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Comprehensive Review

Charting the Course for Careers in Interventional Heart Failure: Training, Challenges, and Future Directions

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A B S T R A C T

Interventional heart failure (IHF) has emerged as a critical subspecialty due to the increasing complexity of heart failure (HF) treatment now spanning both pharmacological and nonpharmacological device-based therapies. Although initially existing at the intersection of interventional cardiology and advanced HF, IHF has expanded to encompass multiple domains of cardiology including cardiogenic shock (CS), transcatheter valve therapies, relief of increased left atrial pressures, and coronary intervention in low ejection fraction and after heart transplant. Although rapidly growing, training pathways remain elusive, and existing training pathways are not well equipped to deliver necessary training components and encourage growth in the field. Those with a career in IHF can be divided into 3 main phenotypes. Those who are not formally interventional trained, but might implant pressure sensors, perform endomyocardial biopsies, and place nonlarge bore devices. Those who have formal interventional cardiology training might focus on coronary interventions, shock calls, and large-bore devices. Those with structural training might focus on transcatheter valve therapies and structural procedures in HF. There are several possible training pathways for IHF and we propose 5 focuses for training. Finally, we describe areas of interest and growth for careers in IHF. The field of IHF has been misunderstood as one of "jack of all trades" but actually represents the trend of increasing specialization for careers within cardiology due to the increasing complexity of therapeutic options within cardiovascular disease. By addressing current training challenges, the field is poised to make significant strides. Trainees entering this specialty will have the opportunity to be at the forefront of cardiovascular care, contributing to innovative treatments and improving outcomes for patients with complex HF.

Introduction

With the advent of balloon angioplasty in 1977 by Gruentzig and coronary stents a decade later,[1] invasive/interventional cardiology grew tremendously in the 1990s in part driven by the introduction of P2Y12 antiplatelet therapy. Subsequently, its growing need was recognized, with several societies creating guidelines for training and continuing competence.[2–4] Since the first transcatheter pulmonic valve implant in 2000 by Bonhoeffer et al,[5] and the first transcatheter aortic valve implant in 2002 by Cribier,[6] structural interventional cardiology has also seen tremendous growth in the following 2 decades and is now perceived as a unique career pathway with its own specific training competencies separate from coronary and peripheral vascular interventions.[7]

In parallel, the need for a separate specialty with its own training and competency requirements for the management of chronic heart failure (HF)emerged. Pioneers 2 decades ago even then recognized the need for specialized training not just for complex pharmacological therapies

Abbreviations: AHFTC, advanced heart failure and transplant cardiology; CS, cardiogenic shock; CVD, cardiovascular disease; ECMO, extracorporeal membrane oxygenation; GDMT, guideline-directed medical therapy; HFSA, Heart Failure Society of America; IC, interventional cardiology; IHF, interventional heart failure; LVAD, left ventricular assist devices; MCS, mechanical circulatory support.

Keywords: careers; clinical competence; heart failure; interventional cardiology; interventional heart failure; training.

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effective in reducing HF morbidity and mortality, but also in interventional and device-based therapies.[8] A viewpoints letter in 2004 noted the need for interventional heart failure (IHF) specialists to implant cardiac resynchronization devices, implantable hemodynamic monitoring systems, and percutaneously inserted ventricular assist devices (VAD) among other devices. The authors suggested goals for training and competency of a 2-year IHF program after 2 years of general cardiology training.[9] Many of the novel interventional approaches for optimizing cardiac structure and valve function that these pioneers alluded to 2 decades ago have since become a reality today. The need for IHF has subsequently been highlighted with regard to its importance in the multidisciplinary approach,[10] as well as in the longitudinal care of HF patients.[11] Subsequently, with the introduction of the advanced heart failure and transplant cardiology (AHFTC) specialty and board certification in 2012, the need to adapt to the "ongoing evolution of novel devices and interventional procedures that will enter clinical practice as a result of current and future clinical investigations" continues to be evident today.[12]

During this developing period for IHF, HF specialists pursuing a career in IHF did so through dual training, often only able to do so at their own institutions where training slots in separate subspecialties could be simultaneously guaranteed. The importance of interventional techniques and management of HF in patients undergoing cardiac resynchronization therapy lent itself to trainees seeking dual training in electrophysiology along with AHFTC.[13,14] Moreover, cardiogenic shock (CS) due to acute decompensated HF (as opposed to acute myocardial infarction) is increasingly supported by mechanical circulatory support (MCS) which has led to increased interest in dual training in AHFTC and critical care.[15,16] Temporary MCS is also being increasingly utilized as a bridge to durable VAD or heart transplantation. In fact, the emergence of critical care cardiology alongside IHF reflects the multifaceted needs of patients with advanced heart failure (AHF) and CS. Both critical care cardiology and IHF require a deep understanding of hemodynamics and are both heavily involved in caring for patients in CS. IHF specialists are asked to make decisions in the catheterization laboratory based on clinical presentation, hemodynamics, and potential interventional, structural, or advanced therapy exit strategies to decide on the best type of hemodynamic support, and safely implant this support. They will consult on the best exit strategy based on the risks and benefits of each procedure, and whether they can be delivered in a sequential manner or are mutually exclusive. Critical care cardiologists instead can predict and prevent clinical decompensation in the intensive care unit and provide critical care procedures like intubation and chest tubes. Both are essential in the care of these increasingly complex patients.

There are others who have also pursued dual training in cardiac imaging and AHFTC. For trainees who sought to pursue IHF, the majority had done so by combining a year of AHFTC training with a year of interventional cardiology (IC) training, with a small number pursuing further training in structural heart interventions.[17] The fact that so many "spokes" of dual training have arisen from AHFTC demonstrates the tremendous need for HF care across several domains of cardiovascular disease (CVD). A brief history of IHF is illustrated in Figure 1.

