may be ductal-dependent and require PGE1 infusion to maintain ductal patency pending surgical or catheter intervention. If, instead, there are adequate collaterals, the ductus may be allowed to close, and many patients will maintain acceptable arterial oxygen saturations in the range of 80% to 90% without treatment. At the other extreme, patients may have excessive collateral flow, and this may further increase with fall in pulmonary arteriolar resistance, and may require anticongestive therapy. The definitive management of Tetralogy of Fallot with major aorto pulmonary collaterals includes combined approach with interventional catheterization and surgery to establish antegrade pulmonary blood flow from the right ventricle, rehabilitate the pulmonary arteries, and close the ventricular septal defect.[30] The precise management is dictated by the individual anatomy in each patient, largely the extent of atresia, the severity of pulmonary artery hypoplasia, and the extent of collateral circulation; many require a staged approach.[31-33] All patients should undergo catheterization as a first step to define the pulmonary artery anatomy and all sources of pulmonary blood flow and coil embolization of some of those collaterals that may be relatively inaccessible at surgery can be done at the same time. A transannular outflow patch is placed at surgery and, if there is long-segment atresia involving much of the main pulmonary artery, a right ventricle-to-pulmonary artery homograft conduit is placed.[34] Additional homograft material may be used at the distal end to augment hypoplastic or even discontinuous branch pulmonary arteries. Occasionally, the mediastinal pulmonary arteries may be so small that a narrow-diameter synthetic tube conduit is used, to be replaced later with a larger homograft. If the native pulmonary arteries supply only a limited number of bronco-pulmonary segments, it is important at operation to recruit additional segments, supplied solely by collateral vessels, into the reconstructed pulmonary arterial tree. This is accomplished in an approach termed “unifocalization,” in which those collateral vessels are detached from the aorta and anastomosed to the central pulmonary artery confluence or to each other.

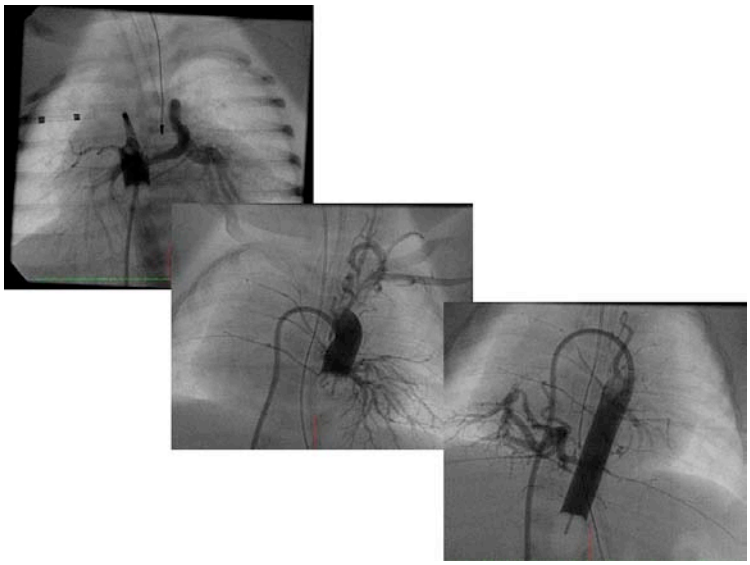

Figure 10. Selected cineangiographic frames in AP view showing multiple aortopulmonary collaterals arising from the thoracic aorta and supplying the lung segments.

Control of aortopulmonary collaterals and patent ductus arteriosus is a critical issue during cardiopulmonary bypass.[34] These must be dissected and looped or ligated to prevent “steal” of systemic flow into the lower-resistance pulmonary circulation, and attendant ischemic injury to end organs, including the brain. Once right ventricle-to-pulmonary artery continuity has been achieved by surgery, there is antegrade catheter access to the pulmonary arterial tree. More precise delineation of the intrapulmonary vessels is possible. Balloon catheters are used to dilate areas of discrete stenosis. Vascular stents are delivered to segments of elastic narrowing for which dilation alone does not suffice. These interventions serve to decrease right ventricular hypertension, increase flow to distal pulmonary segments, and improve the match between ventilation and perfusion. Further, the advent of more effective pulmonary blood flow from the right ventricle allows remaining aortopulmonary collaterals to be coil-occluded without compromising systemic oxygenation.

