diameter depending on the diameter of the PAFR. However, in order to reduce the delivery size and profile of the device, multi-layer nitinol wire mesh was used, without any fabric. In order to more consistently restrict pulmonary blood flow, a single hole was made with a specific diameter based on the diameter of the PAFR. The delivery cable was modified from the stainless steel system to a smaller diameter nitinol wire with a flexible transition zone to attach to the device. The device can be delivered through a 5Fr delivery catheter. While preliminary work is encouraging, more modifications of the PAFR and deliver cable are planned. In addition, it may be that a Hybrid delivery of the PAFR and PDA stent will be "safer" for the baby with HLHS by avoiding placing catheters and wires across the TV and PV and causing hemodynamic compromise. There will be other uses for the PAFR as complex CHD continues to be treated with innovative strategies.

PDA STENTING FOR HLHS: CHOICES AND TECHNIQUES

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Precise stenting of the PDA is crucial for the success of the initial hybrid palliation for HLHS. Probably, the only relative contraindications for PDA stenting is the presence of a significant obstruction in the distal aortic arch, which can become critical after the stent is deployed. This should be diagnosed prior to the procedure using echocardiography. A remarkable posterior shelf in the ascending aorta is seen just after the take-off of the left subclavian artery (the "3-signs"). Retrograde flow acceleration within the arch is also recorded. PDA stenting is preferentially performed in the operating room immediately after the pulmonary arteries are banded. Prostaglandins are discontinued when the neonate arrives in the OR. A 6 Fr short sheath is surgically placed and secured in the MPA just above the pulmonary valve sinuses. Only about 0.5 cm of its tip remain inside the vessel. Some contrast media is manually injected through the lateral port of the sheath and an angiogram is obtained in the left lateral view, sometimes with some cranial angulation. High quality pictures are required for the procedure. Digital measurements are made and the diameters of the descending aorta and the proximal, mid and distal portions of the PDA are recorded. In order to avoid residual ductal stenosis, the stent should cover the whole length of the ductus, extending from the point just after the origin of both pulmonary arteries until the transition with the descending aorta, usually varying from 15 to 25 mm. There are 2 choices of stents: balloon expandable (BE) and self-expanding (SE) stents, both deployed over a guide wire left in the distal descending aorta across the PDA. Some have used the BE stents only for cases with a narrowing in the mid-portion of the PDA. Their diameter should be slightly larger than the proximal or distal ductal diameter, whichever is larger, usually varying from 7 to 10 mm. Pre-mounted, low profile BE stents are easily available in the market because they are commonly used for peripheral arterial procedures. In general, the SE stents are preferentially used because they result in less hemodynamic fluctuations during deployment and are more flexible. However, their precise placement requires more technical skills, training and care. Their diameter should be 10-20% larger than the reference diameter. The Protégé (EV3) and the Precise (Cordis) are SE stents also designed for peripheral procedures that have been used successfully for PDA stenting, with the former having a special "anti-jump" mechanism that facilitates the final deployment. Other brands are available in different countries. Whatever the type of stent used, it is crucial to select their diameter and length appropriately in order to avoid inadvertent migration and proximal or distal protrusion. Uncovered ductal tissue with residual obstruction, significant neointimal proliferation and retrograde aortic obstruction are possible complications. Alternatively, PDA stenting can be performed in the catheterization laboratory through the femoral vein a couple of days after the pulmonary bands are placed surgically. Because of the need to cross the tricuspid and the pulmonary valve, more hemodynamic instability should be expected if this approach is undertaken.

HOW TO DEAL WITH THE ATRIAL SEPTUM IN PATIENTS WITH HLHS

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Patients with hypoplastic left heart syndrome (HLHS) often have restrictive or no atrial level communication. Such patients usually carry poor prognosis. The initial management of such patients include decompressing the left atrium by performing balloon atrial septostomy (BAS). However, due to the thickness of the atrial septum in such patients, BAS may not be effective. Over the last few years, we have employed stent placement in the atrial septum to provide unrestricted flow from the left to right atrium.

Stent implantation can be accomplished at the same time as the hybrid stage-I intervention using what we call "peratral" or it can be done at a separate stage, percutaneously. I'll outline the advantages and disadvantages of each technique and discuss the types of atrial communications present in these babies.

