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Original Article

A Conceptual Framework for Evaluating the Adoption and Implementation of IoT-Based Remote Patient Monitoring Systems for Heart Failure

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Abstract

Background: Heart failure (HF) is a leading cause of morbidity, mortality, and healthcare burden globally. Internet of things (IoT)-based remote patient monitoring (RPM) systems have potential for enhanced care through continuous data collection and timely interventions, yet their adoption and implementation remain inconsistent due to multifaceted barriers, including technological, organizational, and patient-related challenges. This study aimed to develop and validate a conceptual framework for evaluating the adoption and implementation of IoT-based RPM systems in the management of HF, drawing on systematic evidence synthesis and expert consensus.

Methods: A two-phase study was conducted including: (1) a PRISMA-guided systematic review of literature from PubMed, Web of Science, Scopus, Embase, and IEEE Xplore databases up to May 1, 2025, focusing on adoption, barriers, facilitators, and outcomes and (2) a three-round modified Delphi consensus process with 22 multidisciplinary experts (cardiologists, health informaticists, telehealth managers, and policy experts) to validate and prioritize factors.

Results: The systematic review included 23 studies, identifying key barriers (e.g., connectivity issues, digital literacy deficits, and provider workload) and facilitators (e.g., user-friendly interfaces, patient education, and multidisciplinary collaboration) across technological, patient-related, organizational, and systemic domains. High feasibility and patient satisfaction (75–96% adherence) were noted, alongside clinical benefits such as reduced hospitalizations (19%) and emergency visits (28%). The Delphi process achieved strong consensus (Kendall's W = 0.82) on 30 core factors in five domains, with top priorities including user-friendly interfaces (95% rated highly important), patient education (92%), and reliable connectivity (90%).

Conclusion: This evidence-based conceptual framework provides a multidimensional guide for stakeholders to promote sustainable adoption of IoT-based RPM in the management of HF, emphasizing interconnected domains and prioritized interventions to overcome barriers and enhance patient outcomes, self-management, and healthcare efficiency.

Keywords: Heart failure, Remote patient monitoring, Internet of things, Adoption, Implementation, Conceptual framework, Systematic review, Delphi method

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Background

Heart failure (HF) continues to be one of the most prevalent chronic conditions worldwide, contributing to high morbidity, mortality, and frequent hospital readmissions that impose significant clinical and financial burdens on healthcare systems (1,2). Advances in digital health and the Internet of Things (IoT) have introduced new opportunities for remote patient monitoring (RPM), enabling continuous collection of physiological data and patient-reported outcomes beyond traditional clinical settings (3,4). These technologies hold promise for improving the quality of care, supporting timely clinical interventions, empowering patients in self-management, and ultimately reducing preventable hospitalizations (5-7).

Despite these advantages, the real-world adoption and implementation of IoT-based RPM systems for HF remain inconsistent and fragmented (8). Healthcare providers and organizations often encounter challenges such as interoperability issues, lack of standardized protocols, technical complexity, organizational readiness, and concerns about data security and patient privacy (9,10). On the other hand, patients may face barriers related to digital literacy, usability, and trust in technology (11). At the same time, important facilitators, including demonstrated clinical benefits, stakeholder engagement, supportive policy environments, and regulatory incentives, have been shown to encourage uptake and integration (12).

Although the body of literature on RPM in HF management has grown rapidly, much of it has focused either on clinical outcomes of specific interventions or on technical aspects of IoT-enabled systems (8,13). What

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remains underexplored is a comprehensive understanding of the multidimensional factors that influence their adoption and implementation, especially within complex healthcare ecosystems involving multiple stakeholders (14). Without such a structured perspective, efforts to integrate these technologies into routine care remain limited in scope and sustainability (15).

To address this gap, the present study seeks to develop a conceptual framework for evaluating the adoption and implementation of IoT-based RPM systems for HF. By systematically reviewing the existing literature and validating findings through expert consensus in a Delphi process, this study aims to provide a holistic evidence-based model that can guide healthcare providers, policymakers, and technology developers in promoting the successful integration of these systems into clinical practice.

Materials and Methods

This study employed a two-phase sequential design, consisting of (a) a systematic review of the literature conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure methodological rigor and transparency in the identification, selection, and synthesis of the available evidence, and (b) a Delphi consensus process with experts in digital health, clinical cardiology, and health information management. The aim was to identify, synthesize, and validate the key factors influencing the adoption and implementation of IoT-based RPM systems for chronic disease management, with findings from the review further refined and validated in the second phase.

Systematic Review

This systematic review was conducted in accordance with the PRISMA guidelines to ensure methodological transparency and rigor.

Review Question

The review was guided by the following PICO-based research question:

- Population (P): Patients diagnosed with HF, including congestive, left-sided, and right-sided HF
- Intervention (I): Implementation and use of IoT-based RPM systems, telemedicine, or telemonitoring approaches
- Comparison (C): Usual care, traditional monitoring methods, or alternative digital health interventions
- Outcome (O): Adoption and implementation outcomes, including feasibility, usability, barriers, facilitators, patient engagement, clinical effectiveness, and healthcare utilization

Thus, the primary review question was: "In patients with HF, how does the adoption and implementation of IoT-based RPM systems differ from usual care or alternative monitoring methods in terms of feasibility, barriers, facilitators, and clinical outcomes?"

Inclusion and Exclusion Criteria

Eligible studies were original peer-reviewed research articles (quantitative, qualitative, or mixed-methods) focusing on the adoption, acceptance, feasibility, barriers, facilitators, or clinical implementation of IoT-based RPM systems for HF patients. Only studies published in English with full-text availability were considered.

Exclusion criteria included editorials, letters, commentaries, and conference abstracts without full data; studies not specific to heart failure (e.g., those on general cardiovascular disease without subgroup analysis); research focusing solely on technology design or algorithm development without addressing adoption or implementation; as well as narrative reviews or papers with insufficient methodological rigor.

Search Strategy

A comprehensive search was performed across PubMed, Web of Science, Scopus, Embase, and IEEE Xplore databases, covering all available studies until May 1, 2025. Google Scholar and manual reference list checks were additionally employed to capture grey literature and supplementary data sources.