In fact, it is often the same complex HF patient that has needs across several domains of CVD. And indeed "treatment options now span pharmacotherapy, ablations, coronary revascularization, percutaneous structural heart interventions, implantation of devices, valvular surgeries, durable VAD, and transplantation."[11] Instead of a linear, stepwise ladder, a "jungle gym" approach has been suggested, a far nimbler and interdisciplinary approach to patient care. In this jungle gym, IHF cardiologists can think like HF specialists while operating like interventional cardiologists. They can best assess the efficacy of an intervention or device and understand how it fits with other complementary or competing therapies. Moreover, they can help patients navigate an increasingly complex therapeutic landscape. Finally, the IHF operator can more comprehensively manage patients before, during, and after intervention with the optimal application of guideline-directed medical therapy (GDMT) for HF in a timely manner, closer follow-up for HF-related issues, and can more directly engage with AHF referral centers to appropriately recommend transfer of care when necessary. The net advantage of the IHF operator is more efficient and potentially cost-effective care for HF patients requiring intervention. A classic example is the HF patient referred for complex percutaneous coronary intervention requiring mechanical support. All the coronary acrobatics are performed to perfection with MCS support and meticulous MCS removal. However, the patient is still discharged on hospital day 2 with persistent congestion and without any optimization of GDMT beyond a beta blocker and angiotensin-converting enzyme inhibitor. These patients are likely to be readmitted with worsening HF. Herein lies the opportunity to optimize care and patient outcomes without the need for routine external consultation.

Treatment options for patients with HF are growing, and more specifically, device-based interventions are more prevalent.[18,19] Changes in the United Network for Organ Sharing donor allocation for heart transplant in 2018 prioritized patients with CS requiring temporary MCS. There was a resultant increase in the use of temporary MCS in intensive care units of heart transplant centers (in part due to increased heart transplant volumes nationally due to uptake of donation after circulatory death),[20] and greater utilization of MCS in patients

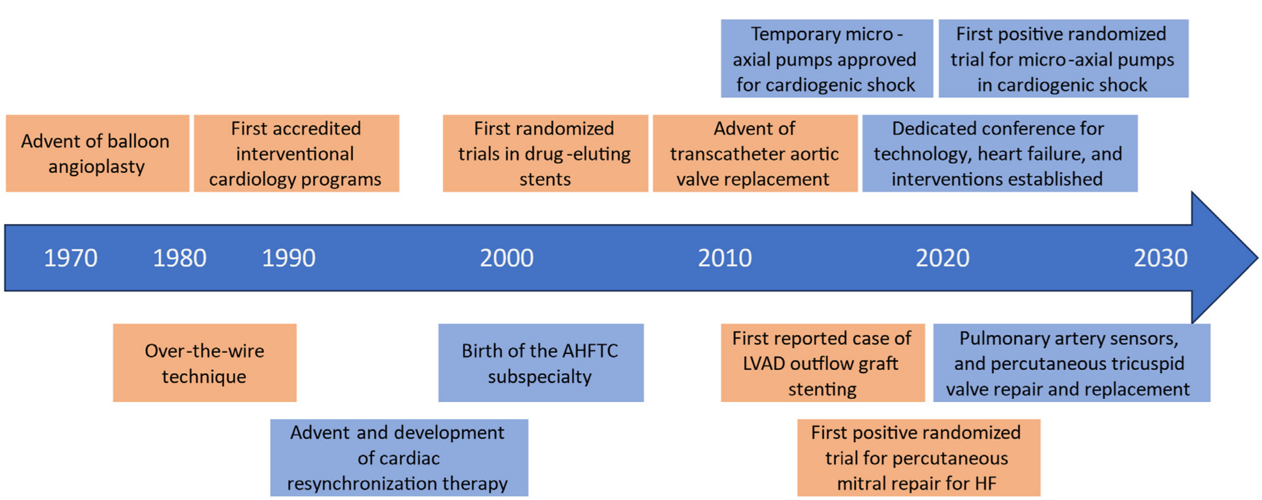


Figure 1.
History of interventional heart failure. AHFTC, advanced heart failure and transplant cardiology; HF, heart failure; LVAD, left ventricular assist device.

transplanted after 2018.[21] Technological advances such as smaller but more powerful heart pumps and their expanding indications in CS, infarct size reduction, and cardiorenal syndrome,[22–24] have accelerated the need for dual-trained interventional and HF specialists. Furthermore, spearheaded by the results of the COAPT trial for transcatheter edge-to-edge repair of secondary mitral regurgitation, evolving structural and valvular interventions targeted at HF patients across all ejection fractions are further intensifying the need for IHF specialists.[25–27] Five-year results from COAPT continue to show the benefit of structural heart intervention for HF including a durable 47% reduction in death or HF hospitalization compared to pharmacological therapy alone.[28]

This review will further explore the need for IHF specialists, career trajectories and phenotypes, training considerations and challenges for trainees, and growth areas for the field, as well as future directions.

The unmet need for interventional and structural HF

There is an increasing demand for interventionalists with comprehensive knowledge of advanced invasive hemodynamics, progressive HF therapies, and an overall global understanding of patients' potential clinical trajectories. Ideally, IHF specialists function as a bridge between all the disciplines involved in patient care, with a clear understanding of the patient's immediate and long-term needs. This will ensure that all the appropriate interventions are delivered promptly and in line with the overall management strategy. Nowhere is this need more pronounced than in patients with acute CS, in whom patient survival depends on a deep understanding of phenotype and physiological presentations, potential hemodynamic responses to specific devices, risk profiles, possible complications, and specific management strategies.[29] These devices require proper device implantation and positioning, frequent monitoring, and adjustment of settings to match the patient's dynamic condition, and, not infrequently, emergent replacement. With the complexity of patients and device expansion, there is a disconnect between device implantation, immediate hemodynamic response, and clinical outcomes. This acute management is arguably best done by a dedicated specialist who provides daily (even hourly) management and appreciates the long-term strategies, as well as potential upcoming obstacles that may exclude the patients from receiving advanced therapies (ie, left ventricular assist devices [LVAD] or transplant).

On the flip side of the argument, IC and AHFTC, in their current forms, can be seen as incompatible with each other. IC is a specialty driven by a simple number of procedures, not only to maintain clinical competency but also to maintain credentialing. Each side might look at an IHF specialist as a "dabbler"—the interventionalist who dabbles in AHFTC, or the AHFTC doctor who plays around with catheterization techniques. The reality is more nuanced, with some techniques such as percutaneous coronary intervention, structural procedures, or large-bore arterial access requiring specific training, much as endomyocardial biopsy requires specific training and mentorship to perfect the technique. These techniques can be pursued with formal IC training (and further advanced training for structural procedures) and continually honed at a supportive institution after training. In fact—although few AHF doctors would have the technical proclivity—some techniques such as coronary angiography, intraaortic balloon pump placement, and other 9F or similar arterial systems or right-sided venous support placement might be performed safely by an AHF doctor with specific training and mentorship. Recommended training pathways are described later in the document.

