

Review Article

Opportunities and challenges of remote monitoring implementation in peritoneal dialysis: A scoping review

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Abstract

Background: Peritoneal dialysis (PD) offers several advantages over hemodialysis but faces challenges related to patient monitoring and limited clinical oversight. Remote monitoring (RM) has the potential to improve monitoring effectiveness, yet it remains underutilized and warrants further investigation.

Objective: This scoping review aims to identify the types of RM implementation, opportunities, and challenges in PD patients.

Methods: A systematic literature search was conducted in PubMed, ScienceDirect, ProQuest, and Scopus on 24 August 2024 to identify original research published between August 2014 and August 2024. The search combined terms related to PD and remote care, including “peritoneal dialysis,” “continuous ambulatory peritoneal dialysis,” “telemonitoring,” “remote monitoring,” “telemedicine,” and “remote consultation.” Original research articles describing the implementation of RM in PD patients aged 18 years and older were included. Retrieved records were exported to Rayyan for screening and study selection, with two review teams evaluating titles, abstracts, and full texts. Disagreements in study selection and data extraction were resolved through consensus and team discussion. Data were mapped according to the seven domains of the Model for Assessment of Telemedicine (MAST).

Results: A total of 23 studies were included, identifying five types of RM implementation. Data coding identified 132 opportunity items and 56 challenge items across the MAST domains. Cloud-based software supporting automated peritoneal dialysis was the most frequently represented RM modality, appearing in 12 studies, whereas telephone-based monitoring was represented in two studies. Across all included evidence, clinical effectiveness accounted for the largest proportion of both reported opportunities (40%) and challenges (43%). Several MAST domains, including safety, organizational aspects, sociocultural and ethical considerations, and legal issues, were less frequently reported.

Conclusion: RM has been implemented through several approaches in PD care and shows reported opportunities and challenges across multiple domains, particularly clinical effectiveness. However, interpretation of these findings should consider the heterogeneity of the included evidence, unequal representation of RM modalities, and limited reporting across several MAST domains.

Background

End-stage kidney disease (ESKD) is a global health problem that burdens patients and healthcare systems due to its increasing prevalence, mortality, and cost (Thurlow et al., 2021). Patients with ESKD require kidney replacement therapy to prolong their lives, either with transplantation or dialysis (Gupta et al., 2021; Thurlow et al., 2021). Among dialysis modalities, peritoneal dialysis (PD) offers several advantages, including greater patient autonomy, quality of life, and cost-effectiveness compared with hemodialysis (Novelia et al., 2017). However, it remains underutilized, particularly in developed countries

(Manani et al., 2018). Currently, only 11% of patients with ESKD worldwide undergo PD (Cho et al., 2021).

PD is performed by patients or their caregivers in the home-based setting. This home-based and self-managed nature of PD requires patients to perform dialysis procedures, monitor their condition, adhere to treatment regimens, and recognize potential complications with relatively limited direct clinical supervision (García et al., 2018; Jonny et al., 2022). Regular and timely monitoring is particularly important for identifying changes in treatment parameters, detecting complications, and supporting

appropriate adjustment of PD prescriptions (García et al., 2018).

Remote monitoring (RM) has emerged as a potential approach to address these limitations by enabling the transmission of health-related and physiological data from patients' homes to healthcare providers via telephone, internet-based platforms, connected devices, or other digital technologies (Farias et al., 2020). In PD, RM can facilitate closer follow-up than conventional care by enabling regular monitoring of treatment, patient status, and dialysis parameters, and by supporting individualized adjustments to PD prescriptions (Gajarawala & Pelkowski, 2021). Several forms of RM have been implemented in PD, including telephone-based monitoring, web- or internet-based platforms, automated PD systems integrated with cloud-based software, and other device- or application-based approaches. These approaches may improve clinical outcomes and cost-effectiveness, reduce emergency department visits and hospitalizations, and increase patient satisfaction and acceptance of PD care (Manani et al., 2020). Despite these advantages, some challenges that hinder the adoption of RM have been noted, including security vulnerabilities, physical examination limitations, privacy concerns, varying levels of patient literacy, and regulatory barriers (Agarwal & Wilkie, 2019).

Previous studies investigating the implementation of RM have demonstrated its advantages (Alipour & Hayavi-Haghighi, 2021; Biebuyck et al., 2022; Nygård et al., 2022). However, these reviews have primarily provided a broad overview of telehealth applications, digital interventions, or home dialysis rather than systematically mapping the opportunities and challenges associated with each specific type of RM implemented in PD.

A comprehensive understanding of these aspects is needed to determine which RM approaches may offer the greatest potential benefits and what limitations need to be addressed during implementation. Therefore, this scoping review aimed to identify the types of RM implemented in patients with PD and to map the associated opportunities and challenges. The scoping review approach was selected because of the heterogeneous nature of the available evidence and its suitability for mapping the breadth and characteristics of evidence across different RM approaches (Munn et al., 2018).

