Oklahoma Heart Institute

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Complex Retrograde Chronic Total Occlusion

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The Oklahoma Heart Institute Magazine is mailed directly to referring physicians and other referring health care professionals in the Tulsa area and is also available in our patient waiting rooms.

features

ON THE COVER *Tulsa's iconic Route 66 through the lens of photographer Tyler Lane.*

to our readers

This issue of Oklahoma Heart Institute magazine focuses on newer therapies for treating common to complex problems in cardiology.

Diabetes mellitus is a very common problem affecting millions of Americans. Newer classes of medicine not only lower the elevated blood sugars, but also have been shown to decrease adverse cardiac events.

This issue also looks at the treatment of more complex problems such as pulmonary hypertension and chronic total occlusions.

Finally, the lifesaving procedure of ECMO (Extracorporeal Membrane Oxygenation) is highlighted.

We hope you enjoy the articles and welcome any comments or suggestions regarding the magazine content.

Sincerely,

Wayne Leimbach

Wayne N. Leimbach, Jr., MD
Publisher/Editor,
Oklahoma Heart Institute Magazine

Newer Diabetic Medications Are Good For Patients With Heart Disease

By Wayne N. Leimbach, Jr., MD, FACC, FACP, FSCAI, FCCP, FAHA

Diabetes mellitus is a chronic disease increasing in its prevalence in the United States. Cardiovascular disease continues to be the leading cause of death in patients with Type 2 diabetes mellitus (T2DM).

Newer diabetic medications have been shown in large randomized clinical trials to not only lower blood glucose levels but also reduce adverse cardiovascular events.

The prevention of cardiovascular complications should be a primary objective when treating patients with diabetes mellitus. These trials indicate that these newer medications should be used more frequently and considered earlier in the treatment strategies for patients with Type 2 diabetes mellitus.

GLP – 1 RECEPTOR AGONISTS

A newer class of diabetic medication is referred to as the glucagon-like peptise -1 receptor agonist (GLP-1RA). Included in this class are: liraglutide (Victosa), semaglutide (Ozempic), exenatide XR (Bydureon) and dalaglutide (Trulicity).

These diabetic medications have been shown to improve glycemic control along with reducing weight, and they seem to lower blood pressures.

Three large clinical trials (LEADER, SUSTAIN 6 and HARMONY) showed risk reductions in cardiovascular events. LEADER (liraglutide) and SUSTAIN-6 (semaglutide) showed superiority in the reduction of cardiovascular events when compared to placebo.

The LEADER trial was published in 2016. The study included 9340 patients who were randomized to standard diabetic treatment plus liraglutide or placebo.

After a mean follow up period of 3.8 years, the group of patients receiving liraglutide experienced a 23% reduction in major adverse cardiovascular events (MACE). The primary end point was a reduction in CV death, nonfatal MI and nonfatal stroke.

Numerous mechanisms to explain the benefits of GLP-1 receptor agonists beyond glucose lowering have been discussed, but the actual mechanisms for the CV protective effects are not known.

SGLT-2 INHIBITOR

Another class of diabetic medications shown to have beneficial effects in patients with heart disease is the SGLT-2 inhibitors. SGLT-2 inhibitors (sodium-glucose cotransporter 2 inhibitors) are a newer class of diabetic medications that are approved for use with diet and exercise to lower blood sugars in adults with Type 2 diabetes mellitus. Three of these medications have been studied in large randomized clinical trials including empagliflozin (Jardiance), dapagliflozin (Farxiga), and canagliflozin (Invokana).

Since diabetic patients are at increased risk of cardiovascular events, these new classes of diabetic medications should be considered early when initiating medical treatment strategies for patients with Type 2 diabetes mellitus.

These medications lower blood sugars primarily by preventing glucose from being absorbed in the kidneys. As a result, they lower blood sugars by causing the sugar to spill into the urine where it is then excreted.

More recently, large randomized clinical trials, including the EMPA-REG outcome trial and the DECLARE-TIMI-58 trial have shown reductions in cardiovascular adverse events when the SGLT-2 inhibitors were used to lower blood sugars along with standard of care as compared to standard of care plus placebo.

A recent meta-analysis of three randomized trials involving SGLT-2 inhibitors showed a 31% relative risk reduction for hospitalizations for heart failure in patients treated with the SGLT-2 inhibitors. Patients with reduced left ventricular ejection fractions showed the greatest benefit.

The EMPA-REG trial showed that using empagliflozin (Jardiance) to lower blood sugars also produced a significant relative risk reduction in the end point of cardiovascular death, nonfatal MI and nonfatal stroke. The primary endpoint of CV death, nonfatal MI and nonfatal stroke was reduced by 14%. CV death was reduced by 38% in patients treated with empagliflozin.

In these trials, SGLT-2 inhibitors had acceptable safety profiles and the major side effect was an increased risk of genital mycotic infections.

A recently released study, the DAPA-HF trial, looked at the use of dapagliflozin (Farxiga) in patients with heart failure associated with a reduced left ventricular ejection fraction. The study showed a significant reduction in the risk of worsening heart failure or death from cardiovascular causes among patients receiving dapagliflozin versus placebo.

Since diabetic patients are at increased risk of cardiovascular events, these new classes of diabetic medications should be considered early when initiating medical treatment strategies for patients with Type 2 diabetes mellitus.

The GLP-1 agonists and the SGLT-2 antagonists not only decrease blood sugars, but are associated with weight loss, have a favorable effect on blood pressures and produce a significant reduction in cardiovascular adverse events. People with Type 2 diabetes mellitus should ask their doctors about whether these medications would be suitable for them.

Dr. Leimbach is a specialist in interventional and structural cardiology, including cardiac catheterization, coronary angioplasty, stents, atherectomy, laser, intravascular ultrasound imaging, and direct PTCA/stents for acute myocardial infarction. He also specializes in percutaneous closure of PFOs, ASDs, PDAs and percutaneous valve replacement or repair procedures such as TAVR and MitraClip. He is Director of the Cardiac and Interventional Laboratories at Oklahoma Heart Institute Hospital. Dr. Leimbach is Co-Founder of the Lipid and Wellness Clinic at Oklahoma Heart Institute. He is Director of the James D. Harvey Center for Cardiovascular Research at Hillcrest Medical Center, as well as Director of the Oklahoma Heart Research and Education Foundation. He serves as Clinical Associate Professor of Medicine at the University of Oklahoma College of Medicine-Tulsa.

Complex Retrograde Chronic Total Occlusion

Percutaneous Coronary Intervention Case Presentation

By Raj H. Chandwaney, MD, FACC, FSCAI, FSVM

INTRODUCTION

Chronic total occlusion (CTO) percutaneous coronary intervention (PCI) is very challenging. The hybrid algorithm[1] is presented in Figure 1. It integrates all possible wire crossing strategies, including antegrade wire escalation, antegrade dissection/reentry, and retrograde. The algorithm directs the operator to the safest, most effective, and most efficient strategy based on the anatomy of the CTO. Working through challenges that occur during CTO PCI with algorithmic solutions is at the heart of the hybrid approach. Every CTO case is unique and requires a different set of strategies for success.

The following case was recently selected for presentation at the Trans Catheter Therapeutics International meeting in San Francisco, California on September, 28, 2019. This case illustrates a situation in which a primary retrograde strategy was required because of the presence of an ostial right coronary artery CTO. During the retrograde approach, obstacles were encountered during several steps of the procedure. However, by efficiently moving forward with algorithmic solutions for each of the obstacles that were encountered, a successful outcome was achieved for the patient.

(Please note that a video of the following case summary can be viewed on YouTube by searching Raj Chandwaney and clicking on the CTO video.)

CASE REPORT

A 50 year old male was referred for ongoing angina refractory to maximum tolerated medical therapy. The patient had a remote history of right coronary artery stent approximately five years ago. A recent myocardial perfusion study revealed significant ischemia in the right coronary artery territory. The ejection fraction was normal. Recent coronary angiogram revealed severe single vessel coronary artery disease involving an ostial right coronary artery CTO within a previously placed stent (Figure 2). Dual guide catheter angiography suggested a short segment ostial right coronary artery CTO. After confirming that a hydrophilic wire would not easily cross the lesion via an antegrade approach, a contralateral angiogram was performed via the left coronary artery to map the septal collaterals and facilitate prompt conversion to a retrograde approach (Figure 3). A selective septal angiogram was performed with a Turnpike LP microcatheter to better understand the anatomy of the first septal perforator. Septal surfing with a Fielder FC guidewire was used to efficiently cross the septal collaterals. After crossing the septal collaterals with the wire, the Turnpike LP microcatheter could not be advanced through the septal collateral. Therefore, angioplasty with 1.2 x 20 mm Trek, was performed using a 1.0 x 15 mm Sapphire angioplasty balloons (Figure 4). After optimizing support with a Guideliner guide extension, the septal collateral was ultimately crossed using a lower profile Finecross microcatheter. After crossing the septal collateral with the Finecross microcatheter, the Fielder FC guidewire was replaced with a Pilot 200 guidewire. The Pilot 200 guidewire and Finecross microcatheter were advanced to the distal cap of the right coronary artery CTO. The Pilot 200 guidewire then successfully crossed the CTO retrograde into the aorta. The wire was then advanced

Figure 1

The hybrid CTO algorithm

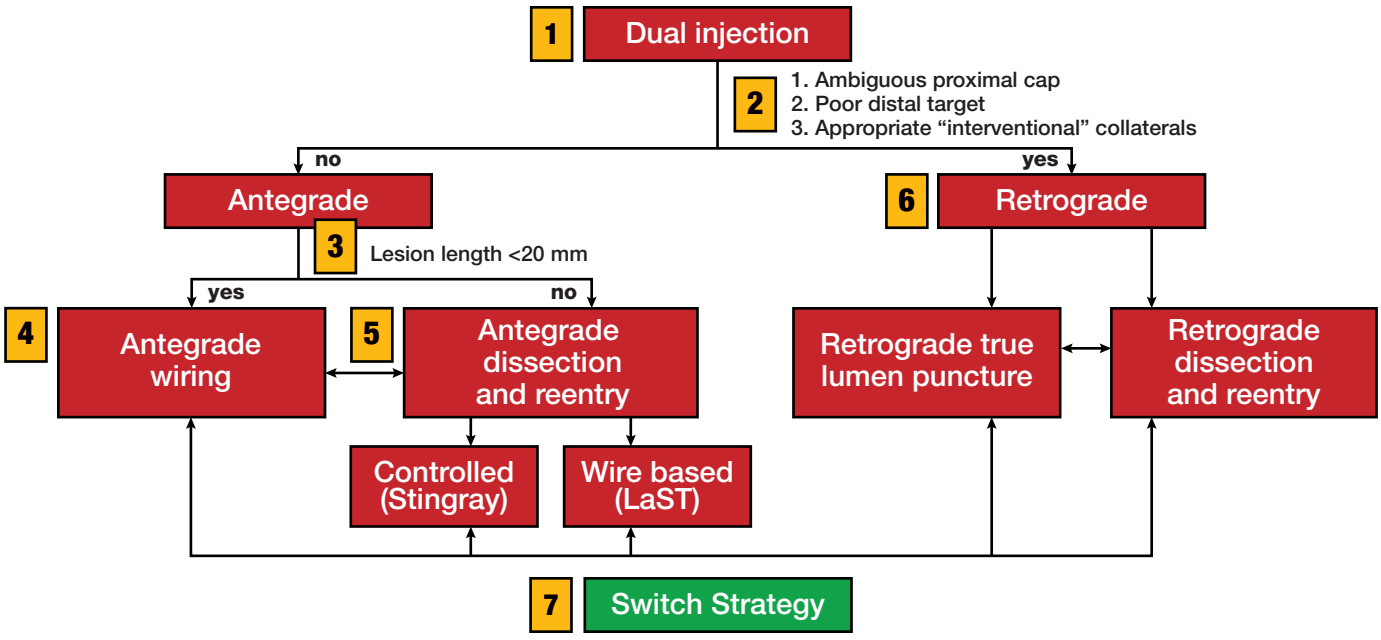
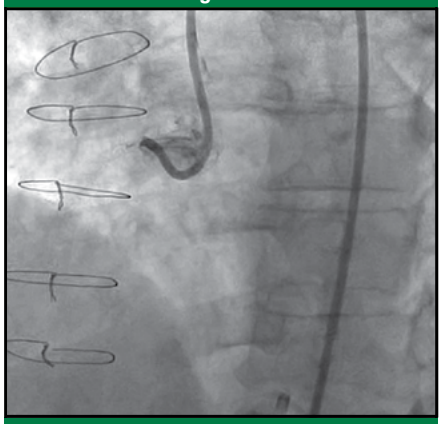
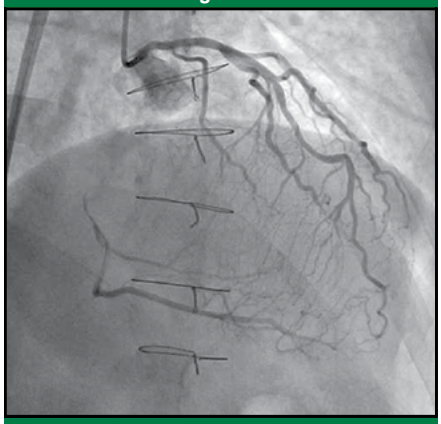