What is clear is that trainees in CVD are often drawn to both the complexity of the care and management of HF patients, as well as the opportunity to engage in and provide cutting-edge devices, implants, and interventions for these patients. Being able to follow an HF patient through their journey from the clinic to the catheterization laboratory whether for advanced invasive hemodynamics or coronary and/or structural interventions can be appealing, and gratifying on a personal level—a driving force for dual-trained physicians. Historically the field of IHF has been plagued by straddling 2 specialties, like the bird and the fish who fall in love but can never last in a relationship due to the lack of a suitable place to live. But IHF has been rapidly evolving and is ripe for a change in perception and to grow a place of its own. And perhaps finally meet the motivation of trainees for our field.

A career in IHF

Given the absence of dedicated IHF departments, physicians with dual training in IC and HF typically hold positions in 1 of these 2 areas while contributing expertise to the other. This leads to a diverse combination of tasks, responsibilities, and clinical involvement. Moreover, hospital privileges, job duties, and career trajectories are heavily modified by practice environments, whether due to differences in regulatory bodies on a national or state level or even between hospital systems.

For example, in Europe, it is not uncommon to find HF specialists with an interventional background, skilled in coronary interventions who actively participate in ST-segment elevation myocardial infarction (STEMI) calls and the management of patients requiring MCS systems. On the other side of the spectrum, interventional cardiologists skilled in structural heart interventions, such as transcatheter valvular repair or replacement, often round in AHFTC units or clinics supporting HF teams. Although the combination of electrophysiology and AHFTC has not become a reality in the US, in Europe, an emerging area within IHF is the integration of electrophysiology expertise, particularly for patients with AHF. The combination of EP and HF provides a holistic approach to patients with chronic HF, ensuring both mechanical and electrical optimization of cardiac function. Practice patterns in the US might hinder the practice of more than 1 subspecialty, but the fluidity of training in Europe illustrates the expertise needed to care for an HF patient often transcends any 1 subspecialty.

Although these different paths may be influenced by personal interest, organizational structure, and availability of opportunity, a dual appointment (or interest) can yield important synergistic effects for patient care. Dual-trained physicians can serve as the cornerstone of multidisciplinary heart teams, helping to evaluate complex patients for interventional programs and contributing to clinical decision-making on the ward. However, these dual roles come with challenges. Physicians splitting their time between the cardiac catheterization laboratory and the HF clinic may face challenges in maintaining proficiency in both areas (or the perception of not having proficiency due to having less volume in each subspecialty). This is especially relevant in subspecialties with a high demand for perceived proficiency, such as coronary chronic total occlusions or LVAD/transplant management. Defining a clear role within departments can also be difficult. A few examples of pragmatic challenges that could be tackled at each institution and at a societal level include: (1) creating scopes of practices and competencies in training for IHF; (2) creating robust training pathways that can be readily integrated into existing Accreditation Council for Graduate Medical Education (ACGME)-accredited programs; (3) promoting IHF as a separate subsection with IC similar to structural heart disease with its own hiring needs; and (4) coordination of AHFTC and STEMI call to ensure parity of effort to non–dual-trained colleagues at similar levels of their careers, among other considerations.

Significant differences exist when comparing the specialty of IHF in the US and Europe due to regulatory and training framework differences. In the US system, formalized subspecialization pathways allow for dual training during cardiology fellowships, offering the possibility of board certification in AHFTC, as well as IC. To pursue a career in IHF, both fellowships are typically required. Some programs, however, offer

Table 1. Opportunities and challenges at various career stages in interventional heart failure.

Career stage	Opportunities	Challenges/concerns
Early training	- Pursuit of training in multiple areas of interest including AHFTC, device-based and interventional therapies, cardiogenic shock, and critical care cardiology - Integration of HF and interventions as role models for comprehensive patient care	- Perception of lack of focus
Advanced training	- Research opportunities in the junction of HF, devices, and interventional cardiology - Potential to be seen as unique and an expert across a large swath of cardiovascular disease	- Longer training for dual qualification - Perception of being seen as rusty when returning to the cardiac catheterization laboratory
Early career	- Value added as an IC in the AHFTC selection committee, and as an HF specialist in valve and/or revascularization multidisciplinary conferences - Call synergies for AHFTC call and STEMI call	- Challenges with siloed programs, being "boxed" into less desired roles, and how to split time
Midcareer	- Leadership opportunities for device-based and interventional trials drawing from HF populations - Research opportunities - Opinion leader - Being dual-boarded (US) will have several options for how to practice in the inpatient or outpatient settings - Not be limited to 1 pathway for clinical and/or academic practice	- Higher tendency for AHFTC and cardiogenic shock focus, less for complex PCI and structural heart interventions
Late career	- Ideally positioned to head cardiology departments/divisions and/or device-related regulatory bodies	- Unlikely to be able to sustain clinical practice in both specialties at high volumes

AHFTC, advanced heart failure and transplant cardiology; HF, heart failure; IC, interventional cardiology; PCI, percutaneous coronary intervention; STEMI, ST-segment elevation myocardial infarction.

the opportunity to achieve this combination through a single, integrated fellowship. Despite the formalized training paths, the strict division between HF and IC sections creates both challenges and opportunities for IHF physicians. In the US, work productivity is often measured by generated relative value units (RVU), and compensation is often closely tied to work productivity. Interventions typically bring more RVU for hours spent, and complexity is not rewarded compared with generating absolute volume. This presents a challenge for the IHF specialist who often takes on the most complex and time-consuming cases, and yet may have to achieve interventional RVU benchmarks. For example, advanced hemodynamics in the catheterization laboratory is poorly compensated.

In Europe, particularly Germany, training pathways within cardiology subspecialties are less rigid. Although certificates of qualification exist for HF or IC from national societies, there is no formal board certification. This creates a more flexible, albeit less structured, career path where interventionalists focusing on hemodynamics and HF can pioneer IHF therapies. However, the lack of formalized training in AHFTC and fewer transplant/LVAD centers present challenges for physicians seeking to specialize in IC from an HF perspective in Germany. Opportunities and challenges at various career stages in IHF are represented in Table 1.

Current phenotypes of interventional and structural HF cardiologists

Practice environments

The career phenotypes of the IHF specialist are diverse and reflective of a wide range of training pathways coupled with various practice opportunities. In particular, the practice environment can significantly influence the role and scope of an IHF cardiologist, especially in those locations that service an AHF population.

