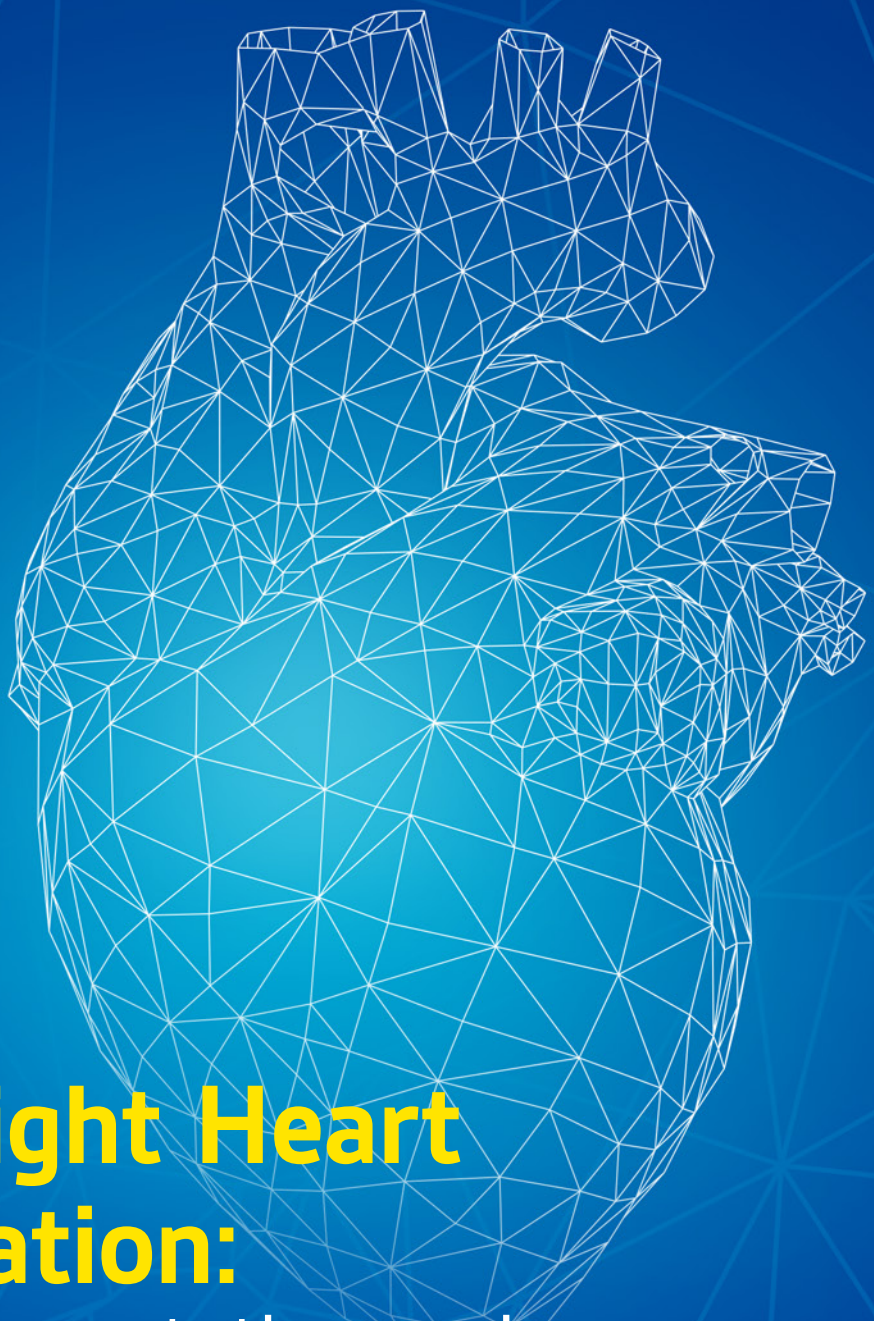
CardioVascular Learning Network



CATHLAB SPOTLIGHT 2

Exercise Right Heart Catheterization:

Practical Implementation and Evolving Role in Heart Failure Care

In order to fulfill this educational activity, please visit Hfpeftherapies.com to complete the evaluation and obtain your certificate.

HMP Education

Provided by HMP Education, an HMP Global Company

Supported by an educational grant from Edwards Lifesciences LLC.