Methods

Study Design

This study was conducted as a scoping review to identify the types of remote monitoring (RM) implemented in patients undergoing peritoneal dialysis (PD) and to map the associated opportunities and challenges. The scoping review approach was selected because of the heterogeneous nature of the available evidence and its suitability for mapping the breadth and characteristics of evidence across different RM approaches (Munn et al., 2018). The study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018).

Research Question

This scoping review addressed the following research question: What types of remote monitoring have been implemented in patients undergoing peritoneal dialysis, and what opportunities and challenges have been reported for these approaches?

Inclusion and Exclusion Criteria

Studies were eligible if they met the following criteria: (1) original research studies using quantitative, qualitative, mixed-methods, or other empirical study designs; (2) published from August 2014 and August 2024; (3) published as peer-reviewed full-text articles; (4) written in English or Indonesian; (5) included adult patients with PD aged 18 years and older; (6) involved patients receiving PD either continuous ambulatory peritoneal dialysis (CAPD) or automated peritoneal dialysis (APD); (7) evaluated or described the implementation of RM, including RM delivered as part of a multicomponent intervention; and (8) explicitly described the characteristics, implementation, outcomes, opportunities, and/or challenges of RM in PD.

Studies involving mixed populations were eligible when data specific to adult PD patients could be identified and extracted separately. Studies were excluded if they (1) did not involve patients receiving PD; (2) focused exclusively on hemodialysis, kidney transplantation, or other populations; (3) did not involve RM or a remote telemonitoring component; (4) did not provide

sufficient information regarding RM implementation or its outcomes; (5) were protocols, editorials, commentaries, letters, conference abstracts, dissertations or theses, technical reports, or other non-original publications; or (6) were not available in English or Indonesian.

Gray literature from reputable institutional or publishing websites was searched separately to identify potentially relevant evidence; however, conference abstracts, theses, dissertations, and technical reports were excluded from the final analysis because they did not provide sufficient peer-reviewed full-text evidence for the objectives of this review. The restriction to English and Indonesian was applied because these were the languages in which the review team had sufficient proficiency to independently assess study eligibility, extract data, and accurately interpret the findings without relying on translation.

Search Strategy

A systematic literature search was conducted in four electronic databases: PubMed, ScienceDirect, ProQuest, and Scopus. The final search was conducted on August 27, 2024, and covered studies published between August 2014 and August 2024. The search strategy combined terms related to PD and remote care, including ("peritoneal dialysis" OR "continuous ambulatory peritoneal dialysis") AND ("telemonitoring" OR "remote monitoring" OR telemedicine OR "remote consultation"). The literature search was conducted by two reviewers (GK and IS) and further refined through team discussions.

Study Selection Process

The final search results were exported to Rayyan for screening and study selection. Two review teams, comprising DNM and GK and AFL, IS, and SR, evaluated the titles, abstracts, and full texts of identified publications sequentially. Disagreements regarding study selection were resolved through consensus and reviewer discussion. Critical appraisal was not conducted because the objective of this scoping review was to capture a broad range of evidence and provide a comprehensive overview of the available findings rather than to assess the methodological quality or risk of bias of individual studies.

Data Extraction and Synthesis

We collaborated in creating a data charting form to identify variables for extraction. We abstracted data on article characteristics (e.g., country, types of RM, outcomes) and opportunities and challenges (e.g., characteristics of RM types and opportunities and challenges for each type).

To ensure consistent classification of RM technologies across studies, RM implementations were categorized according to the primary RM system or technology used as the main mechanism for remote monitoring, rather than according to individual features or supplementary devices within the system. Five operational categories were used: (1) APD with cloud-based software, (2) mobile device application, (3) remote biometric monitoring devices (RBM), (4) instant messaging software, and (5) telephone monitoring. APD with cloud-based software was defined as RM systems integrated with an APD device that automatically collected and transmitted dialysis-related data to a cloud-based platform, regardless of whether the platform could also be accessed through a web portal, smartphone, or tablet.

Mobile device applications were defined as applications serving as the primary platform for patients to record, transmit, receive, or share PD-related information remotely, when the application itself constituted the main RM intervention. RBM was defined as the use of connected devices primarily designed to collect and transmit physiological or biometric data, such as blood pressure, body weight, or blood glucose, to a monitoring center; tablets or computers used only as supporting tools for data entry did not change the classification to mobile application. Instant messaging software was defined as the use of messaging platforms as the primary mechanism for remote communication and monitoring between patients and healthcare providers. Telephone monitoring was defined as RM primarily conducted through voice telephone communication; video conferencing or internet-based communication used as supplementary methods did not change the primary classification. When multiple technologies were used within a study, the study was classified according to the technology identified as the primary RM intervention or the principal mechanism for monitoring.