The search strategy was developed based on prior research and consultation with experts in health informatics and telemedicine. The final Boolean syntax combined three major concepts: Heart Failure AND Remote Patient Monitoring/IoT AND Adoption/Implementation.

("Heart Failure" OR "Cardiac Failure" OR "Myocardial Failure" OR "Heart Disease" OR "Congestive Heart Failure" OR "Heart Decompensation" OR "Left-Sided Heart Failure" OR "Right-Sided Heart Failure") AND ("Remote Patient Monitoring" OR "Telemedicine" OR "Telemonitoring" OR "Internet of Things" OR "IoT" OR "RPM") AND ("Adoption" OR "Acceptance" OR "Implementation" OR "Feasibility" OR "Barriers" OR "Facilitators")

Study Selection

All identified records were imported into EndNote for management and duplicate removal. Screening was conducted in three phases: title, abstract, and full-text review. Each phase was independently performed by two reviewers, with disagreements resolved through discussion or consultation with a third reviewer. Studies excluded at the title or abstract screening stage required agreement by at least two reviewers.

Data Extraction

Data were extracted using a standardized form, including:

- Bibliographic information (authors, year, and country)
- Study design and methodology
- Population characteristics (sample size and

demographics)
- Description of IoT/RPM intervention
- Adoption/implementation outcomes (facilitators, barriers, feasibility, usability, and engagement)
- Reported clinical or organizational outcomes (readmission, quality of life, and healthcare utilization)

To ensure accuracy, data extraction was independently verified by a second reviewer.

Quality Assessment

The methodological quality of included studies was evaluated using appropriate tools depending on study design:

- Randomized controlled trials (RCTs): Cochrane Risk of Bias Tool
- Observational studies: Newcastle-Ottawa Scale (NOS)
- Qualitative studies: CASP Qualitative Checklist

Each study was independently appraised by two reviewers, with disagreements resolved by consensus. The overall confidence in findings was categorized as high, moderate, or low.

Reporting

The study selection process was documented using a PRISMA flow diagram. Results were synthesized narratively and presented in structured tables summarizing study characteristics, interventions, and outcomes. Visual tools (e.g., charts, word clouds, and Xmind) were employed to highlight thematic trends, barriers, and facilitators in the adoption of IoT-based RPM for HF.

Delphi Phase

The Delphi phase aimed to validate and refine the candidate factors identified in the systematic review and to achieve expert consensus on the structure and priorities of a conceptual framework for the adoption and implementation of IoT-based RPM systems for HF. A structured iterative Delphi process was used to ensure anonymity, controlled feedback, and statistical aggregation of expert judgments.

Design Overview

A modified Delphi design (three rounds) was chosen. The process began with a closed (structured) Round 1 based on the list of candidate factors generated from the systematic review (i.e., a modified Delphi rather than an open first round), followed by two feedback rounds to build consensus and prioritize factors. The modified approach accelerates the process and grounds the study in empirical evidence while still allowing experts to suggest new items and provide qualitative comments.

Pane l: Target Population, Eligibility, and Sample Size

The Delphi panel targeted multidisciplinary experts with demonstrated experience in digital health, cardiology (particularly management of HF), health informatics, telehealth program implementation, or healthcare management/policy relevant to RPM.

Inclusion criteria for panelists required at least five years of professional experience in one or more relevant domains (cardiology, telemedicine, health informatics, and health information management); evidence of expertise demonstrated by (a) at least one peer-reviewed publication on telehealth, RPM, or IoT, (b) a leadership or managerial role in implementing telemonitoring programs, or (c) recognized clinical expertise in heart failure care with telehealth involvement; and willingness to participate in multiple rounds and provide informed consent.

Briefly, 18–25 experts were invited to allow for some attrition while maintaining diverse viewpoints. Literature recommends panels of 10–50; therefore, we selected this range to balance representation and manageability.

A purposive (expert) sampling strategy was used, supplemented with snowball sampling:

1. Purposive identification**:** The research team compiled an initial list of potential experts via (a) authorship of relevant publications identified in the systematic review, (b) professional networks, (c) members of national/international telehealth or cardiology associations, and (d) stakeholders identified by institutional partners.
2. Invitation: Potential panelists received an invitation email describing the study purpose, expected time commitment (20–30 minutes per round), confidentiality procedures, and a copy of the informed consent form. Those who accepted were enrolled.
3. Snowballing: Enrolled experts were asked to suggest additional qualified colleagues (a maximum of two recommendations each) to broaden representativeness.

Instrument Development and Pilot Testing

The Delphi questionnaire was developed from the systematic review output:

- Item generation: The research team consolidated the candidate factors (barriers/facilitators) into clear non-redundant items and organized them preliminarily into thematic domains (technological, organizational, patient, provider, policy/system-level).
- Question format: For each item, experts were asked to:

- Rate importance on a 5-point Likert scale (1 = not important, 2 = slightly important, 3 = moderately important, 4 = important, and 5 = extremely important)
- Rate clarity of item wording on a 4-point scale (1 = not clear, 4 = very clear) or provide suggestions to improve wording (optional)

- Provide open-ended comments and suggest additional items not present in the list
- Pilot testing: The draft questionnaire was piloted with 2–3 independent experts (not on the main panel) to check clarity, length, and technical functioning. Feedback from the pilot informed minor revisions in wording and average completion time estimates.

Data Collection Procedure

- Mode: Online survey platform (e.g., Qualtrics, REDCap, or Google Forms, depending on institutional access) to ensure ease of use, secure data capture, and ability to export responses
- Anonymity and confidentiality: Responses were anonymized in analysis, and panelists were assigned ID codes. Individual responses were kept confidential, and only aggregated anonymized feedback was circulated between rounds.
- Round schedule and reminders:
- Round 1: invitation + survey link; 10–14 days to respond; reminder emails sent at day 5 and day 10
- Round 2: results summary + revised survey; 10–14 days; reminders at day 5 and day 10
- Round 3 (final): final confirmation/ranking; 10 days; reminder at day 7
- Non-responders were contacted by email up to two times per round. The survey progress and attrition were logged.