The timing of closure of the ventricular septal defect in Tetralogy of Fallot with MAPCAs also depends on the pulmonary artery anatomy. Once the ventricular defect is closed, the pulmonary arteries must have adequate capacity to receive all systemic venous return from the right ventricle. If the total cross-sectional area of the pulmonary arteries is too small, right ventricular failure and low cardiac output will ensue.[35] Often, ventricular septal defect closure is scheduled to coincide with surgical revision of the right ventricle-to-pulmonary artery conduit (discussed later). Patients with Tetralogy of Fallot with pulmonary atresia typically require one or more additional operations as they grow in size. Right ventricle-to-pulmonary artery conduits are, by their nature, fixed in diameter, and so they must be replaced or otherwise enlarged when they become restrictive. Serial interventional catheterizations are also generally indicated in these patients throughout infancy and childhood, more so than in other tetralogy variants. New or recurrent pulmonary artery stenoses can be dilated (balloon angioplasty/ cutting balloon angioplasty) and, if necessary, stented. Existing stents can be redilated up to their maximum diameter. Obstructed right ventricle-to-pulmonary artery homograft conduits can also be dilated and stented, often permitting surgical conduit revision to be postponed for months or years and potentially reducing the total number of such operations that the patient will ultimately have to undergo.

TYPE IV. TOF WITH SYNDROME OF ABSENT PULMONARY VALVE

The principle features of absent pulmonary valve syndrome are absent or rudimentary pulmonary valve cusps causing pulmonary insufficiency, pulmonary valve ring hypoplasia producing pulmonary stenosis and massive dilatation of the main and major branch pulmonary arteries resulting in varying degrees of compression of the tracheobronchial tree. This is a rare congenital heart defect and constitutes 3 to 5% of Tetralogy of Fallot cases. This syndrome is usually associated with ventricular septal defect and pulmonary stenosis, although it may be occasionally seen as an isolated malformation or with other defects, namely, atrial septal defect, ventricular septal defect, patient ductus arteriosus, endocardial cushion defect and double outlet right ventricle.

Symptoms

Two types of clinical presentation are recognized:

1. Those who present in early infancy with severe cardio-respiratory distress (because of tracheobronchial compression) and
2. those who present beyond infancy with milder respiratory difficulty. In neonates with respiratory distress, ventilation may be worse in the supine, as compared with prone, position because of greater bronchial compression by the aneurismal pulmonary arteries.[36,37] The clinical severity of respiratory symptoms appears not to correlate reliably with the degree of pulmonary artery enlargement, suggesting that intrinsic bronchial abnormalities may be a more important determinant.

Physical Examination

Apart from respiratory difficulty, the infants may have signs of heart failure and are mildly cyanotic. Hyper-dynamic cardiac impulses, single second sound, and a to-and-fro murmur of pulmonary stenosis and insufficiency at the left upper sternal border are the other physical findings.

Noninvasive Evaluation

Chest X-ray. Increased heart size may be due to right ventricular dilation caused by the volume overload of free pulmonary regurgitation. Very large main and branch pulmonary arteries are evident. Signs of bronchial compression may be seen, including segmental or overall hyperinflation.

Electrocardiogram is suggestive of right ventricular hypertrophy.