To provide a structured assessment, the identified RM implementations, opportunities, and challenges were examined using the seven domains of the Model for Assessment of Telemedicine (MAST), which encompasses seven domains: (1) Health problem and characteristics of application, (2) safety, (3) clinical effectiveness,

(4) patient's perspective, (5) economic aspects, (6) organizational aspects, and (7) sociocultural, ethical, and legal aspects (Kidholm et al., 2012; WHO, 2016a). Domain 1 describes the types of RM, whereas domains 2–7 analyze the opportunities and challenges associated with each type of RM.

Table 1. Domains of the Model for Assessment of Telemedicine Applications (MAST)

Domain	Definition	Content
(1) Health problem and characteristics of the application	Description of the health problem of the patients expected to use the telemedicine application and the application being assessed include a description of the current use.	• Health problem • Description of application • Technical characteristics • Current use of application
(2) Safety	Identification and assessment of harms	• Clinical safety (patients and staff) • Technical security (technical reliability)
(3) Clinical effectiveness	Effects on the patients health	• Effects on mortality • Effects on morbidity • Effects on health-related quality of life (HRQoL) • Effects on habits and behavior. • Use of health care service • Other outcomes related to PD*
(4) Patients' perspective	Issues related to the perception of the patient or the relatives of the telemedicine application including the patients and relatives' acceptance of the technology.	• Satisfaction and acceptance • Understanding of information • Trust • Capacity to use the application • Access and accessibility • Empowerment and self-efficacy
(5) Economic aspects	A societal economic evaluation comparing a telemedicine application with relevant alternatives in terms of costs and consequences and a business case describing the expenditures and revenues for the healthcare institutions using the telemedicine application.	• Economic evaluation: • Number of resources used for the application and for comparators • Price of each resource • Changes related to the use of health services • Cost-effectiveness* • Business case: • Annual expenses • Annual income
(6) Organizational aspects	Assessment of what kind of resources have to be mobilized and organized when implementing new technology, and what kind of changes or consequences the use can further produce in the organization	• Process • Structure • Culture
(7) Sociocultural, ethical, and legal aspects	Sociocultural aspects include the context where the patient lives and acts while using the telemedicine application. The ethical analysis assesses ethical aspects presented by the technological application itself and by the consequences of using or not using it. Legal aspects focus on legal obligations that should be fulfilled and specific legal barriers that may exist for widespread application deployment.	• Ethical aspects • Legal aspects • Social aspects

Each domain consists of specific content or aspects that highlight key elements to be evaluated within that domain. We expanded the MAST content to cover more areas linked to PD outcomes in domain 3, using insights from the Standardised Outcomes in Nephrology-Peritoneal Dialysis (SONG-PD). Additionally, we included cost-effectiveness content in domain 5. Details regarding the MAST are presented in Table 1.

Each opportunity or challenge item represented a distinct coded finding identified from the reported results or discussion of an included study. A single study could contribute multiple opportunity or challenge items when it reported distinct findings across different MAST domains or aspects. Related findings were grouped under the same conceptual code when they represented the same underlying issue within a study, while distinct findings were retained as separate items. The total of 132 opportunity items and 56 challenge items therefore represents the number of coded findings, rather than the number of studies or the strength, magnitude, or quality of evidence. The number of supporting studies was considered separately when interpreting the findings. Because the number of studies representing each RM modality varied substantially, particularly between cloud-based APD and telephone monitoring, item counts were not used to make direct comparative claims regarding the relative effectiveness or superiority of RM modalities.

Results

Our search identified 180 publications for screening. After removing a total of 143 records, 37 articles remained for full-text screening. Finally, 23 studies that satisfied all eligibility criteria were included for analysis. A flow diagram for the selection of studies is presented in Figure 1.

Table 2. Characteristics of Included Studies

Author, year (country, study design)	Sample	Type of RM intervention	Outcomes	Result
Cao et al., 2018 (China, RCT)	n= 160 on CAPD Male 58%, Age 52.2 ± 15y	Instant Messaging Application	Mortality	Lower in the intervention group (4 deaths vs 11 deaths)
			Patient satisfaction	Significantly higher in the intervention group (p<0.001)

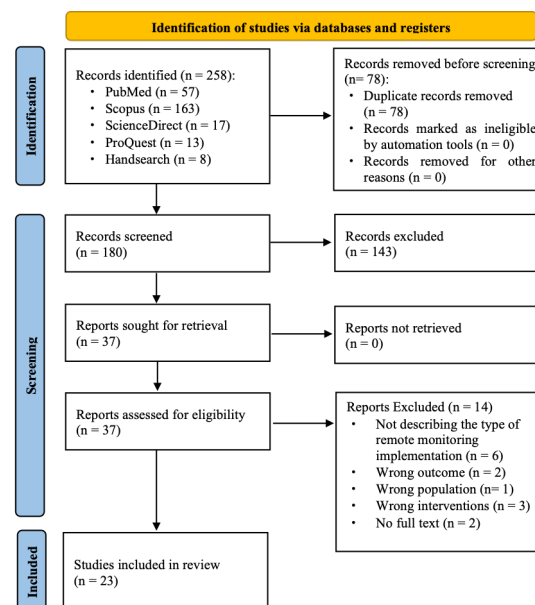


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram for selection of studies

