Remote Patient Monitoring and Connected Technologies in Inflammatory Bowel Disease

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Abstract: Remote patient monitoring (RPM) has emerged as a valuable complement to traditional in-person clinical assessments, particularly since the COVID-19 pandemic. RPM encompasses a wide range of tools and technologies that enable the longitudinal collection of biometric, behavioral, and biochemical data outside the conventional clinic setting. These programs have been successfully integrated across several medical subspecialties, such as cardiology, endocrinology, and psychiatry, where the availability of real-time data has facilitated timely evaluation and management of chronic conditions. Building on these successes, the field of inflammatory bowel disease (IBD) has begun adopting RPM and connected health technologies to enhance both access to and quality of care. These innovations include the integration of point-of-care testing for conventional biomarkers, the development of novel biomarkers from other biospecimens (eg, mucus and sweat), and the advent of passive physiologic monitoring aimed at predicting and preventing disease relapses. This article examines current literature on RPM across chronic diseases, explores its emerging applications in IBD, and presents key barriers hindering its broader implementation.

Keywords
Remote patient monitoring, wearable devices, digital health, inflammatory bowel disease

Chronic disease management is hindered by inconsistent follow-up, fragmented care, and escalating cost—challenges that were underscored during the COVID-19 pandemic when in-person care became restricted. In this setting, remote patient monitoring (RPM) has emerged as a tool to bridge care gaps and extend management beyond traditional clinical encounters.[1,2] By enabling proactive, longitudinal collection of biometric, behavioral, and biochemical data, connected technologies are reshaping health care delivery into more efficient, patient-centered models. RPM has already become integral to care in fields such as cardiology, endocrinology, and psychiatry, with adoption expanding rapidly across other specialties.[3-5] In gastroenterology, inflammatory bowel disease (IBD), with its chronic, relapsing course and need for ongoing personalized management, is ideal for RPM integration. This article summarizes existing research on RPM, explores its application in IBD, and identifies critical barriers to its implementation.

Types of Remote Patient Monitoring

RPM involves the collection of clinical data outside traditional health care settings and has become an increasingly important tool in patient-centered care.[6] By enabling continuous data collection in real-world environments, RPM supports a paradigm shift from reactive to proactive monitoring. This enables earlier detection of disease activity, targeted preventative strategies, and timelier therapeutic interventions. The information generated through RPM can be categorized into 3 domains: biometric, behavioral, and biochemical.

The biometric domain refers to the longitudinal measurement of physiologic parameters such as heart rate (HR), body temperature, and blood oxygen saturation.[7-9] These metrics can provide early signals of clinically meaningful changes, including acute illness, psychological stress, or other health events.[10,11] The behavioral domain captures factors such as mood, sleep, physical activity, and treatment adherence. By capturing real-time daily events, these measures help contextualize clinical status and support more personalized care approaches.[5,6] The biochemical domain encompasses the remote collection of biospecimens, such as blood, saliva, or sweat, for the analysis of disease-specific biomarkers.[12,13]

RPM can be delivered through passive or active modalities. Passive monitoring leverages connected technologies to collect physiologic data continuously and unobtrusively, whereas active monitoring generally requires patient engagement, such as performing home-based point-of-care (POC) testing.[14] For optimal effectiveness, RPM must be supported by enabling technologies, including cloud-based data infrastructure, smartphone interfaces, and artificial intelligence (AI) or machine learning–driven analytics.[15,16] When integrated properly, these systems provide clinicians with real-time, multidimensional insights into patient health trajectories, facilitating more timely and individualized interventions.

Implementation of Remote Patient Monitoring Across Chronic Diseases

In clinical practice, the implementation of RPM varies across care settings. In academic medical centers, RPM often leverages institutional infrastructure and electronic health record systems to integrate real-time data directly into clinical workflows and patient records.[17] This enhances patient care and supports large-scale research, quality improvement initiatives, and population health management through reductions in health care utilization.[18-20] Private practices frequently partner with third-party companies and rely on commercially available platforms. These programs are typically designed to optimize clinical outcomes while improving efficiency and cost-effectiveness. Regardless of setting, successful RPM models share common elements, including integrated systems to manage incoming data streams and standardized protocols to ensure timely identification and response to clinically significant findings.