Round 1 (Item Rating and Suggestion) Procedures and Decision Rules

- Panelists rated all candidate items for importance and clarity, and could add free-text comments or propose new items.
- Analysis after Round 1: Median, interquartile range (IQR), mean, standard deviation (SD), and percentage of respondents rating the item as 4 or 5 (% ≥ 4) were calculated for each item. Qualitative comments were coded thematically to identify rewording needs and additional candidate factors.
- Decision rules post-Round 1:
- Items with median ≥ 4 and IQR ≤ 1 were considered provisionally accepted (high importance + agreement).
- Items with median 3–4 or IQR > 1 were retained for re-rating in Round 2 after possible rewording.
- Items with median < 3 and % ≥ 4 below 30% were considered for removal unless qualitative comments strongly supported retention.
- Newly suggested items that were conceptually distinct were added to the next round.

Round 2 (Controlled Feedback and Re-rating) Procedures and Decision Rules

- Panelists received: (a) the aggregated quantitative summary (median, IQR, % ≥ 4) for each item, (b) anonymized qualitative comments, and (c) the revised item list including new items.
- Participants were asked to re-rate items considering group feedback.
- Analysis after Round 2: Median, IQR, and % ≥ 4 were recomputed. Movement toward consensus was assessed, and items still lacking agreement were identified.
- Decision rules post-Round 2:
- Items reaching predefined consensus threshold (see below) were retained in the final list.
- Items close to threshold but with important qualitative support were moved to Round 3.
- Redundant items were merged, and ambiguous items reworded.

Round 3 (Final Consensus and Prioritization) Procedures and Decision Rules

- Provide panelists with updated aggregated results and request final ratings. In this round, panelists may also be asked to rank the top 10 items or to assign a priority score (e.g., 1–10) for implementation focus.
- Final inclusion criteria (consensus definition): an item is included in the validated framework if ≥ 75% of responding experts rate it as 4 or 5 and the median ≥ 4 with IQR ≤ 1. Alternative sensitivity thresholds such as ≥ 70% or median ≥ 4 may be reported in the supplement.
- Items not meeting consensus in Round 3 were excluded from the final core set but can be reported as "suggested/lower consensus" items.

Quantitative Analysis

- Descriptive statistics for each item: mean, SD, median, IQR, and % of panelists rating 4–5.
- Consensus threshold: primary rule = ≥ 75% of respondents rating 4 or 5 and median ≥ 4 and IQR ≤ 1. Justification: A combination of percent agreement and dispersion (IQR) gives both the level and consistency of agreement.

Agreement Measures

- Kendall's W (coefficient of concordance) was used to assess overall agreement across items/rounds. Values near 1 indicate strong concordance.
- Wilcoxon signed-rank test (or paired tests) was applied to examine statistically significant shifts in item ratings between rounds (optional).
- Cronbach's alpha was employed to assess internal consistency of the importance ratings across items (if items form scales).
- Attrition analysis: report response rates per round and compare median ratings of completers vs dropouts to assess bias.

Qualitative Analysis

- Open-ended comments were analyzed using thematic content analysis: initial coding, grouping into themes

(e.g., wording suggestions, context concerns, newly proposed factors), and triangulation by two coders. NVivo or manual Excel coding can be used.
- Qualitative findings informed item rewording, merging, and the emergence of new items.

Handling of New Items, Merging, and Rewording
- New items proposed in Round 1 were reviewed by the research team for conceptual uniqueness and clarity; validated new items entered Round 2.
- Redundant or overlapping items were merged with wording refined to preserve key content.
- Rewording was guided by panel comments and piloting with a small subset to ensure semantic clarity.

Handling Attrition and Nonresponse
- Expect some drop-out and to mitigate it, send timely reminders, keep surveys concise, and emphasize the value of continued participation.
- If attrition exceeded 40% by Round 2, the research team would (a) perform sensitivity analyses to detect bias, (b) consider contacting non-responders for a final input, and (c) transparently report attrition and its potential impact.
- No replacements were made mid-process; initial over-recruitment accounted for expected attrition.

Data Management, Ethics, and Confidentiality
- The study obtained institutional ethics approval (IRB). All panelists provided informed consent electronically before participation.
- Data were stored on secure institutional servers; personal data were separated and access restricted.
- Aggregated anonymized results were shared with participants; individual responses remained confidential.

Tools and Software
- Survey administration: Qualtrics/REDCap/Google Forms (depending on institutional availability)
- Quantitative analysis: SPSS or R (for descriptive stats, Kendall's W, Wilcoxon tests)
- Qualitative analysis: NVivo or manual thematic coding in Excel
- Documentation: all versions of questionnaires, anonymized response datasets, and analytic scripts archived for reproducibility

Outcome of the Delphi Phase
- The Delphi yields: (a) a validated list of core adoption/implementation factors (consensus items), (b) prioritized factors (ranking/weighting), and (c) refined item definitions and domain structure for the final conceptual framework.
- Reporting will include the number invited/participated per round, response rates, criteria used for consensus, median/IQR/percent agreement for each item, Kendall's W, and anonymized qualitative comments. A flow diagram summarizing Delphi rounds and retention will be provided (analogous to PRISMA for the review phase).

Timeline (indicative)
- Recruitment and pilot: 2 weeks
- Round 1 open: 10–14 days; analysis and revision: 5–7 days
- Round 2 open: 10–14 days; analysis: 5–7 days
- Round 3 open: 7–10 days; final analysis and reporting: 2 weeks
  Total estimated time for Delphi rounds: 8–10 weeks (it can be compressed or extended depending on panel availability)

Results

Systematic Review

Study Selection Process

The systematic review adhered to the PRISMA guidelines to ensure transparency and rigor. A total of 2778 articles were identified through searches in PubMed, Web of Science, Scopus, Embase, and IEEE Xplore databases, supplemented by Google Scholar and manual reference checks. After removing 1384 duplicates, 1394 unique records remained. Title screening excluded 564 articles, and abstract screening eliminated 675 articles, leaving 155 for full-text review. Of these articles, 6 were excluded due to inaccessible full texts (n = 5) or non-English full texts (n = 1). A further 53 articles were excluded based on inclusion/exclusion criteria (e.g., not specific to HF, insufficient focus on adoption/implementation), and 73 were excluded following quality assessment using the Cochrane Risk of Bias Tool, Newcastle-Ottawa Scale, or CASP Qualitative Checklist. Ultimately, 23 studies were included in the final analysis. The study selection process is summarized in Figure 1.