Figure 2



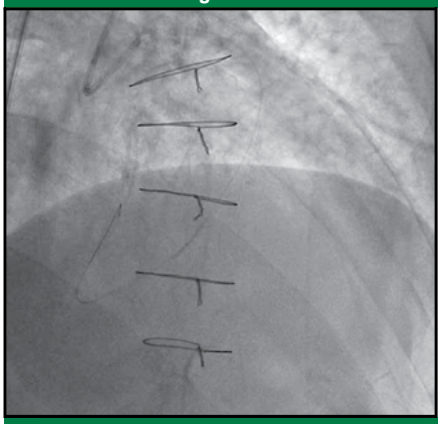
Baseline angiogram of the ostial right coronary artery CTO.

Figure 3



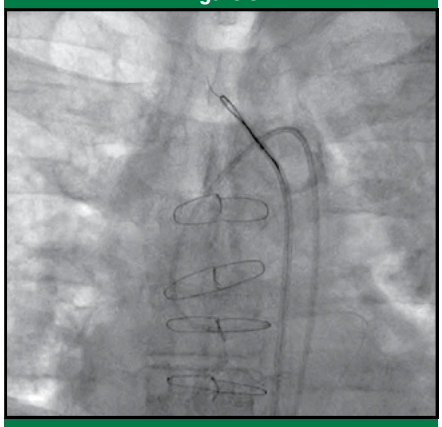
Left coronary angiogram performed to map the septal collaterals to the right coronary artery CTO.

Figure 4



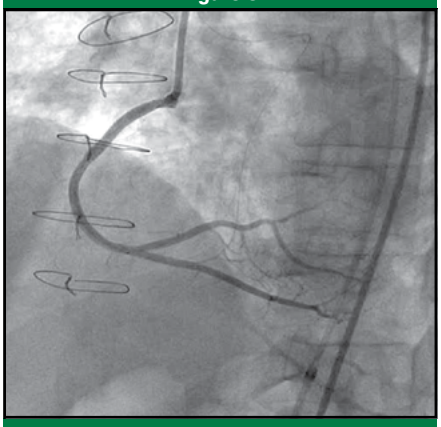
Angiogram demonstrating septal collateral angioplasty with an ultra low-profile balloon advanced over a wire that crossed the septal collateral.

Figure 5



Angiogram demonstrates snaring the retrograde wire into the antegrade guide catheter. This maneuver was performed within the brachiocephalic artery.

Figure 6



Final angiogram reveals an excellent result after treating the right coronary artery CTO with angioplasty and stenting.

up into the brachiocephalic artery, where it was snared into the antegrade guide catheter (Figure 5). The antegrade guide catheter was then carefully seated into the right coronary artery. After advancing the retrograde Finecross microcatheter into the antegrade guide catheter, the Pilot 200 guidewire was replaced with the R350 guidewire that was externalized through the antegrade guide. Angioplasty and stenting was ultimately performed with two Xience Sierra drug eluting stents. An excellent angiographic result was achieved (Figure 6).

DISCUSSION

This case highlights the benefits of applying the hybrid algorithm to CTO PCI. Aorto-ostial CTOs are exceptionally challenging to treat with PCI because of the poor guide catheter stability that is achieved. Prior to the development of advanced CTO PCI techniques, aorto-ostial CTOs would be declared impossible to treat using catheter based techniques. By applying the hybrid algorithm, a strategy can be formulated for aorto-ostial CTOs that have a high chance of success. However, during this case additional obstacles were encountered that needed to be overcome.

After advancing a soft wire across a septal artery collateral, we were initially unable to advance a microcatheter through the collateral. This step is critical to the retrograde approach because it is required to allow exchange of the soft wire for a stiffer wire that could actually cross the CTO. To overcome this obstacle several strategies were applied, including optimizing support of the contralateral guide catheter with a Guideliner, use of a lower profile Finecross microcatheter, and performing septal collateral angioplasty using an ultra low profile 1.0 mm balloon.

Secondly, after wire crossing the length of the CTO retrograde, the wire could not be advanced directly into the antegrade guide catheter because of the inability to stabilize the position of the antegrade guide catheter at the ostium of the right coronary artery. This step is essential to the retrograde approach because it enables the operator to externalize a retrograde wire so that the procedure can ultimately be completed using standard antegrade delivery of angioplasty balloons and stents. This obstacle was overcome by snaring the retrograde wire into the antegrade guide catheter. However, rather than trying to snare the wire at the aortic root (which is usually very challenging and time consuming because of the relatively large size of the aortic root compared to the size of the snare), a 25 mm snare was deployed in the brachiocephalic artery where it fills the entire diameter of the vessel. The retrograde wire was then easily advanced up the ascending aorta and into the brachiocephalic artery, where it tends to travel because of preferential flow towards the brain. Once the wire was in the brachiocephalic artery (and within the loop of the snare), it was efficiently snared into the antegrade guide catheter to allow wire externalization and completion of the case.

Although the hybrid CTO algorithm provides advanced CTO operators a framework to approach challenging CTO cases that were previously declared untreatable, unique obstacles are often encountered during CTO PCI procedures. By applying algorithmic solutions to the obstacles encountered during CTO PCI, a high rate of success can still be achieved with the most complex cases.[2]

Dr. Chandwaney is an interventional cardiologist at Oklahoma Heart Institute with expertise in coronary angioplasty, and related interventional procedures, such as coronary stents, atherectomy, intravascular ultrasound, and peripheral vascular interventional procedures. Dr. Chandwaney was recently invited to participate in PROGRESS CTO. PROGRESS CTO is an international registry that collects data from approximately 60 of the world's most advanced CTO operators to help advance the field of CTO PCI through rigorous study of techniques and outcomes.

REFERENCES

1. Brilakis E, et al. JACC Cardiovasc Interv. 2012; 5: 367-79.
2. Riley R, et al. Cather Cardiovasc Interv. 2019; 93: 286-297.

LET'S DO BRUNCH!

During this busy time of year, brunch is the very best of both worlds where breakfast and lunch come together in one single meal. You may prefer something sweet or you might have more savory tastes. Happily, there's always something for everyone when brunch is served!

SAVORY SAUSAGE AND CHEDDAR BREAKFAST CASSEROLE

Serves 6 to 8

5 cups (1-inch) cubes sourdough or white bread
1/2 pound bulk breakfast sausage cooked and drained (about 1 cup cooked)
1 cup spinach leaves
8 eggs
2 cups reduced-fat (2%) milk
2 cloves garlic finely chopped
1/2 teaspoon fine sea salt
1/2 teaspoon black pepper
1/4 teaspoon dried sage
1 cup grated cheddar cheese

Layer bread, sausage and spinach in an 8-inch baking dish. In a medium bowl, whisk together eggs, milk, garlic, salt, pepper and sage then pour over contents in baking dish. Sprinkle with cheese, cover and chill for at least 2 hours, or preferably overnight.

Preheat the oven to 350°F. Uncover dish and bake until cooked through and golden brown, 50 to 60 minutes. Set aside to let rest for 10 minutes then serve.

MANGO MIMOSAS Serves 6

This refreshing combination of mango purée and sparkling Prosecco is easy to throw together for a quick brunch or cocktail hour. For a variation, substitute pineapple chunks for the mango.

1 small mango, diced (about 1 cup)

1 (750-ml) bottle chilled Prosecco

Place mango in a food processor and process until very smooth, stopping frequently to scrape down the sides of the bowl.

Transfer the purée to a container. Spoon about 1 1/2 tablespoons of the purée into 6 glasses and carefully pour in Prosecco; the drinks will foam up.

Allow foam to settle, then stir each drink once or twice to combine Prosecco and purée.

Serve immediately.

TROPICAL FRUIT WITH HONEY-YOGURT SAUCE

Serves 4

1 cup lowfat vanilla yogurt

1 tablespoon honey

1 (15-ounce) can pineapple rings packed in natural juice drained

1 orange peeled and cut into rounds

2 kiwi peeled and cut into rounds

1/2 cup granola

In a small bowl, stir together yogurt and honey until smooth. On each of 4 small plates, layer pineapple, orange and kiwi to create a stack. Spoon yogurt mixture over the top and sprinkle with granola.

(continued on p. 10)

Continued from p. 9

BLUEBERRY COFFEE CAKE Serves 12

Canola spray oil
2 tablespoons plus 1 cup whole wheat pastry flour divided
1/4 cup light brown sugar
2 tablespoons unsalted butter cut into small pieces
1/2 teaspoon ground cinnamon
1/4 teaspoon ground cardamom
1/2 cup all-purpose flour
1/4 cup sugar
2 teaspoons baking powder
1/2 teaspoon baking soda
1/4 teaspoon fine sea salt
1 cup nonfat plain yogurt or blueberry yogurt
1 teaspoon pure vanilla extract
2 eggs
2 cups fresh or frozen (thawed and drained) blueberries divided
1/3 cup sliced almonds

Preheat the oven to 350°F. Grease a 9-inch springform pan with cooking spray; set aside. Put 2 tablespoons of the whole wheat pastry flour, sugar, butter, cinnamon and cardamom in a medium bowl and mix together with a fork or your fingers until well combined and mixture is in large clumps; set streusel aside.

Put remaining 1 cup whole wheat pastry flour, all-purpose flour, sugar, baking powder, baking soda and salt in a large bowl and stir to combine; set aside. In a medium bowl, whisk together yogurt, vanilla and eggs then pour into bowl with dry ingredients and stir until combined. Gently fold in 1 cup of the blueberries.

Spoon batter into prepared pan and sprinkle reserved streusel over the top. Scatter remaining 1 cup blueberries over the streusel then top with almonds. Bake until a toothpick inserted in the center cake comes out clean, 30 to 40 minutes. Once cooled, loosen edges of cake and transfer to a plate. Cut into slices and serve.

EGG SOUFFLE Serves 4-6

A snap to prepare, this egg dish may not puff up high like a more traditional soufflé, but the light, cheesy cornbread-like texture makes for a truly delicious breakfast and brunch dish.

3 large eggs
1 1/2 cup small curd cottage cheese
3 tablespoons sour cream
1 tablespoon sugar
1/2 cup all-purpose baking or biscuit mix
4 tablespoons unsalted butter melted

Preheat oven to 350°F. Oil or spray a 9x9-inch square glass baking dish and set aside. In a medium bowl, beat eggs. Add cottage cheese, sour cream, sugar, baking mix, and melted butter. Using a wire whisk beat everything together for 1 minute. Pour batter into prepared dish. Bake for 45 to 50 minutes.