This review included 12,241 patients treated with peritoneal dialysis (PD) across four continents, with individual study sample sizes ranging from 6 to 6,343 participants. Among the 12,241 participants, 5,227 (42.7%) were treated with automated peritoneal dialysis (APD), while two studies did not specify the PD modality (Chaudhuri et al., 2020; Magnus et al., 2017). Overall, 57% of participants were male, calculated based on the total number of individual participants across studies. After analyzing the 23 included studies, five types of RM were identified, with more than half of the studies implementing cloud-based software. Table 2 summarizes the characteristics of the included studies, stratified according to study design.

Author, year (country, study design)	Sample	Type of RM intervention	Outcomes	Result
			Peritonitis	Higher in the intervention group (60 cases vs 40 cases)
			Exit-site infection	Lower in the intervention group (4 patients vs 7 patients)
			Hospitalization	Lower in the intervention group (4 events vs 7 events)
Uchiyama, 2022 (Japan, RCT)	n=15, on APD Male 67%, Age 65(62- 67) y	APD with cloud-based software	Patient satisfaction	Higher in the intervention group (66.7±16.6 vs 59.4±24.0)
			Use of healthcare resources	Significantly lower in the intervention group (p=0.02)
			Effect on other PD outcomes	Significantly higher in ultrafiltration volume (p=0.03), PD Kt/V (p=0.04), and PD CCr (p=0.02). Significantly lower in serum PTH (p=0.03)
			QoL	Significantly higher in subscales of general health (p<0.001) and vitality (p<0.05)
Gultom et al, 2021 (Indonesia, quasi-experiment)	n= 60, on CAPD Male 62% Age <60 y (80%)	Mobile device application	QoL	Significantly higher in the intervention group (p<0.05)
Manani, 2019 (Italy, cohort)	n=85, on APD Male 75%, Age 56.5±15.5 y	APD with cloud-based software	Cost-effectiveness	The intervention reduced patient distance traveled by 1,134 km with a time saving of 1,554 min
			Night alarms	Significantly lower in the intervention group (p=0.002)
			Hospital visits	Significantly lower in the intervention group (p=0.01)
Polanco, 2021 (Dominican Republic, North America, cohort)	n=946, on PD (CAPD 98%) Male 62%, Age 51(19- 96) y	Instant messaging application or telephone monitoring	Hospitalization	Lower after intervention implemented (128 events vs 166 events)
			Transfer to HD	Lower after intervention implemented (8 vs 11)
			Peritonitis	Higher after intervention implemented (25 cases vs 15 cases)
Chaudhuri, 2020 (USA, cohort)	n= 6343 on PD (% CAPD n.d)	Mobile device application	Hospitalization	Significantly lower in patients with frequent using intervention (p=<0.001)

Author, year (country, study design)	Sample	Type of RM intervention	Outcomes	Result
	Male 57%, Age 56.9 ± 15.2 y		PD discontinuation	Significantly lower in patients with frequent using intervention (p=<0.05)
Nerbass, 2023 (Brazil, cohort)	n=103, on APD Male 45% Age 56.9 ± 16.2 y	Telephone monitoring	Hospitalization	Higher after intervention implemented (27 events vs 13 events)
			Metabolic disorders	Only serum potassium levels were significantly higher after intervention (p=<0.01)
Lew, 2019 (USA, cohort)	n=269, on PD (CAPD <10%) Male 56% Age 56 (43.6-64.3) y	Remote biometric monitoring devices	Hospitalization	Lower for RBM collected weight and higher for RBM collected blood pressure (number of events and length not reported)
			Cost-effectiveness	Significantly lower in overall cost after intervention (US\$- 734.51, p < 0.05).
Sanabria et al., 2019 (Colombia, cohort)	n=360, on APD Male 56%, Age 57±17 y	APD with cloud-based software	Hospitalizations	Significantly lower after intervention (p=0.029)
Sanabria et al., 2022 (Colombia, cohort)	n=1464, on APD Male 63%, Age 60.2 ± 16.5 y	APD with cloud-based software	Time on APD therapy	Significantly longer in the intervention group (p< 0.001)
			Mortality rates	Lower in the intervention group (0.10 vs 0.12 events per patient-year)
Tabuti, 2022 (Brazil, cohort)	n=747, on APD Male 54%, Age 59.7±16.6 y	Telephone monitoring and videoconferencing	Metabolic control	N.S difference
			Peritonitis rates	Higher after intervention implemented (37 cases vs 33 cases)
			Hospitalization	Significantly higher after intervention implemented (p=0.009)
Manani, 2020 (Italy, cohort)	n=73, on APD Male 77%, Age 60.4(47.4- 75.1) y	APD with cloud-based software	QoL	Only QoL PD questions were significantly higher in the intervention group (p=0.018)
			Frequency of visit	Lower in the intervention group (5 events vs 11 events)

