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Closure of Huge Pulmonary Arteriovenous Malformations: A Review of the Literature

Ahmed M. El-Emam, MD; Hanan M. Hassan, MD; Ahmed S. Youssef, MSc

Introduction

Pulmonary arteriovenous malformations (PAVMs) are abnormal communications directly between pulmonary arteries and pulmonary veins without formation of a capillary bed; it is a rare anomaly of the cardiovascular system.[1,2]

The PAVMs consist of three anatomical components: one, or more than one, feeding artery(ies), an aneurysmal sac and one or more draining vein(s).[3] PAVMs may be simple or complex; simple PAVMs have a solitary feeding artery, a bulbous, aneurysmal, non-septated communication to one or more draining veins. Complex PAVMs have two or more feeding arteries opening into a septated aneurysmal sac to two or more draining veins.[4] Diffuse PAVMs are AVMs involving minimally one segment diffusely included.[5]

PAVMs are mostly congenital, frequently associated with hereditary hemorrhagic telangiectasia (HHT). Isolated cases have also been reported. Diffuse PAVMs are rarely found with unoperated congenital heart diseases like Polysplenia Syndrome. Acquired causes of PAVMs include: tuberculosis, trauma, juvenile hepatic cirrhosis and schistosomiasis. Glenn operation is a documented acquired cause of PAVMs.[6] PAVMs may clinically present with findings such as: dyspnea, hemorrhage, chest pain and desaturation. Neurological complications may occur due to: impaired capillary bed filtration including cerebral abscess, ischemic strokes, migraine headaches, myocardial infarctions and pregnancy-related deaths.[7]

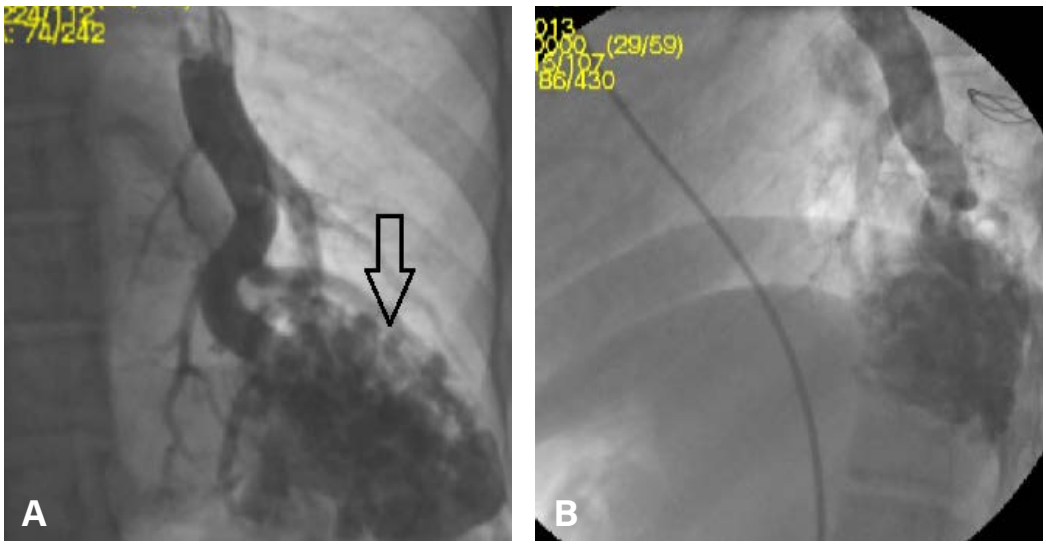

FIGURE 1 *Pulmonary artery angiography in AP view showing large complex PAVM in the left lower-posterior lung lobe, supplied by multiple feeding arteries (A), and in lateral view (B).*

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Case Report

A seventeen-year-old female patient presented to our unit in December 2013, with shortness of breath, fatigue and cyanosis, which was dated since birth. Apart from cyanosis and clubbing, the only relevant clinical finding was distant soft continuous sound which was just heard on the left lower chest segment. Oxygen saturation (SPO2) was 74% by pulse oximetry. She had a normal electrocardiogram (ECG) and normal echocardiography. Chest X-ray showed a patch of opacity in the left lower lung zone. Diagnostic cardiac catheterization was recommended, and the patient had right-heart catheterization under general anesthesia. The procedure was initiated with right femoral-venous puncture using the Seldinger technique and advancement of guidewire to right atrium (RA) and right ventricle (RV), then advancement of Right Judkin 6F catheter to cross the pulmonary artery. The mean right atrial pressure was 7 mmHg, systolic pulmonary artery pressure (PAP) was 24 mmHg, diastolic and mean PAP were 9 and 14 mmHg respectively. Exchange to Pigtail 6F catheter was done, pulmonary artery, right and left pulmonary angiography were performed in both anteroposterior (AP) and lateral views showing large complex PAVM in the left lower posterior lung lobe, supplied by multiple feeding arteries arising from a large main feeding artery (**Figure 1**).

The main feeding artery measured about 16.5 mm in diameter, and the mass of malformations measured about 84 mm X 97.5 mm.

The patient was given a bolus dose of heparin, and an exchange 260 cm J-tipped guidewire was advanced through the Right Judkin catheter to exchange it for a 100-cm 8-F Mullins sheath (Medtronic, Minneapolis, Minn.) for deployment of the Amplatzer ASD occluder device 16 (St. Jude Medical Inc.) at the site of the main feeding artery (posterior basal) that supplies the feeding arteries of the PAVM (**Figure 2**).

A test dose of contrast material was used to adjust the position of the delivery sheath. An Amplatzer ASD occluder device (16 mm) attached to the delivery cable was introduced using the device loader into the Mullins sheath to be deployed in the proper position under fluoroscopic guidance, then the device was released.

There was a dramatic improvement in the color and oxygen saturation of the patient, cyanosis disappeared and oxygen saturation became 97% within a few minutes of device release. The patient was observed for 24 hours with no early complications. Clinical condition and laboratory findings were normal, only D-dimer was elevated due to induced pulmonary infarction. She had clopidogrel 75 mg tablet daily for one month, and aspirin 150 mg daily for six months, with regular follow-up, showing no late complications. Three years later in 2016, clinically the patient was doing well, there was no cyanosis and oxygen saturation was 95%. Pulmonary function tests were performed and showed normal resting pulmonary function values. The Multi-slice Computed Tomography (MSCT) of the heart and chest showed the device in place with occlusion of the feeding arteries, and there was no recurrence of PAVMs (**Figures 3, 4**).