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Dr. Leimbach is a specialist in interventional and structural cardiology, including cardiac catheterization, coronary angioplasty, stents, atherectomy, laser, intravascular ultrasound imaging, and direct PTCA/stents for acute myocardial infarction. He also specializes in percutaneous closure of PFOs, ASDs, PDAs and percutaneous valve replacement or repair procedures such as TAVR and MitraClip. He is Director of the Cardiac and Interventional Laboratories at Oklahoma Heart Institute Hospital and also is Past Chief of Cardiology. Dr. Leimbach is Co-Founder of the Lipid and Wellness Clinic at Oklahoma Heart Institute. He is Director of the James D. Harvey Center for Cardiovascular Research at Hillcrest Medical Center, as well as Director of the Oklahoma Heart Research and Education Foundation. He also serves as Clinical Associate Professor of Medicine at the University of Oklahoma College of Medicine-Tulsa. Dr. Leimbach completed a Clinical Cardiology Fellowship and a Research Fellowship at the University of Iowa Hospitals and Clinics. He also completed his Internal Medicine Internship and Residency Programs at Iowa, where he was selected Chief Resident in Medicine. He received his medical degree from Northwestern University in Chicago and his Bachelor of Science degree from the University of Michigan.

Board certified in Internal Medicine, Cardiovascular Disease and Interventional Cardiology

Robert C. Sonnenschein, MD, FACC, ASE, RVT, RPVI

Dr. Sonnenschein specializes in echocardiography and noninvasive peripheral vascular imaging. He is Director of Echocardiography at Hillcrest Hospital South and past Director of Peripheral Vascular Ultrasound Imaging at Hillcrest Medical Center and Oklahoma Heart Institute and serves as Clinical Associate Professor of Medicine at the University of Oklahoma College of Medicine – Tulsa. He completed his Cardiology Fellowship at the State University of New York Upstate Medical Center in Syracuse, where he also completed his Internal Medicine Internship and Residency programs. Dr. Sonnenschein received his medical degree from Rush Medical College in Chicago and his Bachelor of Arts degree from the University of Pennsylvania.

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James J. Nemec, MD, FACC

Dr. Nemec is a specialist in echocardiography, stress echocardiography and nuclear cardiology. He serves as Director of Nuclear Cardiology for Oklahoma Heart Institute. Dr. Nemec has served as Assistant Professor of Internal Medicine, Division of Cardiology, at Creighton University and as Assistant Professor, Department of Radiology, also at Creighton University. He completed his Clinical Cardiology Fellowship at the Cleveland Clinic Foundation and his Internal Medicine Internship and Residency at Creighton University. Dr. Nemec also completed a year of training in pathology at the University of Missouri, Columbia, MO. He received his medical degree from Creighton University, where he also received his Bachelor of Arts degree.

Board certified in Internal Medicine, Cardiovascular Disease and Nuclear Cardiology

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Dr. Johnsen is an interventional cardiologist with expertise in cardiac catheterization, angioplasty and related interventional procedures, such as stents and atherectomy. He is Director of Cardiac Rehabilitation at Hillcrest Medical Center and Director of the Hillcrest Exercise and Lifestyle Programs. He completed his Clinical Cardiology Fellowship at the University of Oklahoma – Oklahoma City, where he then finished an extra year of dedicated training in interventional cardiology. He completed his Internal Medicine Internship and Residency training at the University of Oklahoma – Oklahoma City, where he also received his medical degree. Dr. Johnsen received his Bachelor of Science degree from Oklahoma State University.

Board certified in Internal Medicine, Cardiovascular Disease and Interventional Cardiology

Alan M. Kaneshige, MD, FACC, FASE, RPVI

Dr. Kaneshige is a noninvasive cardiologist with expertise in adult echocardiography, stress echocardiography and transesophageal echocardiography. He is past Chief of Cardiology at Hillcrest Medical Center. Dr. Kaneshige completed his Internal Medicine Internship and Residency at Creighton University School of Medicine, where he also received his medical degree. He received a Bachelor of Science in chemistry at Creighton University. Dr. Kaneshige completed his Clinical Cardiology fellowship at Creighton, where he also served as Chief Cardiology Fellow for two years. He completed an additional Cardiac Ultrasound Fellowship at the Mayo Clinic in Rochester. Dr. Kaneshige served as Assistant Professor of Medicine at Creighton University School of Medicine, where he was Director of the noninvasive Cardiovascular Imaging and Hemodynamic Laboratory.

Board certified in Internal Medicine, Cardiovascular Disease, Adult and Transesophogeal Echocardiography

Edward T. Martin, MS, MD, FACC, FACP, FAHA, FSCMR

Dr. Martin is a noninvasive cardiologist with subspecialty expertise in noninvasive imaging. He is Director of Cardiovascular Magnetic Resonance Imaging at Oklahoma Heart Institute and Hillcrest Medical Center. In addition, he is a Clinical Associate Professor of Medicine at the University of Oklahoma College of Medicine – Tulsa. Dr. Martin has specialty training in Nuclear Medicine, as well as additional training dedicated to Cardiovascular Magnetic Resonance Imaging. He completed his Cardiology Fellowship at the University of Alabama and Internal Medicine Internship/Residency training at Temple University Hospital in Philadelphia. He received his medical degree from the Medical College of Ohio. Dr. Martin completed his Master of Science degree in mechanical engineering at the University of Cincinnati and his Bachelor of Science degree in physics at Xavier University. Dr. Martin is a founding member of the Society of Cardiovascular Magnetic Resonance and is a past editorial board member of the Journal of Cardiovascular Magnetic Resonance. He has been the principal investigator in many clinical research trials and authored numerous peer-reviewed manuscripts and book chapters. Dr. Martin has also been actively involved with the American College of Cardiology (ACC) on a national level participating on numerous committees, writing groups and leadership positions. He is also a past ACC Governor of the State of Oklahoma. He is also a two-time past President of the Board of Directors of Tulsa Metropolitan Division of the American Heart Association and past President of the Intersocietal Commission for the Accreditation of Magnetic Resonance Laboratories (ICAMRL). Locally, he is the current Director of Cardiovascular MRI at OHI and the current Chief of Staff at Hillcrest Hospital South.

Board certified in Internal Medicine and Cardiovascular Disease

Roger D. Des Prez, MD, FACC

Dr. Des Prez is a noninvasive cardiologist with specialty expertise in echocardiography, nuclear cardiology and cardiac computed tomography. He is Director of Cardiac Computed Tomography Services of the Cardiology Department at Bailey Medical Center. Dr. Des Prez received his medical degree and Bachelor of Arts degree from Vanderbilt University. He completed his Residency in Internal Medicine and Pediatrics at University Hospital of Cleveland. Dr. Des Prez practiced for six years as an internist with the Indian Health Services in Gallup, NM. He returned to Vanderbilt University as a member of the Internal Medicine Faculty, at which time he also completed his cardiology training.

Board certified in Internal Medicine, Cardiovascular Disease, Echocardiography, Pediatrics and Nuclear Cardiology

Christian S. Hanson, DO, FACE

Dr. Hanson is a specialist in Endocrinology, Metabolism and Hypertension at Oklahoma Heart Institute with expertise in diabetes, lipids and hypertension. He also serves as Clinical Associate Professor of Medicine in the College of Osteopathic Medicine – Oklahoma State University. He completed a Fellowship in Endocrinology, Metabolism and Hypertension at the University of Oklahoma in Oklahoma City. Dr. Hanson's Internal Medicine Residency and Rotating Internship were completed at Tulsa Regional Medical Center. He received his medical degree from Oklahoma State University and his Bachelor of Science degree from Northeastern Oklahoma State University in Tahlequah.

Board certified in Internal Medicine, Endocrinology and Metabolic Diseases

David A. Sandler, MD, FACC, FHRS

Dr. Sandler is a cardiologist with subspecialty expertise in electrophysiology, complex ablation, and atrial fibrillation management. Dr. Sandler is Director of Electrophysiology at Oklahoma Heart Institute Hospital. He completed his Cardiac Electrophysiology Fellowship and his Cardiovascular Medicine Fellowship at New York University Medical Center, New York, NY. Dr. Sandler performed his Internal Medicine Internship and Residency at Mount Sinai Medical Center, New York, NY. He earned his medical degree from Georgetown University School of Medicine in Washington, DC. Dr. Sandler received his Bachelor of Arts degree at the University of Pennsylvania in Philadelphia.

Board certified in Internal Medicine, Cardiovascular Disease and Cardiac Electrophysiology

Raj H. Chandwaney, MD, FACC, FSCAI, FSVM

Dr. Chandwaney is an interventional cardiologist with expertise in cardiac catheterization, coronary angioplasty and related interventional procedures such as coronary stents, atherectomy, intravascular ultrasound and peripheral

vascular interventional procedures. Dr. Chandwaney is Chief of Cardiology and Director of the Chest Pain Center and Cardiology Telemetry Unit at Oklahoma Heart Institute Hospital. He completed his Clinical Cardiology Fellowship at Northwestern University Medical School in Chicago, IL., where he also completed an Interventional Cardiology Fellowship. Dr. Chandwaney's Internal Medicine Internship and Residency were performed at Baylor College of Medicine in Houston, TX. He received his medical degree from the University of Illinois at Chicago. Dr. Chandwaney completed his Master of Science degree at the University of Illinois at Urbana-Champaign, where he also received his Bachelor of Science degree.
Board certified in Internal Medicine, Cardiovascular Disease, Interventional Cardiology and Endovascular Medicine

D. Erik Aspenson, MD, FACE, ECNU
Dr. Aspenson is a subspecialist in Endocrinology, Metabolism and Hypertension at Oklahoma Heart Institute, with expertise in diabetes, lipids, hypertension and thyroid diseases. He completed a fellowship in Endocrinology at Wilford Hall Medical Center, Lackland AFB, Texas. Dr. Aspenson's Internal Medicine Internship and Residency were completed at David Grant Medical Center, Travis AFB, California where he served as Chief Resident. He received his medical degree from the University of Oklahoma and his Bachelor of Science degree at Oklahoma State University.
Board certified in Internal Medicine, Endocrinology and Metabolic Diseases

Frank J. Gaffney, MD, FACC
Dr. Gaffney is an interventional and noninvasive cardiologist with subspecialty expertise in transesophageal echocardiography, nuclear cardiology, and coronary angiography. Dr. Gaffney is Director of Cardiology at Bailey Medical Center. He completed his Cardiovascular Medicine Fellowship at Scott & White Memorial Hospital in Temple, Texas. Dr. Gaffney completed his Internal Medicine Internship and Residency at Brooke Army Medical Center in San Antonio. He then remained on staff at Scott & White Memorial Hospital for several years, before entering his Fellowship in Cardiovascular Medicine. Dr. Gaffney earned his medical degree from New York Medical College, Valhalla, New York, and he received his Bachelor of Arts degree at Hofstra University in Hempstead, New York.
Board certified in Internal Medicine, Cardiovascular Disease and Nuclear Cardiology

Eric G. Auerbach, MD, FACC
Dr. Auerbach is a general cardiologist whose major interest is preventive cardiology and cardiovascular risk reduction. He completed his Cardiology Fellowship at the University of Miami/Jackson Memorial Hospital in Miami, FL, following which he obtained additional subspecialty training in cardiovascular MRI, nuclear cardiology, and cardiac CT imaging. His areas of expertise also include echocardiography, stress testing and management of lipid disorders. In addition to holding board certification in cardiovascular disease, he is a diplomat of the American Board of Clinical Lipidology. Dr. Auerbach's Internal Medicine Internship and Residency were performed at the University of Miami/Jackson Memorial Hospital. He earned his medical degree at the University of Miami, Miami, FL, and his Bachelor of Arts degree at Princeton University, Princeton, NJ. Dr. Auerbach is the Director of Preventive Cardiology at Oklahoma Heart Institute, the medical director of The Weight Loss & Wellness Center at Oklahoma Heart Institute and a Clinical Associate Professor of Medicine at the University of Oklahoma College of Medicine – Tulsa.
Board certified in Internal Medicine, Cardiovascular Disease and Nuclear Cardiology