INTENDED LEARNERS

This program is intended for physicians, cath lab teams and institutions treating heart failure patients, interested in learning more about future heart failure treatment technologies.

LEARNING OBJECTIVES

- Understand the indications and procedure of exercise right heart catheterization (eRHC)
- Learn how to establish a eRHC team, including, economic implications of the program and team member roles and responsibilities
- Identify the collaboration of specialties, needed to create a heart failure team and determine the necessary pathways for patient referrals throughout the health care system

CLAIMING CREDIT

To be eligible for documentation of credit for each session attended, learners must participate in the activity and complete the activity evaluation. **Participants who complete the evaluation online within active dates of the training will receive documentation of credit.** Your certificate may not load if you are accessing it from a smartphone, or if your browser settings do not allow a new tab/window to open.

Once a certificate has been claimed, physicians and pharmacists may elect for credits to be submitted on their behalf to their boards via additional fields that will appear within the Claim Certificate page. Credits must be submitted through this process to be reported to the American Board of Surgery and the National Association of Boards of Pharmacy.

Release Date: September 5, 2025
Expiration Date: October 30, 2026
Estimated Time to Complete: 0.25 hour
There is no fee associated with this activity.

CONTINUING EDUCATION

In support of improving patient care, HMP Education is jointly accredited by the Accreditation Council for Continuing Medical Education (ACCME), the Accreditation Council for Pharmacy Education (ACPE), and the American Nurses Credentialing Center (ANCC), to provide continuing education for the healthcare team.

Note: This statement is not an indication of approved credits. Please see below for full accreditation details, including credit types and totals, for this activity.

PHYSICIANS

HMP Education designates this internet enduring activity for a maximum of 0.25 *AMA PRA Category 1 Credit™*. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

NURSES

This continuing nursing education internet enduring activity awards 0.25 contact hour.

NURSE PRACTITIONERS

American Academy of Nurse Practitioners National Certification Program accepts *AMA PRA Category 1 Credit™* from organizations accredited by the ACCME.

PHYSICIAN ASSISTANTS

HMP Education has been authorized by the American Academy of PAs (AAPA) to award AAPA Category 1 CME credit for activities planned in accordance with the AAPA CME Criteria. This internet enduring activity is designated for 0.25 AAPA Category 1 credit. Approval is valid until October 30, 2026. PAs should only claim credit commensurate with the extent of their participation.

ARDMS & CCI SONOGRAPHERS, TECHNICIANS,TECHNOLOGISTS

American Medical Association (AMA) Physicians Recognition Award, Category I CME meets the requirements of the ARDMS Accepted Continuing Education Evaluation Model System (AACEEMS). You may submit your CME credits to ARDMS.

ARDMS Credentials

- RDMS® Registered Diagnostic Medical Sonographer®
- RDCS® Registered Diagnostic Cardiac Sonographer®
- RVT® Registered Vascular Technologist®
- RPVI® Registered Physicians Vascular Interpretation®

This ACCME accredited opportunity meets the Category 1 CEU requirements of the Cardiovascular Credentialing International (CCI) credential maintenance acceptance policy. You may submit your CME credits to CCI.

CCI Credentials

- RCS: Registered Cardiac Sonographer
- RVS: Registered Vascular Specialist
- CCT: Certified Cardiographic Technician
- ACS: Advanced Cardiac Sonographer
- CRAT: Certified Rhythm Analysis Technician
- RCES: Registered Cardiac Electrophysiology Specialist

INTERNATIONAL RECOGNITION

Visit this link for countries and regions have reciprocity with the ACCME.

Visit this link for additional countries that accept ACCME-accredited continuing medical education (CME).

USE OF PROPRIETARY NAMES

This continuing medical education activity may include device or medicine brand names for participant clarity purposes only, due to the presence of different branded versions of the same product. No product promotion or recommendation should be inferred.

UNAPPROVED AND/OR INVESTIGATIONAL USES OF DRUGS AND DEVICES

This activity may contain information about experimental and other uses of drugs or devices that are not currently approved by the European Medicines Agency (EMA) of the European Union or the Food and Drug Administration (FDA) of the United States. Participants are strongly encouraged to consult approved product labeling for any drug or device mentioned in this activity before use. The opinions expressed during this activity are the opinions of the respective authors, presenters, or moderators and do not necessarily reflect the opinions of HMP Education.