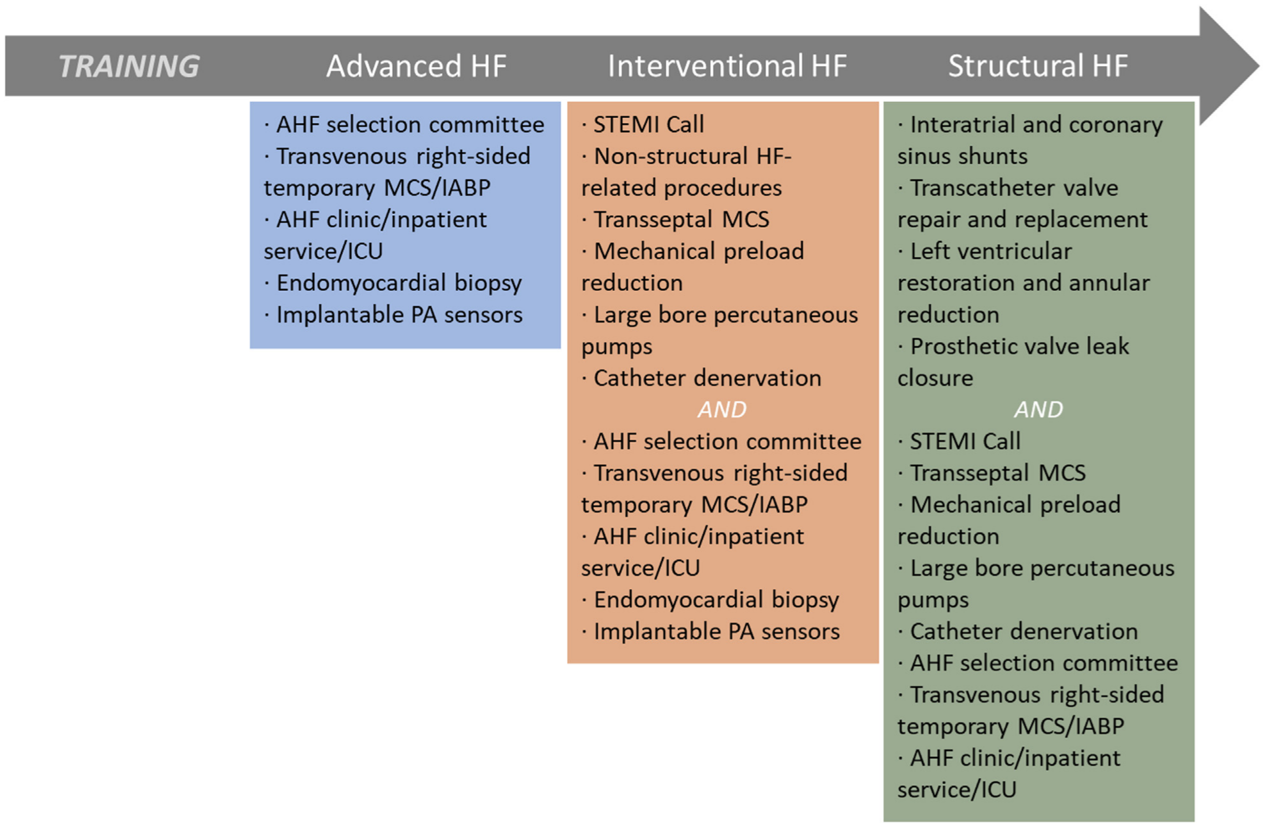
In hospital-based settings, IHF cardiologists are integral to a multidisciplinary team-based approach to clinical decision-making, collaborating with surgeons, intensivists, and imaging specialists. Academic centers offer comprehensive programs like heart transplant, durable LVAD, and extracorporeal membrane oxygenation (ECMO) platforms, which further provide IHF cardiologists the opportunity to engage in complex clinical cases involving AHF therapies, making this choice of practice environment particularly attractive to IHF-trained physicians. Additionally, IHF cardiologists at academic centers are often involved in clinical trial enrollment and the development of new catheter-based technologies, which allows these specialized physicians the ability to utilize their interventional skills to deliver new therapies for an acutely ill patient population.

Indeed, the results of a previously published survey that solicited responses from 54 dual-trained (AHFTC + IC) cardiologists showed that most respondents worked in academic university-based hospital settings (61%), followed by nonuniversity-based hospital settings (30%), and nonhospital-based private practice (9%).[17] Among hospital-based practices, most had a heart transplant program (59%), a durable LVAD program (69%), and an extracorporeal membrane life support program (89%). In these environments with exposure to AHF patient populations, IHF cardiologists may be expected to implant various configurations of temporary MCS, perform denervation techniques, implant transseptal devices such as shunts and sensors, and participate in weekly transplant and LVAD selection committee meetings.

Additionally, training pathways for the IHF physician may take various forms and result in different levels of procedural expertise and opportunities. The Central Illustration depicts expected clinical proficiencies at different stages of training, although actual proficiencies vary between training programs.

AHF with invasive focus

Although traditional IHF training requires both a year of dedicated ACGME-accredited IC fellowship coupled with an AHFTC fellowship, a subset of cardiologists who undergo AHFTC training alone might choose to specialize in invasive procedures, particularly those related to the care of HF patients. These invasive-driven AHF cardiologists might focus on performing endomyocardial biopsies, implanting pulmonary artery pressure sensors, or deploying temporary right-sided venous access MCS. Some AHFTC-trained physicians who are comfortable with arterial access might also choose to implant intraaortic balloon pumps and other nonlarge bore arterial temporary MCS devices—relevant given ongoing miniaturization of MCS including collapsible microaxial pumps (that target ~9F systems). Although not many non-IC trained physicians would have the proclivity for invasive procedures, underserved and/or extremely busy practice locations could benefit from this phenotype. Training would include 4 to 6 months of interventional training during general cardiology and AHFTC fellowships and device-specific training. These cardiologists will have a larger footprint in the



Central Illustration.
Potential procedural competencies and focuses on various stages of training in interventional heart failure. AHF, advanced heart failure; HF, heart failure; IABP, intraaortic balloon pump; ICU, intensive care unit; MCS, mechanical circulatory support; STEMI, ST-segment elevation myocardial infarction.

cardiac catheterization laboratory and will dedicate more time to procedures than their colleagues performing noninvasive procedures, which might allow for more continuity of care. Hospital systems might choose not to require dedicated IC training for some of these device privilege clusters, and rather focus on an operator's prior experience, proctoring requirements, and minimum yearly procedural volume.