Robert L. Smith, Jr., MSc, MD, FACC, FSCAI
Dr. Smith specializes in interventional cardiology including cardiac catheterization, coronary angioplasty, and related interventional procedures such as coronary stents, atherectomy, intravascular ultrasound, and peripheral vascular interventional procedures. Dr. Smith is Director of Cardiology and the Cardiac and Interventional Laboratories at Hillcrest Hospital South. He completed an Interventional Cardiology Fellowship at the University of Florida College of Medicine in Jacksonville, FL. Dr. Smith performed his Clinical Cardiology Fellowship at Vanderbilt University School of Medicine in Nashville, TN and Tulane University School of Medicine in New Orleans. He received his medical degree from the University of Oklahoma College of Medicine in Oklahoma City and then completed his Internal Medicine Internship and Residency at Emory University School of Medicine in Atlanta, GA. Dr. Smith received his Bachelor of Arts, Bachelor of Science and Master of Science degrees at the University of Oklahoma in Norman, OK.
Board certified in Internal Medicine, Cardiovascular Disease, Interventional Cardiology and Nuclear Cardiology

Craig S. Cameron, MD, FACC, FHRS
Dr. Cameron is a specialist in cardiac electrophysiology, including catheter complex ablation, atrial fibrillation management, pacemakers, implantable defibrillators, cardiac resynchronization devices, and lead management and left atrial appendage closure. Dr. Cameron is Director of Electrophysiology at Hillcrest Hospital South. He completed his Cardiac Electrophysiology Fellowship and his Cardiovascular Disease Fellowship at Baylor University Medical Center in Dallas, TX. Dr. Cameron's Internship and Internal Medicine Residency were performed at Baylor College of Medicine in Houston. He earned his medical degree from the University of Kansas School of Medicine in Kansas City, KS. Dr. Cameron received his Bachelor of Science degree at Pittsburg State University in Pittsburg, KS.
Board certified in Cardiovascular Disease and Cardiac Electrophysiology

Eugene J. Ichinose, MD, FACC
Dr. Ichinose specializes in interventional cardiology including cardiac catheterization, coronary angioplasty and related interventional procedures such as coronary stents, atherectomy, intravascular ultrasound and peripheral vascular interventional procedures. Dr. Ichinose is Director of Vein Services at Hillcrest Medical Center. He completed his Interventional and Clinical Cardiology Fellowships and his Internal Medicine Residency at the University of Massachusetts Memorial Health Care Center in Worcester, MA. Dr. Ichinose received his medical degree from Louisiana State University in New Orleans. He earned his Bachelor of Science degree from Texas Christian University in Fort Worth, TX.
Board certified in Internal Medicine, Cardiovascular Disease, Interventional Cardiology and Nuclear Cardiology

Cristin M. Bruns, MD
Dr. Bruns is a specialist in Endocrinology, Diabetes and Metabolism at Oklahoma Heart Institute, with expertise in diabetes, thyroid disease (including thyroid cancer) and polycystic ovary syndrome. She completed her Internal Medicine Internship and Residency and Endocrinology Fellowship at the University of Wisconsin Hospital and Clinics in Madison, WI. Dr. Bruns earned her medical degree from Saint Louis University School of Medicine in St. Louis, MO and her Bachelor of Arts and Bachelor of Science degrees in biology from Truman State University in Kirksville, MO. Prior to joining Oklahoma Heart Institute, Dr. Bruns worked as a clinical endocrinologist at the Dean Clinic in Madison, Wisconsin.
Board certified in Internal Medicine, Endocrinology and Metabolic Diseases

John S. Tulloch, MD
Dr. Tulloch is a noninvasive cardiologist with expertise in adult echocardiography, peripheral vascular imaging, nuclear cardiology, cardiac computed tomography and MRI. Dr. Tulloch is Director of the Cardiac and Vascular Ultrasound Department of Oklahoma Heart Institute/Hillcrest Medical Center's Cardiovascular Diagnostics. He completed his Cardiovascular Fellowship at the University of Kansas Medical Center in Kansas City, KS. Dr. Tulloch's Internal Medicine Internship and Residency also were completed at the University of Kansas Medical Center. He earned his medical degree from Ross University School of Medicine in New Brunswick, NJ and received his Bachelor of Science degree in biology from Avila University in Kansas City, MO.
Board certified in Internal Medicine, Cardiovascular Disease, Cardiovascular Tomography, and Nuclear Cardiology

Anthony W. Haney, MD, FACC
Dr. Haney is a noninvasive cardiologist with expertise in nuclear cardiology, echocardiography, peripheral vascular imaging and MRI. He also performs diagnostic cardiac catheterization. He completed his Cardiovascular Fellowship at the Medical College of Virginia in Richmond. Dr. Haney's Internal Medicine Internship and Residency were completed at the Mayo Clinic in Scottsdale, AZ. He earned his medical degree from the University of Oklahoma School of Medicine.
Board certified in Internal Medicine, Cardiovascular Disease and Nuclear Cardiology

Douglas A. Davies, MD, FACC, FASNC
Dr. Davies is a hospital-based cardiologist who provides continuity of care for patients admitted to Oklahoma Heart Institute – Hospital. He completed a Clinical Cardiology Fellowship and additional training in nuclear cardiology at the Medical College of Virginia, where he also completed his Internal Medicine and Residency programs. Dr. Davies received his medical degree from Johns Hopkins University School of Medicine in Baltimore.
Board Certified in Internal Medicine, Cardiovascular Disease, Nuclear Cardiology and Cardiovascular Computed Tomography Angiography

Kamran I. Muhammad, MD, FACC, FSCAI
Dr. Muhammad is a subspecialist in interventional cardiology. In addition to expertise in traditional areas of interventional cardiology, such as coronary intervention (angioplasty, stent placement, atherectomy, intravascular imaging) and peripheral vascular and carotid artery intervention, Dr. Muhammad has a special interest and expertise in interventional therapies for structural and valvular heart disease including the percutaneous non-surgical replacement and repair of heart valves — TAVR and MitraClip. As such, he currently serves as the Director of the Structural Heart Disease Program at OHI.

With dedicated and advanced training in structural heart disease intervention from the world-renowned Cleveland Clinic, Dr. Muhammad has been a pioneer in this field in Oklahoma. He led a team of OHI physicians in performing the first transcatheter aortic valve replacements (TAVR) and first transcatheter mitral valve repairs (MitraClip) in Tulsa and the region. Under his direction, these programs are the most experienced and comprehensive programs of their kind in the state, providing our patients with expert care and class-leading technologies for the non-surgical treatment of structural and valvular heart diseases.

In addition to his clinical experience, Dr. Muhammad has authored many peer-reviewed articles and textbook chapters on important cardiology topics. He also serves as Clinical Associate Professor of Medicine at the University of Oklahoma College of Medicine — Tulsa.

Dr. Muhammad completed his Clinical Cardiology and Interventional Cardiology Fellowships at the Cleveland Clinic which included additional dedicated training in peripheral vascular and structural cardiac intervention. Dr. Muhammad completed his Internal Medicine Internship and Residency at Yale University where he was selected and served as Chief Resident. He earned his medical degree from the University of Massachusetts Medical School, graduating with top honors and election to the Alpha Omega Alpha (ΑΩΑ) honor society. Dr. Muhammad earned his Bachelor of Science degree in computer science from the University of Massachusetts, Amherst.

Board certified in Internal Medicine, Cardiovascular Disease, Nuclear Cardiology and Interventional Cardiology

Arash Karnama, DO, FACC

Dr. Karnama is a specialist in interventional cardiology, including cardiac catheterization, coronary intervention, nuclear cardiology, echocardiography (TEE/TTE), cardioversion, peripheral angiography, peripheral intervention, carotid angiography, intravascular ultrasound, atherectomy, and PTCA/stenting for acute myocardial infarction. He is Director of the Cardiology Department at Hillcrest Hospital Claremore. Dr. Karnama completed his Interventional and Clinical Cardiology Fellowships at Oklahoma State University Medical Center and his Internal Medicine Internship and Residency at the Penn State Milton S. Hershey Medical Center in Hershey, PA. Dr. Karnama received his medical degree from Des Moines University in Des Moines, IA and his Bachelor of Arts degree from the University of Iowa in Iowa City.

Board certified in Internal Medicine, Interventional Cardiology, Cardiovascular Disease, Nuclear Cardiology, and Cardiovascular Computed Tomography

Jana R. Loveless, MD

Dr. Loveless is a sleep specialist, with expertise in the diagnosis and treatment of sleep disorders. She is Director of the Sleep Medicine Program at Hillcrest Hospital Claremore, Hillcrest Hospital Henryetta, and Hillcrest Hospital South. Prior to joining Oklahoma Heart Institute, Dr. Loveless was with Nocturna of Tulsa. She completed her Internal Medicine Residency program at the University of Oklahoma, Tulsa, where she was Chief Resident. She also earned her medical degree from, the University of Oklahoma, Tulsa. Dr. Loveless completed graduate studies at Texas Tech University, and she earned her Bachelor of Arts degree at Davidson College in Davidson, North Carolina.

Board Certified in Internal Medicine and Sleep Medicine

Mathew B. Good, DO, FACC, RPVI

Dr. Good is an invasive/noninvasive cardiology specialist with expertise in adult echocardiography, nuclear cardiology, cardiac computed tomography, peripheral vascular ultrasound and MRI. He completed his Cardiovascular Fellowship at the University of Kansas Medical Center in Kansas City, KS, where he also completed his Internal Medicine Internship and Residency. Dr. Good received his medical degree from the Oklahoma State University Center for Health and Sciences in Tulsa and his Bachelor of Arts degree from the University of Colorado in Boulder.

Board certified in Internal Medicine and Cardiovascular Computed Tomography

Stanley K. Zimmerman, MD, FACC, FSCAI

Dr. Zimmerman is the Director of the Catheterization Laboratory and Peripheral Vascular Services at Hillcrest Hospital South. He is the medical director of OHI vascular imaging laboratory. He is a specialist in interventional cardiology, including cardiac catheterization, coronary angioplasty, and related interventional procedures such as coronary stents, atherectomy, vascular ultrasound, and peripheral interventional procedures. Dr. Zimmerman specializes in complex vascular interventions, endovascular repair of abdominal aortic aneurysms and complex aorto-iliac disease, treatment of critical limb ischemia, and vascular management of arterial and venous based wounds.

He completed his Interventional and Cardiovascular Fellowships at the University of Kansas Medical Center in Kansas City, KS, as well as his Internal Medicine Internship and Residency. In addition, Dr. Zimmerman received his medical degree from the University of Kansas Medical Center and his Bachelor of Arts degree from the University of Kansas in Lawrence.

Board certified in Internal Medicine, Cardiovascular Disease and Interventional Cardiology

Michael Phillips, MD, FACC, FACS

Dr. Phillips is a Cardiovascular Thoracic Surgeon at Oklahoma Heart Institute. He completed his fellowship at Mid America Heart Institute in Kansas City, MO and his general surgery residency at the Mayo Graduate School of Medicine. He earned his medical degree from the University of Missouri. Dr. Phillips received his undergraduate degrees in Biology and Chemistry at William Jewell College in Liberty, MO.

Board certified in Thoracic and General Surgery

James B. Chapman, MD, FACC, FSCAI

Dr. Chapman is a specialist in interventional cardiology, including cardiac catheterization, coronary angioplasty and related interventional procedures such as stents, atherectomy, laser, intravascular ultrasound imaging and direct PTCA for acute myocardial infarction. He completed a Clinical Cardiology Fellowship at St. Vincent Hospital and Health Care Center in Indianapolis, IN. He also completed his Internal Medicine Internship and Residency programs at St. Vincent. Dr. Chapman received his medical degree from Indiana University School of Medicine in Indianapolis and his Bachelor of Science degree from Indiana University in Bloomington, IN.

Board certified in Internal Medicine, Cardiovascular Disease and Interventional Cardiology

Joseph J. Gard, MD, FACC, FHRS

Dr. Gard is a cardiologist who specializes in electrophysiology, complex ablation and atrial fibrillation management. He completed his Cardiac Electrophysiology Fellowship and his Cardiology Fellowship at the Mayo School of Graduate Medical Education in Rochester, Minnesota. Dr. Gard also performed his Internal Medicine Residency at Mayo. He earned his medical degree from the University of Nebraska in Omaha, Nebraska. Dr. Gard received his Bachelor of Science degree from Boston College in Chestnut Hill, Massachusetts.