DISCLAIMERS

The material presented and related discussions are not intended to be medical advice, and the presentation or discussion of such material is not intended to create and does not establish a provider-patient relationship. Medical advice of any nature should be sought from an individual's own healthcare provider.

The opinions expressed in this educational activity are those of the faculty and are not attributable to HMP Global or any of its subsidiaries or affiliates. Clinical judgment must guide each professional in weighing the benefits of treatment against the risk of toxicity. Dosages, indications, and methods of use for products referred to in this activity are not necessarily the same as indicated in the package insert for each product, may reflect the clinical experience of the presenters, and may be derived from the professional literature or other clinical sources. Consult complete prescribing information before administering.

DISCLOSURE OF RELEVANT FINANCIAL RELATIONSHIPS

HMP Education is an independent provider of continuing medical education. HMP Education has no proprietary or financial interest in medical or healthcare products over which the FDA (USA) or EMA (EU) has regulatory authority.

In accordance with our disclosure policies, HMP Education is committed to ensuring balance, independence, objectivity, and scientific rigor for all accredited continuing education. These policies include assigning relevance to and mitigating all perceived or real relevant financial relationship (conflicts of interest) between any individual with control over the content and any ineligible company (commercial interest) as defined by the ACCME and CPME.

Any individual with control over accredited content, including planner, faculty, and reviewer, is required to globally disclose:

1. Individual relationship(s) or lack thereof, and its nature, with any/all ineligible company, and;
2. Any investigational, off-label, or non-FDA approved content or discussion

HMP Education has reviewed these disclosures, assigned relevance based on the relationship and scope of content, and identified those with the potential to compromise the goals and educational integrity of the education. Relevant relationships, or lack thereof, are shared with the learner.

Education has been independently peer-reviewed to validate content, mitigate identified financial relationships (conflicts of interest), and ensure:

1. All recommendations involving clinical medicine are based on evidence that is accepted within the medical profession as adequate justification for their indications and contraindications in the care of patients.
2. All scientific research referred to, reported, or used in accredited continuing education in support or justification of a patient care recommendation conforms to generally accepted standards of experimental design, data collection, and analysis.
3. Content is appropriate, fair and balanced, unbiased, referenced, and non-promotional.

All relevant financial relationships have been mitigated.

FACULTY

The faculty have reported the following:

Dr. Stroud: Advisory Board – Johnson and Johnson, United Therapeutics; Consultant – Edwards Lifesciences

Dr. Muhammad: Proctor/Speaker – Abbott, Edwards Lifesciences, Medtronic; Consultant/Research Funding – Abbott, Ancora Heart, Edwards Lifesciences, Emboline, Medtronic

CLINICAL REVIEWER

Peter Oettgen MD FACC FAHA FACP
Preventive Cardiology
Beth Israel Deaconess Medical Center
Boston, MA

Dr. Oettgen has disclosed no relevant financial relationship with any ineligible company (commercial interest).

PLANNING COMMITTEE

Planning for this activity was conducted by faculty advisors. To further support the development of the content, additional information regarding professional roles, responsibilities, and teamwork was gathered through survey input from our target audience and/or a comprehensive literature review.

HMP Education planners and staff include Samantha Bella; Brielle Calleo; MaryEllen Fama; Samantha Joy; Mary Johnson; Randy Robbin; and Andrea Zimmerman, EdD, CHCP. No HMP Education staff has disclosed a relevant financial relationship with any ineligible company (commercial interest).

ADA STATEMENT

HMP Education complies with the legal requirements of the Americans with Disabilities Act and the rules and regulations thereof. Any participant in this educational activity who needs accommodation(s) may submit a request to the support team.

PRIVACY POLICY

HMP Education protects the privacy of personal and other information regarding participants, educational partners, and joint providers. HMP Education and our joint providers will not release personally identifiable information to a third party without the individual's consent, except such information as is required for reporting purposes to the appropriate accrediting agency. HMP Education maintains physical, electronic, and procedural safeguards that comply with federal regulations to guard your nonpublic personal information.