Echocardiogram. Echo-Doppler studies demonstrate a large ventricular septal defect, markedly dilated main and branch pulmonary arteries, absent or rudimentary pulmonary valve leaflets and Doppler evidence for pulmonary stenosis and pulmonary insufficiency. The bronchi and their relationship with the pulmonary arteries cannot be demonstrated by echocardiography, and other imaging modalities, such as computed tomography or magnetic resonance imaging may be important in some cases before surgery.

Cardiac Catheterization and Angiography

Cardiac catheterization data are suggestive of left-to-right shunt at ventricular level, mild systemic arterial desaturation (secondary to both pulmonary venous desaturation and small interventricular right-to-left shunting), significant peak-to-peak systolic pressure gradient across the pulmonary valve and an increased ratio of systemic-to-pulmonary flow. Selective cineangiography demonstrates a large subaortic perimembranous ventricular septal defect, moderate-to-severe pulmonary valve ring stenosis and impressive dilatation of main, right and left pulmonary arteries (Figure 11).

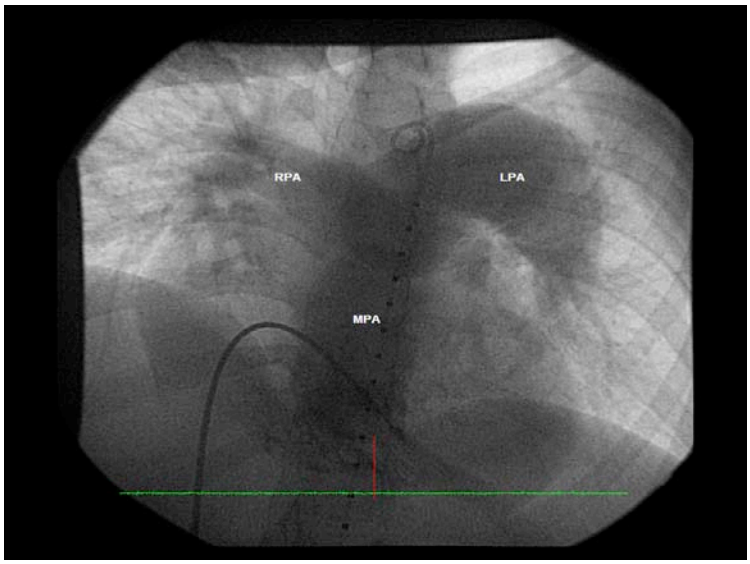

Figure 11. Cineangiogram in AP view in a patient with TOF with absent pulmonary valve syndrome showing severely dilated main and branch pulmonary arteries.

Management

Treatment consists of anticongestive measures, chest physiotherapy and ventilatory support to stabilize the patient followed by total surgical correction (under cardiopulmonary bypass), including closure of the ventricular septal defect, relief of pulmonary stenosis by a transannular pericardial patch as necessary and partial resection and plastic repair (Figure 12) of aneurysmally dilated pulmonary arteries.[38] There is some controversy with regard to prosthetic replacement of the pulmonary valve at the time of primary repair[38] but, valve replacement may not be necessary in all cases at the time of primary repair.[39]