Board certified in Cardiovascular Disease, Internal Medicine, Electrophysiology and Clinical Cardiac Electrophysiology

Michael B. Newnam, MD

Dr. Newnam is Director of Sleep Medicine at Hillcrest Medical Center and Hillcrest Hospital Cushing. He is a Board Certified specialist in the diagnosis and treatment of sleep disorders. He completed his Family Practice Internship & Residency programs at the Womack Army Medical Center in Ft. Bragg, NC. Dr. Newnam earned his medical degree from the University of Oklahoma and his Bachelor of Science degree from Oral Roberts University in Tulsa, OK.

Board Certified in Family Medicine and Sleep Medicine

John M. Weber, MD, RPVI

Dr. Weber is a Peripheral Vascular Surgeon at Oklahoma Heart Institute who specializes in complex vascular disease. He offers both open and endovascular treatment of arterial and venous disease. Areas of interest include open and endovascular treatment of aortic pathology, cerebrovascular surgery, limb salvage surgery, vascular access, and complex venous therapies. He completed his residency in Vascular Surgery at the Cleveland Clinic in Cleveland, Ohio. Dr. Weber earned his medical degree at the University of Oklahoma College of Medicine. He also completed his undergraduate degree at the University of Oklahoma.

Board certified in Vascular Surgery

Saran Oliver, MD

Dr. Oliver is an invasive/noninvasive cardiology specialist with specific interests in adult echocardiography, nuclear cardiology, and women's cardiovascular health. She completed her Cardiovascular Fellowship at Scott and White Memorial Hospital in Temple, TX. Dr. Oliver performed her Internal Medicine Internship and Residency at the University of Texas Southwestern Medical Center in Dallas, TX. She also earned her medical degree from the University of Texas Southwestern Medical Center. Dr. Oliver attended Rice University in Houston, TX where she received her Bachelor of Arts degree in Sports Medicine.

Board certified in Internal Medicine, board eligible in Cardiovascular Medicine

Jordan A. Brewster, MD

Dr. Brewster is a specialist in electrophysiology, with expertise in electrophysiology, complex ablation, and atrial fibrillation management. He completed his Fellowship in Electrophysiology at Indiana University in Indianapolis, IN. Dr. Brewster performed his Fellowship in Cardiovascular Disease at the University of Kentucky Division of Cardiovascular Medicine in Lexington, KY, where he was Chief Fellow. He completed his Internal Medicine Internship and Residency at Vanderbilt University in Nashville, TN. Dr. Brewster received his medical degree from the University of Virginia School of Medicine in Charlottesville, VA. and his Bachelor of Science degree in Biochemistry from the University of Oklahoma.

Board certified in Internal Medicine, Cardiovascular Disease and Nuclear Cardiology

Ahmad Iqbal, MD, FACC

Dr. Iqbal is an invasive/noninvasive cardiologist at Oklahoma Heart Institute who specializes in advanced heart failure patients, including those with left ventricular assist devices (LVAD) as well as patients with cardiac transplantation. His special interest is mechanical circulatory support options for patients requiring additional life support measures including ECMO, Impella, and LVADs. Dr. Iqbal also is a diplomate of the National Board of Echocardiography and specializes in adult comprehensive echocardiography, including stress echocardiography and transesophageal echocardiography. He also has an interest in nuclear and preventative cardiology. He completed his Advanced Heart Failure and Transplant Fellowship at Northwestern University Feinberg School of Medicine in Chicago, IL. Dr. Iqbal completed his Cardiovascular Disease Fellowship at Mid America Heart Institute at St. Luke's Hospital/University of Missouri-Kansas City, MO. Dr. Iqbal completed his Internal Medicine Residency at the University of Texas Southwestern in Dallas, TX. He received his medical degree from Tulane University School of Medicine and his Bachelor of Business Administration degree from Loyola University in New Orleans, LA, where he graduated summa cum laude.

Board certified in Internal Medicine, Cardiovascular Diseases, Echocardiography and Heart Failure. Board eligible in Nuclear Cardiology. Board eligible in Advanced Heart Failure and Transplant

Siva Soma, MD, FACC, FHRS

Dr. Soma is a specialist in electrophysiology, with expertise in complex catheter ablation of cardiac arrhythmias and management of atrial fibrillation, ventricular tachycardia, pacemakers, defibrillators and cardiac resynchronization devices.

He completed his Fellowship in Electrophysiology at the University of Pittsburgh Medical Center in Pittsburgh, PA. Dr. Soma performed his Fellowships in Cardiovascular Disease and Advanced Heart Failure/Transplantation at Allegheny General Hospital in Pittsburgh. He completed his Internal Medicine Internship and Residency at Hahnemann University Hospital, Drexel University College of Medicine in Philadelphia, PA.

Dr. Soma completed a Master's degree in public health from West Virginia University and received his medical degree from Armed Forces Medical College in India.

Board certified in Internal Medicine, Cardiovascular Disease and Nuclear Cardiology

Ajit K. Tharakan, MD, M.Ch, FACS

Dr. Tharakan is a Cardiovascular Thoracic surgeon at Oklahoma Heart Institute. He was Chief Resident of Cardiothoracic Surgery at Massachusetts General Hospital, Harvard Medical School, Boston, MA, as well as Chief Resident of Cardiovascular Surgery at Boston Children's Hospital, Harvard Medical School, Boston, MA.

He was also Chief Resident for General Surgery at the Hugh E. Stephenson Department of Surgery, School of Medicine, University of Missouri, Columbia, MO, where he did his General Surgery Residency. He also was Chief Resident in Cardiothoracic Surgery at Christian Medical College & Hospital, Vellore, Tamilnadu, S. India. Dr. Tharakan has done additional training at St. John's National Academy of Health Sciences, Bangalore, India and Christian Medical College Hospital, Vellore, India where he secured the M.Ch (Master of Chirurgi) degree.

Dr. Tharakan performed his Internship at Sri Ramachandra Medical College & Research Institute, The Tamilnadu Dr. M.G.R. Medical University, Porur Madras, Tamilnadu, India, where he also earned his medical degree. Prior to joining Oklahoma Heart Institute, Dr. Tharakan was the Director of Cardiothoracic Surgery at the Hugh E. Stephenson Department of Surgery at the University of Missouri-Columbia. He has numerous publications, patents, and inventions. He was recognized as one of MU's Top Faculty Achievers in 2017.

Board certified in Thoracic and General Surgery

Allen Cheng, MD

Dr. Cheng is a cardiovascular surgeon who served as the Surgical Director of Heart Transplantation at Rudd Heart and Lung Center, Jewish Hospital, University of Louisville prior to joining Oklahoma Heart Institute.

He completed his general surgery residency at UCLA, cardiothoracic surgery training at Massachusetts General Hospital/Harvard Medical School, cardiovascular surgery postdoctoral fellowship at Stanford University and specialty training at University of Rochester.

Dr. Cheng specializes in heart transplantation, mechanical circulatory support, ECMO, minimally invasive cardiac surgery, atrial fibrillation surgery (MAZE), and transcatheter aortic valve replacement. He is also a scientific investigator at Cardiovascular Innovation Institute. Dr. Cheng has received multiple national awards including the Howard Hughes Medical Institute research award, American Heart Association (AHA) research award, Thoracic Surgery Foundation for Research and Education (TSFRE) research award and the Society of Heart Valve C. Walton Lillehei research award.

He has an extensive publication record in major international cardiovascular journals including Circulation, Annals of Thoracic Surgery, Journal of Heart and Lung Transplantation and ASAIO, and is also serving as a reviewer for the above journals.

Dr. Cheng serves as the Surgical Director of Advanced Heart Failure and Mechanical Circulatory Support at Oklahoma Heart Institute.

Board certified in Surgery and Thoracic Surgery

Adel M. Barkat, MD, RPVI

Dr. Barkat is a Vascular Surgeon at Oklahoma Heart Institute, who specializes in vascular and endovascular cases, including cerebrovascular, aortoiliac and infrainguinal occlusive disease, abdominal aneurysms, visceral arterial disease, arteriovenous access and venous interventions.

He performed a Vascular Surgery Fellowship at Loyola University Medical Center in Chicago, IL. Dr. Barkat completed his General Surgery Residency at Louisiana State University Health and Sciences Center in New Orleans, LA. He earned his medical degree at Louisiana State University Medical Center.

Dr. Barkat completed his Bachelor of Science degree at Louisiana State University with a degree in Biochemistry.

Hoda Butrous, MD

Dr. Butrous is an Advanced Heart Failure and Transplant specialist at Oklahoma Heart Institute, with expertise in managing advanced heart failure and pulmonary hypertension, including the evaluation and treatment of patients needing Mechanical Circulatory Support (LVAD).

She performed an Advanced Heart Failure and Cardiac Transplant Fellowship at the University of Utah School of Medicine in Salt Lake City, Utah and completed her Cardiology Fellowship at Beaumont Hospital in Dearborn, Michigan.

Dr. Butrous completed her Internal Medicine Residency at the Loma Linda University Medical Center in Loma Linda, California. She earned her medical degree at Benha Medical School, Benha University, Egypt.

Board certified in Cardiovascular Disease and Internal Medicine

Adel E. Ghuloom, MD, FCCP

Dr. Ghuloom is a Cardiovascular Critical Care Intensivist at Oklahoma Heart Institute, with expertise in advanced heart failure, including mechanical circulatory support (LVAD and ECMO) and heart transplant cardiovascular intensive care.

He performed a Fellowship in Critical Care at Baylor College of Medicine in Houston TX. Dr. Ghuloom completed his Internal Medicine Residency at Wayne State University in Detroit, MI.

He earned his medical degree at Arabian Gulf University, Manama, Bahrain, where he also received his Bachelor of Science Degree. Prior to joining Oklahoma Heart Institute, he was a Cardiovascular Critical Care specialist at Tufts University.

Board certified in Critical Care and Internal Medicine

Wendell E. Williams, MD

Dr. Williams is a cardiologist at Oklahoma Heart Institute who specializes in the evaluation, diagnosis, treatment and education of congestive heart failure, coronary artery disease, hypertension and high cholesterol. He completed a Cardiovascular Fellowship at St. Luke's Episcopal Presbyterian Hospital in Chesterfield, Missouri Dr. Williams performed his Internal Medicine Internship and Residency Programs at Washington Hospital Center in Washington, D.C.

Dr. Williams received his medical degree from Baylor College of Medicine in Houston, Texas and his Bachelor of Arts & Sciences degree from Howard University in Washington, D.C.

Board certified in Internal Medicine and Cardiovascular Disease

Elie Abed, MD

Dr. Abed is a specialist in endocrinology at Oklahoma Heart Institute. He completed a Fellowship in endocrinology, diabetes and metabolism at the University of Oklahoma Health Sciences Center in Oklahoma City, OK. Dr. Abed performed his Internal Medicine Internship and Residency Programs at Mount Sinai St. Luke's and Mount Sinai West Hospitals in New York, NY. He received his medical degree from Saint Joseph University, Beirut, Lebanon.

Board certified in Internal Medicine

Tobie L. Bresloff, MD

Dr. Bresloff is a specialist in endocrinology, metabolism and hypertension with expertise in diabetes, lipids and thyroid diseases. She serves as a clinical assistant professor of internal medicine in the School of Community Medicine at the University of Oklahoma in Tulsa.

Dr. Bresloff performed a fellowship in Endocrinology & Metabolism at Vanderbilt University of Medicine, Nashville, Tennessee. She completed her Internship and Residency in Internal medicine at Sinai Hospital in Detroit, Michigan. Dr. Bresloff earned her Medical degree at Wayne State University in Detroit, and her Bachelor & Master of Science degrees at the University of Michigan in Ann Arbor, Michigan.

Board certified in Internal Medicine

Cole I. Tunnell, MD

Dr. Tunnell is an invasive cardiologist with expertise in adult echocardiography, peripheral vascular imaging, nuclear cardiology and cardiac catheterization. He performed his Fellowship in Cardiovascular Disease at the University of Oklahoma Health Science Center in Oklahoma City, OK, where he also completed his Internal Medicine Internship and Residency. Dr. Tunnell earned his medical degree from the University of Texas Medical Branch in Galveston TX. and received his Bachelor's degree from Oklahoma Baptist University in Shawnee, OK.