COMMERCIAL SUPPORT

Supported by an educational grant from Edwards Lifesciences LLC.

CONTACT US

For immediate assistance, please explore our HMP Education Help Center or chat with our Virtual CE Assistant, which can answer most common questions related to claiming credits and the HMP Education website. If you have a question or grievance that cannot be answered by our Virtual CE assistant and Help Center, please contact the support team. Our accreditation and compliance team will respond to your inquiry within one business day.

1. INTRODUCTION

Right heart catheterization (RHC) is a foundational diagnostic tool in the evaluation of patients with suspected cardiac disease. When performed during exercise, RHC can unmask functional and hemodynamic abnormalities, such as diastolic dysfunction, that may not be evident at rest. This is particularly relevant in patients with suspected heart failure with preserved ejection fraction (HFpEF), a condition often complicated by comorbidities that obscure resting findings.[1] Among various stress methods, exercise is more effective than methods such as giving fluid through an IV to see how the heart responds (fluid challenge) in revealing the characteristic hemodynamic signature of HFpEF, specifically, a marked rise in pulmonary arterial wedge pressure during exertion.[2] As such, exercise RHC (eRHC)—either alone or combined with gas exchange analysis in invasive cardiopulmonary exercise testing (iCPET)—is now considered the gold standard for diagnosing HFpEF.[1, 3] A recent systematic review and meta-analysis further reinforces the diagnostic value of exercise-based hemodynamics in this population.[4]

Despite its demonstrated clinical value and safety, catheterization laboratories have struggled to widely adopt eRHC/iCPET. According to a recent Medicare claims analysis, only 10% of right heart catheterizations included exercise.

This article follows a previously published CME article, "Recognizing & Treatment Options in Patients with HFpEF," which highlighted the challenges in identifying HFpEF, particularly when resting studies are inconclusive. That discussion emphasized the role of exercise-induced hemodynamics in uncovering early disease. This current article expands upon that foundation by outlining how to implement an eRHC program, including team structure, logistics, and collaborative care models essential for effective integration into clinical practice.

Steven C. Stroud, MD
Director, Pulmonary Hypertension
Oklahoma Heart Institute
Tulsa, Oklahoma

2. ROLES AND COLLABORATION IN THE CATH LAB

At our institution, there was a strong desire to establish a rapid pathway to identify and risk-stratify heart failure and pulmonary vascular disease, with the goal of reducing diagnostic and treatment lag.[5] This initiative was spearheaded by a collaboration between advanced heart failure and interventional cardiology physicians, with critical support from the catheterization (cath) lab leadership. Before launching the program, numerous meetings were held with key stakeholders, including the cath lab manager, nurses, radiation technologists, and hospital administration.

Once the foundational team was in place, planning centered on defining workflows and establishing the necessary resources to support these procedures, which are more complex than standard RHCs because they include exercise components and advanced physiologic measurements. During each eRHC or iCPET procedure, physician leadership may vary depending on the referral pathway and institutional structure but typically includes either a heart failure specialist or an interventional cardiologist. Alongside the physician performing the catheterization, staffing largely mirrors that of a standard resting RHC, but also includes a registered nurse or exercise physiologist responsible for managing the ergometer and/or metabolic cart in the case of iCPET.

Following program launch, the cath lab team has played a key role in ongoing process improvement. Their input has contributed to refinements in equipment use, room set-up, and patient flow, enhancing both efficiency and safety over time.

Steven C. Stroud, MD
Director, Pulmonary Hypertension
Oklahoma Heart Institute
Tulsa, Oklahoma

3. A PRACTICAL GUIDE TO eRHC IMPLEMENTATION

Prior to program launch, education programs were held for catheterization lab registered nurses and radiology technologists, focusing on three core areas: 1) physiologic rationale, 2) equipment set-up and use, and 3) potential procedural pitfalls. In addition, three simulated cases were performed to evaluate team coordination and protocol execution. The total implementation time—from initial planning to the first iCPET—was approximately four months.

eRHC is typically performed in the supine position with venous access obtained via the right internal jugular or right brachial vein. Supine positioning is generally more familiar to cath lab personnel and requires less equipment repositioning. Clinicians should also bear in mind that supine positioning may not as readily identify preload failure as an etiology of dyspnea.[6] Regardless of patient position, appropriate transducer leveling at mid-chest (½ the anterior-posterior diameter) should be ensured.[7] A radial artery line may also be used for direct assessment of arterial oxygen content, although contemporary data suggest that appropriate transcutaneous pulse oximetry is likely sufficient to estimate oxygen saturation.[8]