Author, year (country, study design)	Sample	Type of RM intervention	Outcomes	Result
			Hospitalization	Higher in the intervention group (11 events vs 9 events)
Cuevas-Budhart et al., 2023 (Mexico, cohort)	n=509, on APD Male 65%, Age 49.8 ± 14.8 y	APD with cloud-based software	Infections, adverse events, hospitalizations, and deaths from COVID-19	N.S difference
Corzo et al., 2022 (Colombia, cohort)	n=558, on APD Male 60%, Age 53.8 ± 16.9 y	APD with cloud-based software	PD discontinuation	Lower in RM intervention group (0.08 [0.05–0.15] vs 0.18 [0.12–0.26]) episodes/patient-year
Chang et al., 2023 (Taiwan, cohort)	n= 51, on APD Male 61%, Age 51.5 ± 12.6 y	APD with cloud-based software	Non-adherence rate	Decreased between 3 phases of intervention (10.5%, 5.1% and 4.9%)
			Peritonitis rate, hospitalization rate, and length of hospitalization	N.S differences
Manani et al., 2018 (Italy, case-control)	n=37, on APD Male 86%, Age 60.7 ± 14.1y	APD with cloud-based software	APD Prescription	Significantly frequent in the intervention group (p= 0.002)
			Frequency in-person visits	Significantly lower in the intervention group (p=0.008)
Yeter, Akcay, et al., 2020 (Turkey, observational study)	n=15, on APD Male 40%, Age 47 (19–81) y	APD with cloud-based software	Treatment adherence	Significantly higher after intervention (p=0.001).
			Small solute	Significantly increased 6th month after intervention (p=0.03)
			Blood pressure	Significant decreases in the intervention group (p=0.01)
			Sleep and QoL	N.S difference
Yeter, Karacalik, et al., 2020 (Turkey, observational study)	n=35, on PD (CAPD 21 %) Male 45%, Age 53±14 y	APD with cloud-based software	Peripheral blood pressure and central hemodynamic parameters	Significantly different in the intervention group (p≤ 0.05).
Magnus, 2017 (USA, observational study)	n=300, on PD (% CAPD n.d)	Remote biometric monitoring devices	Patient satisfaction	The number of people that were satisfied (90.7%) was higher than at baseline (p<0.001)

Author, year (country, study design)	Sample	Type of RM intervention	Outcomes	Result
	Male 51%, 45 to 64 y (50.5%)		Emergency visit	Lower after post- intervention (50 vs 52)
			Hospitalization	Lower after post- intervention (36 vs 41)
			Exit-site infection	Higher after post- intervention (24 vs 13)
Amici et al., 2021 (Italy, pilot study)	n= 21, on APD; Male 47%, Age 69 ± 13 y	APD with cloud-based software	Hospital visits	Significantly lower after intervention (62 vs 92)
			Hospitalizations	N.S difference
			Cost-effectiveness	Lower after intervention (€412 vs €951).
Sriyuktasuth, 2023 (Thailand, pilot Study)	n=104, on CAPD Male 60% Age 52.8 ± 13.9 y	Mobile device application	QoL	Only significant on two domains of the 36-Item Short Form Survey-general health (p=0.002) and reported health transition (p=0.018).
			Self-management and clinical outcomes	N.S difference
Harrington, 2014 (USA, pilot Study)	n=6, on CAPD Male 50% Mean 52.2 ± 6.5y	Mobile device application	Patient satisfaction	5.2 out of 10
Dey, 2016 (UK, pilot study)	n= 22 on APD Male 55 % Age 61.6(26.4- 93.4) y	Remote biometric monitoring devices	Patient Satisfaction and QoL	N.S difference

APD Automated Peritoneal Dialysis, N.S non statistical, PD Peritoneal dialysis, RBM Remote biometric monitoring devices, QoL Quality of Life, y years, Kt/V Fractional urea clearance, Ccr Creatinine clearance.

Varying types of RM had been implemented in the 23 studies analyzed. Notably, we identified the following five types of RM based on the primary system used as the intervention in the studies.

A total of 12 studies used APD with additional cloud-based software as their RM system. These devices autonomously collected and transmitted post-dialysis data status, fluid details, alarms, body weight, and blood pressure. Additionally, remote adjustments and prescriptions for APD were feasible.

Mobile device application

In four studies, patients used mobile device applications to access and share their daily health and dialysis records with the dialysis center. Some applications included reminders and alarms (Harrington et al., 2014; Sriyuktasuth Aurawamon et al., 2023), whereas others provided health advice and information (Sriyuktasuth Aurawamon et al., 2023). Healthcare workers securely accessed this data through a web application on a secure server. Three applications were accessible via a smartphone, whereas one

(Harrington et al., 2014), was exclusively for tablets.