Board certified in Internal Medicine
Board eligible in Cardiovascular disease

Adam C. Betz, MD

Dr. Betz is an Intensivist at Oklahoma Heart Institute who specializes in neuro and cardiac critical care, including ECMO and VAD management. He completed a Fellowship in Critical Care Medicine at the University of Kentucky in Lexington. Dr. Betz also performed his Internship and Residency in General Anesthesiology at the University of Kentucky, where he was Chief Resident. He received his medical degree from the University of Oklahoma College of Medicine in Oklahoma City, OK.

Board eligible in Critical Care and Anesthesia

Ankit K. Chothani, MD, FACC

Dr. Chothani is a specialist in interventional and peripheral endovascular cardiology, including cardiac catheterization, coronary angioplasty, stents, atherectomy, laser, intravascular ultrasound imaging, direct PTCA/stents for acute myocardial infarction and peripheral angioplasty and stenting. He completed an Interventional and Endovascular Interventions Fellowship at Northwell Lenox Hill Hospital in New York City. He also completed a Fellowship in Cardiovascular Medicine at Mount Sinai Saint Luke's-Roosevelt Hospital in New York City, where he was Chief Fellow. Dr. Chothani's Internal Medicine Internship and Residency Programs were performed at Medstar Washington Hospital Center at Georgetown University in Washington, DC. He earned his Bachelor of Medicine and Bachelor of Surgery degrees at BJ Medical College, Gujarat University, Ahmedabad, India.

Board certified in Internal Medicine, Cardiovascular Disease, and Nuclear Cardiology
Board Eligible in Interventional Cardiology

Pulmonary Hypertension

by Hoda Butrous, MD

High blood pressures in the blood vessels in the lung is referred to as pulmonary hypertension.

Pulmonary hypertension is a hemodynamic and pathophysiological condition defined as increase in mean pulmonary artery pressure more than 20 mmHg at rest as measured by right heart catheterization. Pulmonary pressure is determined by pulmonary blood flow (Cardiac output), back pressure in the circuit (PAWP) and Pulmonary vascular resistance.

There are different reasons why a patient may have pulmonary hypertension. It is important to clarify the type of pulmonary hypertension a patient has since it affects the treatment used and the expected prognosis.

Pulmonary hypertension can be classified into 3 categories based on the Pulmonary artery wedge pressure (PAWP) and Pulmonary vascular resistance (PVR). (Table 1)

PVR (WU) = mean PAP- PAWP / CO (Cardiac Output)

The 3 Categories of Pulmonary Hypertension Include:

1. Precapillary PH is what is known as Pulmonary Arterial Hypertension, PAWP is ≤15 mmHg and PVR ≥3 WU
2. Isolated Post Capillary Pulmonary Hypertension is due to pulmonary venous hypertension, PAWP >15 mmHg and PVR <3 WU
3. Combined Pre and Post Pulmonary Hypertension, PAWP > 15 mmHg and PVR ≥3 WU

It is important to differentiate between pulmonary hypertension (PH) which is found in multiple different clinical conditions and pulmonary artery hypertension (PAH) which is subgroup of patients with pulmonary hypertension as shown in Table 2.

Evaluation of pulmonary hypertension:

Diagnosis of PH requires a clinical suspicion. PH should be suspected in patients with progressive dyspnea or unexplained dyspnea, fatigue or syncope. Detailed history and physical exam are crucial to identify diseases associated with pulmonary hypertension, which will guide further work up.

All patients with suspected pulmonary hypertension should have detailed history & physical exam, chest X ray, EKG, 2 D Echocardiogram.

Clinical symptoms of pulmonary hypertension are non-specific and can be easily overlooked and incorrectly attributed to age, deconditioning or other coexisting co-morbidities. Dyspnea, fatigue, dizziness, syncope and exertional chest pain are the common presenting symptoms, and less commonly cough and exercise induced nausea and vomiting. Right ventricular failure symptoms including abdominal distension, ascites and peripheral edema will occur later in advanced cases with progression of the disease and development of right ventricular failure.

Detailed history of other medical problems that could be associated with pulmonary hypertension including heart failure, COPD, previous history of DVT or PE, or connective tissue diseases. History of risk factors for pulmonary artery hypertension including family history of PAH or known heritable gene, social history of illicit drug use.

Physical exam findings of PH include left parasternal heave due to RV failure, accentuated pulmonary component of second heart sound, RV S3 sound, a holosystolic murmur of tricuspid regurgitation and pulmonary regurgitation diastolic murmur. Elevated jugular venous pressure, hepatomegaly, ascites and peripheral edema will be present in patients with advanced disease indicating RV failure.

EKG can be normal earlier in the disease, so normal EKG does not exclude PH. EKG will be abnormal in advanced cases of PH. EKG abnormalities in

Table 1

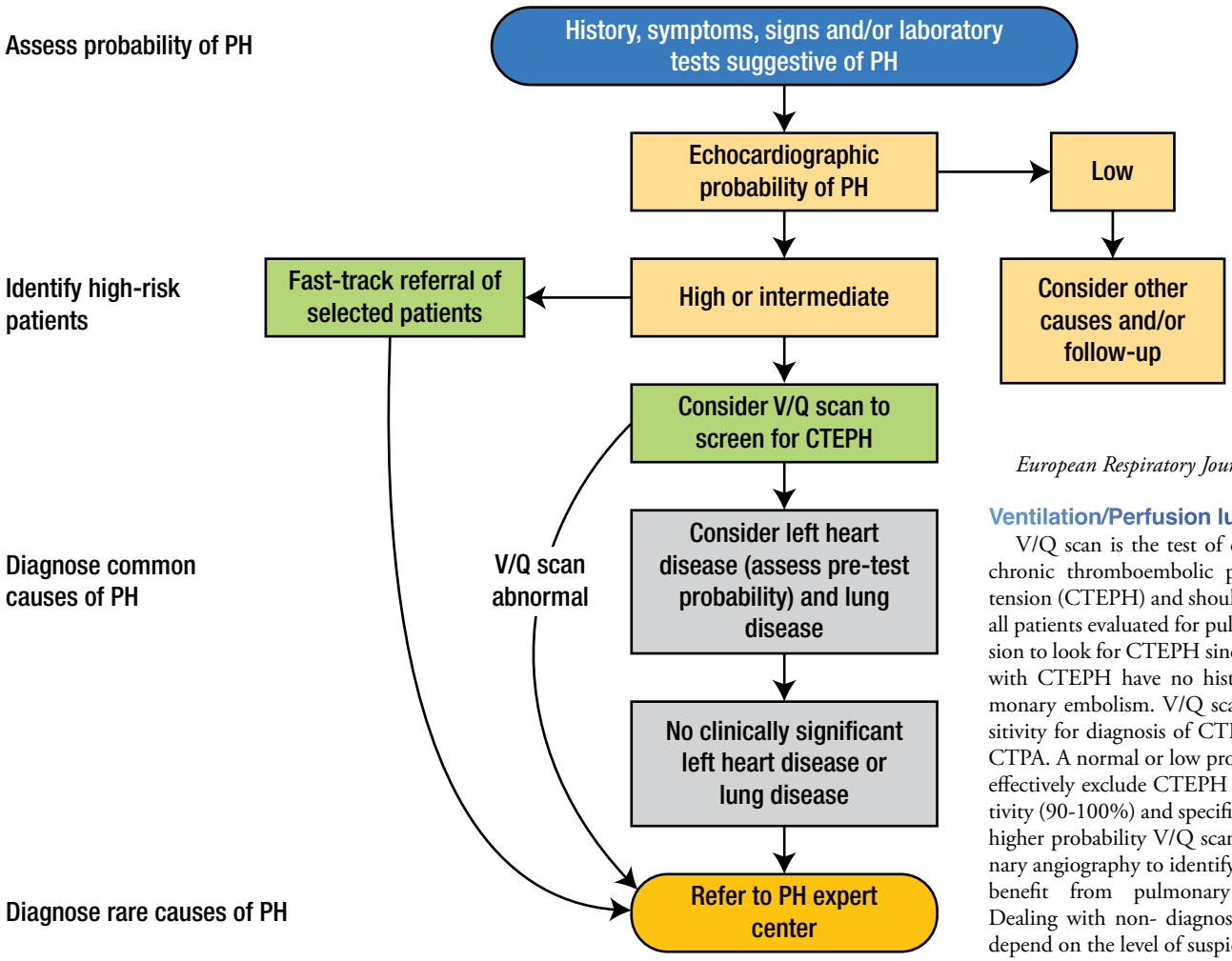
Hemodynamic Classification of Pulmonary Hypertension

Definition	Characteristics	Clinic Groups
Pre-capillary PH	mPAP >20 mmHg	WHO 1: PAH
	PAWP ≤15 mmHg	WHO 3: PH due to lung disease and/or hypoxia
	PVR ≥3 WU	WHO 4: PH due to PA obstructions
		WHO 5: PH with unclear and/or multifactorial mechanisms
Isolated post-capillary PH	mPAP >20 mmHg	WHO 2: PH due to left heart disease
	PAWP >15 mmHg	WHO 5: PH with unclear and/or multifactorial mechanisms
	PVR <3 WU	
Combined pre- and post-capillary PH	mPAP >20 mmHg	WHO 2: PH due to left heart disease
	PAWP >15 mmHg	WHO 5: PH with unclear and/or multifactorial mechanisms
	PVR≥3 WU	

mPAP: mean Pulmonary Artery Pressure, PAWP: Pulmonary Artery Wedge Pressure, PVR: Pulmonary Vascular Resistance, WHO: World Health Organization

Figure 1

Algorithm for the diagnosis of Pulmonary Hypertension (PH) and its causes: V/Q: ventilation/perfusion; CTEPH: Chronic Thromboembolic PH



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PH patients include P Pulmonale, right axis deviation, right bundle branch block, and RV hypertrophy with strain.

Chest X ray will classically show enlargement of the central pulmonary vasculature and attenuation of the peripheral vessels. Right atrial enlargement (prominent right heart border) and right ventricular enlargement (diminished retrosternal space) will be noted in advanced cases of PH. CXR can show evidence of underlying lung or heart disease.

Transthoracic echocardiogram is the most important screening tool for PH. 2 D Echo evaluates the probability of pulmonary hypertension based on tricuspid regurgitation velocity (TRV), assess the left heart for diseases that could be potential etiologies of PH, and lastly evaluates right ventricular size, thickness and function which dictates the severity and prognosis of PH.

Doppler estimated RVSP or PASP more than 40 mmHg warrants further evaluation in patients with unexplained dyspnea.

Other ECHO findings suggestive of pulmonary hypertension are listed in Table 3.

Pericardial effusion is a poor prognostic finding in patients with pulmonary hypertension.

"Is it group 1?" is the most important question to answer when dealing with pulmonary hypertension patients. The importance of this question comes from the poor prognosis of pulmonary arterial hypertension (group 1) if not promptly diagnosed and appropriately managed.

To answer this question, we order several tests to exclude other etiologies of pulmonary hypertension. Figure 1 illustrates the recommended algorithm for initial work up for suspected PH. Referral of these patients to center of expertise for work up and further management is recommended.

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Ventilation/Perfusion lung scan:

V/Q scan is the test of choice to rule out chronic thromboembolic pulmonary hypertension (CTEPH) and should be performed in all patients evaluated for pulmonary hypertension to look for CTEPH since 50% of patients with CTEPH have no history of acute pulmonary embolism. V/Q scan has higher sensitivity for diagnosis of CTEPH compared to CTPA. A normal or low probability V/Q scan effectively exclude CTEPH with higher sensitivity (90-100%) and specificity (94-100%). A higher probability V/Q scan warrants pulmonary angiography to identify those who would benefit from pulmonary endarterectomy. Dealing with non- diagnostic V/Q scan will depend on the level of suspicion.

Pulmonary function test and arterial blood gases to diagnose or rule out underling airway and parenchymal lung disease.

Most patients with pulmonary hypertension will have decreased lung diffusion capacity for carbon monoxide (DLCO). However, DLCO < 45% is associated with poor outcome.

