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Equitable Remote Monitoring for People With Multiple Chronic Conditions

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Abstract

Remote patient monitoring has become an important approach to extending chronic-disease management beyond conventional clinical encounters. Connected blood-pressure monitors, glucose meters, pulse oximeters, weighing scales, symptom-reporting systems, mobile applications, and other home-based technologies can allow health information to be reviewed between visits and may support earlier identification of deterioration. For people living with multiple chronic conditions, however, remote monitoring is more complex than transmitting several disease-specific measurements simultaneously. Multimorbidity frequently requires coordinated interpretation of interacting conditions, medications, symptoms, self-management tasks, functional limitations, and treatment priorities. Evidence available through 2021 indicates that remote monitoring can reduce acute-care use in selected chronic-disease populations, while multimorbidity-focused initiatives such as ProACT demonstrate the feasibility of integrated digital self-management over extended periods.

The present study develops a simulation-based framework for equitable remote monitoring among people with multiple chronic conditions. Equity is defined not as providing every participant with an identical device but as ensuring a realistic opportunity to enroll, generate usable health data, receive clinically meaningful follow-up, understand monitoring instructions, and remain engaged regardless of age, income, connectivity, digital literacy, disability, language, or caregiving context. Because no original patient dataset was supplied, 720 synthetic profiles were modeled across a standard remote-patient-monitoring pathway and an equity-adapted pathway incorporating device provision, connectivity support, low-complexity interfaces, onboarding assistance, caregiver options, accessible communication, and non-digital fallback channels.

The simulation shows higher participation across every modeled equity indicator under the adapted pathway. Enrollment completion increases from 68% to 86%, 90-day retention from 61% to 82%, valid data transmission from 72% to 88%, alert follow-up from 64% to 84%, and care-plan adherence from 58% to 79%. These hypothetical differences illustrate the central proposition that remote-monitoring effectiveness depends partly on whether patients can remain meaningfully connected to the intervention. This interpretation is consistent with realist evidence showing that remote-monitoring outcomes vary according to intervention design, patient selection, timely clinical response, and self-management support.

Keywords: remote patient monitoring; multiple chronic conditions; multimorbidity; digital health equity; telemonitoring; chronic disease management; digital inclusion; patient-centered care

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1. Introduction

People living with multiple chronic conditions frequently manage several forms of treatment simultaneously. Blood-pressure control may coexist with diabetes self-management, chronic respiratory symptoms, cardiovascular disease, pain, impaired mobility, kidney disease, depression, or other long-term conditions. Conventional disease-specific care can therefore create fragmented monitoring requirements in which different measurements, medications, appointments, specialists, and self-management instructions compete for the patient's attention. Multimorbidity research has increasingly emphasized the need for coordinated and patient-centered care rather than simply applying several single-disease protocols in parallel. Stewart and colleagues' 2021 evaluation of Telemedicine IMPACT Plus examined precisely this problem through a patient-centered intervention for individuals with three or more chronic conditions.

Remote patient monitoring offers one possible response to this complexity by allowing selected health measures to be generated outside the clinic and incorporated into ongoing care. Earlier systematic reviews described remote monitoring as the digital transmission of health-related information that may facilitate detection of deterioration, patient education, clinical communication, and treatment adjustment. De Farias and colleagues reviewed 272 telemonitoring studies and found that cardiovascular conditions represented a large part of the evidence base, while wireless devices and smartphone-based approaches were increasingly prominent. Peyroteo and colleagues' 2021 systematic review further demonstrated the expanding role of health remote-monitoring systems in primary care and highlighted their potential relevance for chronic-disease populations.

The clinical promise of monitoring nevertheless does not guarantee universal effectiveness. Taylor and colleagues' 2021 systematic review found evidence that remote patient monitoring can reduce acute-care use among people with cardiovascular disease and chronic obstructive pulmonary disease, but effects varied across populations and evidence for other disease groups was less conclusive. Thomas and colleagues' realist review subsequently examined why interventions produce different outcomes and emphasized the importance of context, appropriate targeting, timely care responses, and mechanisms that support self-management. These findings suggest that the relevant question is not whether remote monitoring works in the abstract but for whom, under which conditions, and through what care pathway it becomes useful.