IHF: CS focus

The role of the IHF physician in the management of CS is not limited to implanting support devices and interpreting hemodynamic waveforms, which can be done without dedicated AHFTC training.[30] In fact, many IHF physicians choose to specialize clinically in shock management. The previously described survey study notes that almost half of surveyed IHF cardiologists (42%) reported CS as their primary clinical focus at their institutions.[17] Although most ACGME-accredited IC training programs focus on training in the implantation of temporary MCS,[31] the IHF cardiologist might receive additional exposure to both the front-end decision-making (such as participation in shock calls and shock team discussions regarding patient candidacy and exit strategies), as well as the back-end of clinical care while in the intensive care unit.[32–34] Additionally, IHF physicians might be exposed to emerging devices for HF, such as renal denervation procedures (or other emerging denervation techniques such as a pulmonary artery or splanchnic nerve denervation), transseptal devices (shunts or sensors), or temporary intraaortic microaxial flow pumps. Although transseptal access is currently reserved for structural-trained interventional cardiologists, the replacement of the transseptal needle with a curved radiofrequency wire has made septal crossing safer and more predictable, allowing the possibility of IHF specialists learning transseptal access for left atrial VA ECMO, balloon septostomy, and/or interatrial shunt placement. Although still somewhat futuristic, this may be a way to increase access to these therapies for patients. The role of the IHF specialist also often extends to participation in research and clinical trials evaluating novel devices and treatment strategies for CS, contributing to the evolution of shock management practices.

Structural HF

Cardiologists with a focus on both structural heart disease and HF generally have dedicated training that extends beyond the standard ACGME IC program. They may or may not have formal AHFTC training. They may also hold certifications such as the Heart Failure Society of America (HFSA) GDMT certification and have dedicated time, usually 4 to 6 months, during their cardiology fellowship specifically for AHFTC.

These specialists concentrate on HF-related structural procedures, including transcatheter edge-to-edge repair for secondary mitral regurgitation and tricuspid regurgitation (TR), transcatheter valve replacement for TR, and the use of transseptal temporary MCS, shunts, and left ventricular remodeling devices. They typically achieve a volume of at least 100 structural heart procedures over their career or perform at least 30 left-sided structural procedures annually.[35]

These cardiologists might also be involved in weekly AHFTC selection committees and participate in both HF clinics and valve clinics, reflecting their dual focus on structural and HF interventions.

Training considerations

Formal training in IHF currently requires the completion of 2 independent fellowship programs: IC and AHFTC. In the US, both fellowships are recognized by ACGME and require the prior completion of a 3-year CVD fellowship. In this model, IC and AHFTC fellowships are completed in tandem, in varying order, and with no crosstalk between the programs. As a result, there is no unified curriculum for the IHF specialist. Moreover, in a recent survey of IHF specialists, 48% of US-trained physicians who reported their training sites completed each fellowship at a different institution, and 50% of these did so in different regions of the country altogether.[17]

This structure places a high burden on trainees who in addition to a longer training duration must undergo 2 consecutive application and interview processes and often relocate to a new region for short-duration programs. It also places the onus on the trainee to obtain competency in areas of specific interest to the IHF specialist, which may be challenging in certain training settings.

Hence, an integrated model of training focused on a curriculum designed for the IHF specialist could benefit this emerging field. First, an ability for 1 program to commit to training an aspiring IHF specialist for both an AHFTC and an IC year. Such a 2-year program could be completed in tandem with 1 year dedicated to each specialty or in an intercalated manner. The manner of intercalation could include alternating rotations in AHFTC and IC, or with the addition of IC block time near the end of the AHFTC year. It could also be based on allowing protected time to be involved in IHF cases as they occur, and to be part of the shock team through a 2-year program.

Developing a dedicated IHF training program requires a clear definition of the specialty's scope of practice. The most evident intersection of IC and AHFTC is in the inpatient management of complex acute cardiovascular patients. For instance, in the aforementioned survey, the areas of primary clinical focus for IHF cardiologists were coronary artery disease (42%) and CS (42%). Key clinical services provided otherwise included coronary care unit rounds (95%), STEMI calls (84%), and posttransplant care (53%).[17] Other important areas of intersection between IC and AHFTC include valvular heart disease and treatment of left atrial hypertension and pulmonary hypertension among others.

During a 2-year training program for IHF, the development of cognitive and procedural competencies in both fields must be balanced. This requires sufficient exposure to a broad range of patients within a center equipped to provide the minimal clinical volumes recommended for the AHFTC and IC fellowships.[36,37]

In addition, there should be sufficient exposure to areas of specific interest for the IHF specialist that should be evaluated through formal competency assessment at the completion of training. These could be divided into different areas of focus (Figure 2). Below are some suggested areas and specific competencies for an IHF curriculum (Table 2).

This model would render the IHF trainee board eligible in both subspecialties and allow for the integration of the training curriculum. It can also be flexible and adapt to trainees' interests, such as in CS, heart transplant, durable LVAD, etc. Although significant barriers exist to the creation of a 2-year IHF program, particularly the existence of separate match processes for each specialty, there are also important opportunities for programs to create a formalized IHF training pathway when interest in the ACGME AHFTC fellowship is steadily declining. The integration of other subspecialties such as IC with AHFTC has been proposed by the HFSA as a potential solution to revive interest in the field among trainees.[38] Figure 3 illustrates potential training pathways.

In the HFSA training statement, the society proposes areas of subspecialty focus to be newly integrated into AHFTC training programs to enhance the value derived from the training year. Our first proposed model is an invasive AHFTC track with competencies in

