Seeing the Unseen: Remote Monitoring for Early Intervention

Dr. Jasjit Bhinder

Northwell℠
Cardiovascular Institute

Overview

- Identify limitations of traditional telemonitoring
- Compare implantable pressure sensor technologies (PAP, LAP, IVC)
- Apply hemodynamic-guided GDMT optimization
- Evaluate wearable devices and their current evidence
- Implement patient self-management frameworks
- Recognize the role of AI and multiparametric monitoring

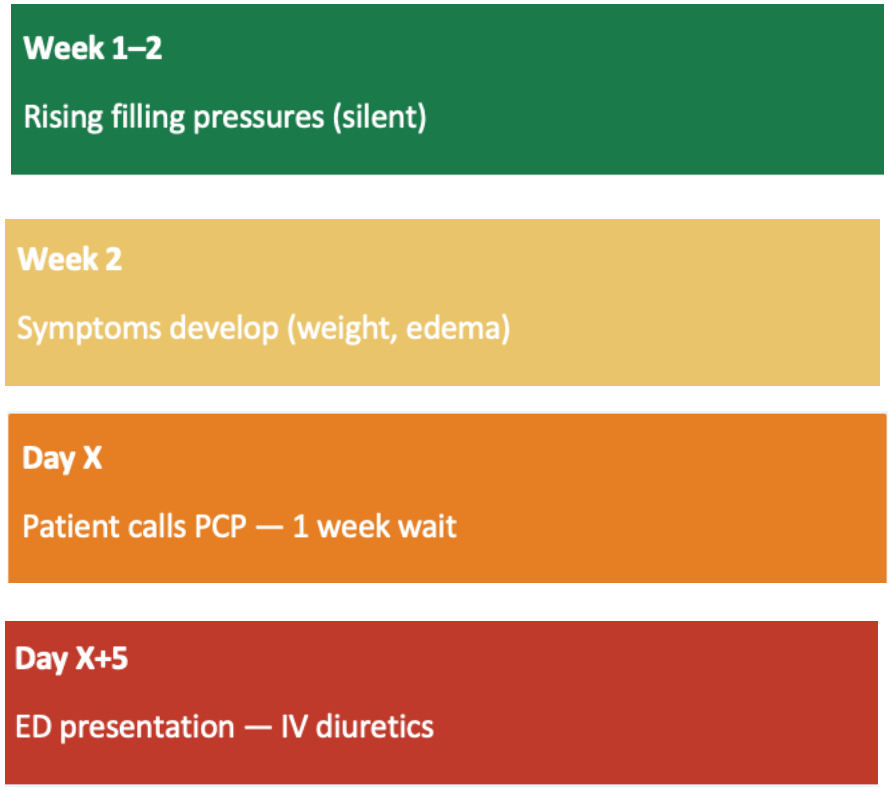
The Problem: A Typical Heart Failure Case in 2026

A 62-year-old man with a history of ischemic cardiomyopathy (LVEF 30%) presents with gradually worsening symptoms over 10 days. He reports increasing abdominal bloating, decreased appetite, and a 6-pound weight gain. He has noticed that his pants feel tighter and that he becomes short of breath when climbing a single flight of stairs. He has also started sleeping in a recliner due to discomfort when lying flat.

He contacted his cardiology office early in the course of symptoms but was advised to monitor his weight and keep his upcoming appointment scheduled in 5 days. Over the next several days, his symptoms progressed, with worsening fatigue and new onset lower extremity edema.

Two days before his scheduled visit, he developed significant dyspnea at rest and presented to the emergency department. On arrival, he was found to be volume overloaded with elevated jugular venous pressure, pulmonary edema on chest imaging, and required admission for intravenous diuresis and optimization of heart failure therapy.

The Gap in Care



This presentation will be preventable — with the right monitoring.

