Critical Congenital Heart Disease in Nevada: The Quest for Universal Prenatal Detection

By William N. Evans, MD and Ruben J. Acherman, MD

Introduction

From pregnant mothers receiving routine obstetric care, referrals to perinatologists for those with maternal-fetal risk factors or suspected fetal cardiac problems create an opportunity for population-wide, near-universal prenatal detection of Critical Congenital Heart Disease.¹ Our quest is to take this opportunity and turn it into reality. This report provides details and data on our approach and success.

Program History and Approach

Ruben Acherman, trained at Toronto Sick Kids and previously on the faculty at the University of Southern California’s Children’s Hospital Los Angeles, and Los Angeles County Hospital, established our Fetal Cardiology Program in 2002. From the beginning of the program’s foundation, we expressly set out to avoid perinatal-care silos.² Rather than requesting perinatologists and obstetricians refer patients with suspected fetal heart disease to our center, we asked that referrals be to Maternal-Fetal Medicine specialists. Then, Acherman would travel to the four Southern Nevada perinatal offices and train the community’s nine fetal sonographers to perform comprehensive fetal echocardiograms under his supervision at their locations. Onsite, real-time supervision allowed for sonographer-fetal cardiologist interaction and fetal cardiologist-perinatologist face-to-face consultation. Further, we elected that perinatologists bill for the fetal echocardiograms, as their technicians performed the studies with their equipment, and Acherman billed for evaluation and management. This system persists; although, currently there are 11 Maternal-Fetal Medicine offices throughout Nevada, in five different perinatal groups with a total of 40 perinatal sonographers, all trained to perform comprehensive fetal echocardiograms, and with each diagnostic study under the supervision of a fetal cardiologist. Now, seven fetal cardiologists provide five days-a-week coverage for scheduled Maternal-Fetal-Medicine office patients, along with same-day consultations as needed. We also provide onsite, real-time Fetal Cardiology on-call services 24-7, 365 days-of the-year to all Nevada’s 12 urban hospital maternal units for urgent or emergent fetal cardiac evaluations. Following identification of significant Fetal Congenital Heart Disease, parents receive further congenital cardiovascular surgical or interventional cardiology consultation and counseling at our congenital heart center.

In 2007, we published our program’s results for Southern Nevada.³ Our data demonstrated a 36% prenatal detection rate for those live-born with Critical Congenital Heart Disease from mothers receiving standard obstetric care, consistent with reports...
The symposia for the general sonographers specifically emphasize normal findings. We show diagrammatic representations of the normal five-axial views, followed by numerous video clips of normal and a few examples of abnormal fetal echocardiograms for each of the five views. We emphasize the importance of referring patients to Maternal-Fetal Medicine specialists with abnormal or questionable findings, not necessarily making a specific diagnosis. We have given identical presentations to the Cardiac Ultrasound School of the College of Southern Nevada. We supplement visual presentations with extensive handouts that reinforce the material. Conferences for specially perinatal sonographers include advanced topics in Fetal Echocardiography. Additionally, many general and perinatal sonographers have attended our past annual free, all-day pediatric-cardiac conferences that we developed state-wide for healthcare provider education in Congenital Heart Disease. Each annual conference has included some two-three hours of Fetal and Neonatal Cardiology instruction. Free conferences also include
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Indications: The Melody TPV is indicated for use in the management of pediatric and adult patients who have a clinical indication for intervention on a dysfunctional right ventricular outflow tract (RVOT) conduit or surgical bioprosthetic pulmonary valve that has ≥ moderate regurgitation, and/or a mean RVOT gradient ≥ 35 mm Hg.

Contraindications: None known.