This question becomes especially important when monitoring is delivered digitally. Lam and colleagues estimated substantial telemedicine unreadiness among older adults in the United States and identified difficulties related to technology use as well as hearing, vision, cognition, and communication. Ramsetty and Adams described the digital divide as a healthcare-access problem during the rapid expansion of telehealth, while Crawford and Serhal warned that digital innovation could reinforce the social gradient of health if access barriers were ignored. Sieck and colleagues subsequently argued that digital inclusion itself should be viewed as a social determinant of health because access, affordability, and digital literacy increasingly shape participation in technology-enabled healthcare.

For people with multiple chronic conditions, these inequities may be compounded by treatment burden. A participant may be asked to operate several devices, interpret multiple thresholds, respond to repeated notifications, remember charging requirements, maintain connectivity, distinguish clinically meaningful symptoms, and communicate with different services. ProACT was developed specifically to

address multi-condition self-management through a single digital platform, and its one-year proof-of-concept study demonstrated sustained engagement among older adults managing multimorbidity. The present study extends this literature by focusing explicitly on equity within remote monitoring, proposing that a technologically sophisticated system should not be considered effective if the patients with the greatest clinical need are systematically less able to enroll, transmit usable data, receive responses, or remain engaged.

2. Objectives of the Study

2.1 To Examine Equity as a Core Dimension of Remote-Monitoring Effectiveness

The first objective is to conceptualize equity as part of intervention effectiveness rather than as an optional implementation consideration. Conventional evaluation commonly examines clinical indicators, emergency use, hospital admission, adherence, or patient satisfaction. These outcomes remain important, but they can obscure unequal participation if only patients who successfully adopt the technology remain in the analytical sample. Digital-health equity scholarship has warned that interventions may appear effective among connected users while excluding people with inadequate broadband, devices, skills, language support, accessibility features, or confidence.

The study therefore proposes equity indicators at multiple stages: enrollment completion, sustained participation, successful data transmission, clinical response to alerts, and care-plan follow-through. A pathway is considered more equitable when barriers are actively reduced before nonparticipation occurs rather than when patients who cannot use the system are subsequently classified as disengaged.

2.2 To Evaluate an Integrated Approach for Multiple Chronic Conditions

The second objective is to assess remote monitoring as an integrated multimorbidity pathway instead of a collection of disconnected disease programmes. The ProACT project demonstrated the feasibility of a platform explicitly designed to support self-management of multiple chronic conditions over a one-year period, while Telemedicine IMPACT Plus evaluated coordinated patient-centered multimorbidity care delivered with telemedicine support. These approaches reflect a broader shift away from disease silos toward coordinated management of the person as a whole.

The proposed model therefore combines physiological monitoring with symptom reporting, medication-context review, patient-priority setting, and clinical escalation rules. Not every condition requires continuous digital measurement. The intended principle is minimum sufficient monitoring: collect only information that has a defined clinical purpose, a responsible recipient, and an agreed response pathway.

2.3 To Examine Whether Equity Adaptations Improve Sustained Participation

The third objective is to compare a conventional device-centered pathway with an equity-adapted monitoring pathway. The adapted pathway includes device provision where needed, connectivity assistance, initial and repeated training, accessible interface design, telephone alternatives, caregiver participation where appropriate, multilingual communication, and active outreach after missing data or unresolved alerts.

These adaptations are theoretically grounded in research identifying broadband access, digital literacy, age, socioeconomic disadvantage, language, and disability-related barriers to digital healthcare. The study hypothesizes that reducing these barriers will improve not only enrollment but the complete monitoring pathway from successful measurement to clinically meaningful action.

3. Review of Literature

3.1 Remote Monitoring in Chronic Disease and Multimorbidity

Remote-monitoring research has historically developed around individual chronic diseases such as heart failure, hypertension, chronic obstructive pulmonary disease, and diabetes. The 2020 systematic review by de Farias and colleagues documented a rapidly expanding literature and generally favorable study findings while also showing considerable variation in intervention structure, monitored conditions, follow-up duration, and clinical outcomes. Such heterogeneity makes it difficult to assume that one monitoring architecture is appropriate for every chronic condition.

Evidence concerning healthcare use also varies. Taylor and colleagues concluded that remote patient monitoring can reduce acute-care use for cardiovascular disease and chronic obstructive pulmonary disease but reported considerable variability and limited evidence in other conditions. Thomas and colleagues' realist analysis suggested that successful programmes are influenced by appropriate targeting, timely clinical intervention, and patient self-management mechanisms rather than by monitoring technology alone. Thus, transmitting a reading is only the beginning of a clinical process.