Marvasti T et al. Can J Card. 2024;40(10):1934–1945

Why Weight and Vital Signs Monitoring Has Failed

TEN-HMS / Chaudhry 2010 (NEJM)

N = 1,653

Inpatient education + home daily weights + voice-response telemonitoring
did NOT reduce rehospitalizations (for any reason) or death.
HR 1.04 (95% CI 0.91–1.19), P = 0.58

Enrolled 2006–2009

Ong et al. 2016 (JAMA Intern Med)

N = 1,437

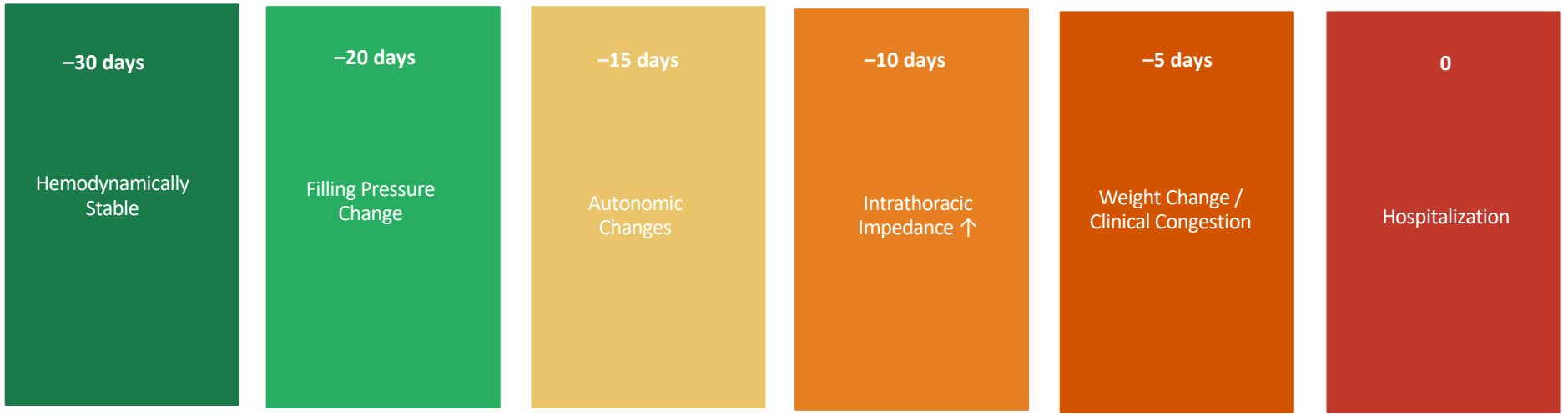
Health coaching + phone calls + telemonitoring of BP, HR, symptoms, and weight
did NOT reduce 180-day rehospitalizations.
HR ≈ 1.0, P = NS

Enrolled 2011–2013

Key Insight: Weight gain is a LATE sign — hemodynamic congestion precedes clinical congestion by days to weeks

Chaudhry SI et al. NEJM. 2010;363:2301–2309. | Ong MK et al. JAMA Intern Med. 2016;176(3):310–318.

Heart Failure Decompensation: The Temporal Cascade



← GAIN TIME WITH EARLY INTERVENTION ←

Implantable Pressure Sensors
Detect earliest hemodynamic changes

CIED / Impedance
Autonomic & impedance signals

Wearables / Weight
Clinical congestion (too late!)

Adamson PB. Curr Heart Fail Rep. 2009;6:287–292. | Boriani et al. EJIM. 2023. | Stevenson et al. JACC. 2023;81(23):2272–2291.

ADHF Is Multifactorial — No Single Parameter Suffices

Congestion
- Rising filling pressures (PAP/LAP)
- Weight gain / fluid retention
- Intrathoracic impedance changes
- Orthopnea / PND

Arrhythmia
- Heart rate trends
- Reduced HRV
- AF / ventricular arrhythmias
- Device-detected burden

Non-Cardiac Drivers
- Infection / inflammation
- Renal dysfunction
- Medication non-adherence
- Lifestyle / activity changes

Multimodal Signals for Early Detection

- Heart sounds (S1/S3)
- HR / HRV
- Intrathoracic impedance
- Respiratory rate / tidal volume
- Physical activity
- Filling pressures (PAP/LAP)
- Weight / symptoms

No single device captures all these data points

Mastoris I, Gupta D, Sauer A. Card Clin. 2023;41(4):557–573. | Gupta D, Mastoris I, Sauer A. HF Clin. 2024;20(1):1–13.