Characteristics of Included Studies

A total of 23 studies, published between 2007 and 2025, originated from 12 countries, with the United States (n = 4), Canada (n = 3), and Italy (n = 2) representing the highest number of studies. Study designs included feasibility studies (n = 8), mixed-methods studies (n = 4), qualitative studies (n = 1), observational studies (n = 3), design and implementation studies (n = 1), longitudinal studies (n = 1), randomized controlled trial protocols (n = 1), pilot studies (n = 3), and single-center experience-based studies (n = 2). The target population primarily comprised HF patients, with some studies specifying chronic heart failure (CHF), congenital heart disease, or HF with specific ejection fraction categories (e.g., HFrEF, HFmrEF, and HFpEF). Sample sizes ranged from 5 to 141 participants, with most studies focusing on elderly patients (mean age range: 53–84 years).

The word cloud presented in Figure 2 was generated from a frequency analysis of key terms extracted from

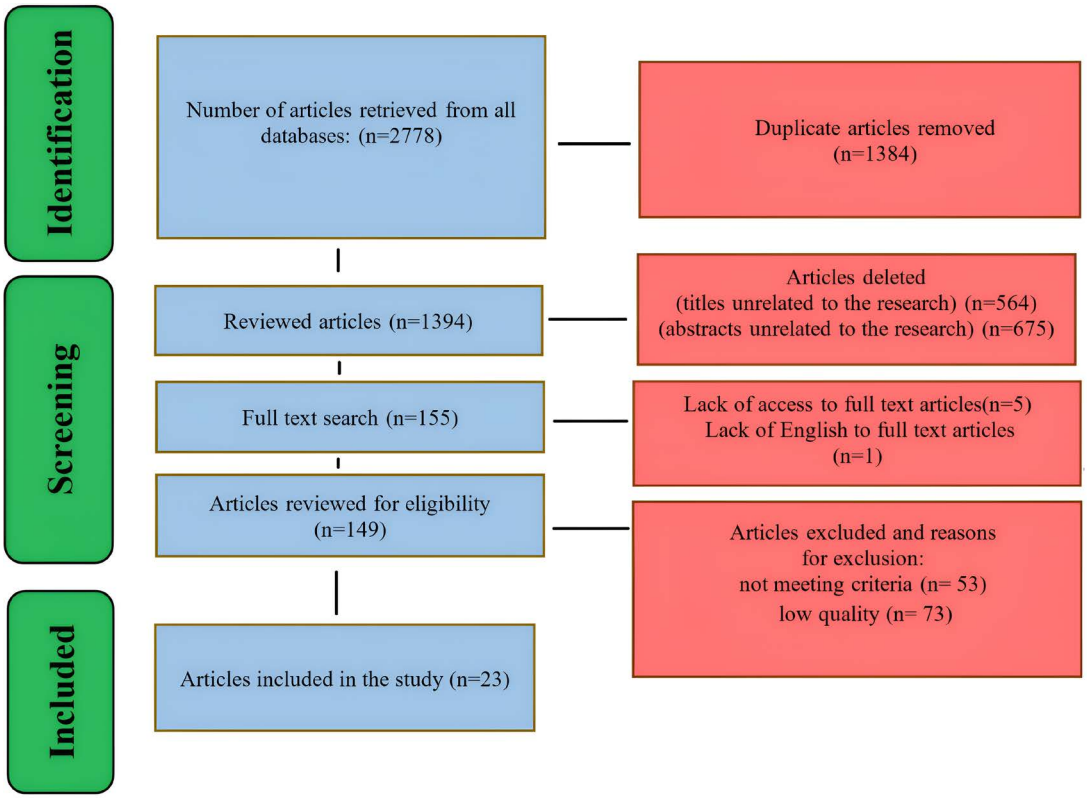

Figure 1. PRISMA Flow Diagram

Figure 2. Word Cloud of Key Themes

the data extraction of studies included in this systematic review, offering a visual synthesis of the dominant themes related to the adoption and implementation of IoT-based RPM systems for HF. Central terms such as "IoT", "RPM", "Patient", and "HF" underscore the focus on integrating IoT technologies with remote monitoring to enhance HF management. Key clusters highlight critical implementation factors including "Adoption", "Feasibility", "Barrier", and "Facilitator" alongside technological and clinical enablers such as "Wearable", "Telemedicine", and "EHR" (electronic health records), reflecting the infrastructure supporting these systems. Additional themes such as "Privacy", "Regulatory", "Training", and "Cost" emphasize the multifaceted challenges and considerations in scaling IoT-based RPM for HF, while "Decision Support" and "Workflow"

suggest potential benefits in clinical decision-making and operational efficiency. This visualization encapsulates a conceptual framework for evaluating the adoption and implementation of such systems, highlighting critical areas for technological innovation, policy development, and future research to optimize HF care delivery.

IoT-based RPM interventions utilized diverse technologies: mobile apps and smartphone-based systems (n = 6), telemonitoring platforms with Bluetooth-enabled devices (e.g., weight scales, blood pressure monitors) (n = 5), wearable biosensors (n = 1), handheld ultrasound devices (n = 1), digital pen technology (n = 1), camera-based telemonitoring (n = 1), tele-echocardiography systems (n = 1), and specialized software suites (n = 2). Features such as real-time alerts, cloud computing, or nurse-led coaching were common. Study characteristics are summarized in Table 1.

Barriers to Adoption and Implementation

Barriers were categorized into technological, patient-related, organizational, and systemic domains:

- Technological barriers: Connectivity issues (e.g., 79.5% Internet failures in Agapov et al, 2022), device malfunctions (e.g., broken scales, 1.9%), and EHR integration challenges. Usability issues, such as complex set-ups for elderly patients or inappropriate alert thresholds, were also reported.
- Patient-related barriers: Low adherence due to younger age, physical/cognitive impairments, and limited digital literacy. Concerns about surveillance and language barriers were noted.
- Organizational barriers: Increased provider workload, lack of physician incentives, and workflow integration challenges. Recruitment and retention issues were also prevalent.
- Systemic barriers: Lack of funding/reimbursement, regulatory/data privacy concerns, and limited infrastructure in underserved areas. Small sample sizes and selection bias limited generalizability.