Multiple chronic conditions complicate the monitoring task because measurements can have different meanings across diseases. Blood-pressure reduction, for example, may be desirable but treatment decisions must account for medication interactions, renal function, falls, frailty, and patient symptoms. Sheppard and colleagues' individual-patient-data meta-analysis found that blood-pressure self-monitoring could lower clinic blood pressure despite hypertension-related multimorbidity, although the intensity of accompanying interventions mattered for some comorbid groups. This illustrates an important distinction: monitoring data become more effective when embedded within appropriate co-interventions rather than functioning as isolated measurements.

3.2 Digital Divide, Accessibility, and Unequal Participation

Digital health can improve access for some patients while simultaneously creating new barriers for others. Crawford and Serhal argued that rapid digital-health expansion should not reproduce existing socioeconomic gradients, particularly where access to technology, literacy, housing, and other social determinants already shape health outcomes. Saeed and Masters likewise reviewed healthcare disparities associated with the digital divide and emphasized that technologies may fail to reduce inequity when structural barriers remain unresolved.

Connectivity is one component of this divide. Benda and colleagues argued that broadband access should be considered a social determinant of health, while Early and Hernandez later linked digital disenfranchisement with healthcare access during the pandemic. Eruchalu and colleagues described significant disparities in broadband subscription and digital access among lower-income, older, racially minoritized, and non-English-speaking populations in New York City. These findings are

directly relevant to remote monitoring because continuous transmission cannot occur reliably when connectivity itself is unstable or unaffordable.

Digital readiness also involves more than internet availability. Lam and colleagues found that many older adults could be unready for video telemedicine because of difficulties with technology or sensory, cognitive, and communication limitations. Sieck and colleagues therefore conceptualized digital inclusion through access, affordability, and digital literacy rather than mere presence of technology. An equitable monitoring programme must consequently anticipate low vision, hearing impairment, limited dexterity, cognitive load, language variation, caregiver dependence, and unfamiliarity with digital interfaces.

3.3 From Data Collection to Responsive Integrated Care

The clinical value of remote monitoring depends on what happens after data are transmitted. Peyroteo and colleagues' systematic review described remote data acquisition and interaction between patients and healthcare personnel as core characteristics of chronic-disease monitoring systems in primary care. A device that identifies abnormal readings without a reliable review and escalation workflow may increase monitoring activity without improving care.

Thomas and colleagues emphasized timely care as one of the mechanisms through which remote monitoring can influence acute-care utilization. This creates a governance requirement: every monitored parameter should have an agreed threshold, review responsibility, response timeframe, and escalation pathway. For multimorbidity, these rules should also avoid contradictory disease-specific alerts. A mildly abnormal value may require a different response in a frail patient with several conditions than in a younger patient with a single disease.

Patient-centeredness is equally important. Stewart and colleagues' multimorbidity intervention emphasized coordinated planning around complex patients, and qualitative findings from the study highlighted the importance of a care model that addressed the person's broader experience rather than only individual conditions. The same principle applies to remote monitoring: technology should support patient-defined goals and coordinated clinical judgment rather than creating an additional stream of disconnected disease data.

4. Research Methodology

4.1 Research Design

The study employs a simulation-based explanatory quantitative design. No patients were recruited, no protected health information was accessed, and no physiological readings were collected. The simulation is intended to provide a transparent model for evaluating equity in future remote-monitoring programmes rather than to represent completed clinical research.

A synthetic sample of 720 adults with multiple chronic conditions was generated. Participants were conceptually assumed to have at least two long-term conditions requiring ongoing self-management. The synthetic cohort was divided equally between a standard remote-monitoring pathway and an equity-adapted pathway, with 360 modeled participants in each condition.

The standard pathway included device provision or device connection, routine onboarding, automated reminders, and conventional alert review. The equity-adapted pathway incorporated the same

clinical monitoring functions plus technology-needs assessment, device or connectivity support when required, simplified onboarding, repeated skills checks, accessible communication formats, telephone fallback, caregiver participation, and proactive follow-up after disengagement.

4.2 Operationalization of Equity and Monitoring Outcomes

The study defines equity through successful progression across the monitoring pathway rather than demographic parity alone. This reflects the wider digital-inclusion literature, which distinguishes physical access to technology from the skills and support necessary to use digital health effectively.