Implantable Pressure-Based Remote Monitoring: Device Landscape

PAP Sensor
(CardioMEMS – Abbott)

Position: Supine, PA (L or R)

- CHAMPION: 37% ↓ HFH (supine)
- GUIDE-HF: HFrEF + HFpEF, 28% ↓ HFH
- MONITOR-HF: 44% ↓ HFH

PAP Sensor
(Cordella – Endotronix)

Position: Supine / Seated, PA (R)

- SIRONA I/II: Safe & effective
- PROACTIVE-HF: Switched to single-arm after GUIDE-HF result

LAP Sensor
(V-LAP – Vectorious)

Position: Transseptal, LA

- LAPTOP-HF: 41% ↓ HFH (stopped early – complications)
- VECTOR-HF: Accurate vs PCWP at 3 months

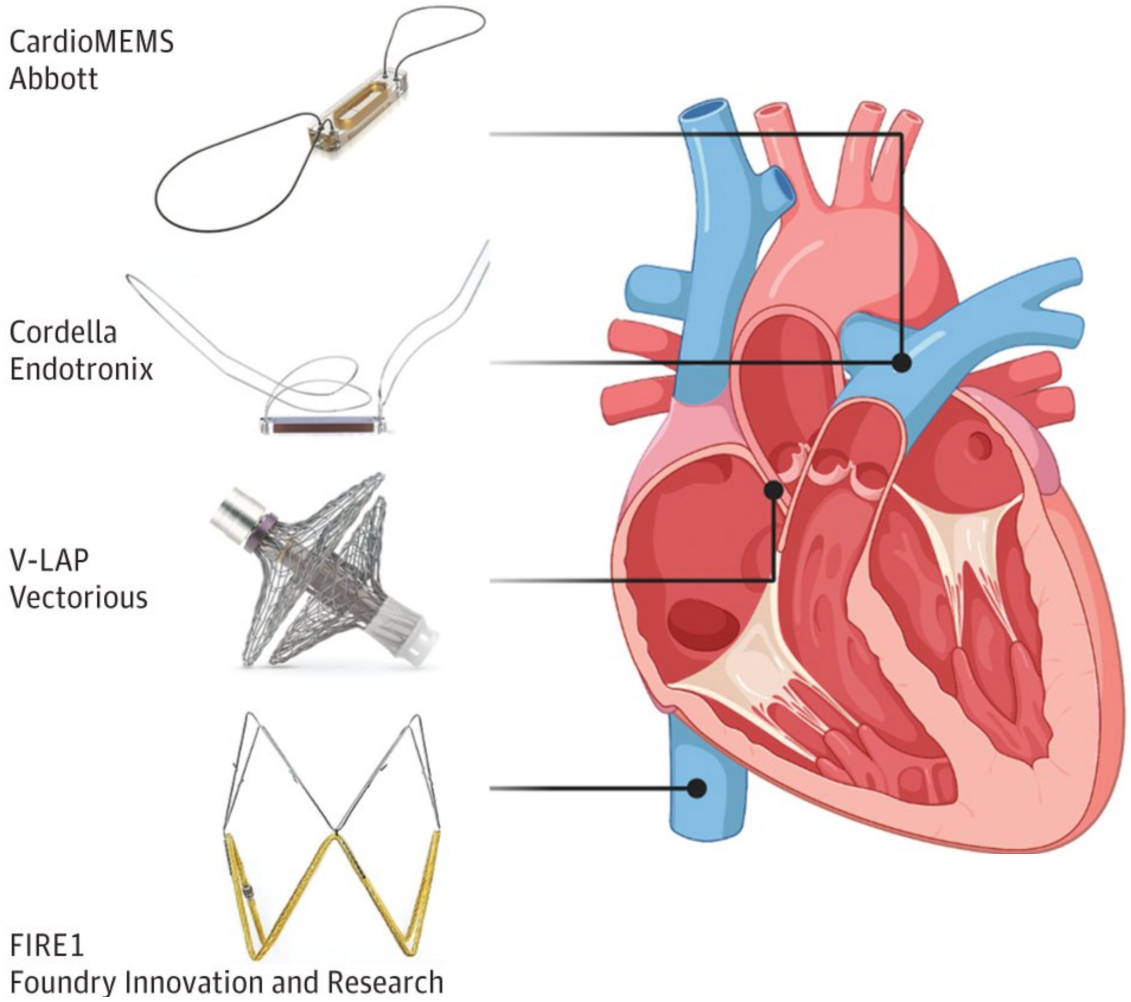
IVC Sensor
(FIRE 1 System)