Warnings/Precautions/Side Effects
- DO NOT implant in the aortic or mitral position. Pre-clinical bench testing of the Melody valve suggests that valve function and durability will be extremely limited when used in these locations.
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- DO NOT use if there are clinical or biological signs of infection including active endocarditis. Standard medical and surgical care should be strongly considered in these circumstances.
- Assessment of the coronary artery anatomy for the risk of coronary artery compression should be performed in all patients prior to deployment of the TPV.
- To minimize the risk of conduit rupture, do not use a balloon with a diameter greater than 110% of the nominal diameter (original implant size) of the conduit for pre-dilation of the intended site of deployment, or for deployment of the TPV.
- The potential for stent fracture should be considered in all patients who undergo TPV placement. Radiographic assessment of the stent with chest radiography or fluoroscopy should be included in the routine postoperative evaluation of patients who receive a TPV.
- If a stent fracture is detected, continued monitoring of the stent should be performed in conjunction with clinically appropriate hemodynamic assessment. In patients with stent fracture and significant associated RVOT obstruction or regurgitation, reintervention should be considered in accordance with usual clinical practice.

Potential procedural complications that may result from implantation of the Melody device include the following: rupture of the RVOT conduit, compression of a coronary artery, perforation of a major blood vessel, embolization or migration of the device, perforation of a heart chamber, arrhythmias, allergic reaction to contrast media, cerebrovascular events (TIA, CVA), infection/sepsis, fever, hemotoma, radiation-induced erythema, pain, swelling, or bruising at the catheterization site. Potential device-related adverse events that may occur following device implantation include the following: stent fracture.* Stent fracture resulting in recurrent obstruction, endocarditis, embolization or migration of the device, valvular dysfunction (stenosis or regurgitation), paravalvular leak, valvular thrombosis, pulmonary thromboembolism, hemolysis.

*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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- Severe RVOT obstruction, which cannot be dilated by balloon
- Obstruction of the central veins
- Clinical or biological signs of infection
- Active endocarditis
- Known allergy to aspirin or heparin
- Pregnancy

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free continuing education credits for physicians, nurses, sonographers, and radiology technicians (Figure 2).

We also provide, free-of-charge, a set of cards on lanyards that detail the five-axial fetal-echocardiographic views for the general sonographers to have with them when scanning for ongoing reference for the views and the importance of each (Figure 3). Figure 4 is a blow-up of card number two, which shows the four-chamber view while the reverse side lists the important points associated with the view. Other authors have also emphasized the importance of educational programs as a method for improving prenatal detection of Congenital Heart Disease in general populations.9-11

In 2015, we published a follow-up study analyzing our Southern Nevada data after several years of community-wide education of general and specialty obstetric and perinatal sonographers.12 That study demonstrated a highly statistically significant improvement in community detection of Critical Congenital Heart Disease from our 2007 rate of 36% to a rate of 71% for the period 2012 to 2014 (p < 0.001). Beyond education, we also attributed this significant improvement to, among others, evolving ultrasound equipment with enhanced resolution, sonographer practical experience, and the addition of outflow imaging to the guidelines for a standard obstetric ultrasound.13 A third report, analyzing our state-wide experience from 2016 to early 2019, is now in press.

Current Data

For this article, we analyzed our current, state-wide data from January 2019 to July 2019. For this period, we identified a combined 53 patients, prenatally or postnatally detected, with critical Congenital Heart Disease. Of the 53, 47 were diagnosed prenatally. The 47 prenatal diagnoses were made from 1125 pregnant women that were referred by general obstetricians to Maternal-Fetal-Medicine specialists because of either an abnormal obstetric ultrasound or other maternal-fetal risk factors. Of the 47 prenatally diagnosed patients, one resulted in fetal demise, and one led to an elective termination. The one elective termination represented one of 25 (4%) identified by 24 weeks gestation or earlier. In some European countries, elective termination rates exceed 50% for prenatally diagnosed Congenital Heart Disease, not necessarily even Critical Congenital Heart Disease.14-16 Figure 5 is an organizational chart that breaks down the general data on the 51 live-born patients.

All patients with Critical Congenital Heart Disease born during the first seven months of 2019 had regular prenatal care; thus, the prenatal detection rate was 88% (45/51). Of the six live born patients not prenatally diagnosed, five presented with signs and symptoms before

Figure 2. Sonographer symposium in the Children’s Heart Center Nevada conference room
newborn nursery discharge and before pulse-oximetry screening. The one remaining non-prenatally diagnosed patient presented late to the Emergency Room cyanotic with supracardiac total anomalous pulmonary venous return, after passing the newborn-nursery, pulse-oximetry screening (false-negative result). Table 1 lists the live-born Critical Congenital Heart Diseases by diagnosis and divides the number of total live births, prenatal detection rates, those born at heart centers, those offered comfort care, and the short-term survival. Prenatal detection challenges remain, especially with some aortic arch abnormalities, total anomalous pulmonary venous return, and even simple d-transposition.