Equipment needs include an ergometer and, if performing ICPET, a metabolic cart. An exercise ramp protocol of 10-20 Watts, increased every 2-3 minutes until maximal exercise is achieved, is frequently used. In the case of iCPET, a metabolic cart is used for gas exchange analysis as well as flow-volume loop measurements.[9]

Thermodilution cardiac outputs should be obtained at each stage, with a minimum of measurements taken at rest and peak exercise. Indirect or assumed Fick assessment is not accurate during exercise due to a mismatch with oxygen consumption. With iCPET, the direct Fick method is used, with or without thermodilution, as thermodilution tends to overestimate cardiac output during exercise.[10]

Room logistics should allow for supine cycling with safe access to central venous and arterial lines. In many labs, pre-catheterization pulmonary function testing is performed in a staging area to streamline room turnover. Our lab schedules eRHC/iCPET procedures in 1.5-hour blocks—longer than a typical resting RHC—but this allows for sufficient recovery and throughput of up to four cases in a half-day session.

Steven C. Stroud, MD
Director, Pulmonary Hypertension
Oklahoma Heart Institute
Tulsa, Oklahoma

4. ECONOMICS OF eRHC

To further ensure the eRHC/iCPET program was meeting financial expectations, a financial analysis was performed on the first sixty cases. This review showed a cost margin percentage (CM%) of approximately 60% with a mixed payer group, with commercial insurance yielding a CM% of 70 and Medicare a CM% of 45. In comparison, a resting RHC has a cost margin percentage of approximately 30%. Based on our institution's payer mix, the average reimbursement for eRHC/iCPET is approximately $1,700, compared to $400 for a resting RHC, depending on payer source.

Naturally, this higher reimbursement reflects the procedure's higher complexity and time. In our laboratory's experience, eRHC/iCPET cases are scheduled in 1.5-hour blocks, compared to the standard 1-hour slot for resting RHC. iCPET metabolic analysis often includes baseline pulmonary function testing, which can be completed in the pre-catheterization area, freeing up procedural time and increasing throughput. Our center typically performs four iCPETs in a half-day lab session, optimizing staff and equipment use.

Beyond favorable margins, eRHC/iCPET is consistently safe and well-suited for outpatient settings, with a low rate of serious complications.[11] In over 200 cases performed at our center, there have been no significant adverse events; only one patient was admitted for severe hemodynamic derangement, in line with the reported safety profile. The typical post-procedure recovery time at our institution is approximately one hour.

In addition to procedural revenue, the program provides downstream value by identifying patients eligible for advanced therapies, such as TEER, TAVR, LAAO, pulmonary hypertension treatments, and enrollment in clinical trials. This broader return on investment helps justify lab time, staffing, and capital investment.

As reimbursement policies may vary by institution and payer mix, it is essential to engage finance and billing departments early in program development. Medicare and commercial insurers generally reimburse eRHC/iCPET at higher levels than resting catheterizations due to the added complexity and physiologic measurements obtained. Documenting medical necessity, protocol adherence, and diagnostic impact can support both initial billing and appeals when needed.

Steven C. Stroud, MD
Director, Pulmonary Hypertension
Oklahoma Heart Institute
Tulsa, Oklahoma

5. COLLABORATIVE APPROACH TO CARE

Heart failure care is increasingly complex, with patients presenting multiple challenges and a growing number of treatment options—many still under investigation. To meet these demands, strong collaboration between advanced heart failure physicians and interventional cardiologists is essential. A dedicated Heart Failure Team—typically including heart failure specialists, interventional cardiologists, surgeons, electrophysiologists, imaging experts, and nurse coordinators—ensures comprehensive, patient-centered care.

This multidisciplinary team is also critical to developing and sustaining a successful heart failure research program, as many emerging therapies lie at the intersection of multiple specialties. At our institution, this collaborative model has supported program growth, enabled delivery of complex therapies, and positioned us as active participants in multiple pivotal clinical trials.