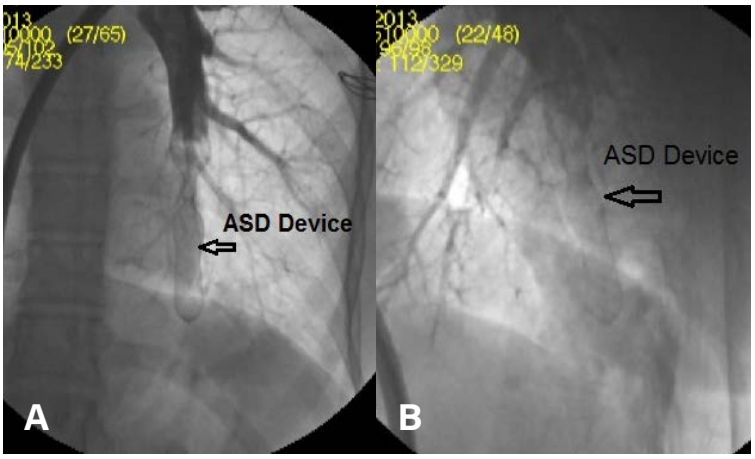

FIGURE 2 *Deployment of Amplatzer ASD occluder 16 (St. Jude Medical Inc.) at site of the main feeding artery (posterior basal) that supplies the feeding arteries of the PAVM in AP view (A), and lateral view (B).*

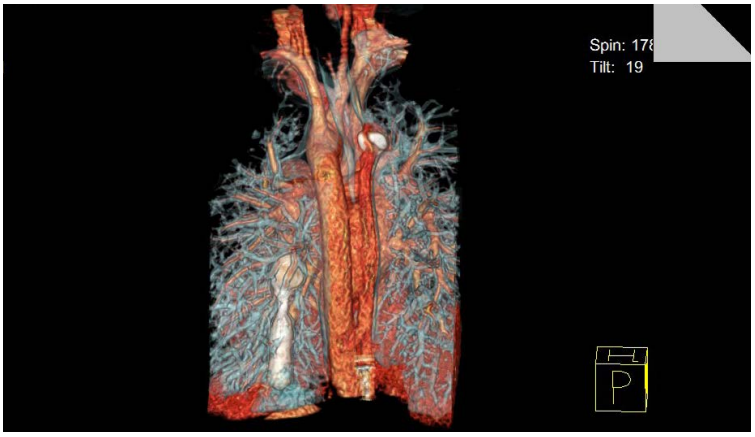

FIGURE 3 *Multi-Slice CT heart and chest PA view showing ASD occlusion device sealing the main feeding artery with PAVM not visualized.*

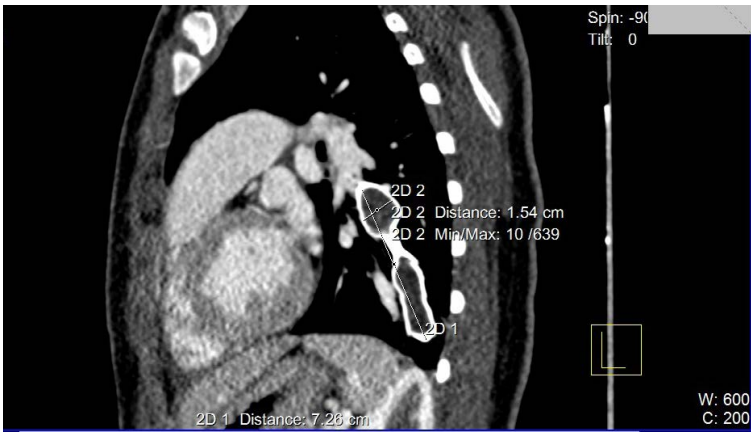

FIGURE 4 *Multi-Slice CT heart and chest lateral view showing dimensions of ASD occlusion device.*

Long-term follow-ups showed sustained normal oxygen saturation, clinical disappearance of cyanosis, improvement of effort tolerance and no adverse outcomes.

Discussion

PAVMs are high-flow, low-resistance vascular shunts. Closure of PAVMs is very important to avoid stroke and brain abscess,[8] also to achieve increase in oxygen saturation and effort tolerance,[9] and to prevent a pulmonary hemorrhage.

In the past, surgical intervention was the chief line of treatment of PAVMs, but it has significant morbidity and mortality; it was performed in the form of pneumonectomy,[10] then it developed to lobectomy in 1950, and in 1959, local excision was applied.[11,12]

Percutaneous closure of PAVMs is an alternative to surgery with minimal invasive hazards; the use of steel coil (or balloon) embolization for their occlusion is one of the more difficult procedures in Interventional Cardiology. Coils are placed at the neck of the malformation immediately proximal to the dilated aneurysmal sac.[9] Percutaneous closure of PAVMs was first described by Taylor et al. in 1978. They used Gianturco embolization coil and six mechanical occluding devices were placed into the vessels, feeding the AV malformations.[13] This method was feasible with no complications. It is preferred to surgical closure as it is less invasive and can be repeated more easily. The anatomy of PAVMs vasculature determines the type of device used for closure. Hsu et al reported in a Cochrane review that transcatheter device closure has less mortality and morbidity than surgery in PAVMs closure based on observational studies with no evidence from randomized controlled trials (RCTs).[14]

Surgical removal of PAVMs is mainly indicated if there is massive bleeding, PAVM rupture, failed transcatheter closure, or marked allergy to contrast.[15]

Coils, detachable balloons, and devices are used for PAVMs transcatheter closure. In large, complex lesions vascular plugs and Amplatzer duct occluders are frequently used. Vascular plugs can be repositioned to fit the anatomy of the feeding vessel, but they are costlier than coils, and their relatively big size make them difficult to handle in a peripheral feeding vessel. Closure of distal feeding vessels is sometimes preferred to closure of the large main feeding vessel as closure of a proximal feeding artery precipitates lung infarction and parenchymal damage, which also leads to formation of systemic collaterals by bronchial arteries and may induce pulmonary hemorrhage.[16]