Position: IVC

- FUTURE-HF (NCT04203576): Phase 2 non-randomized, recruiting

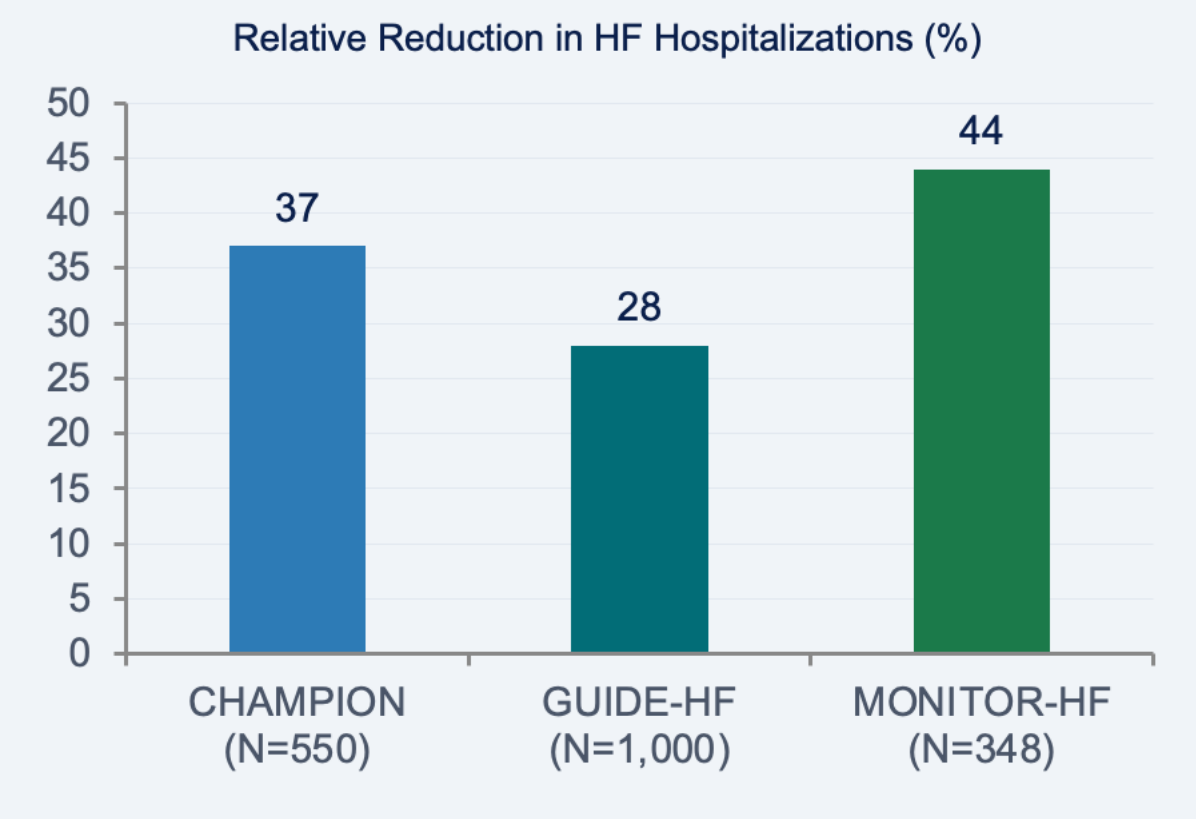
Beghini et al. ESC Heart Fail. 2024. | Klein L. J Card Fail. 2025;31:1731–1742. | Lindenfeld J et al. JACC. 2024;83(6):682–694.