The adoption of RPM differs by specialty, reflecting variations in disease characteristics, care delivery models, and technologic infrastructure. In psychiatry, RPM ranges from wearable devices that collect biometric data to digital platforms that administer daily mood surveys, enabling early identification of worsening mental health symptoms.[21,22] Wrist-worn actigraphy and accelerometry have emerged as digital biomarkers in the monitoring of mood disorders. For example, one study reported that individuals with late-life depression exhibited reduced physical activity and slower fine motor movements, which were associated with impaired activities of daily living and lower quality of life.[23] In another study, machine learning models applied to biometric data from wearable devices (eg, Fitbit) were able to predict episodes of major depression, mania, and hypomania within a 3-day window, achieving area under the curve (AUC) values of 0.937, 0.957, and 0.963, respectively.[24] This passive collection of biometric data, when integrated with regularly administered digital symptom surveys, has demonstrated utility in predicting relapse in schizophrenia. In one pilot study, the rate of behavioral anomalies, defined by shifts in self-reported symptoms along with wearable-derived mobility and sociability metrics, was 71% higher during the 2 weeks preceding relapse, highlighting the potential for early clinical intervention.[25]

In endocrinology, finger stick glucose testing represented one of the earliest forms of remote biochemical monitoring, improving the safety and accuracy of insulin self-administration.[26] One study found that higher frequency of finger-stick glucose monitoring was associated with a greater reduction in glycated hemoglobin independent of baseline glucose or diabetes regimen, indicating an important relationship between self-monitoring frequency and glycemic control.[26] This laid the framework for subsequent continuous glucose monitoring (CGM), which captures real-time glucose fluctuations and provides a dynamic, longitudinal view of glycemic control.[27,28] In a well-defined national cohort of nearly 13,000 patients from the Veterans Affairs health care system, CGM was associated with a 21% reduction in all-cause mortality, 9% reduction in all-cause hospitalizations, 12% reduction in hyperglycemia-related hospitalizations, and 16% reduction in cardiovascular events.[29]

Cardiology has taken an even broader approach, with extensive research exploring the use of remote blood pressure monitoring, electrocardiographic (ECG) tracking,

and pulmonary artery pressure monitoring in patients with heart failure.[30-32] Given the discrepancy often observed between clinic- and home-based blood pressure measurements, RPM has been increasingly adopted to provide a longitudinal, real-world assessment of hypertension burden in high-risk patients. In one study, 12 weeks of home blood pressure telemonitoring in patients with hypertension led to a higher reduction in systolic blood pressure than in those receiving routine care (12 mm Hg vs 7 mm Hg, respectively; $P<.001$).[32] Another notable application of RPM is the use of insertable cardiac monitors (ICMs), which enable continuous, long-term ECG monitoring in patients with atrial fibrillation. This has been shown to be valuable for the evaluation of cryptogenic stroke, where underlying arrhythmias have been identified in 8.9% of patients who had ICMs, compared with 1.4% of patients who had conventional ECG monitoring.[33] Similarly, RPM has become popular within heart failure, where pulmonary artery pressure monitoring has been shown to be associated with reduced symptom burden and improved quality of life (odds ratio [OR], 1.69) as well as decreased rate of clinical deterioration (OR, 0.45).[31] Overall, the development of these technologies in cardiology has facilitated continuous physiologic assessment, earlier detection of decompensation, and more personalized treatment strategies. The future of RPM will likely be shaped by disease-specific needs and the willingness of practitioners to integrate these tools into routine care.

The broad adoption of RPM across specialties underscores both its clinical promise and implementation challenges. Since the COVID-19 pandemic, uptake has accelerated, as patients and providers have grown increasingly comfortable with digital health tools.[34,35] By supporting frequent at-home communication with clinicians, RPM enables proactive disease management, improves outcomes and satisfaction, and may also advance health equity by reducing the burden of in-person visits on patients facing professional, caregiving, or transportation barriers.[6,36-39]

Remote Patient Monitoring and Improvements in Care

Across multiple specialties and practice settings, RPM has demonstrated measurable benefits for patient care. Studies show that RPM can improve medication and medical device adherence, particularly in high-risk and vulnerable patient populations.[6,40-42] For example, a study assessing tuberculosis treatment in Tibet found that integration of RPM into a digital health platform significantly improved treatment adherence (90% vs 63%; $P<.0001$) and success (94% vs 73%; $P<.0001$) compared with those undergoing usual care.[40] Similar successes have been seen with medical device adherence, the most studied of which is the continuous positive airway pressure (CPAP) device. CPAP is widely used but limited by poor adherence, with most studies citing a 30% to 50% nonadherence rate.[43] One study of patients with high cardiovascular risk found that the integration of a multimodal telemonitoring RPM system resulted in higher hours of CPAP adherence (5.28 vs 4.75 hours; $P=.05$) and improved patient-reported outcomes (Epworth Sleepiness Scale and Physical Short form; $P<.05$) compared with those undergoing usual care.[41] Together, these findings suggest a role in leveraging RPM and digital health solutions to improve treatment adherence, especially in high-risk patient populations.