Our case had left-side large complex PAVM, clinical signs suggesting significant right to left shunt were present e.g. cyanosis, polycythemia, fingers and toes clubbing, also presence of symptoms like exertional dyspnea. In our patient, the PAVM had more than one feeding artery arising from a large branch from the artery to left-posterior basal lung segment. By angiography, it was clear that the main feeding artery and its branches were not giving any supply to parenchymatous lung tissue. The presence of multiple feeding arteries and the large size of the draining vein suggested a need to close the main feeding artery rather than individual closure of distal feeding arteries to avoid using multiple devices which is much more expensive and technically more difficult, and to ensure closure of unnoticed branches. The main feeding artery measured about 16.5mm in diameter, and the mass of malformations measured about 84 mm X 97.5 mm. Owing to the large diameter of the feeding artery and to avoid risk of embolization, choice of Amplatzer ASD occluder 16 was done taking the configuration of the feeding vessel and achieving complete sealing of forward flow. Dramatic rapid improvement of cyanosis and oxygen saturation was noticed. Induced pulmonary infarction was noticed, no other complications were reported. The case was diagnosed and transcatheter intervention performed in 2013, but to provide long-term follow-up for possible complications, reporting of the case was delayed to 2019.

In contrast to our concept, Sulaiman et al. used multiple devices to close the distal feeding vessels sparing the main feeding vessel in a 23-year-old HHT male patient having a huge left-side complex PAVM measuring 63 mm X 49 mm X 47 mm. The main two feeding arteries measured 8 and 7 mm respectively. A 12-mm vascular plug system (Cera, Lifetech Scientific Co., Shenzhen, P.R. China), and three devices 8 mm-10 mm Amplatzer duct occluders (St. Jude Medical, St. Paul, MN, USA) were used to close the feeding arteries. They had chosen the sizes of devices by oversizing the diameter of each feeding artery by 30–50%. Angiogram showed minimal residual filling. On follow-up after 12 months, there were no symptoms with almost total closure of the PAVM.[15]

Similar to our case, Agha et al. described a case of conglomerate serpinginous and tortuous vessels in right upper and middle zones in a two-year old patient. There was aneurysmal dilatation at the distal venous end before entering the left atrium. They used Amplatzer ASD occluder device (12mm) to occlude a right upper pulmonary artery and its branches. The patient showed improvement of symptoms, oxygen saturation, and effort tolerance during six months of follow-up [17]. Also, Küçükay et al. reported a case of PAVMs in an HHT patient with desaturation. CT showed two PAVMs, one in the right lower lobe posterior-lateral basal segment measuring (7x4.5 cm) and another one in the left lower lobe antero-medial basal segment measuring (4x3cm). Selective angiography revealed that the feeding artery diameter was 10 mm, therefore they used an AVP (AGA Medical Corporation, Golden Valley, MN, USA) sized 14 mm to occlude the feeding artery. The PAVM in the right lower lobe was complex with several feeding arteries derived from the posterior basal and lateral basal segmental branches, so they decided to occlude the common trunk of posterior basal and lateral basal segmental arteries which measured 13 mm in diameter and they used a 16 mm AVP. At the six-month follow-up there was a reduction in the diameter of both PAVMs, and increased saturation to 96% on room air.[18]

In comparison to our case, Aggarwal et al. reported the case of a four-month-old patient having persistent desaturation. A chest CT showed the presence of a large (>3 mm) right lower lobe PAVM. Angiography showed complex single right lower lobe PAVM

with multiple afferent large arteries and a single efferent vessel. It was successfully occluded using MReye coils (Cook Medical, Bloomington, IN) and Amplatzer Vascular Plug–II devices (two 4 mm, two 6 mm, and one 10 mm) (St. Jude Medical, St. Paul, MN). The infant was discharged after five days with oxygen saturations of 98–100% on room air.[19] They had chosen to occlude multiple distal feeding vessels using multiple devices, which is more costly.

Conclusion

Transcatheter closure of PAVMs has been used for several years. It is an effective, but one of the most difficult, interventional procedures. Choice of device closure differs according to anatomical variations and center experience. Coils, ASD devices, duct occluder or vascular plugs are also used. Our experience of a PAVM's main feeding artery occlusion by use of the Amplatzer ASD occluder was successful, effective and safe, with no adverse outcomes on long-term follow-up. To our knowledge, our case showed the largest PAVM closed by the transcatheter approach.

No Conflict of Interest

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New Pediatric Heart Failure and Transplant Program Launches at Hassenfeld Children's Hospital at NYU Langone

NYU Langone's Transplant Institute and Hassenfeld Children's Hospital have launched a new pediatric heart failure and transplantation program, bolstering the institution's comprehensive offering of solid organ and blood and bone marrow transplants, as well as expanding regional access to this specialized level of care for children.

The program is led by two nationally renowned experts in the field: Rakesh Singh, MD, Pediatric Cardiologist and faculty member of the Department of Pediatrics, who serves as Medical Director of pediatric heart failure and transplantation; and T.K. Susheel Kumar, MD, Pediatric Cardiac Surgeon and Associate Professor in the Department of Cardiothoracic Surgery, who serves as the Surgical Director.

Dr. Singh joined Hassenfeld Children's Hospital in March 2020 from Rady Children's Hospital San Diego, where he served as the Medical Director of heart failure and transplantation from 2014 to 2019. He has been directly involved in more than 150 pediatric heart transplants in his career. Dr. Kumar, whose decades-long career spans across two continents, spent the last 15 years as a cardiac surgeon in both India and the United States. He has performed dozens of complicated heart transplants in infants and children.

"We are thrilled to have Dr. Singh and Dr. Kumar lead our efforts to develop a successful pediatric heart failure and transplantation program here at Hassenfeld Children's Hospital," says Catherine S. Manno, MD, the Pat and John Rosenwald Professor of Pediatrics and Chair of the Department of Pediatrics. "The new program further enhances our already robust Congenital Heart Program with the advanced expertise to care for children with the most complex cardiac needs."

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*The term "stent fracture" refers to the fracturing of the Melody TPV. However, in subjects with multiple stents in the RVOT, it is difficult to definitively attribute stent fractures to the Melody frame versus another stent.