Implantable Pressure-Based Remote Monitoring: Device Landscape



Beghini et al. ESC Heart Fail. 2024. | Klein L. J Card Fail. 2025;31:1731–1742. | Lindenfeld J et al. JACC. 2024;83(6):682–694.

CardioMEMS Evidence: Three Pivotal Trials



CHAMPION (2011)

N=550 HFrEF. 37% ↓ HFH; consistent over full study duration (HR 0.69). Pivotal FDA-approval trial.

Abraham WT. Lancet 2011.

GUIDE-HF (2021)

N=1,000 HFrEF + HFpEF. Pre-COVID analysis: 28% ↓ HFH. First RCT to include HFpEF.

Lindenfeld J. Lancet 2021.

MONITOR-HF (2023)

N=348 European RCT. 44% ↓ HFH (HR 0.56) + improved QoL. Largest effect size.

Brugts JJ. Lancet 2023.

GUIDE-HF Survival (2024)

1,250 patients, 2 years. Hemodynamic monitoring reduced overall mortality (HR 0.75, p=0.043) and HFH (HR 0.64, p<0.0001).

Lindenfeld J. JACC 2024;83(6):682–694.

Comparing Pulmonary Artery Pressure Sensors: CardioMEMS vs. Cordella

Feature	CardioMEMS (Abbott)	Cordella (Endotronix)
PA Location	Left or Right PA	Right PA only
Ease of Implant / Safety	Easy / Safe	Relatively Easy / Safe
PAP Readings	Supine	Supine + Seated
Heart Rate	Yes	Yes
Cardiac Output	In development	In development
Peripheral Integration	No	Yes (BP, SaO2, HR)
Clinical Trial Data	+++++ (multiple RCTs)	+++ (non-randomized)
FDA Approved	Yes	CE Mark (EU)
Ideal Patient Profile	HFrEF / HFpEF, Pulm HTN	Obese, COPD, seated readings preferred

Klein L. J Card Fail. 2025;31:1731–1742. | *Mullens W et al. JACC Heart Fail. 2024;12:785–788.*

Beyond PAP: Left Atrial and IVC Pressure Sensors

	LPA/RPA (PAP)	LA / LA+RA	IVC
Implant Difficulty	+ / Safe	+++ / Safe	++ / Safe
Hemodynamic Measure	PAP	LAP / RAP	Congestion Surrogate
HR / Cardiac Output	Y / In dev.	Y / But limited	N/A
Clinical Trial Data	+++	In progress	In progress
FDA / EU Approved	Yes	No	No
Diuretic Titration	✓	✓	✓
GDMT / Device Titration	Y / Maybe	Y / Y	Unclear
Disease Progression Marker	Yes	Yes	Maybe
Ideal Patient	Pulm HTN	MR / TR / AF	'Garden variety'

Klein L. J Card Fail. 2025;31:1731–1742. | Meerkin D et al. Eur J Heart Fail. 2024;26:1814–1823. | Fudim M et al. J Card Fail. 2026; in press.

PA Pressure as a Mortality Biomarker: HFrEF and HFpEF

PA Diastolic ≤15 mmHg

–14.7%

Reduction in 18-month mortality vs. those with rising pressures

PA Diastolic ≥+2 mmHg at 6 mo

+26.7%

Increase in 18-month mortality (HR 1.03 per mmHg, p=0.004)

PA Mean >25 mmHg

Both HFrEF & HFpEF

Significantly elevated mortality risk — similar risk curves regardless of EF

Clinical Implications of the PA Pressure–Mortality Relationship

- Reducing PA diastolic pressure by ≥2 mmHg over 6 months translates to 14.7% lower mortality over the next 18 months
- The pressure-mortality relationship is CONTINUOUS — every mmHg matters
- HFpEF patients carry the same risk as HFrEF at equivalent filling pressures
- RV function is strongly linked to chronic PA pressure elevation — early intervention may prevent RV failure

Zile MR, Abraham WT, Stevenson LW et al. Circ Heart Fail. 2025. (Relationship Between Remote, Ambulatory PAP and All-Cause Mortality in Chronic HF)

How PAP Monitoring Enables Better GDMT: A Synergistic Relationship

1 See pressure in real time

Daily PAP readings reveal whether filling pressures are rising, stable, or falling — BEFORE symptoms develop.