Effective heart failure care also depends on collaboration beyond the core heart team. Electrophysiologists, genetic counselors (GCs), pulmonary hypertension (PH) specialists, and primary care providers all benefit from timely communication and shared decision-making. For example, PH specialists may request eRHC to clarify pre- vs. post-capillary contributions, and GCs may be engaged when cardiomyopathy is suspected. Clear documentation and coordinated follow-up plans ensure that all providers have access to relevant hemodynamic and clinical data.

Kamran I. Muhammad, MD, FACC, FSCAI
Director, Structural Heart Disease Program
Co-director, Cardiac Catheterization Laboratory
Director, Cardiovascular Research
Physician Lead, Cardiovascular Service Line
Oklahoma Heart Institute
Hillcrest Healthcare System
Tulsa, Oklahoma

6. PATIENT REFERRAL PROCESS

The patient population referred for exercise right heart catheterization (eRHC) or invasive cardiopulmonary exercise testing (iCPET) is diverse, reflecting the diagnostic uncertainty that often surrounds patients with unexplained dyspnea or suspected HFpEF. Referrals most commonly originate from advanced heart failure specialists and general cardiologists, but pulmonary and internal medicine physicians are also frequent referral sources. Pulmonary hypertension clinics may also refer patients when post-capillary contributions to elevated pulmonary pressures are suspected.[12] In some institutions, sports cardiologists, electrophysiologists, and congenital heart disease specialists may also direct patients to eRHC evaluation when exercise intolerance is a concern.

Early identification of appropriate referral sources was essential to the growth of our program. Establishing clear indications, providing structured referral templates, and offering educational sessions for both cardiology and pulmonology divisions helped build awareness and clinical confidence. Pulmonologists, in particular, found value in eRHC/iCPET for distinguishing pulmonary vascular disease from HFpEF and deconditioning, enhancing triage for therapies like pulmonary vasodilators or transplant evaluation.

Our team also engaged in proactive outreach—meeting with outpatient providers, providing feedback reports post-procedure, and emphasizing turnaround time for test results. These strategies helped strengthen the referral network and establish the eRHC program as a valuable diagnostic tool. Direct communication between cath lab staff and referring providers improved

scheduling and patient preparation, reducing incomplete studies and no-shows.

The eRHC program has become a cornerstone of our clinical trial infrastructure. Clinical trials for novel heart failure therapies often require precise hemodynamic criteria for inclusion, particularly those aimed at HFpEF, PH, or exercise intolerance. Our experience with standardized protocols and consistent output made the lab an attractive collaborator for industry and investigator-initiated studies. The cath lab team contributes by adhering to trial-specific workflows, collecting protocol-driven measurements, and ensuring compliance with regulatory documentation. *(See Figure 1 for our institution's proposed referral pathway designed to streamline and simplify patient evaluation for eRHC.)*

Steven C. Stroud, MD
Director, Pulmonary Hypertension
Oklahoma Heart Institute
Tulsa, Oklahoma