RPM also enables the detection of meaningful subclinical changes before the onset of symptoms or overt deterioration in several conditions, allowing providers to intervene earlier and more effectively.[44,45] These proactive measures have the potential to reduce emergency department visits and hospitalizations—a benefit already observed in certain specialties. For example, in cardiology, integrating RPM into the management of heart failure has been associated with improved clinical outcomes and cost-effectiveness.[46,47] A recent meta-analysis found that RPM was associated with a 22% and 19% lower odds of heart failure–related hospitalization and mortality, respectively, compared with usual care.[48] Notably, studies that incorporated self-management education ($P<.028$) and telemedicine check-ins ($P=.047$) demonstrated the greatest reductions in hospitalization risk.[48] However, there was significant heterogeneity between studies, likely reflecting variations in the types and implementation of RPM technologies. As access to these technologies expands and provider familiarity increases, a broader population of patients across a range of chronic diseases may benefit.

In addition to its clinical benefits, RPM has been found to have high levels of patient engagement and satisfaction. These positive perceptions are thought to be driven in large part by RPM's ability to facilitate close communication with care teams, enhance patients' understanding of their health, and reduce the need for travel and time away from professional or personal responsibilities.[45,49] One study of the Mayo Clinic health care system found that RPM implementation after hospitalization or in patients with chronic illnesses was met with significant satisfaction, with 93.58% of individuals reporting being satisfied with the RPM program and 92.76% stating they would recommend it to individuals with similar conditions.[37] Additionally, continuous monitoring with feedback provides reassurance and strengthens patients' confidence in the self-management of their disease.[45,50] These factors, combined with the longitudinal data RPM provides to practitioners, are believed to play a key role

in reducing emergency department visits and hospitalizations across conditions. This approach has already demonstrated efficacy across several specialties, including oncology, cardiology, pulmonology, and nephrology, among others.[51-54]

Current Landscape in Inflammatory Bowel Disease

As the management of IBD continues to shift toward a treat-to-target approach, the need for continuous and reliable monitoring through RPM has grown substantially. Current technologies under development include a variety of biochemical markers, such as stool, blood, sweat, and salivary assays, as well as efforts to integrate and validate novel biometric measures. Together, these tools have the potential to expand monitoring capabilities, establish new therapeutic targets, and enable earlier, more effective interventions.

Extension of Care Integration Models

Longitudinal RPM with fecal calprotectin (FC) testing has become increasingly popular owing to its noninvasive nature and high sensitivity for detecting intestinal inflammation. Several companies have introduced home-based assays that are both feasible and acceptable to patients.[55] For example, one study evaluating the now discontinued IBDoc RPM program, which integrated FC and patient-reported outcomes, found a 96% satisfaction rate, with 80% of patients expressing interest in continued use.[55] In terms of diagnostic accuracy, studies have varied in their findings. One study found that a POC FC assay demonstrated a moderate positive correlation (correlation coefficient of 0.685) with laboratory-based testing, achieving a sensitivity of 82% and specificity of 85% using an FC cutoff of 150 μg/g.[56] However, other studies found that mild to moderate elevations in home-based FC testing (≤500 μg/g) correlated closely with conventional laboratory results, whereas higher values (>500 μg/g) showed less reliability.[57,58] Clinical implementation of home FC testing has been associated with closer contact with health care providers and treatment escalation, with one study finding home-based FC testing was associated with a 33% odds of treatment increase compared with 15% of controls.[59] Despite initial positive findings, RPM studies utilizing stool-based testing have yet to show significant changes in long-term clinical outcomes.[59] Further, these studies have consistently found that patient adherence remains a key limitation to broader implementation. Challenges likely stem from historically low completion rates of laboratory-based FC testing, compounded by the practical difficulties of performing repeated home-based biochemical self-assessments.[60]