2 Link pressure changes to GDMT

You can directly observe how each drug titration changes PA pressure within days to weeks — something clinic visits cannot capture.

3 Titrate with confidence

Uptitrate ARNI/MRA when pressures are stable or high. Hold or slow beta-blockers if PAP rises. Catch over-diuresis before hypotension hits.

The Evidence: CHAMPION Substudy (JACC 2017) — More GDMT = More Benefit from PAP

Patients on ACEI/ARB and/or Beta-blocker

47%

lower mortality

with PAP-guided care (p = 0.029)

Patients on BOTH ACEI/ARB + Beta-blocker (full GDMT)

57%

lower mortality

with PAP-guided care (p = 0.0026)

→

What PAP Monitoring Reveals About Each Drug:

ARNI *Sacubitril/Valsartan*	**Consistently lowers PAP** → *Uptitrate when PAP stable or elevated*
MRA *Spironolactone/Eplerenone*	**Lowers PAP — clear dose-response** → *Down-titration promptly raises PAP*
Beta-Blockers *Metoprolol / Carvedilol*	**Variable — may transiently raise PAP** → *Monitor closely at initiation / up-titration*
SGLT2i	**May over-deplete volume** → *Watch for low PAP + dizziness = over-diuresis*

Givertz MM, Stevenson LW et al. JACC. 2017;70:1875–1886. | Zalawadiya S, Kiernan M, Borlaug B, Stevenson LW et al. JCF. 2026;32:32–42.

Monitoring via Cardiac Implantable Electronic Devices

OptiVol™ / TriageHF™ | Medtronic

Parameters:

Intrathoracic impedance + diagnostic algorithm

HeartLogic™ | Boston Scientific

Parameters:

HF Index: heart sounds (S1/S3), thoracic impedance, RR, activity, tidal volume, HRV

CorVue™ | Abbott

Parameters:

Thoracic impedance monitoring

Lumax™ + CardioMessenger | Biotronik

Parameters:

Thoracic impedance + HR variability + patient activity + home monitoring integration

CIEDs detect autonomic changes 2–3 weeks before clinical congestion — earlier than weight/BP but later than filling pressures

Kennel PJ et al. JAMA Cardiol. 2022;7(5):556–564.

LINK-HF: Wearable Device Predicts Hospitalization

The wearable gave clinicians a 6.5-day head start

Alerts fired a median of 6.5 days before a heart failure event — enough time to call the patient, adjust medications, or schedule a visit before crisis hits.

6.5 days
Median early warning

3 in 4 worsening events were detected in advance

The algorithm correctly flagged 76% of worsening HF events — meaning most hospitalizations weren't surprises; they were preceded by a detectable signal days earlier.

76%
Sensitivity — events caught

Alerted patients had significantly more events — confirming alerts were clinically real

Patients who received alerts had statistically higher rates of both worsening HF and unplanned hospitalizations — validating the algorithm identified truly high-risk patients, not noise.

p = 0.001
Worsening HF

p = 0.008
Unplanned hosp.