Facilitators of Adoption and Implementation

Facilitators were identified across similar domains:

- Technological Facilitators: User-friendly interfaces, reliable systems, real-time alerts, and automated self-care instructions. Switchable camera options and care platform integration were beneficial.
- Patient-related Facilitators: High patient satisfaction, perceived safety/empowerment, and education/training. Ease of use and direct feedback enhanced engagement.
- Organizational Facilitators: Multidisciplinary collaboration, structured education, nurse-led support, outsourcing to external providers, and hospital support (e.g., CMIO teams)

Table 1. Characteristics of Included Studies

Authors	Year	Country	Study design	Technology Used	Population	Sample size
Auener et al (16)	2023	Netherlands	Qualitative	Non-invasive telemonitoring	Chronic HF	25 stakeholders
Seto et al (17)	2019	Canada	Feasibility	Mobile phone-based TM	HF	6 patients
Ekola et al (18)	2024	Finland	Mixed-methods	Android tablet, digital scale	HF	47 patients
Baginski et al (19)	2021	USA	Observational	CardioMEMS, HeartLogic	HF	141 patients
Safdari et al (20)	2017	Iran	Design/implementation	Mobile app, web service	CHF	10 patients
Reamer et al (21)	2022	USA	Mixed-methods	Wearable biosensor, smartphone	HF	5 (Phase 1)
Borchers et al (22)	2023	Germany	Feasibility	Camera-based telemonitoring	Heart disease	18 patients
Chiem et al (23)	2021	USA	Pilot	Handheld ultrasound	HF	44 patients
Jaana et al (24)	2019	Canada	Longitudinal	Telemonitoring monitor	CHF	23 patients
Basso et al (25)	2024	Italy	RCT protocol	Smartphone-based TM	HF	Planned 45 patients
Agapov et al (26)	2022	Russia	Observational	Software suite, Bluetooth scales	CHF	30 patients
Borrelli et al (27)	2025	Italy	Single-center	Telemedicine platform	Congenital HD	Not specified
Ware et al (28)	2018	Canada	Mixed-methods	Smartphone, Medly app	HF	Planned 108 patients
Kagiyama et al (29)	2024	Japan	Observational	Handheld heart sound recorder	HF	77 patients
Hjorth-Hansen et al (30)	2020	Norway	Feasibility	Tele-echocardiography	HF	50 patients
Diez et al (31)	2023	Argentina	Pilot	24/7 TM platform	HF	20 patients
Ammenwerth et al (32)	2018	Austria	Pilot	Mobile phone, web software	HF	43 patients
Lind et al (33)	2016	Sweden	Pilot	Digital pen technology	HF	14 patients
Graever et al (34)	2025	Brazil	Mixed-methods	Videoconferences, web platform	HF	83 patients
Clark et al (35)	2007	Australia	Mixed-methods	Telephone-monitoring	CHF	79 patients
Davis et al (36)	2015	USA	Feasibility	Telemonitoring	HF, COPD	Not specified
Yatabe et al (37)	2022	Japan	Feasibility protocol	IoT monitoring devices	HF	Planned 20 patients
Noguchi M et al (38)	2025	Japan	Prospective multicenter cohort study	LAVITA home telemonitoring system	HF	35 patients

- Systemic Facilitators: Reimbursement developments, telemonitoring as a standard service, and the COVID-19 pandemic as a digital adoption catalyst.

Key Findings and Outcomes

- Feasibility and acceptability: High feasibility and patient satisfaction (86%), with adherence rates of 65.8% to 96% were reported. Technical challenges and patient burden were also noted.
- Clinical outcomes: Reductions in hospitalizations (19%) and ED visits (28%), improved pharmacological adherence ($P = 0.019$), and early detection of HF deterioration were found.
- Patient empowerment: Enhanced confidence in symptom management and self-care support were reported, though some reported reduced self-care maintenance in elderly patients.
- Healthcare utilization: Reduced readmissions (50%) and length of stay (51–62%), with potential cost savings were observed.

Delphi Consensus Study

Delphi Process and Participation

The Delphi study consisted of three rounds to validate and prioritize factors influencing the adoption and implementation of IoT-based RPM systems for HF. A total of 22 experts were recruited, including cardiologists (n = 8), health informatics specialists (n = 6), telehealth program managers (n = 5), and health information management (n = 3), with ≥ 5 years of experience in relevant fields. The panel was recruited via purposive sampling from systematic review authorship, professional networks, and snowball sampling. Response rate was 100% (22/22) in Round 1, 95% (21/22) in Round 2, and it was 91% (20/22) in Round 3, with minimal attrition (9% overall). Sensitivity analyses showed no significant bias from dropouts (Wilcoxon signed-rank test, $P > 0.05$).

Round-by-Round Results

- Round 1: Experts rated 42 candidate factors (derived from the systematic review) on importance (5-point Likert scale) and clarity (4-point scale). Thirty factors achieved provisional consensus (median ≥ 4, IQR ≤ 1), including user-friendly interfaces, patient education, and reimbursement policies. Five new factors were proposed (e.g., patient trust in data security, provider training programs), and three items were reworded for clarity based on qualitative feedback.
- Round 2: Experts re-rated 37 items (30 retained, 5 new, 2 merged). Thirty-two items reached consensus (≥ 75% rated 4 or 5, median ≥ 4, IQR ≤ 1). Qualitative comments emphasized the need for scalable infrastructure and stakeholder engagement. Kendall's W was 0.78, indicating strong agreement.
- Round 3: Experts confirmed 30 items as core factors and ranked the top 10 by implementation priority. Final consensus was achieved for 30 items (≥ 75% rated 4 or 5, median ≥ 4, IQR ≤ 1), with Kendall's W increasing to 0.82. Two items (e.g., advanced AI analytics, community-based support) were retained as "suggested" due to lower consensus (70% rated 4 or 5) (Figure 3).