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Estimated Cost per Case of Significant and Critical Congenital Heart Disease Detected Prenatally

William N. Evans, MD & Ruben J. Acherman, MD

Introduction

In contrast to postnatal oximetry screening, fetal cardiac evaluation and diagnosis is the best evidence-based method for perinatal detection of specific cardiovascular malformations.[1,2] Utilizing ongoing community-wide, general obstetric and specialized perinatal sonographer education, coupled with non-siloed fetal cardiology and perinatology care, a system of near-universal prenatal detection of critical congenital cardiovascular malformations is achievable in large, geographically diverse populations.[3,4] Organized in this manner, universal fetal echocardiography is not necessary. Rather, educationally-driven general-obstetric sonographer identification of possible fetal cardiovascular abnormalities increases the probability of a specific malformation diagnosis when referred to an integrated fetal cardiology-perinatology care system for fetal echocardiography. Previous reports have commented on or modeled possible costs of prenatal detection of congenital cardiovascular malformations.[5,6] To evaluate our program, this study analyzed estimated costs per case of a cardiovascular malformation prenatally detected in Nevada for both significant and critical malformations. To the best of our knowledge, no previous study has analyzed non-theoretically modeled cost data from a state-wide population.

Materials and Methods

The study protocol conforms with the principles of the Declaration of Helsinki of 1975, as revised in 2013. The local Sunrise Institutional Review Board approved this study and exempted consent. We accessed data for this observational, non-randomized report by inquiring into our research database (Epi-InfoTM), an internal congenital cardiovascular surgery database, and our electronic health records (EHR). The Epi-Info database is maintained by the Children's Heart Center Nevada's Research Director, and data is exclusively entered from coding sheets completed by our center's physicians from each patient encounter or procedure. No individual or other party external to our center has access to our Epi-Info database, congenital cardiovascular malformation database, or EHR. For the searchable parts of our EHR, we used Perspective Software by Lexmark International, Inc., Lexington, Kentucky. As the sole provider of prenatal and postnatal congenital cardiology services in the state, our electronic databases include information on all patients diagnosed with congenital cardiovascular malformations in Nevada. Following the database and EHR inquiry, we reviewed patient records and collated data for analysis. We used descriptive statistics to report averages, percentages, and rates, and we did not utilize statistical testing to compare values. From the inquired databases and EHR, we identified all patients born in Nevada between March 2019 and March 2020, between zero and twelve months of age, that underwent or are likely to undergo a primary cardiovascular surgery or a neonatal emergent catheter interventional procedure rather than a surgical procedure or who have received comfort care for a complex malformation. Conditions, requiring neonatal procedures at ≤ 30 days old, were deemed as critical congenital cardiovascular malformations, and conditions requiring, or likely to require, a surgical procedure between one and twelve months of age were deemed as significant congenital cardiovascular malformations. From this cohort, we identified those mothers who received standard prenatal care that included at least one obstetric ultrasound and were referred to a maternal-fetal-medicine center for fetal risk factors or a suspected fetal cardiac abnormality to undergo a fetal-cardiologist-supervised, diagnostic-fetal echocardiogram. Similar to Pinto and associates,[5] we utilized Medicaid reimbursement figures, **Table 1**, as average values for fetal echocardiography and evaluation of management services performed.

For an estimate of the cost per case detected, we first determined the number of total fetal cardiac evaluations and divided that total by the number of prenatal fetal cardiovascular malformations detected to determine the number of fetal cardiac evaluations per detected malformation. The number of fetal cardiology evaluations per malformation detected was multiplied by the total cost for each fetal cardiology evaluation to calculate an estimated cost per case detected. In addition, we also analyzed the percentages of those with Medicaid, commercial insurance, or no insurance coverage separately for those prenatally diagnosed and those non-prenatally diagnosed. Beyond this, we performed no other cost analysis, such as estimated savings from reduced utilization of emergent neonatal transport services or any other prenatal or postnatal expense or savings from the diagnosis and management of congenital cardiovascular malformations.

TABLE 1 Cost of Individual Fetal Cardiology Evaluation

Fetal cardiology evaluation	CPT	NV Medicaid 2019
Fetal Echo: imaging	76825	$289
Fetal Echo: pulsed or CW Doppler	76827	$79
Fetal Echo: color flow Doppler	93325	$23
Consultative services	99243	$123
Total		$514

CPT current procedural terminology

We have described Nevada's state-wide fetal cardiology program elsewhere in detail.[3,4] We began a community-based, comprehensive fetal cardiology program to improve prenatal detection of Congenital Heart Disease in Nevada.[7,8] Briefly, the program encompasses ongoing educational programs for general obstetric and specialized perinatal sonographers and on-site fetal cardiologists that supervise all diagnostic fetal echocardiograms at each of the state's perinatology clinics five-days-a-week with 24/7 on-call services. General obstetric sonographer training includes a series of half-day didactic lectures that detail the 5-axial view fetal echocardiographic screening method. For the analysis period, seven fetal cardiologists provided coverage to 11 maternal-fetal-medicine offices, throughout the state of Nevada, in five different perinatal groups with a total of 40 perinatal sonographers, all trained to perform comprehensive fetal echocardiograms, with each diagnostic study under the supervision of a fetal cardiologist.

Results

We identified 176 live-born patients that met inclusion criteria. Total estimated state-wide, live-births for March 2019 to March 2020 was approximately 29,000[9] for a combined prevalence of critical plus significant congenital cardiovascular malformations of 176 per 29,000 (6 per 1,000) live-births. Of the 176, 97 (55%) were male. Of the 176, 86 (49%) had critical conditions, requiring cardiovascular surgery or catheter intervention 30 days of age, and 90 (51%) had significant conditions, requiring cardiovascular surgery or pending cardiovascular surgery between the ages of one month and 12 months. Of the 86 critical malformations, 73 (85%) were prenatally diagnosed, and of the 90 significant malformations, 68 (76%) were prenatally diagnosed for an overall prenatal detection rate of 141/176 (80%). **Table 5** lists the critical conditions with individual prenatal detection rates, and **Table 2** lists the significant conditions with individual prenatal detection rates. **Table 3** lists the primary presentation sign for non-prenatally diagnosed patients. **Table 4** lists the comparison for insurance coverage between those prenatally and non-prenatally diagnosed, for which we found no statistically significant differences.