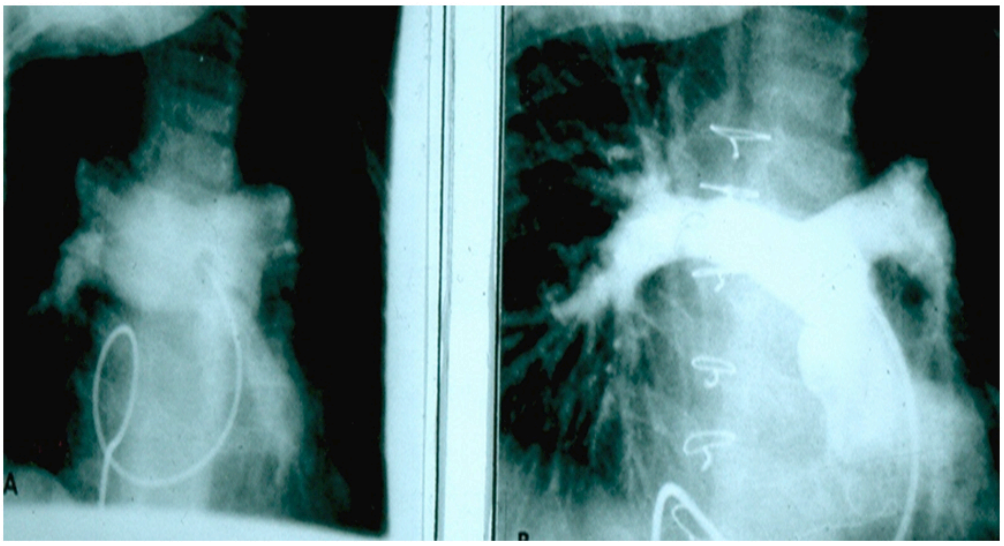

Figure 12. Selected cine angiographic frames from right ventricular cineangiograms prior to (A) and after surgical pliacation of the pulmonary arteries at the time of surgical repair.

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Srilatha Alapati, MD
Fellow in Pediatric Cardiology
UT-Houston Medical School
Children's Memorial Hermann Hospital
Houston, TX USA

Corresponding Author

P. Syamasundar Rao, MD
Professor of Pediatrics and Medicine
Director, Division of Pediatric Cardiology
UT-Houston Medical School
6410 Fannin
UTPB Suite # 425
Houston, TX 77030 USA
Phone: 713-500-5738
Fax: 713-500-5751

P.Syamasundar.Rao@uth.tmc.edu

Global Neonatology Today - A Monthly Column: *Summit 2010 and The Progress of Millennium Development Goals 6, 7 and 8*

By Dharmapuri Vidyasagar, MD, FAAP, FCCM

The discussions at *Summit 2010* showed that considerable progress has been made in achieving Millennium Development Goals (MDG) 6, 7 and 8; this progress is largely due to key interventions. In a report, Sha Zukang, the Under Secretary for Economic and Social Affairs of United Nations summarized the progress of these goals.

He stated that significant improvements have been achieved due to key interventions aimed at preventing malaria and HIV and to an increase in measles immunization. These programs have cut child deaths from 12.5 million in 1990 to 8.8 million in 2003, and the deaths continue to decrease.

The number of people receiving antiretroviral treatment increased ten-fold, from 400,000 to 4 million people - 42% of the 9 million who need the treatment for HIV.

In terms of malarial disease prevention and treatment, the funding commitment has also increased. The increased use of antimalarial interventions, bed netting, and the use of effective drugs has helped in the effective treatment of children.

The rate of deforestation has decreased and there are increased plans for planting and expanding natural forests.

Telecommunications have increased among developing countries; cellular phones per 100 people increased to 50% by 2009. Telephone systems are being used around the globe for health promotion, banking and disaster management.

The Status of MDG #8

Millennium Goal #8 calls for participation of high-income countries in promoting the Millennium Development Goals around the world. It is a challenge to rich nations. Poor countries cannot fulfill their projections of reaching the targets of MDG by 2015 without economic support.

The rich members of United Nations have made commitment of contributing 0.7% of their Gross National Product towards Official Development Assistance (ODA) as early as in 1970.

Unfortunately, according to the UN Department of Economic and Social Affairs, fifty of the least developed countries received only one third of all the aid promised from developed countries. Instead, much of the money has gone to the closest allies of the rich countries. This pattern has put the development in poor countries in jeopardy.