Validated Factors

The Delphi process identified 30 core factors across five domains, with the top 10 prioritized factors highlighted (Table 2):

- Technological (8 factors): User-friendly interfaces (priority #1), reliable connectivity (#3), EHR integration, real-time alerts, scalable platforms, device interoperability, data security measures, and automated feedback systems
- Patient-related (7 factors): Patient education (#2), perceived safety/empowerment (#5), digital literacy training, adherence support, trust in technology, cultural/language accommodations, and self-efficacy enhancement
- Provider-related (6 factors): Provider training (#4), multidisciplinary collaboration (#6), workload management, incentive structures, clinical decision support, and feedback mechanisms
- Organizational (5 factors): Workflow integration (#7), dedicated support teams, resource allocation, leadership commitment, and iterative program evaluation
- Systemic (4 factors): Reimbursement policies (#8), regulatory clarity (#9), infrastructure investment (#10), and policy alignment with universal healthcare

Qualitative Insights

Thematic analysis of open-ended comments highlighted the importance of patient trust in data security, the need for culturally tailored interventions, and the role of iterative evaluations in sustaining programs. Experts emphasized that reimbursement and regulatory clarity are critical for scaling RPM systems globally.

Conceptual Framework for Adoption and Implementation of IoT-Based RPM

Based on the systematic review and Delphi consensus, a conceptual framework was developed to guide the adoption and implementation of IoT-based RPM systems for HF (Figure 4). The framework is structured around five interconnected domains, reflecting the multidimensional nature of RPM integration. Each domain includes validated factors prioritized by experts, ensuring a comprehensive and evidence-based model.

1. Technological Domain

- Core Factors: User-friendly interfaces, reliable connectivity, EHR integration, real-time alerts, scalable platforms, device interoperability, data security, automated feedback
- Role: Ensuring system usability, reliability, and integration with clinical workflows, addressing

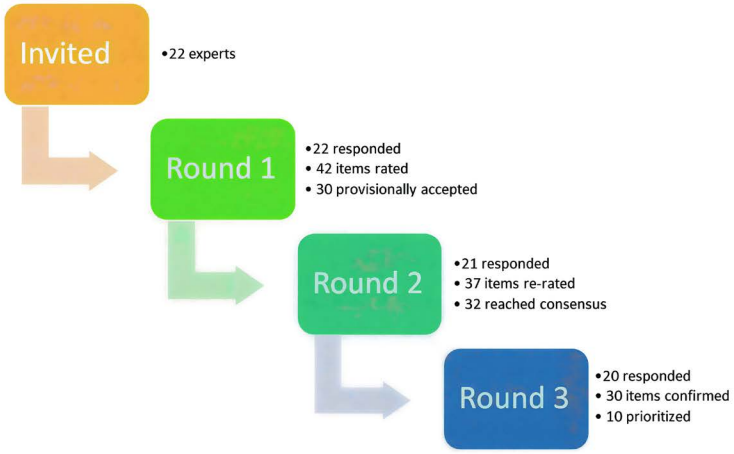

Figure 3. Delphi Consensus Flow Diagram

Table 2. Top 10 Prioritized Factors

Rank	Factor	Domain	% Rated 4/5	Median (IQR)
1	User-friendly interfaces	Technological	95%	5 (4–5)
2	Patient education	Patient-Related	92%	5 (4–5)
3	Reliable connectivity	Technological	90%	4 (4–5)
4	Provider training	Provider-related	88%	4 (4–5)
5	Perceived safety/empowerment	Patient-related	85%	4 (4–5)
6	Multidisciplinary collaboration	Provider-related	82%	4 (4–5)
7	Workflow integration	Organizational	80%	4 (3–5)
8	Reimbursement policies	Systemic	78%	4 (3–5)
9	Regulatory clarity	Systemic	76%	4 (3–5)
10	Infrastructure investment	Systemic	75%	4 (3–4)

technical barriers like connectivity issues and device malfunctions

2. Patient-related Domain
- Core Factors: Patient education, perceived safety/empowerment, digital literacy training, adherence support, trust in technology, cultural/language accommodations, self-efficacy enhancement
- Role: Enhancing patient engagement and adherence by addressing literacy, trust, and cultural barriers, fostering empowerment and self-management.

3. Provider-related Domain
- Core Factors: Provider training, multidisciplinary collaboration, workload management, incentive structures, clinical decision support, feedback mechanisms
- Role: Supporting provider adoption through training and collaboration, mitigating workload and incentive-related barriers

4. Organizational Domain
- Core Factors: Workflow integration, dedicated support teams, resource allocation, leadership commitment, iterative evaluation
- Role: Facilitating organizational readiness and sustainability by aligning RPM with existing workflows and ensuring resource support

5. Systemic Domain
- Core Factors: Reimbursement policies, regulatory clarity, infrastructure investment, policy alignment with universal healthcare
- Role: Addressing systemic barriers like funding and regulation, enabling scalable and sustainable implementation

Framework Application

Figure 5, which is a framework application, actually refers to the following:

- Stakeholders: Healthcare providers use the framework to design user-friendly integrated RPM systems; policymakers leverage it to develop supportive regulations; patients benefit from tailored education and empowerment strategies.
- Implementation: The framework guides iterative program design, prioritizing high-impact factors (e.g., user-friendly interfaces, patient education) and addressing barriers through targeted interventions (e.g., training, reimbursement models).