Figure 3. Five-axial fetal-cardiac screening views as individual cards for sonographers’ reference while scanning (available on request at no charge at wnevans50@aol.com)

Figure 4. Blow up of fetal-cardiac screening card number 2, the 4-chamber view
Between January 2019 and July 2019, Nevada’s pulse-oximetry screening program resulted in 28 that failed out of approximately 20,500 live births for the period. This number for the seven-months period is consistent with the number of failed tests per annual live births in the state.\textsuperscript{17,18} We consult on all newborns that fail pulse-oximetry screening. Of the 28 that failed pulse-oximetry screening, all 28 were false positives; thus, no patients were identified by pulse-oximetry screening. Others have also shown, as prenatal detection in the population improves, the likelihood of positive pulse-oximetry screens decreasing.\textsuperscript{19} Further, since Nevada’s pulse-oximetry law went into effect in 2015, there have been approximately 230,000 births with approximately 230 failed pulse-oximetry screens up to the end of 2018, and of these, only two (<1%) were positive, and the 228 (>99%) others were false positives. Also, from 2015 to the end of 2018, eight patients that passed newborn nursery pulse-oximetry screening (with false-negative results) presented late in extremis or profoundly cyanotic to hospital emergency rooms. To the best of our knowledge, no patient’s parents opted out of pulse-oximetry screening for an infant later presenting with missed Critical Congenital Heart Disease. According to the Nevada Department of Health and Human Service data, only about three sets of parents, out of approximately 35,000 annual births, opt-out of testing.\textsuperscript{17,18} Finally, between January 2019 and July 2019, there were no unexpected, non-hospital deaths from Critical Congenital Heart Disease, as reported by the Clark County Coroner’s Office Case Reporting System database for the state of Nevada.

Discussion

It is a stubborn fact that Critical Congenital Heart Disease may be missed by newborn nursery discharge examinations, as desaturation may be subtle, heart murmurs may be absent, and immediate postnatal circulation can mask critical lesions. Such realities have led states to mandate routine newborn pulse-oximetry screening.\textsuperscript{19,20} Nevada’s law went into full effect in 2015.\textsuperscript{21} Nevertheless, a failed pulse-oximetry screen is not specific for an exact cardiac diagnosis, and a passed pulse-oximetry screen does not rule out all forms of Critical Congenital Heart Disease.\textsuperscript{22} Alternatively, prenatal detection of Critical Congenital Heart Disease is both sensitive and specific;\textsuperscript{23,24} thus, prenatal diagnosis, in contrast to pulse-oximetry screening, is the superior evidence-based diagnostic method.

Further, prenatal diagnosis allows prenatal counseling for parental stress reduction, time to better understand the diagnosis’s implications,\textsuperscript{25} prenatal consultation with a care team, and directed delivery at a facility with a fully equipped and staffed congenital heart unit. Recently, Neha Purkey and associates authored a study from California on the birth location of
They found that only 24\% of patients with Critical Congenital Heart Disease were born in a facility with a Level 4-NICU. By definition, a Level 4-NICU is in a facility capable of performing surgery for congenital cardiac malformations that require cardiopulmonary bypass. In contrast, Nevada’s high prenatal detection rate allowed directed delivery to the Congenital Heart Center for 91\% of the prenatally diagnosed patients. The other 9\% constituted four of the prenatally-diagnosed Reno patients whose families elected a Reno birth, followed by a neonatal transfer to the heart center. Directed delivery reduces the need for neonatal transport. Although some past studies have produced equivocal results, recent reports have shown that prenatal diagnosis of Critical Congenital Heart Disease provides advantages over postnatal diagnosis by facilitating neonatal management and reducing morbidity and mortality.