The 141 prenatally-diagnosed patients came from 2,039 pregnant women referred to a Maternal-Fetal Medicine office for a fetal cardiologist supervised fetal echocardiogram. Estimated combined cost, fetal echocardiogram plus evaluation and management services, was $514 per fetal cardiac evaluation. The average number of fetal echocardiograms per case detected was 14.5 (2,039/141); thus, the estimated cost per case detected was $7,453 (14.5 x $514).

In addition to the 141 critical and significant cardiovascular malformation live-born patients, we identified 18 fetuses with complex malformations of which 10 resulted in fetal demise, and eight led to elective termination. Further, we also identified 40 additional live-born patients with non-surgical congenital cardiovascular malformations: 29 small perimembranous VSDs, eight mild aortic arch hypoplasias, one mild Ebstein's, and one rhabdomyoma.

TABLE 2 Significant Congenital Cardiovascular Malformations

Condition	Total, n	Prenatal DX, n (%)	Surgery, n	Pending, n
Ventricular Septal Defect	35	27 (77)	15	20
Atrioventricular Septal Defect (spectrum)	23	19 (83)	12	11
Vascular ring	13	11 (85)	8	5
Tetralogy of Fallot	10	7 (70)	6	4
Coarctation of the Aorta	8	4 (50)	6	2
Ebstein's Anomaly	1	0	0	1
Total	90	68 (76)	47	43

DX diagnosis

TABLE 3 Principle Presentation Sign for Non-prenatally Diagnosed Patients

Sign	Critical CCM n=13	Significant CCM n=22
Murmur at birth, n (%)	8 (62)	8(36)
Cyanosis at birth, n (%)	4 (31)	0
Failed NB O2 saturation screen, n (%)	1 (7)	0
Suspect Down Syndrome at birth, n (%)	0	10 (45)
Murmur outpatient < 1 week, n (%)	0	1 (5)
Murmur outpatient > 1 month, n (%)	0	2 (9)
Weak femoral pulses > 1 month, n (%)	0	1 (5)

CCM congenital cardiovascular malformations, NB newborn

TABLE 4 Insurance Coverage ComparisonPatients

Insurance Coverage	PN DX n=141	No PN DX n=35	p value
Commercial insurance, n (%)	64 (45)	17 (48)	0.87
Medicaid, n (%)	59 (42)	9 (26)	0.14
No coverage, n (%)	18 (13)	9 (26)	0.55

DX diagnosis, PN prenatal

TABLE 5 Critical Congenital Cardiovascular Malformations

Condition	Total, n	Prenatal Dx, n (%)	Comfort care, n
Coarctation of the Aorta	24	17 (71)	
Univentricle (except Hypoplastic Left Heart)	14	14 (100)	6
Hypoplastic Left Heart Syndrome	10	10 (100)	1
Tetralogy of Fallot + Pulmonary Atresia-VSD	6	6 (100)	
Truncus arteriosus	6	5 (83)	
D-transposition of the Great Arteries	6	4 (67)	
Aortic stenosis (critical)	5	4 (80)	
Double outlet right ventricle	4	4 (100)	
Total Anomalous Pulmonary Venous Connection	3	1 (33)	
Vascular ring	3	3 (100)	
Pulmonic stenosis (critical)	3	3 (100)	
Ebstein's Anomaly	1	1 (100)	1
Interrupted Aortic Arch	1	1 (100)	
Total	86	73 (85)	8

DX diagnosis, VSD Ventricular Septal Defect

Discussion

Previously, Pinto and associates constructed a decision-analytic model, supported by data from the literature, which generated probabilities of Congenital Heart Detection percentages depending on the algorithm utilized.[5] Our fetal cardiology care model for Nevada is not entirely concordant with any of the seven algorithms in Pinto's study. Rather, in our opinion, our approach is unique regarding its application to a statewide population. Our approach is based on repetitive educational experiences for both general obstetric and specialized perinatal sonographers plus a process that embeds fetal cardiologists within the Maternal-Fetal Medicine clinics to provide supervised definite fetal cardiovascular malformation diagnosis. Our approach has resulted in a high prenatal detection rate in Nevada.[3,4] Our high prenatal detection rate allows us to approximate the direct cost of fetal echocardiography and consultative services that occur at the time of fetal diagnosis. Further, the type of insurance coverage was not statistically significantly different between those prenatally diagnosed versus those non-prenatally diagnosed; thus, we found no bias towards those without insurance and non-prenatally diagnosed Congenital Heart Disease in our statewide population.

From our analysis, our approach for prenatal detection of congenital cardiovascular malformations in Nevada results in an estimated cost of about $7,500 per case detected, for those born during the study period. During this same time, Nevada's legally mandated postnatal oxygen saturation screening program identified one patient with Total Anomalous Pulmonary Venous Connection, before discharge from a newborn nursery. Despite inquires, the actual cost per newborn for mandated universal oximetry screening in Nevada could not be obtained. However, Reeder and associates estimated a hospital cost range of $2.60 to $24.52 per screen.[10] If we assume an average of $14 per screen, the 29,000 Nevada infants, born between March 2019 and March 2020, underwent postnatal oxygen saturation screening for an annual cost of approximately $392,000, which, during the analysis period, resulted in the detection of one patient with a critical congenital cardiovascular malformation. Our estimated cost per case detected of $7,500 compares favorably with reported costs per case detected of neonatal hypothyroidism or hearing loss, estimated to be $11,200 and $17,500 respectively.[11,12] Further, a cost of $7,500 per case detected in our program with an 80% fetal cardiovascular malformation detection rate is far less than has been modeled or theorized by some with values ranging from $21,000 to $145,000 per case detected.[6,13,14]