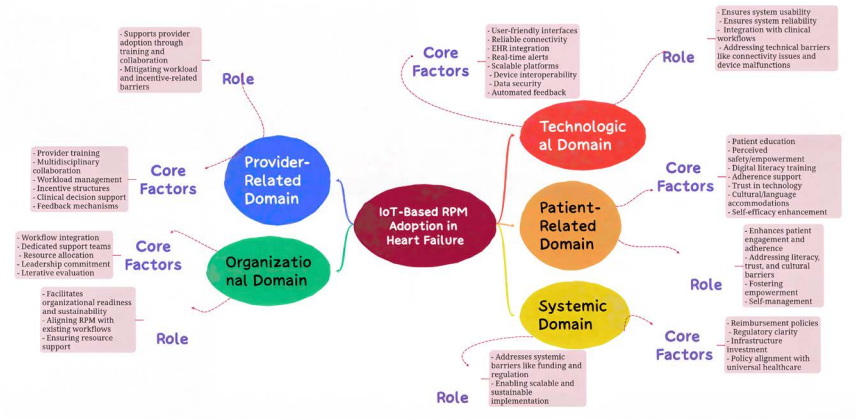

Figure 4. Conceptual Framework for Adoption of IoT-Based RPM in Heart Failure

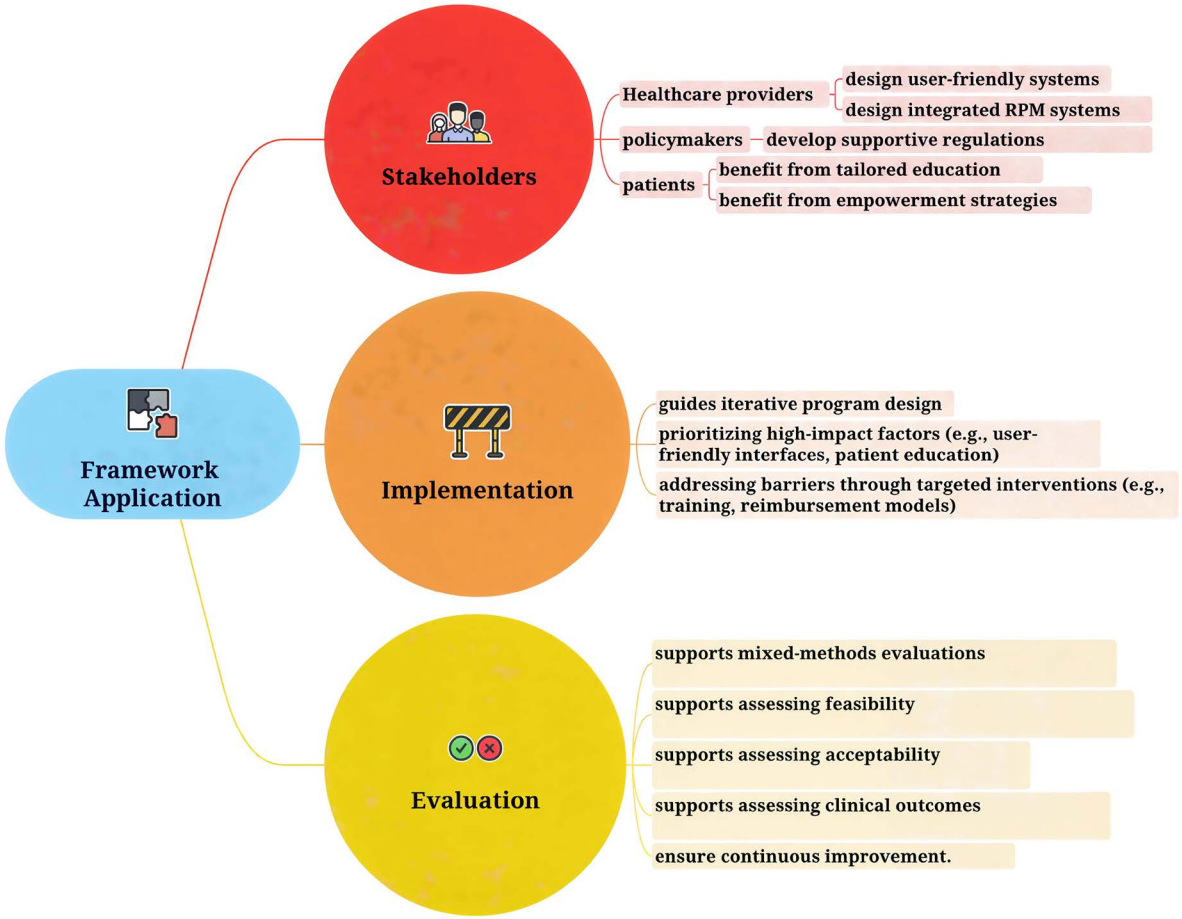

Figure 5. Visual Representation of the Framework

- Evaluation: The framework supports mixed-methods evaluations, assessing feasibility, acceptability, and clinical outcomes across domains to ensure continuous improvement.

Discussion

This study synthesized evidence from a systematic review and a Delphi consensus process to develop a comprehensive conceptual framework for the adoption and implementation of IoT-based RPM systems for HF. The findings highlight the multidimensional nature of RPM integration, identifying key barriers, facilitators, and outcomes across technological, patient-related, provider-related, organizational, and systemic domains. The validated framework, informed by 23 studies and expert consensus from 22 multidisciplinary experts, provides actionable guidance for stakeholders aiming to enhance the scalability and sustainability of RPM systems in the management of HF.

Synthesis of Systematic Review Findings

The systematic review revealed that IoT-based RPM

systems are feasible and acceptable, with high patient satisfaction (31,32) and adherence rates ranging from 65.8% (35) to 96% (29). These findings align with the emphasis of the literature on the potential of RPM to improve patient engagement and self-management (20,24). Clinical outcomes, such as reduced hospitalizations (19%), Baginski and emergency department visits (28%) (19), underscore the capacity of RPM to mitigate healthcare utilization and costs, consistent with prior studies on the efficacy of telemonitoring (27,36). However, barriers such as connectivity issues (79.5%) (26), device malfunctions, and limited digital literacy (33) highlight persistent challenges, particularly for elderly patients with physical or cognitive impairments (21). Organizational and systemic barriers, including increased provider workload (18) and lack of reimbursement models (16), further complicate sustainable adoption, echoing findings from broader telehealth research.

Facilitators identified in the review, such as user-friendly interfaces (24), patient education (23), and multidisciplinary collaboration (32), provide practical strategies to overcome these barriers. The role of the COVID-19 pandemic as a catalyst for digital adoption (16) reflects a broader shift toward telehealth acceptance, suggesting that external factors can accelerate implementation when aligned with supportive policies. These findings emphasize the need for tailored interventions that address specific stakeholder needs, from patients requiring digital literacy support to providers needing workflow integration.

Insights From the Delphi Consensus

The Delphi study validated and prioritized 30 core factors, integrating the findings of the systematic review into a structured framework. The prioritization of user-friendly interfaces (95% rated 4/5) and patient education (92% rated 4/5) as top factors aligns with the emphasis of the review on usability and patient engagement as critical drivers of RPM success. The strong consensus (Kendall's $W = 0.82$ in Round 3) reflects expert agreement on the importance of addressing technological reliability (e.g., connectivity, 90% rated 4/5) and systemic issues like reimbursement policies (78% rated 4/5) and regulatory clarity (76% rated 4/5). Qualitative insights from the Delphi process further highlighted patient trust in data security and the need for culturally tailored interventions, adding depth to the findings of the review on patient-related barriers like surveillance concerns (22) and language barriers (23). The iterative nature of the Delphi process, with high response rates (91–100%) and minimal attrition (9%), strengthens the reliability of these findings.