Remote biometric monitoring devices (RBM)

Three studies implemented RBM for patients, comprising tools to collect data from various sources and transmit it to a central location for monitoring. These kits featured a blood pressure monitor, scale, glucometer, and the HealthPal device for automated data storage and transmission (Lew et al., 2019; Magnus et al., 2017). Alternatively, patients used a computer tablet for manual recording (Dey et al., 2016).

Instant messaging software

Two studies employed instant messaging software for RM, facilitating regular patient-healthcare provider interactions, continuous patient monitoring and patient education. One study used

WhatsApp (Polanco et al., 2021), whereas the other used QQ Apps (Cao et al., 2018).

Telephone monitoring

Two studies employed telephone monitoring as the primary intervention, supplementing it with other methods. Patients communicated signs or symptoms to the monitoring center via phone calls, which were occasionally augmented by different approaches if necessary. One study incorporated video conferencing in just 6% of cases (Tabuti et al., 2022), whereas another utilized the internet, although its usage was not reported (Nerbass et al., 2023).

Evaluation of the six domains in the MAST model revealed 132 opportunities and 56 challenges across the 23 studies on patients with PD who underwent RM (Figures 2 and 3). Detailed information on the domains can be found in Table 3.

Table 3. Opportunities and Challenges of RM Types

Type of RM	Total Studies	Characteristics of the RM	Opportunity		Challenges	
			Domain	Content	Domain	Content
APD with cloud-based software	12	APD with cloud-based software automatically collected and transmitted post-dialysis data, including session status, fluid details, alarms, body weight, and blood pressure. Moreover, APD prescriptions could be remotely performed and modified.	Safety (n=4).	Clinical Safety (n=3), Technical Security (n=1).	Safety (n=0).	None
			Clinical Effectiveness (n=33).	Effects on mortality (n=3), Effect on Health-Related Quality of Life (HRQoL) (n=3), Effect on habits and behavior (n=6), Use of health care service (n= 13), Effects on PD-related parameter (n= 8).	Clinical Effectiveness (n=7).	Effect on HRQoL (n=1), Effect on habits and behavior (n=1), Use of health care service (n=2), Effects on other PD outcomes (n=3).
			Patient's perspectives (n=9).	Satisfaction and acceptance (n=5), Understanding of information (n=2), Capacity to use of application (n=1), Self-efficacy and empowerment (n=1).	Patient's perspectives (n=2).	Access or accessibility (n= 1), Satisfaction and acceptance (n=1).
			Economic aspects (n=5).	Cost-effectiveness (n=2), Price of each resource (n=1), Changes related to	Economic aspects (n=0)	None

Type of RM	Total Studies	Characteristics of the RM	Opportunity		Challenges	
			Domain	Content	Domain	Content
Mobile device application	4	Patients used mobile applications to view and share their daily health and dialysis records with the dialysis center.		the use of health care service (n=2).		
			Organizational aspects (n=8)	Structure (n=1), Culture (n=1), Process (n=6).	Organizational aspects (n=1).	Process (n=1).
			Sociocultural, ethical, and legal aspects (n=1)	Social aspect (n=1).	Sociocultural, ethical, and legal aspects (n=0)	None
			Safety (n=5).	Clinical Safety (n=3), Technical security (n=2).	Safety (n=0)	None
			Clinical Effectiveness (n=7).	Effect on Health-Related Quality of Life (HRQoL) (n=2), Effect on habits and behavior (n=1), Use of health care service (n=3), Effect on other PD outcomes (n=1).	Clinical Effectiveness (n=3).	Effect on habits and behavior (n=1), Effects on other PD outcomes (n=2).
			Patient's perspectives (n=6).	Satisfaction and acceptance (n= 5), Trust (n= 1).	Patient's perspectives (n=6).	Satisfaction and acceptance (n= 2), Access or accessibility (n= 1), Capacity to use the application (n= 2), Self-efficacy and empowerment (n=1)
			Economic aspects (n=0)	None	Economic aspects (n=0)	None
			Organizational aspects (n=2)	Process (n=2).	Organizational aspects (n=2).	Process (n=2).
			Sociocultural, ethical, and legal aspects (n=1)	Social aspect (n= 1).	Sociocultural, ethical, and legal aspects (n=0)	None
Remote biometric monitoring devices	3	Set of tools and devices designed to collect data from various sources and transmit it to a central location	Safety (n=7).	Clinical Safety (n=2), Technical Security (n=5).	Safety (n=1).	Technical security (n=1).
			Clinical Effectiveness (n=6).	Effect on habits and behavior (n=2), Use of health care service (n=4).	Clinical Effectiveness (n=4).	Effect on HRQoL (n=2), Effect on habits and behavior (n=1), Effect on other PD outcomes (n=1).