Our statewide prenatal diagnosis data, similar to others,[15] shows that two conditions remain especially challenging: coarctation of the aorta and total anomalous pulmonary venous connection (TAPVC). Regarding routine obstetric fetal cardiac echocardiographic screening views, both conditions may have essentially normal four-chamber fetal echocardiographic views, other than right-ventricle to left-ventricle size discrepancy, which may be subtle. Coarctation of the aorta may have an abnormal three-vessel-trachea view; however, for TAPVC, all screening views may appear nearly normal, consequently leading to the lowest prenatal detection rate. The one case detected during the study period by mandated state-wide postnatal oximetry screening was a patient with TAPVC; however, all others that had a failed postnatal oximetry screen were false-negative tests suggesting the general ineffectiveness of postnatal oximetry screening in Nevada.[3,4]

A major limitation of this analysis is the small number of patients, inherent in studying rare conditions. Further, we limited our analysis to an estimate of the cost per case of Congenital Heart Disease prenatally detected, rather than a more extensive cost analysis. Nevertheless, a more extensive analysis would have required many additional assumptions that, in our opinion, would not have been consistent with the objective of this study. The major strength of this report is our approach to prenatal congenital heart disease detection, which has allowed us to develop robust internal data management that simultaneously tracks maternal, fetal, and neonatal information for a state-wide population, rather than relying on third-party data such as hospital discharge coding, insurance claims, or other administrative information. The reliance on third-party data has been identified as a possible limitation to quality improvement initiatives directed at enhancing prenatal detection of Congenital Heart Disease.[8]

Conclusion

The estimated cost per case of either significant or critical congenital cardiovascular malformations prenatally detected in Nevada's fetal cardiology program compared favorably with costs per case identified from programs designed to detect other non-cardiac congenital conditions, such as hearing loss.

Acknowledgements

This work would not be possible without the contributions of many. The authors first thank the perinatologists and the perinatal sonographers at the following Nevada maternal-fetal-medicine programs: High Risk Pregnancy Center in Las Vegas and Reno, Desert Perinatal Associates in Las Vegas, UNLV Perinatology in Las Vegas, Healthcare Partners Perinatology in Las Vegas, and Perinatology Associates of Northern Nevada in Reno. Finally, we thank all the fetal cardiologists in Las Vegas and Reno at the Children's Heart Center Nevada.

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PEDIATRIC CARDIOLOGY: How It Has Evolved Over the Last 50 Years

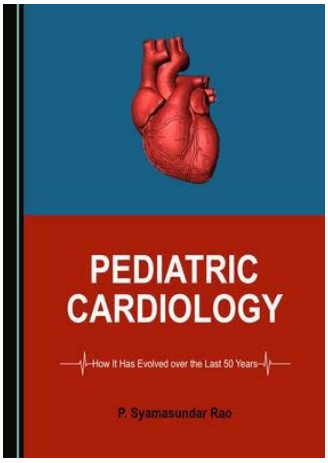
P. Syamasundar Rao, MD

Book Reviewed by *John W. Moore, MD, MPH*

Dr. P. Syamasundar Rao, known as "Syam" to his colleagues, retired recently as a practicing pediatric cardiologist. On the eve of retirement, he occupied the position of Chief of Pediatric Cardiology at the UT Health McGovern Medical School in Houston and held the rank of Professor of Pediatrics & Medicine. Dr. Rao had a long and distinguished career in Pediatric Cardiology beginning in the 1960's. He was one of the early interventional pioneers and played major roles in developing and studying valvuloplasty and angiography, as well as in studying occlusion procedures. He published prolifically about intervention and about other topics in general cardiology. During his career, Dr. Rao held leadership positions in the Pediatric Cardiology programs in Augusta, Georgia; Riyad, Saudi Arabia; Madison, Wisconsin; Saint Louis, Missouri; as well as in Houston. He received numerous awards and recognitions, including the Dr. K.C. Chaudhuri Lifetime Achievement Award from the India Institute of Medical Sciences in New Delhi.

PEDIATRIC CARDIOLOGY: How It Has Evolved Over the Last 50 Years is a companion volume to his recent book entitled: *The Journey of an Indian-American Pediatric Cardiologist A Memoir - With Emphasis on Scientific Contributions to the Medical Literature (*reviewed in *Congenital Cardiology Today's* June 2020 Issue). *PEDIATRIC CARDIOLOGY* more than anything else is a detailed catalogue of Dr. Rao's studies and publications over the many decades of his career. Dr. Rao provides 23 chapters which highlight his life's work to some degree in chronological order.

After two short chapters outlining his career and the statistical methods used in his papers, he proceeds with chapters entitled "Physiologically Advantageous Ventricular Septal Defects" and "Tricuspid Atresia." It is clear at this point that the book is not a comprehensive textbook of pediatric cardiology (as one might expect from its title). He proceeds with chapters highlighting his publications, on diagnostic methods (ECG, Echocardiography, and Cardiac Catheterization). Thereafter he veers into specific lesions which are treated by interventional methods (Pulmonary Stenosis, Aortic Stenosis, Coarctation of the Aorta, ASD, PDA and VSD). In these chapters he devotes most of the content to coverage of his publications and contributions to the interventional treatment of these lesions. Finally, Dr. Rao includes random chapters covering a variety of topics including: Stents, Interventional Treatments in Infants, Cyanotic Congenital Heart Disease, and Adult Congenital Heart Disease. Each of these chapters are likewise largely devoted to describing and summarizing some of his most important reports.



Like his memoir, this book is about the career of a proud and accomplished pediatric cardiologist whose professional life spanned almost the entire history of our specialty. It is the story of Dr. Rao's life's work. Like a number of others in his generation of early practitioners and pioneers, Dr. Rao made significant contributions which are chronicled in detail in this volume.

Available on Amazon
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BEST CHILDREN'S HOSPITALS U.S.News & WORLD REPORT CARDIOLOGY & HEART SURGERY 2019-20

Nicklaus Children's pediatric specialty programs have time and again been ranked among the best in the nation according to *U.S.News & World Report*. Established in January 2015 as Pediatric Specialists of America and rebranded in January 2020, **Nicklaus Children's Pediatric Specialists** is the multispecialty medical group practice of Nicklaus Children's Health System with a regional, national and international presence in providing pediatric-centric care through a collaborative team approach, excellence in clinical care, education and research.

The Heart Program at Nicklaus Children's serves as a beacon to families confronting the reality of a child or newborn with a heart condition. The program offers the most innovative, least invasive approaches to the treatment of congenital heart disease, including many first-in-the-world procedures that were pioneered by our own internationally renowned team.