Table 1: Operational Framework for Equitable Remote Monitoring

Construct	Operational Definition	Proposed Measure	Analytical Role
Enrollment Accessibility	Ability to complete setup regardless of device ownership, connectivity, literacy, or disability	Percentage	Equity outcome
Monitoring Burden	Cognitive, technical, and practical effort required to maintain monitoring	0–100	Implementation variable
Valid Data Transmission	Expected measurements successfully transmitted in interpretable form	Percentage	Process outcome
90-Day Retention	Continued participation through at least 90 days	Percentage	Sustainability outcome
Alert Follow-Up	Clinically relevant alerts reaching an appropriate patient–clinician response	Percentage	Clinical-process outcome
Care-Plan Adherence	Completion of agreed monitoring-related actions	Percentage	Behavioral outcome
Digital Support Intensity	Device, connectivity, training, accessibility, caregiver, and troubleshooting support provided	0–100	Main intervention variable

4.3 Simulation and Analytical Strategy

Synthetic participation probabilities were assigned so that the equity-adapted pathway addressed barriers at multiple points rather than only improving initial recruitment. Enrollment assistance was expected to affect entry into the programme; connectivity and interface adaptation were expected to improve valid data transmission; repeated training and troubleshooting were expected to influence retention; and active clinical routing was expected to improve alert follow-up.

The simulation does not assign clinical benefits automatically to increased monitoring. This is deliberate because previous systematic reviews show that remote-monitoring outcomes vary across conditions and intervention designs. The principal analysis therefore examines equitable participation and pathway completion, not hypothetical reductions in mortality or hospitalization that cannot be defensibly generated without real clinical data.

Descriptive comparisons were used rather than inferential hypothesis testing. Statistical significance calculated from intentionally simulated observations would have no population-level meaning. A future empirical study should prospectively compare participation by age, income, language, rurality, disability, digital literacy, caregiver availability, and broadband access and then test whether equity adaptations narrow disparities without increasing unnecessary clinical workload.

5. Analysis

5.1 Participation Across the Remote-Monitoring Pathway

The simulation demonstrates higher successful participation across every monitored process under the equity-adapted model.

Table 2: Simulated Outcomes for Standard and Equity-Adapted Remote Monitoring

Equity Indicator	Standard RPM Pathway	Equity-Adapted RPM Pathway	Modeled Improvement
Enrollment Completion	68%	86%	+18 points
90-Day Retention	61%	82%	+21 points
Valid Data Transmission	72%	88%	+16 points
Alert Follow-Up	64%	84%	+20 points
Care-Plan Adherence	58%	79%	+21 points

The greatest modeled improvements occur in 90-day retention and care-plan adherence, both increasing by 21 percentage points. This pattern suggests that equity adaptations may matter most after initial enrollment. Providing a device can initiate participation, but sustained use requires the technology to remain understandable, functional, affordable, and connected to a responsive care system.

The smallest modeled improvement occurs in valid data transmission, although the adapted pathway still produces a 16-point advantage. This reflects the assumption that technical reliability can be improved substantially through connectivity support and usability adaptation but cannot be made perfect because monitoring remains affected by illness, travel, device malfunction, caregiving demands, and patient preference.