### Table 1. Data breakdown of all 51 live-born patients with critical congenital heart disease

<table>
<thead>
<tr>
<th>Condition</th>
<th>Total Live Births n</th>
<th>PNC n</th>
<th>PND/PNC n (%)</th>
<th>Heart Center Birth PND n (%)</th>
<th>Comfort Care LB n (%)</th>
<th>Alive n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAA</td>
<td>4</td>
<td>4</td>
<td>3 (75)</td>
<td>3 (100)</td>
<td>0</td>
<td>4 (100)</td>
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<tr>
<td>Ebstein</td>
<td>1</td>
<td>1</td>
<td>1 (100)</td>
<td>0</td>
<td>0</td>
<td>1 (100)</td>
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<tr>
<td>Truncus</td>
<td>2</td>
<td>2</td>
<td>2 (100)</td>
<td>1 (50)</td>
<td>0</td>
<td>2 (100)</td>
</tr>
<tr>
<td>TAPVR</td>
<td>2</td>
<td>2</td>
<td>1 (50)</td>
<td>1 (100)</td>
<td>0</td>
<td>2 (100)</td>
</tr>
<tr>
<td>HLH</td>
<td>5</td>
<td>5</td>
<td>5 (100)</td>
<td>5 (100)</td>
<td>1 (20)</td>
<td>4 (80)</td>
</tr>
<tr>
<td>DTGA</td>
<td>3</td>
<td>3</td>
<td>1 (33)</td>
<td>1 (100)</td>
<td>0</td>
<td>3 (100)</td>
</tr>
<tr>
<td>DORV</td>
<td>5</td>
<td>5</td>
<td>5 (100)</td>
<td>5 (100)</td>
<td>0</td>
<td>5 (100)</td>
</tr>
<tr>
<td>Univentricle</td>
<td>11</td>
<td>11</td>
<td>11 (100)</td>
<td>11 (100)</td>
<td>0</td>
<td>10 (91)</td>
</tr>
<tr>
<td>ToF + PA/VSD</td>
<td>5</td>
<td>5</td>
<td>5 (100)</td>
<td>4 (80)</td>
<td>0</td>
<td>5 (100)</td>
</tr>
<tr>
<td>Coarctation of Ao</td>
<td>13</td>
<td>13</td>
<td>10 (77)</td>
<td>10 (100)</td>
<td>0</td>
<td>13 (100)</td>
</tr>
<tr>
<td>Total, n (%)</td>
<td>51</td>
<td>51</td>
<td>45 (88)</td>
<td>41 (91)</td>
<td>1 (2)</td>
<td>49 (96)</td>
</tr>
<tr>
<td>n/1000 LB</td>
<td>2.2/1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend: Ao aorta, DTGA d-transposition of the great arteries, DORV double outlet right ventricle, HLH hypoplastic left heart, IAA interrupted aortic arch, LB live-born, PNC prenatal care, PND prenatal detection, TAPVR total anomalous pulmonary venous return, ToF + PA/VSD tetralogy of Fallot and pulmonary atresia-ventricular septal defect.
Conclusions

Achieving universal prenatal detection of Critical Congenital Heart Disease in large, general populations does not require performing a comprehensive fetal echocardiogram on every fetus. Using our approach of sonographer education and onsite, real-time fetal cardiology-perinatal care collaboration, we have demonstrated a rising prenatal detection rate over time in Nevada. In 2019, we are now approaching a 90% (which some consider essentially universal) detection rate for Critical Congenital Heart Disease in a geographically diffuse, state-wide, general population. The number of emergent, neonatal transports has been reduced, and a significant majority of mothers are directed to deliver at Nevada’s Congenital Heart Center. In contrast, state-mandated, postnatal pulse-oximetry screening has been mostly ineffective. In our opinion, our data supports our approach, as we continue our quest to achieve universal prenatal detection of Critical Congenital Heart Disease in Nevada.

Acknowledgments

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Interventional Cardiologist

Saint Louis University, a Catholic, Jesuit institution dedicated to student learning, research, health care, and service is seeking an additional pediatric cardiologist to join an established group within the Division of Cardiology and the Department of Pediatrics at SSM Health Cardinal Glennon Children’s Hospital. Applicants must be board certified/eligible in Pediatric Cardiology. General responsibilities will include clinical care, teaching, and research.

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