The prioritization of provider training (88% rated 4/5) and multidisciplinary collaboration (82% rated 4/5) in the Delphi study underscores the importance of organizational readiness, corroborating the identification of workload and workflow integration challenges (16,18). Systemic factors like infrastructure investment (75% rated 4/5) and policy alignment were also prioritized, reflecting the findings of the review on funding and regulatory barriers (16,34). These results suggest that successful implementation of RPM requires coordinated efforts across all domains, with particular emphasis on high-impact factors identified by experts.

Implications of the Conceptual Framework

The proposed framework, structured around 5 interconnected domains (technological, patient-related, provider-related, organizational, systemic), integrates empirical evidence and expert consensus to provide a holistic model for the adoption of RPM. By emphasizing interdependence (e.g., technological reliability supporting patient trust, which enhances provider adoption), the framework addresses the complexity of RPM integration noted in the review (16). Its focus on prioritized factors, such as user-friendly interfaces and patient education, offers a roadmap for designing interventions that maximize feasibility and acceptability while mitigating barriers like technical issues and low adherence.

For healthcare providers, the framework highlights the need for user-friendly interoperable systems integrated with EHRs, as seen in studies reporting integration challenges (16). For patients, tailored education and cultural accommodations can enhance engagement, particularly for elderly or underserved populations (33,34). Providers benefit from training and multidisciplinary support, addressing workload concerns (18), while organizations require dedicated teams and leadership commitment to ensure sustainability (32). Systemically, the framework advocates for reimbursement models and regulatory clarity, aligning with expert calls for policy support (16,22).

Strengths and Limitations

The strengths of the study include its rigorous methodology, combining a PRISMA-guided systematic review with a robust Delphi process, ensuring comprehensive evidence synthesis and expert validation. The inclusion of diverse studies ($n = 23$) from 12 countries and a multidisciplinary expert panel ($n = 22$) enhances the generalizability of findings. The high response rates and strong consensus (Kendall's $W = 0.82$) in the Delphi study further improve reliability.

However, limitations exist. The exclusion of non-English studies and inaccessible full texts ($n = 6$) may have missed relevant perspectives, particularly from non-Western contexts. Small sample sizes in some studies ($n = 5$) (21) and selection bias (22) limit generalizability, as noted in the review. The Delphi panel may not fully represent all stakeholder perspectives (e.g., patients or frontline nurses), and the focus on expert consensus may overlook practical implementation nuances. Additionally, the heterogeneity of study designs and RPM technologies complicates direct comparisons, a challenge inherent to telehealth research.

Recommendations for Future Research and Practice

The framework provides a foundation for future research to test and refine RPM interventions. Randomized controlled trials with larger and more diverse populations are needed to confirm clinical outcomes like reduced hospitalizations (19) and to evaluate cost-effectiveness, particularly in underserved regions (34). Studies should also explore patient trust in data security and culturally tailored interventions, as emphasized by Delphi experts. Implementation research should focus on scalable infrastructure and reimbursement models, addressing systemic barriers identified in both phases (16).

In practice, healthcare organizations should prioritize user-friendly interoperable RPM systems and invest in training patients and providers to enhance adoption. Policymakers should develop reimbursement policies and regulatory frameworks to support scalability, leveraging lessons from the COVID-19-driven telehealth surge (16). Iterative evaluations, as recommended by experts, will ensure continuous improvement and alignment with stakeholder needs.

Conclusion

This study provides a comprehensive understanding of the adoption and implementation of IoT-based RPM systems for HF through a systematic review and a Delphi consensus process. The systematic review of 23 studies demonstrated the feasibility and acceptability of RPM systems, with high patient satisfaction (86%) (32) and significant clinical benefits, including reduced hospitalizations (19% in Baginski et al., 2021) and emergency department visits (28%) (19). However, barriers such as technical challenges, limited digital literacy, and the lack of reimbursement models highlight the complexity of integrating RPM into routine care. Facilitators, including user-friendly interfaces, patient education, and multidisciplinary collaboration, offer practical solutions to enhance uptake.

The Delphi study, involving 22 multidisciplinary experts, validated 30 core factors across five domains, technological, patient-related, provider-related, organizational, and systemic, with prioritized factors like user-friendly interfaces (95% rated 4/5) and patient education (92% rated 4/5) underscoring their critical role. The resulting conceptual framework integrates these findings into a multidimensional model, emphasizing interdependence among domains to guide stakeholders in designing, implementing, and evaluating RPM systems.

By addressing barriers and leveraging facilitators, the framework provides a roadmap for healthcare providers, policymakers, and technology developers to promote sustainable RPM adoption in HF management. Future research should focus on larger and diverse trials to confirm clinical and cost-effectiveness outcomes, while practice should prioritize scalable user-centric systems and supportive policies. Ultimately, this study lays the foundation for advancing HF care through IoT-based RPM, with the potential to improve patient outcomes, enhance self-management, and reduce healthcare utilization globally.

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Competing Interests

The authors declare that they have no competing interests, financial or non-financial, that could influence the results or interpretation of this study.

Consent for Publication

Not applicable, as this study does not include individual participant data or identifiable information requiring consent for publication.

Data Availability Statement

The data supporting the systematic review findings are derived from publicly available peer-reviewed publications, as detailed in the PRISMA flow diagram and Table 1 of the study. The Delphi study data, including anonymized survey responses and qualitative comments, are available upon reasonable request from the corresponding author, subject to ethical and confidentiality restrictions. A list of included studies and extracted data is provided in the supplementary materials.

Ethical Approval

The systematic review component of this study did not require ethics approval as it included the analysis of previously published publicly available data. For the Delphi consensus study, all participants provided informed consent prior to enrollment, which was obtained electronically via the online survey platform. Participants were informed about the purpose of the study, procedures, confidentiality measures, and their right to withdraw at any time without consequence.

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