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Dr. Judy W. Hung Elected President of the American Society of Echocardiography

On July 1, 2020 Judy W. Hung, MD, FASE, took the helm as President of the *American Society of Echocardiography (ASE)*. She has served on the Board of Directors as Vice President and President-Elect prior to ascending to her one-year presidency.

Dr. Hung shared her vision for the future of *ASE* on Saturday, August 8, during the opening session of the *ASE 2020 Scientific Sessions Virtual Experience*, **https://www.asescientificsessions.org/ase-2020-virtual-experience-2/**. When asked about her upcoming presidency, she said "I see tremendous opportunity for *ASE* to advance its mission to be the leader of quality, education, innovation, research, and advocacy in the field of cardiovascular ultrasound. *ASE* is currently well-positioned to adapt to the changing and challenging healthcare environment and to lead innovation in echocardiography through its international reputation, organizational infrastructure, and commitment to quality and research. I have a deep admiration and belief in the goals and mission of the *ASE* and the dedication of my *ASE* member colleagues."

Dr. Hung is Director of the Echocardiography Lab, Division of Cardiology, at Massachusetts General Hospital and Professor of Medicine at Harvard Medical School. She has a special interest in Valvular Heart Disease, Coronary Artery Disease, and in optimizing noninvasive cardiac imaging techniques to improve diagnosis and treatment of heart disease. Her research involves understanding mechanisms of valvular heart disease and development of novel therapies to treat valve disease. Dr. Hung received her undergraduate degree from Harvard University and her medical degree from Tufts University. She completed her internship in Medicine at UCLA Medical Center in Los Angeles before becoming a cardiovascular research fellow at the University of California San Diego (UCSD) Medical Center, San Diego, CA where she also completed her medical residency training. Dr. Hung moved to Massachusetts General Hospital in 1994 where she completed a two-year general cardiology fellowship and then obtained subspecialty training completing a two-year clinical and research advanced echocardiography fellowship. This fellowship included training in Adult Congenital Heart Disease at Children's Hospital in Boston, MA. Upon completion of her clinical and research fellowship training, Dr. Hung joined the Cardiology Division in the Department of Medicine, at Massachusetts General Hospital as an attending cardiologist.

Dr. Hung has a long record of service to the Society. She has served in a number of roles across the organization including Chair of the 2013 Scientific Sessions Committee, Chair of the Education Committee 2014-2017, and a member of the Journal of the American Society of Echocardiography Editorial Board, the Workflow and Lab Management Task Force, and the Finance Committee. In 2001, she presented the 11th Annual Feigenbaum Lecture titled, "A Tale of Two Leaflets: Innovation in Echocardiography." In addition to committee work, Dr. Hung has also served on the writing groups of a number of *ASE* guideline publications. Most recently she was the lead author on the *ASE* Statement on the Reintroduction of Echocardiography Services During the COVID-19 Pandemic, **https://www.asecho.org/wp-content/uploads/2020/05/ASE-Reintro-Statement-FINAL.pdf**. Joining Dr. Hung as new members of the 2020-2021 Executive Committee are Vice President, Stephen H. Little, Houston Methodist DeBakey Heart & Vascular Center, Houston, TX (his term begins Sept. 1, 2020); and Council Representative, Meryl Cohen, MD, FASE, Children's Hospital of Philadelphia, Philadelphia, PA.

Continuing *ASE* officers include: President-Elect, Raymond Stainback, MD, FASE, Texas Heart Institute, Baylor St. Luke's Medical Center, Houston, TX; Treasurer, Carol Mitchell, PhD, RDMS, RDCS, RVT, RT(R), ACS, FASE, University of Wisconsin Hospital, Madison, WI; Immediate Past President, Madhav Swaminathan, MD, FASE, of Duke University Medical Center, Durham, NC; and Secretary, Matt Umland, ACS, RDCS, FASE, Aurora Health Care, Milwaukee, WI.

In addition to the new officers, the *ASE* membership has elected the following new board of directors members to two-year terms: Keith A. Collins, MS, RDCS, FASE, Northwestern Medicine, Chicago, IL (Council on Cardiovascular Sonography Representative); Danita Sanborn, MD, MMSc, FASE, Massachusetts General Hospital, Boston, MA; Vincent Sorrell, MD, FASE, University of Kentucky, Lexington, KY; Ritu Thamman, MD, FASE, University of Pittsburgh Medical Center, Pittsburgh, PA; and Bryan Wells, MD, FASE, Emory Healthcare, Atlanta, GA (Council on Circulation & Vascular Ultrasound Representative).

Board members continuing with their final year of service include Piers Barker, MD, FASE, Duke University Medical Center, Durham, NC (Pediatric Council Steering Committee Chair); Alina Nicoara, MD, FASE, Duke University Medical Center, Durham, NC (Perioperative Council Steering Committee Chair); Alan S. Pearlman, MD, FASE, Seattle, WA (Past President representative); Peter Rahko, MD, FASE, University of Wisconsin, Milwaukee, WI; Jennifer Schaaf, BS, ACS, RDCS, FASE, The Christ Hospital Health Network, Cincinnati, OH; Vandana Sachdev, MD, FASE, National Institute of Health, Bethesda, MD; and Cathy West, MSc, DMU (CARDIAC), AMS, EACVI CHD, FASE, Royal Brompton Hospital, London, UK (International representative); and Geoffrey Rose, MD, FASE, Sanger Heart & Vascular Center, Charlotte, NC.

This announcement underscores the organization's commitment to reflecting the talent and diversity of the cardiovascular field. With the new members, the leadership's gender makeup now comprises 47% women and contains representatives from major sub-specialties in the field including: Circulation, Pediatrics, Anesthesiology, Sonography, and Interventional Echo.