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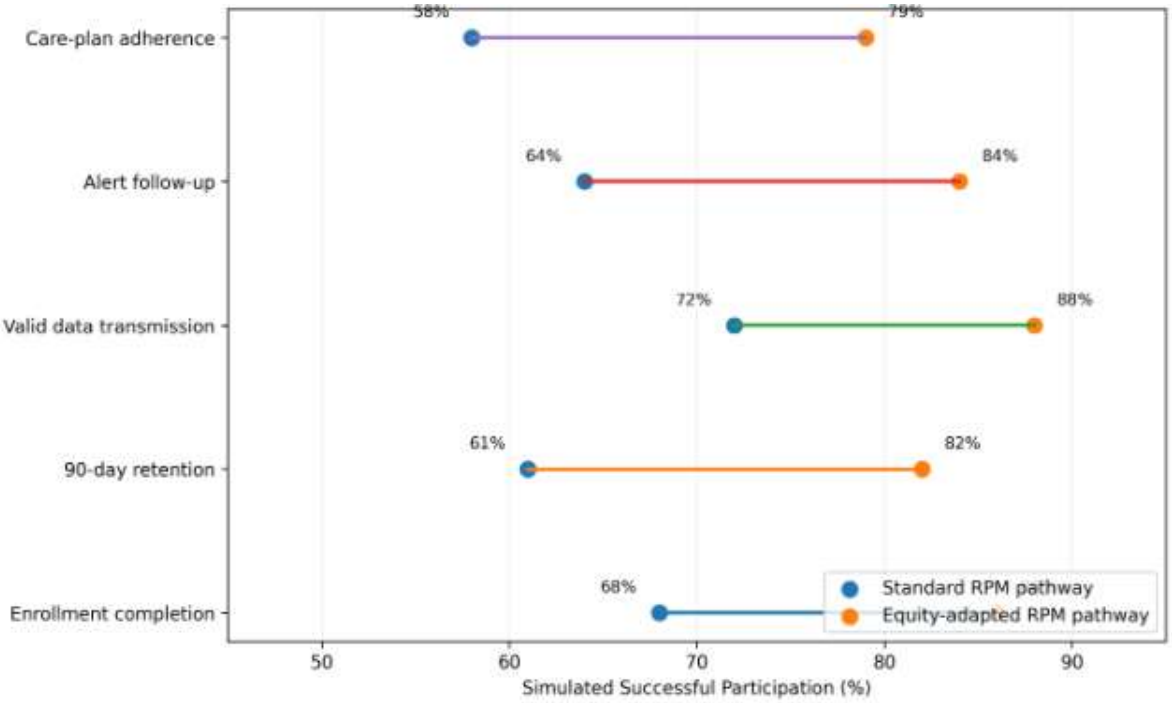
5.2 Equity Gains Across Five Monitoring Indicators

Graph 1: Simulated Equity Gains From an Adapted Remote-Monitoring Pathway



The dumbbell graph illustrates the distance between standard and equity-adapted participation across each indicator. Every equity-adapted endpoint is positioned substantially above its conventional counterpart, demonstrating that the modeled intervention does not rely on one isolated accessibility improvement.

Key Finding: The simulation indicates that equitable monitoring should be evaluated as an end-to-end pathway. A programme can distribute devices successfully yet remain inequitable if patients subsequently cannot transmit data, interpret instructions, receive responses, or maintain participation.

5.3 Why Participation Equity Matters Clinically

Remote monitoring cannot produce useful clinical information when participation is systematically interrupted. Missing measurements may reflect stable health, but they may also indicate device failure, hospitalization, disability, loss of connectivity, treatment burden, worsening illness, or confusion. An equity-oriented programme should therefore avoid automatically interpreting nontransmission as patient noncompliance.

The realist findings reported by Thomas and colleagues are relevant because the effectiveness of remote monitoring depends on context and mechanisms such as patient engagement, self-management, and timely response. A missing measurement should consequently trigger an appropriately proportionate investigation when clinically relevant rather than a punitive classification of the patient.

The multimorbidity context reinforces this point. ProACT showed that older adults could engage with an integrated multiple-condition platform across a prolonged period, suggesting that sustained use is

achievable when systems are designed around the needs of people managing complex conditions. The present simulation extends that principle by proposing that sustained use should also be assessed across groups at risk of digital exclusion.

6. Discussion

6.1 Equitable Remote Monitoring Requires More Than Device Distribution

The principal implication of this study is that distributing identical technology does not necessarily create equitable access. Two patients may receive the same connected blood-pressure monitor while facing completely different barriers. One may possess reliable home internet, smartphone familiarity, good vision, and family support. Another may share a telephone, have intermittent connectivity, speak a different primary language, have reduced dexterity, or be unfamiliar with device pairing. Treating these patients identically may satisfy procedural equality while producing unequal participation.

Digital-health research published before 2022 provides strong support for this distinction. Lam and colleagues demonstrated that telemedicine readiness varies according to technology, sensory, and cognitive capacity among older adults, while Sieck and colleagues argued that digital inclusion should be recognized as a health determinant. Crawford and Serhal similarly cautioned that technological innovation could reinforce existing health gradients if equity was not intentionally designed into implementation.

An equity-adapted monitoring programme should therefore begin with a technology and participation needs assessment, not with assumptions about device ownership or competence. Some patients may need only automated digital onboarding; others may need in-person setup, repeated telephone coaching, caregiver involvement, translated material, accessible screens, or a cellular device that does not depend on household broadband.