7. CONCLUSION

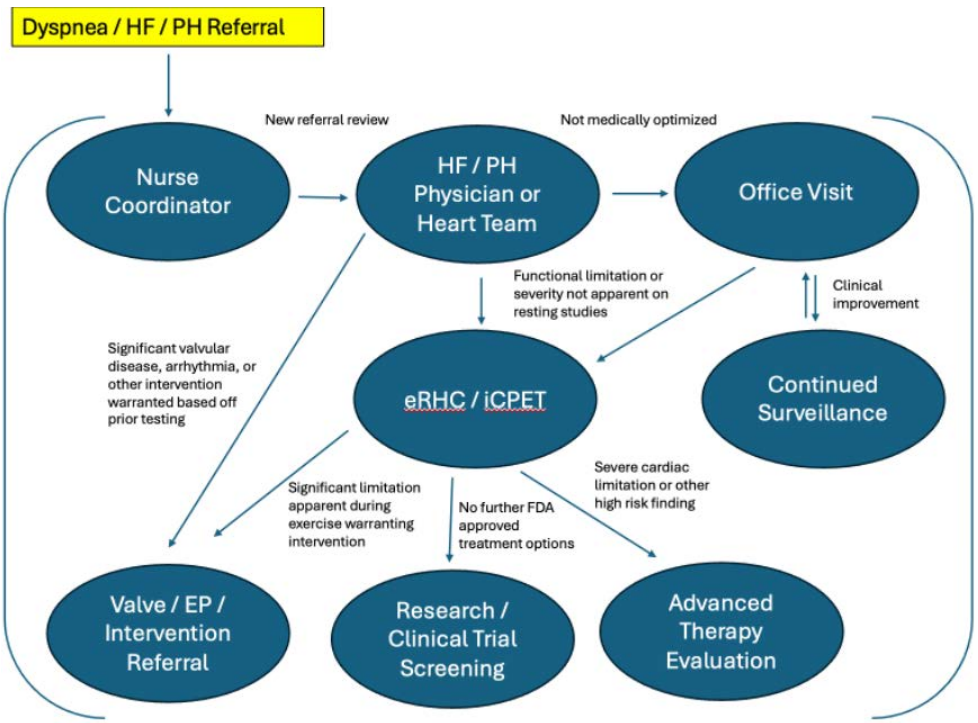
Exercise right heart catheterization and iCPET are increasingly recognized as essential tools for evaluating patients with unexplained exertional symptoms, particularly those with suspected HFpEF. Despite being underutilized, eRHC provides critical hemodynamic data that can directly influence diagnosis and treatment.

Establishing an eRHC program requires careful planning, strong institutional backing, and collaborative leadership, especially between advanced heart failure and interventional cardiology teams. Our center's experience underscores the value of standardized workflows, defined referral criteria, and broad engagement across cardiovascular and pulmonary specialties.

Looking ahead, eRHC is poised to play a more prominent role in heart failure care, particularly as clinical trials demand precise hemodynamic phenotyping and new therapies become available. Expanding access to these programs through provider education, clinical trial involvement, and multidisciplinary coordination may ultimately improve patient outcomes and promote more equitable delivery of advanced care.

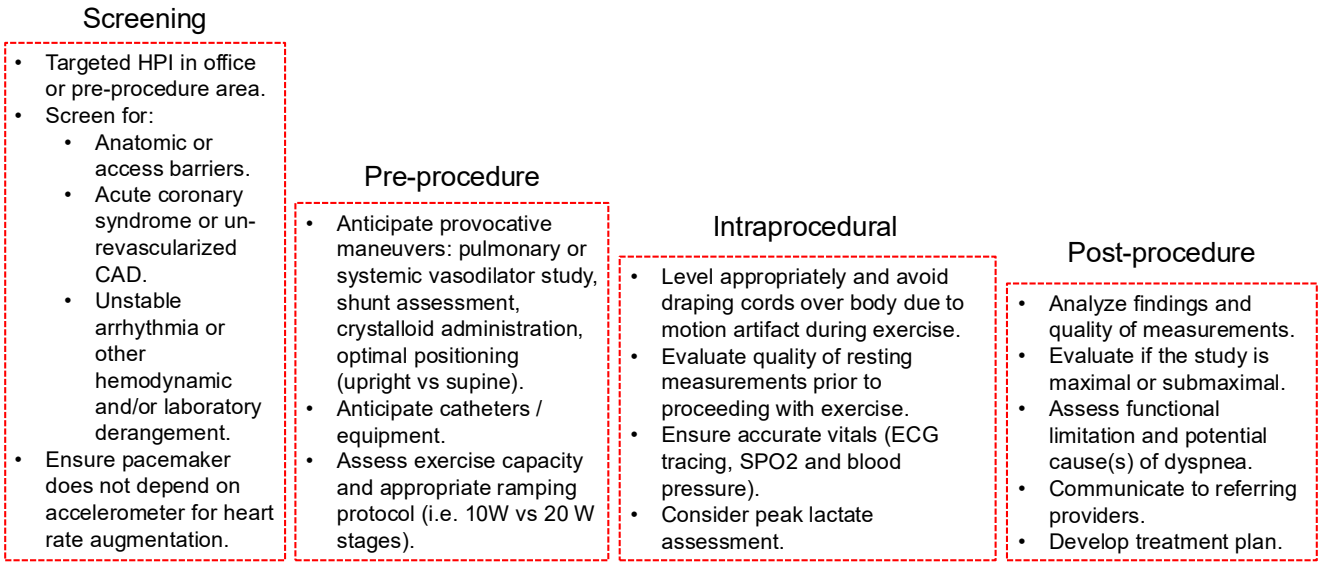
Steven C. Stroud, MD
Director, Pulmonary Hypertension
Oklahoma Heart Institute
Tulsa, Oklahoma

Figure 1: Proposed Referral Pathway for eRHC/iCPET Evaluation.