Blood-based POC testing is emerging as an important tool in IBD, with applications for its use in both disease activity assessment and therapeutic drug monitoring. C-reactive protein (CRP), one of the most widely used biomarkers of systemic inflammation, has become a key target for POC assay development. One study found that capillary-based finger-stick CRP assays correlate significantly with venous CRPs (P<.001), whereas another found that capillary CRPs report slightly lower values than venous samples.[61,62] Despite this, capillary CRP has been found to be sufficiently accurate to differentiate between mild and moderate-to-severe disease activity in IBD and other immune-mediated inflammatory disorders such as rheumatoid arthritis.[62] POC assays for therapeutic drug monitoring are also in development, with early studies demonstrating high concordance between finger-stick–based measurements and gold-standard laboratory testing for infliximab and vedolizumab (Entyvio, Takeda) drug and antibody levels.[63,64] In one study, although POC testing for infliximab demonstrated a mean difference of 1.46 μg/mL compared with enzyme-linked immunosorbent assay measurements, the assays showed 87.4% overall concordance and comparable rates of anti-infliximab antibody detection (2.2% vs 3.7%, respectively).[65] Together, these findings add to the growing body of literature supporting POC testing for biomarkers and drug levels in IBD.

Sweat-based biomarkers represent another promising avenue for noninvasive IBD monitoring. IBD AWARE was among the first devices to demonstrate the feasibility of continuously measuring inflammatory and immune markers in sweat, including CRP and interleukin-6 (IL-6).[66] According to a pilot study, sweat-based CRP measurements at a threshold of 938.9 pg/mL differentiated inflamed from noninflamed states with 82% sensitivity and 70% specificity. Similarly, sweat-derived tumor necrosis factor–α showed strong discriminatory performance in distinguishing individuals with active IBD from healthy controls, with an AUC of 0.962.[67] Although currently investigational, sweat-based sensors appear both feasible and acceptable to patients and hold promise as a novel tool for longitudinal disease activity monitoring.

Emerging biochemical RPM approaches include salivary and colorectal mucus biomarkers for minimally invasive disease monitoring. Saliva is particularly attractive given its ease of collection and is being studied across a range of chronic and infectious diseases.[68] In IBD, several salivary proinflammatory cytokines, including IL-6 and matrix metalloproteinase-10, correlate with serum concentrations, suggesting potential utility for noninvasive monitoring of systemic inflammation.[69,70] Colorectal mucus biomarkers, although more cumbersome to collect, have also demonstrated promise. Although traditionally obtained during endoscopic procedures, advancements

Table 1. Advantages and Limitations of Remote Monitoring Modalities in IBD

Modality	Advantages	Limitations	Stage of development
Fecal calprotectin (home test)	Noninvasive and validated biomarker of intestinal inflammation; aligns with treat-to-target strategies	Suboptimal adherence, reduced accuracy at higher concentrations, and patient burden of repeated sampling	Commercially available (Europe, limited in United States)
Blood-based POC assay	Established biomarkers (eg, CRP) and rapid turnaround; enables therapeutic drug monitoring (infliximab, vedolizumab)	Finger stick required, early-stage validation, and not yet widely available	Early clinical validation
Sweat sensor	Noninvasive and potential for continuous, real-time analyte (CRP, IL-6, TNF-α) monitoring	Investigational, no regulatory approval, and small pilot cohorts only	Pilot studies
Salivary biomarkers	Very easy, painless collection and potential for frequent longitudinal monitoring; cytokines correlate with serum levels	Limited IBD-specific data, variability, and not validated for clinical use	Exploratory
Colorectal mucus biomarkers	Promising diagnostic accuracy when combined with fecal calprotectin and novel inflammatory marker candidates	Collection cumbersome, scalability uncertain, and limited validation	Exploratory
Wearable device (HR, HRV, sleep, steps)	Passive, continuous data collection and widely adopted in general population; can detect physiologic changes weeks before flare	Signal interpretation, limited specificity for IBD, and integration into workflows not standardized	Growing evidence or research setting

CRP, C-reactive protein; HR, heart rate; HRV, heart rate variability; IBD, inflammatory bowel disease; IL-6, interleukin-6; POC, point-of-care; TNF-α, tumor necrosis factor–α.

over the past decade have led to the development of self-collection kits, which allow patients to self-swab the external anal region immediately after defecation and then store this sample in a buffering agent for subsequent laboratory analysis.[71] Individually, these mucus biomarkers exhibit variable predictive accuracy for detecting inflammatory activity. However, their diagnostic performance improves significantly when used in combination with established markers like FC. For example, one study found that the combination of mucus-derived eosinophil-derived neurotoxin and FC achieved a sensitivity of 91% and a specificity of 89% for detecting active inflammation in individuals with IBD.[72] Further, these biomarkers progressively declined throughout the subsequent treatment course, reflecting therapeutic response. Additional exploratory studies have examined other mucus biomarkers, such as total protein and mucin 2, which differentiate individuals with active IBD from those with irritable bowel syndrome and healthy controls.[71] However, neither salivary or colorectal mucus biomarkers have undergone sufficient validation for routine use in IBD, and further investigation is required.