High resolution Chest CT: HRCT provides detailed evaluation of the lung parenchyma for diagnosis of interstitial lung disease or emphysema.

CT chest can raise the suspicion for PH in symptomatic patients or those examined for unrelated conditions if PA is enlarged > 29 mm or PA/Ascending aorta ration is >1. It can also show right atrial and right ventricular enlargement.

Blood test and immunology

No blood test is needed for the diagnosis of pulmonary hypertension; however, multiple blood tests are required for identification

(continued on p. 18)

Table 2

Updated Clinical Classification of Pulmonary Hypertension (PH)

1. **PAH (Pulmonary Artery Hypertension)**
   - Idiopathic
   - Heritable
   - Drug and toxin induced PAH
   - PAH associated with connective tissue disease, HIV, portal hypertension, congenital heart disease and Schistosomiasis
   - PAH long-term responders to calcium channel blockers
   - PAH with overt features of venous/capillaries (PVOD/PCH) involvement
   - Persistent pulmonary hypertension of the newborn syndrome
2. **PH due to left heart disease (most common cause of PH)**
   - PH due to heart failure with preserved ejection fraction
   - PH due to heart failure with reduced ejection fraction
   - Valvular heart disease
   - Congenital/acquired cardiovascular conditions leading to post capillary PH
3. **PH due to lung disease and/or hypoxia**
   - Obstructive lung disease
   - Restrictive lung disease
   - Mixed obstructive and restrictive lung disease
   - Hypoxia without lung disease
   - Developmental lung disorder
4. **PH due to pulmonary artery obstructions**
   - Chronic thromboembolic PH
   - Other PA obstructions
5. **PH with unclear or multifactorial mechanisms**
   - Hematological disorders
   - Systemic and metabolic disorders
   - Others
   - Complex congenital heart disease

PVOD: Pulmonary Veno-Occlusive Disease, PCH: Pulmonary Capillary Haemangiomatosis

Continued from p. 17

of the underlying etiology. Routine hematology, chemistry, liver function tests and TSH are required for all patients. Serological testing for connective tissue diseases, hepatitis and HIV should be ordered based on clinical suspicion.

Right Heart Cath and Vasoreactivity test:

Invasive hemodynamics remains the gold standard for diagnosing PH, it is recommended to be done in centers with PH experience to avoid pitfalls in testing and interpretation. Right heart catheterization is required to confirm the diagnosis of PH, rule out left heart disease, assess the severity of PH and guide medical therapies by evaluating acute vasoreactivity of the pulmonary vasculature. Vasodilator challenge test is done mainly to identify a small group of patients who will respond to oral calcium channel blockers.

Vasoreactivity test is done in selected cases using inhaled nitric oxide, IV Epoprostenol (Prostacyclin analogue that cause pulmonary vasodilation), IV adenosine or inhaled Ilprost (Prostaglandin Analogue which increase intracellular cAMP, causing smooth muscle relaxation). Acute pulmonary vasoreactivity response is defined as reduction of the mean PAP ≥10 mmHg to reach an absolute value of m PAP ≤40 mmHg.

There should be a low threshold for adding left heart catheterization in patients with multiple risk factors for coronary artery disease, HFpEF patients or those with LV systolic or diastolic dysfunction by echocardiogram. Measurement of LVEDP is important to avoid misclassification of patients with falsely elevated PAWP. (Table 4)

Screening for Pulmonary hypertension: PAH carries poor prognosis if not promptly diagnosed and treated. Due to availability of therapies that can impact outcome, screening of high risk patients is recommended even in absence of symptoms.

Systemic sclerosis

- Human immune deficiency virus (HIV)
- Congenital heart disease
- Portopulmonary Hypertension
- Heritable etiologies
- Sickle cell disease

In summary, pulmonary arterial hypertension is an uncommon disease that carries poor prognosis if not promptly diagnosed and appropriately managed; there are many specific therapies that have been approved in the last decade that

Table 3

Other ECHO findings suggestive of pulmonary hypertension used to assess the probability of pulmonary hypertension in addition to tricuspid regurgitation velocity measurement

Pericardial effusion is a poor prognostic finding in patients with pulmonary hypertension

A. The Ventricles – Left Ventricle (LV) and Right Ventricle (RV)	B. Pulmonary Arteries (PA)	C. Inferior Vena Cava (IVC) and Right Atrium (RA)
RV/LV basal diameter ratio >1.0	RV outflow Doppler acceleration tie <105 ms and/or mid systolic notching	IVC diameter >21 mm with decreased inspiratory collapse
Flattening of the interventricular septum (LV eccentricity index >1.1 in systole and/or diastole)	Early diastolic pulmonary regurgitation velocity >2.2 m/sec	RA area (end systole) >18 cm^2
	PA diameter >25 mm	

Echocardiographic features from at least 2 different categories (A/B C) should be present to alter the level of echocardiographic probability of pulmonary hypertension.

Table 4

Acute pulmonary vasoreactivity for patients with idiopathic, heritable or drug-induced PAH	Reduction of mPAP ≥10 mmHg to reach an absolute value of mPAP ≤40 mmHg Increased or unchanged cardiac output
Long-term response to calcium channel blockers	NYHA Class I/II With sustained hemodynamic improvement (same or better than achieved in acute test) after at least 1 year on calcium channel blockers only

change the outcome of this disease. Echocardiogram is an important screening tool, however, invasive hemodynamics from right heart catheterization remains the gold standard to confirm diagnosis and guide management. Suspected pulmonary hypertension cases based on echocardiogram probability or clinical suspicion should be referred to Pulmonary hypertension expert center for comprehensive work up to identify underlying etiology and severity of PH which will guide management plan.

Dr. Butrous is an Advanced Heart Failure and Transplant specialist at Oklahoma Heart Institute, with expertise in managing advanced heart failure and pulmonary hypertension, including the evaluation and treatment of patients needing Mechanical Circulatory Support (LVAD).

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Veno-Venous Extracorporeal Membrane Oxygenation (VV ECMO)

By Adam Betz, MD

INTRODUCTION

With the onset of winter comes respiratory season. From the common cold to influenza and pneumonia, fall and winter herald a rise in respiratory disease. While most cases will abate at home or with antibiotics, a portion of respiratory diseases will progress, leading to hypoxemic or hypercapneic respiratory failure and possibly acute respiratory distress syndrome (ARDS). These more severe cases will be treated with the staples of management and supportive care including antibiotics, supplemental oxygen, lung-protective mechanical ventilation, steroids, neuromuscular blockers, prone positioning, etc. But where should treatment go when optimized conventional therapy remains inadequate to sustain the patient?

Although its first successful use dates to 1972, veno-venous extracorporeal membrane oxygenation (VV ECMO) and its related techniques and technologies have and continue to evolve to yield a better risk-benefit profile (1). The ability to use VV ECMO to oxygenate and ventilate patients independent of their actual lungs allows for the potential rescue of patients in whom conventional therapy has failed.

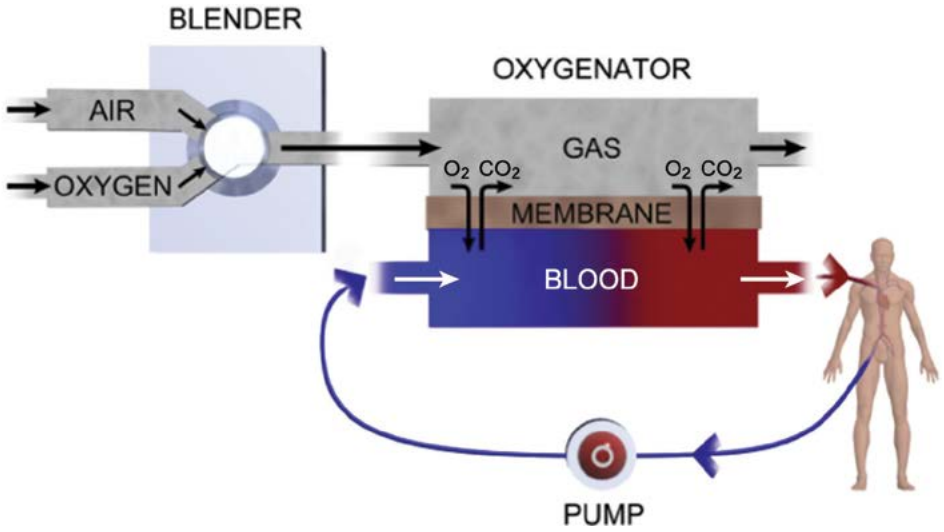
Further, conventional therapy for respiratory failure is not without its own set of risks and benefits. The support provided by the ventilator and its associated injury — ventilator-induced lung injury (VILI) — are thought to play a central role in the morbidity and mortality in ARDS (2). As the safety profile of ECMO continues to improve, it is worth considering whether the risks and benefits of ECMO are the better option for patients in whom the risks and negative effects of conventional management have become too great.

WHAT IS VV ECMO?

The VV ECMO circuit itself begins with a cannula that drains deoxygenated blood from the patient's venous system (Figure 1). This blood then passes through special heparin-coated tubing to a centrifugal pump which then drives the blood through an oxygenator at a set rate of flow. An oxygenator is simply a very fine membrane of hollow tubules through which air and a variable percentage of oxygen flows. The blood is forced across the membrane and, in transit, oxygen diffuses from the gas to the blood, and carbon dioxide diffuses from the blood to the gas. The level of oxygenation provided within the oxygenator is determined by the percentage of oxygen in the gas supplied. This can be varied as needed. The rate of carbon dioxide removal is determined by the rate of flow of gas through the oxygenator and is independent of the blend of oxygen and room air used. The oxygenated blood is then returned to the patient's venous system, albeit at a location more proximal to the heart then where it was drained. This has the effect of creating a "lung before the lungs" or, more precisely, a "lung before the heart." The amount of respiratory support that can be achieved is dependent on patient anatomy, physiology, cannula choice, and circuit design, but the larger the percentage of the patient's cardiac output that can be captured by the circuit, the more complete the support provided.

Figure 1

Schematic of Generic ECMO Circuit



This VV ECMO configuration is typically achieved in one of two ways. The first, and most expeditious, is done by placing a long, large caliber (up to 25fr) multi-stage drainage cannula with a series of drainage holes through the femoral vein and into the inferior vena cava. This then drains much of the venous return from the lower half of the body. The oxygenated blood is then returned via a smaller cannula with a single hole, usually placed in the internal jugular vein, and terminating as close as possible to the right atrium (Figure 2). Oxygenated blood is thus directed directly to the heart and mixes with the deoxygenated blood from the upper body and any deoxygenated blood that bypasses the drainage cannula below.

Alternatively, Getinge and Medtronic both supply bi-caval dual-lumen cannulas that can accomplish this with a single cannula (the Avalon and Crescent, respectively). These cannulas are placed in the right internal jugular vein and terminate in the inferior vena cava. The drainage lumen has ports in both the superior and inferior vena cavae while the return lumen drains through a port directing blood flow into the right atrium and across the tricuspid

valve (Figure 3). Benefits of this system include reduction in indwelling lines, improved patient mobility including ambulation, and capture of both SVC and IVC deoxygenated blood. However, these require more expertise to place, usually under fluoroscopy or echocardiography, as malposition of the return port can easily lead to oxygenated blood being recirculated in the drainage lumen and failing to reach and support the patient.

HOW CAN ECMO IMPROVE OUTCOMES?

Despite extensive research helping to elucidate optimal ventilatory strategies, the role of steroids, neuromuscular blockers, prone positioning, and more, the morbidity and mortality burden of respiratory failure, and ARDS in particular, remains large. ARDS comprises approximately 10% of ICU admissions and as much as a quarter of all patients requiring mechanical ventilation (3). Further, in severe ARDS, defined by the Berlin definition as having a Pa02/FiO2 <100 mmHg, the mortality rate has been reported to be as high as 52% (3).