This schematic outlines a streamlined approach for evaluating patients referred for unexplained dyspnea, suspected heart failure with preserved ejection fraction (HFpEF), or pulmonary hypertension (PH). The pathway begins with a nurse coordinator review and proceeds to multidisciplinary evaluation by a heart failure (HF) or PH specialist, often within a collaborative Heart Failure Team. Based on clinical findings and prior testing, patients may be directed to office optimization, exercise right heart catheterization (eRHC), or invasive cardiopulmonary exercise testing (iCPET). Test results inform further triage for targeted interventions, research enrollment, or advanced therapies. The Heart Failure Team may include specialists in structural cardiology, pulmonology, electrophysiology, and congenital heart disease, depending on institutional resources.

Figure 2: Optimizing Exercise RHC



8. REFERENCES

1. Borlaug BA. Evaluation and management of heart failure with preserved ejection fraction. Nat Rev Cardiol. 2020;17(9):559-73.
2. Andersen MJ, Olson TP, Melenovsky V, Kane GC, Borlaug BA. Differential hemodynamic effects of exercise and volume expansion in people with and without heart failure. Circ Heart Fail. 2015;8(1):41-8.
3. Eisman AS, Shah RV, Dhakal BP, Pappagianopoulos PP, Wooster L, Bailey C, et al. Pulmonary Capillary Wedge Pressure Patterns During Exercise Predict Exercise Capacity and Incident Heart Failure. Circ Heart Fail. 2018;11(5):e004750.
4. Baratto C, Caravita S, Soranna D, Dewachter C, Bondue A, Zambon A, et al. Exercise haemodynamics in heart failure with preserved ejection fraction: a systematic review and meta-analysis. ESC Heart Fail. 2022;9(5):3079-91.
5. Huang W, Resch S, Oliveira RK, Cockrill BA, Systrom DM, Waxman AB. Invasive cardiopulmonary exercise testing in the evaluation of unexplained dyspnea: Insights from a multidisciplinary dyspnea center. Eur J Prev Cardiol. 2017;24(11):1190-9.
6. Rao VN, Kelsey MD, Blazing MA, Pagidipati NJ, Fortin TA, Fudim M. Unexplained Dyspnea on Exertion: The Difference the Right Test Can Make. Circ Heart Fail. 2022;15(2):e008982.
7. Kovacs G, Avian A, Pienn M, Naeije R, Olschewski H. Reading pulmonary vascular pressure tracings. How to handle the problems of zero leveling and respiratory swings. Am J Respir Crit Care Med. 2014;190(3):252-7.
8. Hardin KM, Giverts I, Campain J, Farrell R, Cunningham T, Brooks L, et al. Systemic Arterial Oxygen Levels Differentiate Pre- and Post-capillary Predominant Hemodynamic Abnormalities During Exercise in Undifferentiated Dyspnea on Exertion. J Card Fail. 2024;30(1):39-47.
9. Maron BA, Cockrill BA, Waxman AB, Systrom DM. The invasive cardiopulmonary exercise test. Circulation. 2013;127(10):1157-64.
10. Hsu S, Brusca SB, Rhodes PS, Kolb TM, Mathai SC, Tedford RJ. Use of thermodilution cardiac output overestimates diagnoses of exercise-induced pulmonary hypertension. Pulm Circ. 2017;7(1):253-5.
11. Keusch S, Bucher A, Muller-Mottet S, Hasler E, Maggiorini M, Speich R, et al. Experience with exercise right heart catheterization in the diagnosis of pulmonary hypertension: a retrospective study. Multidiscip Respir Med. 2014;9(1):51.
12. Kovacs G, Bartolome S, Denton CP, Gatzoulis MA, Gu S, Khanna D, et al. Definition, classification and diagnosis of pulmonary hypertension. Eur Respir J. 2024;64(4).