Given the challenges of adherence to frequent biochemical sampling, biometric monitoring through wearable technology has gained increasing attention. These devices capture physiologic parameters such as HR, heart rate variability (HRV), activity, and sleep, which can be leveraged to identify and predict inflammatory activity.[73,74] In the IBD Forecast study, HR, HRV, and activity were not only altered during periods of inflammation and symptoms, but also demonstrated subtle changes up to 7 weeks prior to flare onset.[75] HRV metrics even distinguished whether symptomatic flares had underlying inflammation. A post hoc analysis of this study revealed alterations in sleep architecture, specifically increased rapid eye movement and reduced light sleep, starting approximately 45 days before inflammatory activity.[76] Collectively, these findings highlight the potential of wearable devices to detect early physiologic signatures of impending disease activity, offering a noninvasive complement to biochemical monitoring (Table 1).

Gaps in Evidence and Implementation Science

Despite growing evidence supporting the benefits of RPM in IBD, several barriers continue to limit its widespread implementation. A major challenge is the lack of regula-

Table 2. Barriers and Facilitators to Remote Patient Monitoring Implementation in IBD

Domain	Barriers	Facilitators
Patient	Technology fatigue, burden of frequent sampling, anxiety or uncertainty with self-monitoring, and variable long-term adherence	Digital health coaches and care coordinators, streamlined and user-friendly interfaces, and real-time feedback and education
Provider	Data overload from continuous streams, workflow disruption, and uncertain reimbursement or liability	Integration with EHR systems, standardized alert thresholds, and AI-driven clinical decision support tools
System	Limited regulatory approval for biomarkers (stool, blood, digital), device costs, and risk of widening inequities in access	Policy and reimbursement reform, payer coverage models, scalable and cloud-based platforms, and equity-focused deployment
Evidence	Limited long-term outcomes data, adherence variability, and lack of validation for emerging biomarkers	Ongoing RCTs, validation studies across diverse populations, and support from cross-disease evidence

AI, artificial intelligence; EHR, electronic health record; IBD, inflammatory bowel disease; RCTs, randomized controlled trials.

tory approval for key remote monitoring tools, including POC blood and stool assays and digital biomarkers. This gap may reflect unresolved questions regarding the optimal frequency of monitoring, the patient populations most likely to benefit, the relative effectiveness of different modalities, and the overall cost of large-scale implementation.[77] Even with regulatory approval, patient-level challenges persist, such as long-term adherence, technology fatigue, and anxiety related to self-monitoring. At the health system level, barriers include uncertain reimbursement strategies, streamlined integration into current workflows, and risks of worsening inequities in access to connected technologies. Addressing these barriers will require well-designed clinical trials that integrate RPM as part of therapeutic interventions to generate the evidence needed for regulatory approval and sustained integration. Additionally, prior studies have identified limited long-term adherence as a major barrier to RPM in IBD.[78,79] To address this challenge, many programs are incorporating digital health coaches and remote care coordinators to support patient navigation and communication, which has been found to be effective in other conditions utilizing RPM (Table 2).[80,81]

Future Directions

The future of RPM in IBD will be driven by technological innovation aimed at establishing reliable disease biomarkers and improving patient adherence. A central avenue is the integration of AI into RPM platforms to enhance prediction of disease flares and treatment responses.[82] Passive, multimodal monitoring, which combines physiologic, behavioral, and biochemical inputs, offers the potential for greater predictive accuracy and improved adherence compared with active monitoring.[83] Advances in remote biosensing, ranging from ingestible sensors to real-time cytokine-detecting patches, may provide even deeper insights into IBD activity.[84,85] However, the clinical impact of these innovations will depend on parallel progress in regulatory pathways, reimbursement strategies, and health system integration to enable scalability of RPM in IBD care.

Conclusion

Remote monitoring represents a transformative frontier in the care of patients with IBD, with the potential to improve quality, efficiency, and accessibility of care. Lessons from other medical fields, including cardiology, psychiatry and endocrinology, illustrate the opportunities and challenges of embedding RPM within an evolving IBD management paradigm. Realizing this potential will require robust clinical evidence, thoughtful implementation strategies, continued technologic development, and a commitment to equitable access. By addressing these needs, the IBD treatment paradigm can shift toward a prevention-focused, patient-centered model that improves outcomes for both patients and providers.

Disclosures

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