In addition to the mortality burden, disability and long term pulmonary dysfunction remain an issue for survivors. This fact is made more striking when one notes that these long term effects are very often a result of the treatment for ARDS rather than of ARDS itself. Large doses of sedatives required to ensure synchrony and apparent comfort on the ventilator are associated with long-term psychological issues such as PTSD after discharge. Follow-up CT scans in survivors of ARDS demonstrate that the most fibrotic portions of their lungs are the non-dependent regions most recruited by the ventilator while the dependent regions most effected by ARDS show the greatest recovery (4). The degree of fibrosis also worsens with increased ventilator time and higher positive end-expiratory pressures (PEEP) levels used (4). Lastly, the fragility of patients in severe ARDS, along with the discomfort and agitation caused by intubation, hypercapnia, and hypoxemia, means that they are often sedated to the point of obtundation, with muscle wasting, catabolism, and deconditioning resulting.

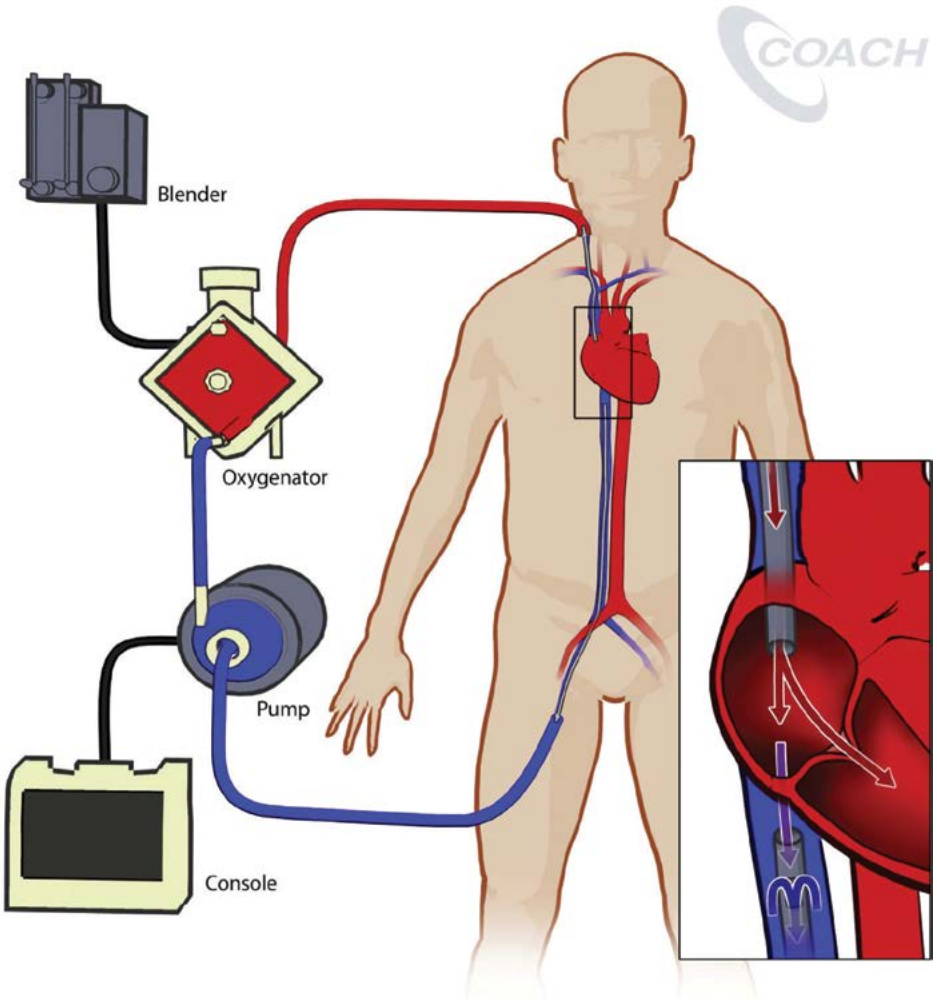
ECMO allows for a management strategy that, by providing extrapulmonary oxygenation and ventilation, allows for much more aggressive lung rest and rehabilitation. Many centers report supporting patients on ECMO for respiratory failure with minimal sedation, ultraprotective ventilator strategies and even, in select patients, extubation and ambulation. This, in theory, should lead to a significant decrease in VILI sedative associated side effects, and deconditioning.

Given the extreme circumstances in which ECMO is deployed, the small yet growing number of patients receiving ECMO, and the amount of case volume seen in any particular center, large, high-quality randomized controlled trials are still lacking and much of the ECMO data reported is observational. Further, given the rapidly developing technology in ECMO and the continually improving safety profile of the equipment, it is difficult to read the results of older studies into modern practice. Notably though, during the 2009 influenza epidemic the CESAR trial, one of the most robust randomized controlled trials to date, found that disability-free survival at six months was significantly greater in ARDS patients randomized to ECMO versus conventional management (63% vs 47%, respectively. P=0.03) (5). Perhaps in contrast, the most recent large randomized controlled trial (EOLIA) showed no difference in 60-day mortality in patients with very severe ARDS randomized to either ECMO or conventional management with ECMO available as rescue (6). Both of these trials, though, still suffer from less than ideal study sizes and a very large amount of crossover stemming from the thought that it would be unethical to withhold ECMO as rescue therapy in those patients randomized to conventional therapy. For instance, in EOLIA, fully 28% of patients randomized to conventional therapy underwent ECMO.

Therefore, as we await more robust data to determine the nature and magnitude of benefit, it remains for clinicians to assess closely on a case by case basis to determine by their best judgment when and whether the risks and benefits of transitioning a particular patient to ECMO outweigh the risks and benefits of continued conventional management.

Figure 2

Dual Cannula VV ECMO Circuit. Drainage occurs by the IVC cannula with blood returned to the right atrium.



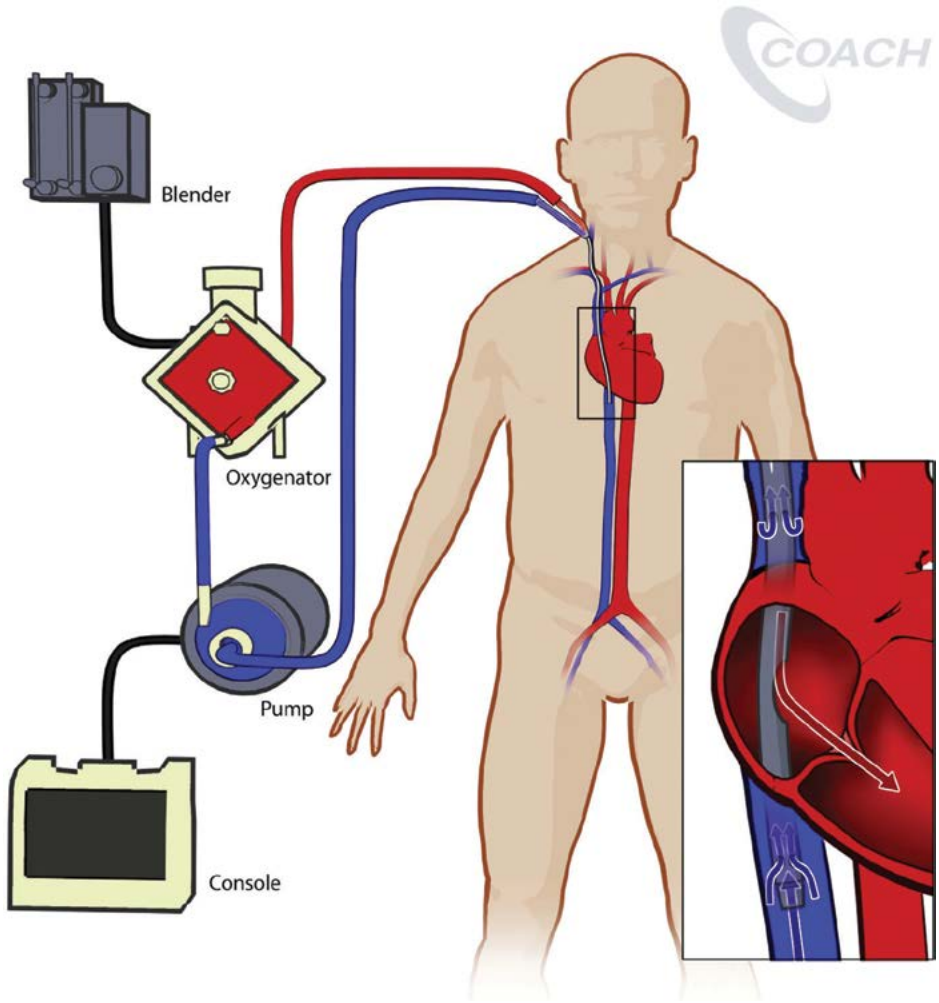
WHO IS APPROPRIATE FOR ECMO?

ECMO care is typically provided in high-volume referral centers and the job of most clinicians is to determine when their patient is appropriate for referral to such a center. The Extracorporeal Life Support Organization (ELSO) states that VV ECMO should be considered for hypoxemic respiratory failure when the expected mortality is >50% and is indicated when expected mortality exceeds 80% (7). 80% mortality is predicted by a P/F ratio <100 on 90% FiO2 and/or a Murray score of 3-4 despite optimal care (7). ECMO should also be considered in patients with severe hypercapnia despite high plateau pressures, as well as in patients with severe air leak syndromes for which positive pressure ventilation would be counterproductive. ECMOnet, CESAR, and EOLIA have all used differing criteria as indications for ECMO though and there remains no consensus, underlining the

(continued on p. 22)

Figure 3

Bicaval Dual-Lumen Cannula VV ECMO Arrangement. A single cannula provides both drainage and return of blood.



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personalized approach that must be taken to ECMO initiation.

The remaining question for clinicians then is, "how do I determine if my patient with severe respiratory failure or ARDS is a candidate for ECMO?" To answer this, two main issues need to be addressed: 1) is there an ultimate destination of either recovery or definitive therapy for this patient? 2) are the risks and benefits of ECMO preferable to the continued risks of conventional management for the particular patient.

First, ECMO is only a supportive therapy and there is no destination version available. ECMO does not cure underlying respiratory pathology. Therefore, it is imperative to ask what exactly ECMO is bridging a patient to. This can be recovery in the case of ARDS, or definitive therapy in those awaiting lung transplants, as well as others. But ECMO should not be used in a patient that has no potential for meaningful recovery. This leads to the dreaded "bridge to nowhere" scenario where a patient may be completely awake and responsive on ECMO with the only option of remaining on ECMO indefinitely until complications take hold.

Second, ECMO is becoming safer but is not without risks. It adds indwelling lines and infectious risk. Systemic anticoagulation is a requirement to keep the circuits flowing and could therefore be extremely high risk to patients such as those with hemorrhagic strokes who would have contraindications to anticoagulation. Hemorrhage requiring transfusion is common on ECMO. Thrombosis, embolism, thrombocytopenia, or vascular injury are all complications as well (7, 8). In the patient failing conventional management, one must judge carefully whether the ongoing complications of barotrauma and other VILI, pneumothoraxes, continued hypoxemia, and the like are not more severe than taking the risks of ECMO. Criteria provided by ELSO and others help guide this decision but ultimately the uniqueness of each patient and their complications to a given point require a thoughtful individualized approach that is often best made in communication with a center experienced in ECMO.

Lastly, ECMO should be considered early. That is not to say that cannulation should always happen early. But data have consistently shown that an increased length of time on high ventilator settings predicts worse outcomes with eventual transition to ECMO (7). ELSO even suggests that high ventilator settings for >7 days serve as a relative contraindication to VV ECMO. But more than this, a thorough evaluation takes consideration and time and deliberating the question of ECMO early on means that when and if the time comes, the necessary teams, procedures, and resources can all be mobilized in a quicker and more controlled manner.

CONCLUSION

In summary, VV ECMO is a rapidly developing tool that allows patients to acutely survive the previously non-survivable and may potentially decrease the overall mortality, morbidity, and disability that comes with conventional management of respiratory failure and ARDS. It comes with its own unique risk-benefit profile and its use and patient selection require a carefully-considered, highly individualized approach best achieved with early communication with a team experienced in ECMO management.

Dr. Betz is an Intensivist at Oklahoma Heart Institute who specializes in neuro and cardiac critical care, including ECMO and VAD management.

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