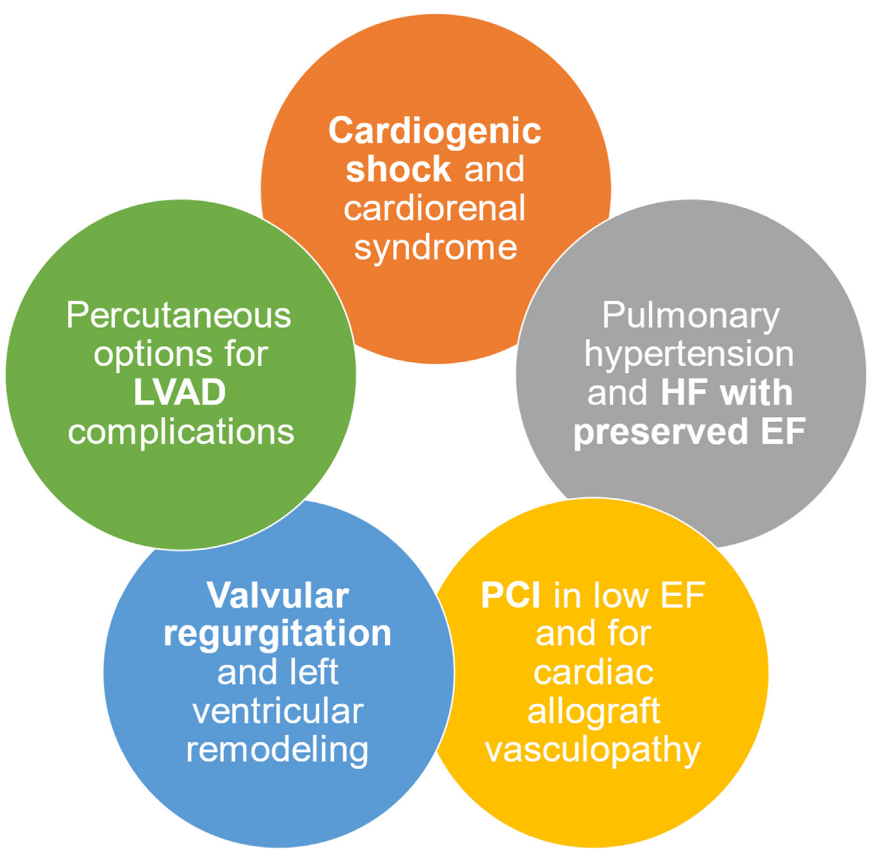


Figure 2.

Suggested areas of focus for training in interventional heart failure. EF, ejection fraction; HF, heart failure; LVAD, left ventricular assist device; PCI, percutaneous coronary intervention.

Table 2. Suggested competencies.

Areas of focus for interventional heart failure	Suggested competencies obtained during training
Cardiogenic shock and cardiorenal syndrome	- ECMO percutaneous cannulation, large bore closure, and management including distal perfusion strategies[a] - Recognition, classification, and management of cardiogenic shock of various etiologies[a] - Management of complex hemodynamics and recognition and treatment of right ventricular failure[a] - Assessment for exit strategies including percutaneous coronary and structural interventions, ventricular assist devices, or heart transplantation
Pulmonary hypertension and heart failure with preserved ejection fraction	- Systematic invasive assessment of pulmonary hypertension[a] - Exercise right heart catheterization assessment and classification of different combined precapillary and postcapillary pulmonary hypertension phenotypes - Assessment for appropriateness for novel shunt or denervation trials - Understand the role of pulmonary artery pressure sensors in heart failure with preserved ejection fraction
PCI in low ejection fraction and for cardiac allograft vasculopathy	- Understand existing literature on PCI in low ejection fraction, and when PCI may or may not change clinical outcomes - Understand the medical therapy and stent patency outcomes of PCI in cardiac allograft vasculopathy
Valvular regurgitation and left ventricular remodeling	- Evaluation and management of patients treated with transcatheter valve therapies including low flow low gradient aortic stenosis, aortic regurgitation, mitral regurgitation, tricuspid regurgitation - Follow patients pretranscatheter valve repair and posttranscatheter valve repair or replacement with secondary mitral and tricuspid regurgitation including the use of inotropic support postrepair or replacement[a] - Understand the overlap of heart failure with preserved ejection fraction, atrial fibrillation, and tricuspid regurgitation - Understand the role of pulmonary artery sensors in heart failure with reduced ejection fraction
Percutaneous options for LVAD complications	- Management and stenting of outflow graft obstruction with or without cerebral protection - Percutaneous LVAD decommissioning of outflow graft after myocardial recovery - Transient outflow graft balloon occlusion to evaluate for recovery - Identify, quantify, and manage LVAD AR peri TAVR/SAVR interventions
Critical care	- Learn the indications, contraindications, complications, and limitations of pericardiocentesis, transvenous pacemaker insertion, CRRT, and hemodialysis - Ventilator management and noninvasive ventilation - Placement, calibration, and operation of pulmonary artery balloon flotation catheters

AR, aortic regurgitation; CRRT, continuous renal replacement therapy; ECMO, extracorporeal membrane oxygenation; LVAD, left ventricular assist device; PCI, percutaneous coronary intervention; SAVR, surgial aortic valve replacement; TAVR, transcatheter aortic valve replacement.
[a] Critical care cardiology-related competencies.

specific devices. To pursue this model, trainees would focus on additional cardiac catheterization laboratory rotations during year 3 of the cardiovascular fellowship. They would match into an AHFTC program that allows an IHF subspecialty focus. An AHFTC program seeking to attract such candidates would build cardiac catheterization laboratory time and IHF-related training milestones into the AHFTC training year and provide the site resources and faculty to support this subspecialty focus. Invasive AHFT cardiologists would focus on noncoronary and nonstructural invasive procedures and undergo specific device-based training as needed during year 5 and throughout their careers. Trainees of this pathway could be particularly helpful for underserved areas to allow the dissemination of needed devices and procedures to HF patients. Outside of endomyocardial biopsies and pulmonary artery sensors, these procedures may include intraaortic balloon pumps and similar sheath-size temporary support devices, and venous procedures such as right-sided MCS, renal venous flow regulators, and denervation procedures. The main challenge of this pathway is the lack of a full year of formalized interventional training,