ASE is the Society for Cardiovascular Ultrasound Professionals™. Over 17,000 physicians, sonographers, nurses, and scientists are members of ASE making it the largest global organization for cardiovascular ultrasound imaging and as such the leader and advocate, setting practice standards and guidelines for the field. The Society is committed to advancing cardiovascular ultrasound to improve lives. For more information about ASE, visit ***ASEcho.org*** *and follow us* ***@ASE360****. For more information about the ASE Scientific Sessions visit* ***ASEScientificSessions.org****. For more information about ASE's charitable arm, ASE Foundation, visit* ***ASEFoundation.org****.*

Abbott's TriClip™ Becomes First Device of Its Kind to Receive CE Mark for Minimally Invasive Tricuspid Valve Repair

- CE Mark for TriClip represents an important treatment option for people with severe tricuspid regurgitation, a difficult-to-manage heart condition
- New system offers a proven safe and effective minimally invasive non-surgical solution
- The TriClip System leverages Abbott's proven clip-based technology used in its MitraClip™ transcatheter mitral valve therapy

PRNewswire - Abbott (NYSE: ABT) announced that its TriClip™ Transcatheter Tricuspid Valve Repair System received CE Mark and is now approved for use in Europe and other countries that recognize CE Mark as a non-surgical treatment for people with a leaky tricuspid valve, a condition known as Tricuspid Regurgitation (TR). With the CE Mark designation, Abbott's TriClip device is the first minimally invasive, clip-based tricuspid valve repair device to be commercially available in the world. Abbott is a global leader in developing transcatheter treatments for heart valve disorders and has brought to market three first-in-class therapies for structural heart disease: MitraClip for mitral valve repair, Tendyne™ for mitral valve replacement, and now TriClip to treat the tricuspid valve.

The tricuspid valve, often referred to as the "forgotten heart valve," has three leaflets that control the flow of blood between the two chambers on the right side of the heart. When those leaflets do not close properly, blood can flow in the reverse direction – known as regurgitation – forcing the heart to work harder. When left untreated, TR can lead to conditions such as atrial fibrillation, heart failure, and ultimately, death. The condition is difficult to treat, however, and options for patients have historically been extremely limited. People with TR are typically older and suffer from multiple co-morbidities, making open-heart surgery a high-risk procedure.

The TriClip procedure repairs the tricuspid valve without the need for open-heart surgery. The device is delivered to the heart through the femoral vein in the leg and works by clipping together a portion of the leaflets of the tricuspid valve to reduce the backflow of blood. This approach allows the heart to pump blood more efficiently, relieving symptoms of TR and improving a person's quality of life.

"Patients suffering from severe tricuspid regurgitation are extremely ill and have very few treatment options," said Georg Nickenig, MD, PhD, Professor and Chief, Department of Cardiology, University Hospital, Bonn, Germany, and lead investigator of the TRILUMINATE trial, which generated strong data that helped lead to the CE Mark of TriClip. "Abbott's TriClip could profoundly impact how physicians treat these patients. The therapy is backed by data proving safety and performance, durability, and improved patient quality of life."

The CE Mark for TriClip follows positive six-month data from Abbott's pivotal TRILUMINATE study examining edge-to-edge repair technique using TriClip, which was published in The Lancet, **https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(19)32600-5/fulltext** in November 2019. The study demonstrated that TriClip reduced severity of TR and was associated with strong improvement in functional capacity and in quality of life at six months.

"Tricuspid regurgitation is a highly prevalent, yet seldom treated disease, which is why this approval is a significant milestone for the healthcare community. TriClip has the potential to fill a treatment gap and transform how doctors are able to help people with tricuspid regurgitation," said Michael Dale, senior vice president of Abbott's structural heart business. "Our clip-based technology provides clinicians a life-changing, proven safe, simple, and effective option to treat people suffering from a crippling and life-threatening disease."

TriClip builds upon the proven success of Abbott's MitraClip device, which treats people with leaky mitral valves, or Mitral Regurgitation (MR). TriClip leverages the same clip-based technology as MitraClip but has a differentiated delivery system designed specifically for delivery to the tricuspid valve. A new, steerable guiding catheter system adapts to the right side of the heart, where the tricuspid valve resides, enabling the physician to effectively grasp and clip the leaflets of the tricuspid valve. Additionally, the TriClip device is available in two different sizes (NT and XT) to accommodate different patient anatomies.

The MitraClip system is the first and only transcatheter mitral valve therapy with more than 16 years of clinical experience and proven safety, survival and durable clinical outcomes. More than 100,000 patients have been treated worldwide with the device. Abbott also recently announced CE Mark approval of its Tendyne Transcatheter Mitral Valve Implantation System, a minimally invasive valve replacement option to add to its portfolio of mitral solutions.

For US important safety information on MitraClip, visit: **https://www.structuralheartsolutions.com/us/mitraclip-isi**.

The TriClip Transcatheter Tricuspid Valve Repair System is an investigational device only in the US.

The Tendyne Transcatheter Mitral Valve Implantation System is an investigational device only in the US.

NOVEMBER

09-10

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18-20

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11-12

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Children's Minnesota and Mayo Clinic Announce Pediatric Cardiovascular Collaboration

Now One of the Largest and Strongest Pediatric Cardiovascular Programs in the Country

PRNewswire - Children's Minnesota and Mayo Clinic announced today that they have reached the next phase of an agreement to collaborate in the care of children with congenital heart disease. This phase of the agreement adds pediatric cardiology to the existing cardiovascular surgery collaboration, which began in January 2020, and builds on each organization's shared culture and passion for children as well as the complementary strengths of both programs.

The Mayo Clinic – Children's Minnesota Cardiovascular Collaborative is one of the largest and strongest pediatric cardiovascular programs in the country.

"This collaboration enables Children's Minnesota and Mayo Clinic physicians to treat increased numbers of patients with serious or complex medical conditions, with the goal to improve outcomes for our most vulnerable patients," said Dr. Marc Gorelick, President and CEO of Children's Minnesota. "Through this collaboration, we will expand our ability to share knowledge and expertise, and drive innovations in care delivery, experience and research."

Children's Minnesota and Mayo Clinic will share talent and resources in order to provide the highest quality pediatric cardiology and cardiovascular surgery services. As part of the agreement, physicians from each organization will provide coverage for each other in Rochester and Minneapolis.

"We are proud to build on our long-standing relationship with Children's Minnesota to provide the best care for our patients," said Dr. Jonathan Johnson, Mayo Clinic Pediatric Cardiologist. "Ultimately, our goal is to enhance patient experience and deliver the highest quality outcomes."

CONGENITAL CARDIOLOGY TODAY

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