Type of RM	Total Studies	Characteristics of the RM	Opportunity		Challenges	
			Domain	Content	Domain	Content
		for analysis and monitoring.	Patient's perspectives (n=8).	Satisfaction and acceptance (n=2), Understanding of information (n=1), Capacity to use the application (n=1), Access or accessibility (n=1), Trust (n=1), Self-efficacy and empowerment (n=2).	Patient's perspectives (n=5).	Satisfaction and acceptance (n= 1), Trust (n=1), Capacity to use the application (n=1), Access or accessibility (n=2).
			Economic aspects (n=3).	Cost-effectiveness (n=2), Changes related to health care service use (n=1).	Economic aspects (n=2)	Price of each resource (n=1), Number of resources (n=1).
			Organizational aspects (n=2)	Culture (n=1), Process (n=1).	Organizational aspects (n=2).	Culture (n= 1), Process (n= 1).
			Sociocultural, ethical, and legal aspects (n=2)	Ethical aspect (n=1), Social aspect (n=1).	Sociocultural, ethical, and legal aspects (n=0)	None
Instant messaging application	2	Instant messaging applications enable ongoing communication between patients and healthcare providers, allowing for visual and verbal interaction. This facilitates information exchange, assistance, and informed decision-making for continuous patient monitoring.	Safety (n=2).	Clinical Safety (n=1), Technical Security (n=1).	Safety (n=0).	None.
			Clinical Effectiveness (n=5).	Effects on mortality (n=1), Effect on habits and behavior (n=1), Changes related to the use of health care service (n=2), and Effects on other PD outcomes (n=1).	Clinical Effectiveness (n=3).	Use of health care service (n=1), Effect on Effect on other PD outcomes (n=2).
			Patient's perspectives (n=3).	Satisfaction and acceptance (n= 1), Trust (n=1), Capacity to use of the application (n=1)	Patient's perspectives (n=0).	None
			Economic aspects (n=1).	Number of resources (n= 1).	Economic aspects (n= 0)	None
			Organizational aspects (n=4)	Structure (n=1), Culture (n=2), Process (n=1).	Organizational aspects (n=0)	None
			Sociocultural, ethical, and legal aspects (n=1)	Social aspect (n= 1).	Sociocultural, ethical, and legal aspects (n=0)	None

Type of RM	Total Studies	Characteristics of the RM	Opportunity			Challenges		
			Domain	Content		Domain	Content	
Telephone monitoring	2	Real-time communication between patients and healthcare professionals allows verbal interaction to exchange information, assist, and make informed decisions.	Safety (n=1).	Technical (n=1).	Security	Safety (n=2)	Technical (n=2)	security
			Clinical Effectiveness (n=2).	Effect on other outcomes (n=2)	PD (n=2)	Clinical Effectiveness (n=7).	Effect on other outcomes (n=5), Use of health care service (n=2).	PD (n=2).
			Patient's perspectives (n=3).	Satisfaction and acceptance (n=1), Access and accessibility (n=2).		Patient's perspectives (n=2).	Self-efficacy and empowerment (n=2).	(n=2).
			Economic aspects (n= 0)	None		Economic aspects (n= 2)	Number of resources (n=1), Change-related healthcare service use (n=1).	
			Organizational aspects (n=0).	None		Organizational aspects (n=5).	Process (n=4), Culture (n=1)	
			Sociocultural, ethical, and legal aspects (n=1)	Ethical aspect (n= 1).		Sociocultural, ethical, and legal aspects (n=0)	None	

The majority of the opportunities originated from APD with cloud-based software (46%), followed by RBM (21%), mobile device applications (16%), instant messaging applications (12%), and telephone monitoring (5%). Meanwhile, most of the challenges primarily originated from telephone monitoring (32%), followed by RBM (25%), mobile device applications (20%), APD with cloud-based software (18%), and instant messaging applications (5%).

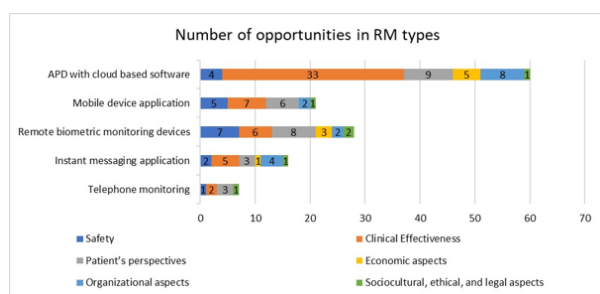


Figure 2. Number of Opportunities in RM types

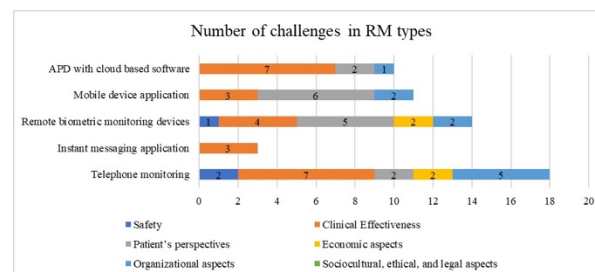


Figure 3. Number of Challenges in RM types

Among the domains, clinical effectiveness provided the most opportunities (40%), followed by patient perspectives (22%), safety (14%), organizational aspects (12%), economic outcomes (7%), and sociocultural, ethical, and legal aspects (5%). This emphasizes their pivotal role in driving the benefits of RM. Regarding challenges, clinical effectiveness contributed the most (43%), followed by patient perspectives (27%), organizational aspects (18%), economic outcomes (7%), safety (5%), and sociocultural, ethical, and legal aspects mentioned (0%).