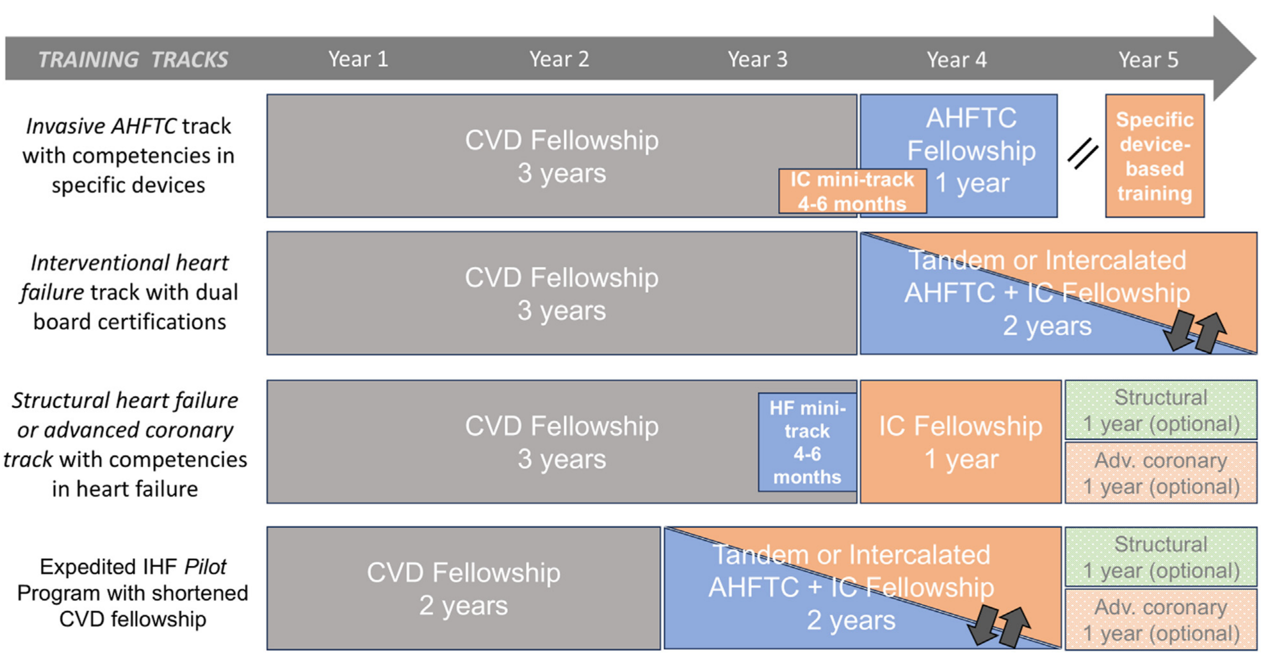


Figure 3.
Possible training pathways for interventional heart failure (IHF). AHFTC, advanced heart failure and transplant cardiology; CVD, cardiovascular disease; HF, heart failure; IC, interventional cardiology.

limiting the breadth and scope of the procedures that can be performed safely.

The standard IHF track would allow dual board certifications. A trainee pursuing this track would match into an AHFTC program and seek to match into an IC training program the following year. Programs that wish to attract trainees in this track would make the subsequent IC match as frictionless as possible and treat the trainee as an "internal candidate." Moreover, the IC program would integrate IHF-related training milestones into the IC training year and provide the site resources and faculty to support this focus. CS would be 1 of the focuses of the track. An intercalated and integrated 2-year fellowship program is possible in the future as well but would likely require changes to the match process.

Trainees might choose to pursue additional training in structural or advanced coronary interventions, but this would require a sixth year of training. Instead, a structural HF or advanced coronary track is more tangible if done in 5 years, at the expense of obtaining board certification in AHFTC. Instead, an IHF trainee seeking to pursue structural HF or an advanced coronary track might pursue 4 to 6 months of AHFTC training within the third year of their cardiovascular fellowship. Instead of board certification, they would pursue HF certification through the HFSA. They would then pursue an IC training year and later a structural or advanced coronary year. CVD and IC training programs seeking to attract and support such candidates would integrate IHF-related training milestones into the IC training year and provide the site resources and faculty to support this focus.

Another alternative for shortening training for those interested in gaining board certification in both subspecialties is to combine the CVD fellowship with the IHF training pathway focusing on competency-based rather than time-based training. A pilot program is underway to integrate CVD and clinical cardiac electrophysiology into a 4-year program: 2 years of CVD and 2 years of clinical cardiac electrophysiology.[39] If successful, this pathway could be adopted in the future by hybrid subspecialties like IHF. A summary of possible training pathways for IHF is provided in Figure 3.

There are reasons to believe that there are economic incentives for hospital systems because of training IHF specialists. In a post hoc analysis of the PARTNER trial of inoperable candidates undergoing medical therapy or transcatheter aortic valve replacement, patients who were technically inoperable had a greater improvement in survival, quality of life, and fewer rehospitalizations, as compared with medically inoperable patients suggesting an economic benefit of patient selection.[40] Such cost analysis have been extended to transcatheter edge-to-edge repair of the mitral valve for mitral regurgitation in HF.[41,42] In CS, shock teams have been shown to be a cost-effective alternative to the traditional standard of care based on lives saved.[43] Further research into the economic benefits for hospital systems for training IHF specialists is needed.

The need for HF specialists remains large and continues to grow. Meanwhile, the interest in the AHFTC fellowship as currently structured, continues to decrease, with >50% of training spots remaining unfilled in recent years. The IHF track provides an innovative pathway for physicians interested in HF and IC to gain these coveted skills within a unique context that goes beyond the care of LVAD and heart transplant patients. As such, this training pathway has the potential to capture the imagination of trainees and boost the HF field in the current generation.

Research opportunities

Morbidity and mortality of patients with HF, irrespective of ejection fraction, remain high despite the contemporary treatment strategies and a large portion of patients remain symptomatic despite maximally tolerated medical therapy.[44,45] Therefore, device-based therapies for patients with different phenotypes and stages of HF have been an area of ongoing research and innovation.

Over the past decade, miniaturized percutaneous MCS systems have been a focus of intense research and device innovation. Lower-profile MCS devices are needed to minimize complications and improve patients' mobility while supported. Hemodynamic phenotyping of patients to optimize patient-device match requires further clinical investigation. Direct LV unloading in acute coronary syndrome with a delayed reperfusion strategy has been proposed to minimize the infarct size and improve the outcomes, which is currently under investigation.[46] The concept of LV unloading or venting and the preferred modality for patients on VA ECMO remains debated and lacks definitive evidence.[47] Finally, when to instead utilize left atrial VA ECMO with direct left atrial drainage via transseptal puncture as an alternative approach remains to be determined.[48]

Another area of investigation is treating increased left atrial pressure with exercise (to treat dyspnea). Sham-controlled randomized trials of 5-mm and 8-mm interatrial shunt devices did not show a difference in the primary end point,[49,50] but did identify responder subgroups. Subsequent 2-year follow-ups continued to show separation in clinical events in the responder and nonresponder groups,[51] and several ongoing clinical trials are testing left atrial shunts in responder subgroups. Novel shunting from the left atrium to the coronary sinus (instead of the right atrium) showed that quality of life improvement appeared consistent across pulmonary vascular resistance, in contrast to interatrial shunts,[52] and a sham-controlled randomized clinical trial is underway. Catheter-based splanchnic nerve ablation to reduce splanchnic vasoconstriction is being investigated.[53] These approaches warrant further investigation.