6.2 Multimorbidity Requires Integrated Rather Than Disease-Silo Monitoring

The second implication concerns the architecture of care. People with several chronic conditions are particularly vulnerable to fragmented digital systems because each disease programme may generate its own application, device, thresholds, education, and alerts. Such fragmentation can increase burden rather than reduce it.

The ProACT proof-of-concept study is important because it deliberately focused on a unified platform for self-management of multiple chronic conditions and demonstrated longitudinal engagement among older adults. Telemedicine IMPACT Plus likewise illustrates the value of coordinated patient-centered multimorbidity care rather than independent specialist management. These models suggest that remote monitoring should prioritize clinically integrated information and patient goals over maximum data collection.

The concept of minimum sufficient monitoring is therefore useful. Each measurement should answer a defined question: What decision could change because this information was collected? Who reviews it? How quickly? What should the patient do if it is abnormal? If these questions cannot be answered, additional monitoring may increase burden without increasing clinical value.

An integrated platform should also permit contextual interpretation. A change in weight may be relevant to heart-failure monitoring but could reflect nutritional change, medication effects, or another condition.

Multimorbidity management therefore requires clinical reasoning that integrates signals rather than treating each measurement as an isolated disease alert.

6.3 Equity, Clinical Responsiveness, and Ethical Implementation

The third implication is that equitable access without clinical responsiveness is incomplete. A programme may succeed in helping disadvantaged patients transmit measurements, but no benefit follows if alerts enter an unmonitored dashboard or responses are delayed. Peyroteo and colleagues emphasize interaction between remote data collection and healthcare professionals as part of functional monitoring systems, while Thomas and colleagues identify timely care as an important mechanism in effective RPM.

Privacy and autonomy also require careful attention. People with multiple chronic conditions should not feel compelled to accept continuous digital monitoring in order to retain access to ordinary healthcare. Digital inclusion means having a meaningful opportunity to participate, not making technology mandatory. Telephone, in-person, paper-assisted, or caregiver-supported alternatives may remain necessary for some patients. This approach is compatible with equity scholarship arguing that digital-health expansion should complement rather than narrow access to care.

The simulation has several limitations. Its numerical outcomes are hypothetical, it does not estimate disease-specific clinical effects, and it cannot establish the cost-effectiveness of equity adaptations. The model also simplifies complex identities into broad access barriers. Real inequalities may be intersectional: an older rural patient with low income, impaired vision, polypharmacy, limited English proficiency, and no caregiver may experience a different combination of barriers than any one variable captures. Future empirical research should therefore evaluate interactions among social, functional, clinical, and technological characteristics rather than using a single “digital literacy” variable as a proxy for all forms of exclusion.

7. Conclusion

Remote patient monitoring has credible potential to support chronic-disease management, particularly when information collected at home is connected to timely clinical response. Systematic reviews available through 2021 indicate possible reductions in acute-care use for selected chronic conditions while also showing meaningful variation in effectiveness across interventions and patient groups. The challenge is therefore not simply to expand remote monitoring but to determine how it can be implemented without leaving behind the patients who may have the greatest clinical need.

For people with multiple chronic conditions, equity and integration are inseparable. Multimorbidity requires coordination across several conditions, while digital exclusion can interrupt that coordination before monitoring begins. ProACT and Telemedicine IMPACT Plus provide pre-2022 evidence that digital and telemedicine approaches can be designed explicitly around multimorbidity rather than a single disease. The present framework extends this logic by treating connectivity, accessibility, training, caregiver support, and alternative communication routes as components of clinical design rather than peripheral technical assistance.

The simulation shows that an equity-adapted pathway can theoretically improve enrollment, 90-day retention, valid data transmission, alert follow-up, and care-plan adherence. These values are

synthetic and should not be reported as empirical effectiveness estimates. Their purpose is to demonstrate that monitoring equity should be measured at several successive stages instead of being inferred from the number of devices distributed.

Future research should prospectively compare standard and equity-adapted remote-monitoring models among people with multimorbidity and report outcomes stratified by digital access, socioeconomic circumstances, age, disability, language, rurality, and caregiver availability. Clinical outcomes should include disease control, urgent-care use, hospitalizations, quality of life, treatment burden, and patient-defined goals, while implementation outcomes should include retention, missing data, support contacts, alert response, and clinician workload. The most successful remote-monitoring system will not necessarily be the one that collects the largest volume of data. It will be the one that enables the widest range of clinically appropriate patients to participate reliably, with the least unnecessary burden, and with a clear pathway from home-generated information to meaningful care.

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