Most of the contributions (50%) have been applied towards the debt relief of the poor countries, thus reducing their economic burden. The remaining is used for development of programs. Misuse of the contributions in billions of dollars by the bureaucratic and corrupt governments is another retardant to progress in developing countries. Further, it raises the cynicism among people and some critics of MDGs. There is also a controversy regarding the commitment of promises made by the rich countries. For example, the US and other countries have been falling behind in fulfilling their commitments. At the recent *Monterrey Consensus Meeting,* the UN urged the developed countries to keep their promised target of payments by 2015. Responding to the statement, the European Union (EU) has recently reaffirmed its commitment to the 0.7% aid targets. Four out of the five countries, which exceeded the UN target for official development assistance (ODA) of 0.7%, of gross national income (GNI) were member states of the European Union (2006). Many organizations are working to bring US political attention to the Millennium Development Goals.

"***The Clock is Ticking!"***

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Dharmapuri Vidyasagar, MD, FAAP, FCCM
University of Illinois at Chicago
Professor Emeritus Pediatrics
Division of Neonatology
Phone: +1.312.996.4185
Fax: +1.312.413.7901
dvsagarmd@yahoo.com

Medical News, Product & Information

Perinatal Safety Initiative Reduces Adverse Obstetrical Outcomes

To increase the chances of a safe labor and delivery, and make way for a memorable birthing experience, the North Shore-LIJ Health System has launched a new prenatal quality initiative, led by Adiel Fleischer, MD, of Obstetrics and Gynecology at North Shore University Hospital and Long Island Jewish (LIJ) Medical Center, and Brian Wagner, MD, a maternal-fetal medicine specialist.

They designed and implemented a two-year comprehensive training program for all staff in the obstetrics wings at North Shore University Hospital and LIJ Medical Center. Staff was required to complete the formalized training that included evidence-based protocols to reduce adverse events.

These protocols included competency in reading electronic fetal heart rate monitors, communication skills and problem solving on a wide range of high-risk obstetrical emergencies through simulation programs. The hope was that the obstetrics initiative would lead to fewer adverse outcomes for mother and child.

It worked.

A team of scientists in the Division of Health Services Research in the health system's Department of Population Health analyzed almost a dozen adverse outcome measures and found that such problems, including returning to the operating room and birth trauma, were significantly reduced by more than half – from two percent to 0.8%. Data also showed better outcomes were maintained over the two-year study period.

The analysis was published in the March issue of the *Journal for Healthcare Quality* .

In addition to improved outcomes, staff perceptions of safety improved significantly, as did perceptions among new mothers, who reported that their obstetrics teams were more cooperative and hard-working. What's more, there were improvements in the documentation of abnormal fetal heart rate tracings and obstetric hemorrhage.

"The importance of the study and its long-term impact is that the safety measures that we introduced have provided better communication among the various healthcare providers. There is earlier identification of at-risk patients and a team approach to patient care is critical to patient care," said Dr. Fleischer.

North Shore-LIJ hospitals deliver more than 21,000 babies every year, which represents nearly 10% of all births in New York State. Following the national trend to identify problems in the delivery of healthcare and reduce medical errors, clinicians implemented internal and external reviews of sentinel events, which included examinations of monthly obstetric charts. The chart reviewers looked at the documentation and management of obstetric hemorrhage and abnormal fetal heart rate tracings. The review led to a comprehensive list of potential causes of adverse events, including an inadequate escalation policy, and lack of standard protocol and standardizations pertaining to the interpretation for fetal heart rates. These factors are thought to play an important role in adverse outcomes.

As part of the program, Dr. Fleischer and his colleagues introduced multidisciplinary teaching rounds to help foster communication. During these daily meetings, the perinatal team reviewed and discussed appropriate assessment and management of obstetrical admissions. They enhanced the electronic medical record and implemented new protocols that have been shown to reduce the risk for adverse events.

Patients were contacted after they left the hospital and asked to complete a questionnaire about their experience during labor and delivery. Staff perceptions of safety were also assessed before and after the program.

"A critical component of the initiative was the educational process designed to improve recognition, appropriately document complications and avoid interventions that increase the risk of complications," the researchers wrote in the journal. The study was led by Renee Pekmezaris, PhD, VP for community health and health services research in the North Shore-LIJ Department of Population Health.

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