In patients with cardiorenal syndrome, adequate diuresis and decongestive strategies remain challenging. A decrease in renal arterial pressure and an increase in venous pressure results in activation of the renin-angiotensin-aldosterone axis and increased proximal tubular sodium and water reabsorption. This leads to oliguria, worsening congestive symptoms, and diuretic resistance.[54] IC-placed devices fall into 2 main categories: increasing renal arterial perfusion pressure,[24,55] or reducing renal venous pressure.[56,57] Several early feasibility studies have shown increased urine output and improved renal function, and randomized control trials are underway.

For patients with dilated cardiomyopathies, ventricular reshaping to promote positive remodeling has shown early promise as the IHF structural procedures. Early feasibility data from 2 devices showing global LV reverse remodeling were detected both at 30 days and 12 months, with clinically significant improvement in quality of life and 6-minute walk tests,[27] and significant reduction in functional MR and LV end-diastolic and end-systolic volumes.[58] Pivotal randomized trials of both technologies are being investigated. Furthermore, other reshaping technologies for dilated cardiomyopathies and exclusion and partitioning devices for LV aneurysms are being investigated and are active areas of interest and innovation.[18]

The impact of regurgitant valvular lesions in HF patients is increasingly recognized, and randomized data showing the benefit of devices and transcatheter valves for valvular regurgitation is rapidly emerging. In COAPT, a trial of transcatheter mitral valve repair in patients with HF, patients with secondary mitral regurgitation despite maximally tolerated GDMT, when randomized to edge-to-edge mitral repair, had a reduction in mortality and HF hospitalizations of 38% and 47%, respectively, at 2-years.[59] Furthermore, transcatheter edge-to-edge repair of TR has been shown to improve quality of life, with the large majority of patients treated with functional TR, and the therapy was recently approved by the FDA.[60] Transcatheter tricuspid valve replacement was also recently approved for the treatment of severe symptomatic TR.[61] Despite these exciting advances, the need for IHF specialists remains especially relevant. In mitral regurgitation, GDMT can not only improve ventricular function but also remodel ventricular size and geometry, leading to the resolution of secondary mitral regurgitation without any intervention.[62,63] In TR, preprocedural admission for diuresis prior to planned tricuspid intervention can reduce TR severity by 38% (sometimes eliminating TR altogether) and reduce the tricuspid valve annular area. Coaptation gaps can be reduced by 33%,[64] which has major clinical and procedural planning ramifications. Also, TR and HF with preserved ejection fraction share significant risk factors.[65] This area of overlap deserves further investigation and research.

In summary, IHF should not continue to straddle 2 specialties, but rather synergize these focuses into a niche where a dual-trained IHF specialist would be uniquely qualified to evaluate and treat complex patients. For example, in a patient with CS, the IHF specialist may interpret invasive hemodynamics, deploy percutaneous MCS, and guide decision-making in the intensive care unit with consideration of bridge and exit strategies, which positions them as a critical decision-making unit at the time of procedural intervention in the cardiac catheterization laboratory. Yet the advantages of IHF training extend beyond the clinical domain. IHF training paves the way for a research-focused career that fosters the development of device-based therapies. Specifically, the unique ability to have a presence in both the IC and HF domains allows the IHF specialist to recruit eligible participants for clinical trials, implant device-based therapies, and identify critical unmet needs in the AHF patient population that could benefit from interventional treatments. This creates a unique opportunity for innovation, enabling IHF-trained physicians to integrate their subspecialty knowledge and ultimately provide improved care for this chronically ill patient population.

Summary and future directions

The field of IHF represents a dynamic intersection of AHF management and procedural expertise, reflecting the explosion of interventional therapies meant for patients with HF. The field of IHF has been misunderstood as one of "jack of all trades" but actually represents the trend of increasing specialization for careers within cardiology due to the increasing complexity of therapeutic options within CVD. Although the field of IHF was proposed over 2 decades ago, the field is only now starting to be realized with positive studies in catheter-based valve interventions and mechanical support for CS. As technology and device-based therapeutics for HF continue to evolve rapidly, so too does the need for specialists who can navigate both worlds of HF management and IC.

A career in IHF offers diverse opportunities for physicians with dual training, allowing them to blend procedural expertise with clinical HF management. Although the role is still evolving, physicians skilled in both areas are becoming increasingly relevant in the management of complex patients with HF. The development of this career path depends significantly on the health care system, the training framework, and the institutional structure, with marked differences between the United States and Europe. As HF therapies become intertwined with interventional procedures, the demand for dual-trained specialists is likely to grow, making this a promising field for the future.

However, the path forward is not without challenges. The traditional separation of training pathways in IC and AHF should be addressed. A solution lies in developing integrated fellowship programs that combine these disciplines, providing comprehensive education and fostering expertise in both areas. Such programs would streamline the training process, support core competencies for trainees in IHF, and better prepare physicians to handle the multifaceted needs of HF patients. Ideally, such a program would intercalate time in the catheterization laboratory with longitudinal care of AHFTC patients. However, it is more feasible to integrate existing AHFTC and IC training programs sequentially. Although training in IC first before AHFTC could more readily allow the performance of procedures in the catheterization laboratory across both programs, procedural volume competency might decay in the less procedural AHFTC second year. Therefore, it is more feasible to integrate AHFTC first with an IC year to follow—and this has been the more common training pathway that current IHF specialists have pursued.

Moreover, the field will benefit from continued research into decision-making tools and the pairing of therapies to optimize patient outcomes. Understanding the patterns of responders and non-responders, alongside a deep grasp of underlying physiology and pathology, will be crucial for effective treatment planning. This opens avenues for research and development of decision-support systems that could enhance clinical practice.

Future developments in the field are promising, and trainees might look forward to working in established interventional HF sections. These sections will provide a platform for professional development and satisfaction, and interdisciplinary collaboration, where specialists can work alongside colleague cardiologists, surgeons, and researchers to advance patient care.

In summary, the future of IHF holds considerable promise. By addressing current training challenges, fostering specialized clinics, and advancing research in decision-making and therapy optimization, the field is poised to make significant strides. Trainees entering this specialty will have the opportunity to be at the forefront of cardiovascular care, contributing to innovative treatments and improving outcomes for patients with complex HF.

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