RETROGRADE AORTIC ARCH OBSTRUCTION

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Retrograde aortic arch obstruction (RAAO) is a serious complication of ductal stenting in neonates and infants undergoing the initial hybrid palliation for HLHS. It should be prevented or treated aggressively when it occurs. Prevention includes the recognition of the only relative contra-indication for ductal stenting in HLHS patients, which is the presence of a severe stenosis in the native distal aortic arch. This should be diagnosed prior to ductal stenting using transesophageal echocardiography. In this setting, a remarkable posterior shelf in the descending
aorta is seen just after the take-off of the left subclavian artery (the "3-sign"). Retrograde flow acceleration within the arch is also recorded, associated or not with RV dysfunction and TR. In this scenario, the obstruction becomes critical or complete if the stent is deployed resulting in severe impairment of the retrograde flow within the arch, ascending aorta and coronary arteries. Acute myocardial ischemia with severe RV dysfunction and TR is the cause of death. In order to avoid this complication and preserve coronary blood flow, some advocate the placement of an inverted shunt between the main pulmonary and the innominate artery. This strategy is debatable and have not been accepted in some centers. RAAO can also occur at any point during the follow-up after PDA stenting for phase I. It is found in approximately 10-15% of patients and its causes include stent malposition (too distal), presence of a previously unrecognized posterior shelf, neointimal proliferation within the stent, insufficient flow across the stent struts to match the infant's growth and stent wire mesh distortion (rare). RAAO should be suspected using serial TTE after stent implantation (once every 1-2 weeks). Newly diagnosed RV dysfunction and/or TR may be the early signs of impaired retrograde coronary blood flow. Retrograde flow acceleration within the aortic arch is diagnostic. Treatment should be established as soon as the diagnosis is made, before clinical deterioration in a rapid vicious cycle occurs. It includes balloon dilation or stenting across the stent struts of the previously implanted ductal stent. The later is preferred because is by far more effective. Depending on the underlying anatomy, vascular access is obtained through the femoral artery or right or left common carotid arteries using a 4 Fr sheath. A coronary wire is passed from the descending aorta to the aortic arch or its branches (or the other way around) usually maneuvered across the ductal stent struts. This is not difficult because either the balloon expandable or the self-expanding stent placed in the ductus have an open cell design. A coronary stent with a diameter equal to the distal arch diameter is then deployed across the struts and the stenosis. Although it is technically demanding and challenging, the procedure is usually highly effective with immediate improvement in the retrograde flow, RV function and TR. The additional "hardware" can be safely (but not that easily!) removed from the arch at the phase II operation.

Session 12.
THE PERVERTRICULAR APPROACH

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CHALLENGES OF PERCUTANEOUS CLOSURE OF MVSD

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Since the first percutaneous VSD closure by Lock et al in 1988, various attempts were made to close these defects using the Rashkind umbrella, Clamshell, Cardiosac, Starflex, Sideris buttoned and Gianturco coils. The success rate was between 77 and 100% and the residual shunt was between 35 to 100% with a difficult and often complicated procedure. The introduction of the Amplatz device has enlarged the application of percutaneous techniques to these kind of defects.

PRE-PROCEDURAL ECHOCARDIOGRAPHIC EVALUATION
Echocardiography is needed to evaluate the size, the number and location of the VSD in order to plan the interventional approach. Furthermore, prior to the procedure, AV valves, ventricular function and size and associated lesions are studied.

DEVICE AND PROCEDURE
The Amplatz Muscular VSD occluder is a self expandable device made of Nitinol, consisting of two flat discs with a diameter 8 mm larger than a central connecting waist, which is used to determine the size of the device (from 4 to 18 mm); polyester fabric is incorporated within the Nitinol wire mesh of both discs and connecting waist. The device is secured to a delivery cable and inserted into a delivery sheath ranging from 6 to 9 French in size. All procedures are performed under general anesthesia, with fluoroscopic and transesophageal echocardiographic control. Routine right and left catheterizations are performed, one or more left ventricular angiographies are obtained in axial projections for best evaluation of VSD size and position, in addition to echocardiographic views. Antibiotic prophylaxis and full heparinization are given routinely.

TECHNIQUE OF DEVICE IMPLANTATION FOR MUSCULAR VSD
The VSD is crossed from the left side using a right Judkins catheter and a soft wire, which is advanced to the pulmonary artery and snared with an Amplatz Gooseneck snare (Microvena Corporation, White Bear Lake, MN) and exteriorized out of right internal jugular vein or femoral vein establishing an artero-venous circuit. When the tip of the sheath is placed in the mid cavity of the left ventricle, the dilator and the wire are gently removed. After a left ventriculogram is performed, an occluder 1 to 2 mm larger than the maximum size of the defect is delivered into the left ventricular cavity and withdrawn towards the septum with the left disk and the waist opened. After a final angiogram, the proximal disk is deployed and released. Patients receive a dose of cephalosporin during catheterization and two further doses at 8 hr intervals.