Stehlik J et al. Circ Heart Fail. 2020;13(3). doi:10.1161/CIRCHEARTFAILURE.119.006513

Wearable Devices for Outpatient HF Monitoring: Current Applications

AF Detection

Apple Watch (Perez NEJM 2019): 0.2% notification rate, 87% AF confirmed by ECG patch
AliveCor KardiaBand: PPV 98.2% for AF on concurrent ECG (Lubitz, Circulation 2022)

HF Risk Prediction

BMAD Trial (ZOLL sensor): 38% relative risk reduction in 90-day HFH (HR 0.62, p=0.03)
Single-lead ECG AI model: Detects LV systolic dysfunction (EF<40%) with HR 5.05 per probability unit

BP Monitoring (Cuffless)

LiveOne wristband (Sayer, Am J Hypertension 2022): r=0.91 systolic, r=0.85 diastolic vs. arterial line
Continuous BP trends may detect hemodynamic decompensation earlier

Sleep Monitoring

Oura Ring validated vs. polysomnography: Good agreement for sleep onset latency and period time
Sleep disturbance may be an early HF decompensation marker

Activity Monitoring

Daily step count correlates with functional capacity and HF prognosis
Activity decline often precedes symptomatic deterioration by 1–2 weeks

AI Data Integration

AI functions: refine sensor outputs, fill data gaps, pattern identification,
clinical workflow integration, data standardization across devices

Perez MV et al. NEJM 2019. | Boehmer JP et al. JACC HF 2024. | Sayer GT et al. Am J Hypertension 2022. | Gill et al. Nature Medicine 2023.

Wearables: Current Roadblocks to Clinical Implementation

Data Quality

Noise from motion artifacts, sporadic use, variable skin contact. Consumer-grade vs. medical-grade distinction critical.

False Positives

Higher false alarm rates in low-prevalence populations → workflow disruption and alert fatigue. PPV drops sharply when prevalence < 5%.

Lack of Interoperability

No standardized data formats across device manufacturers. Integrating Apple Watch, Oura Ring, and ZOLL into one clinical view is currently not scalable.

Missing Clinical Correlates

We know sensors capture signals — but what specific thresholds trigger what clinical actions? Algorithms need prospective validation.

Representation Gaps

Most validation studies are in white male populations. Skin tone affects PPG accuracy. Generalizability to HF populations is limited.

Reimbursement

CPT codes for RPM exist but implementation is complex. Average reimbursement ~$100–300/pt-month — sufficient only if workflow is efficient.

Sayer GT. Columbia / Weill Cornell. THT 2025 — Wearable Devices for Outpatient Monitoring.

Patient Self-Management of PA Pressure: The Virtual HF Clinic

Practical Pressure Self-Management Algorithm

Daily Pressure Reading

Reading Valid? No -> Repeat

Within Green Zone?

No (High)

- No/Mild Sx → Increase diuretics
- Severe Sx → Contact HF Team

Yes

- Continue as usual
- Reinforce adherence

No (Low)

- Dizzy/Fatigue → Hold meds
- Markedly low → Contact HF Team

Team Review → Adjust Targets Periodically

What Works vs. What Doesn't

✓ Works

- Simple patient-specific targets & rules
- Fast feedback — patients see actions change pressures
- Multidisciplinary teams with clear triage pathways

✗ Does Not Work

- Unfiltered alerts → reactive chaos
- Self-treat without explicit boundaries
- Complex high-burden apps with little visible benefit

Ducharme A. THT 2025. Self-Management of PA Pressure as a Virtual HF Clinic. | Desai AS, Stevenson LW. Editorial. NEJM. Nov 2010.

Summary

- Weight and vital sign monitoring are insufficient — hemodynamic congestion precedes symptoms by 2–4 weeks. We must detect it earlier.
- Implantable PA pressure monitoring (CardioMEMS) has evidence for reducing HF hospitalizations AND mortality in HFrEF and HFpEF.
- GDMT and hemodynamic monitoring are synergistic — ARNI and MRA lower PA pressures; PA monitoring enhances GDMT benefit.
- Wearables hold enormous promise but clinical integration remains the critical gap. The technology is ready but workflows however are not
- Patient self-management of pressures is the virtual HF clinic along with physician-directed protocols. Empower patients.
- The future is multiparametric + AI integration. No single sensor captures all triggers of ADHF. Unify data collection to avoid alert fatigue.

Be Proactive, Not Reactive.
The Tools Are Here — It Is Time to Use Them.

Thank You!