APD with cloud-based software provided 60 identified opportunities. This predominantly aligned with clinical effectiveness, followed by patient perspectives, organizational aspects, economic outcomes, safety, and sociocultural, ethical, and legal aspects. Conversely, telephone monitoring, reported in just two studies, posed the most challenges, with eighteen identified challenges. These primarily pertain to clinical effectiveness and organizational aspects.

The opportunities and challenges across the various domains of RM showcased distinct trends. Safety and sociocultural, ethical, and legal domains emerged prominently within RBM. Simultaneously, APD with cloud-based software excelled across multiple fronts, such as clinical effectiveness, patient perspectives, economic outcomes, and organizational aspects. Conversely, challenges presented themselves uniquely such that safety concerns dominated telephone monitoring, clinical effectiveness hurdles persisted in APD with cloud-based software, patient perspectives encountered challenges within mobile device applications, economic outcomes faced obstacles in RBM and telephone monitoring, and organizational complexities loomed in telephone monitoring practices.

Discussion

This scoping review provides an overview of RM implementation in PD and maps the opportunities and challenges reported across different RM approaches. The identified opportunities and challenges were examined using the MAST model, known for its comprehensive evaluation encompassing medical, social, economic, and ethical aspects of telemedicine (WHO, 2016b). As a component of telemedicine, RM has been proposed as a potential approach to support community-based dialysis and the advancement of technology-enabled kidney care (Rosner et al., 2017). One aspect to consider is whether this “virtual” supervision could address healthcare teams’ concerns about reduced oversight for patients with PD, potentially promoting its underutilization (Agarwal & Wilkie, 2019). Prioritizing the patient’s perspective on technology and balancing benefits and drawbacks are crucial for effective adoption (Agarwal & Wilkie, 2019).

APD with cloud-based software was the most frequently reported RM modality and had the

highest number of reported opportunity items across the MAST domains. Ten studies reported opportunities related to this approach, with clinical effectiveness being the most frequently represented domain, followed by patient perspective and organizational aspects. Several studies described potential clinical benefits associated with APD integrated with cloud-based software, including reductions in hospital visits and hospitalization rates (Biebuyck et al., 2022). Some studies also reported potential economic benefits, particularly when remote data enabled healthcare providers to identify issues such as fluid overload, treatment alarms, or nonadherence and respond before complications developed, particularly when two-way communication between patients and clinical teams was available (Makhija et al., 2018). Potential reductions in direct medical, nonmedical, and indirect costs were also reported in relation to APD with cloud-based software (Thilly et al., 2017). These findings indicate potential clinical and economic opportunities associated with this approach; however, they should be interpreted as outcomes reported in individual studies rather than evidence of superior effectiveness or cost-effectiveness compared with other RM modalities.

Patient perspectives were also frequently reported for APD with cloud-based software. Among the nine studies addressing this domain, five reported patient satisfaction, which was associated with perceptions of simple interfaces and good functionality. Patients were also reported to be able to enter treatment-related information, such as body weight and blood pressure, into the system (Gebhardt & Mishra, 2019). Six studies described potential improvements in treatment adherence or compliance associated with real-time monitoring and communication capabilities (Uchiyama et al., 2022). Other studies described the potential of these systems to support patient involvement in decision-making and facilitate communication between nurses and patients, which may contribute to patients’ perceived independence and visibility of treatment processes (Cao et al., 2023; Eyolfson, 2019). Nevertheless, these findings primarily reflect reported patient experiences and perceived benefits rather than evidence that APD with cloud-based software consistently improves adherence or patient autonomy.

Seven studies discussed the domain of organizational aspects. Through the use of APD with cloud-based software, patients perceived a virtual reduction in the distance between them and the clinical staff, thereby improving collaborative care between patients and the team and improving patient compliance (Chaudhuri et al., 2020). From a social perspective, the loss of productivity time for the patients and their caregivers owing to telephone calls, transportation, visits, and hospitalizations decreased from the traditional to APD with cloud-based software (Harrington et al., 2014). These findings suggest that remote access and communication may provide organizational and social opportunities, particularly for patients and caregivers who experience difficulties with frequent in-person healthcare contact.

Despite these reported opportunities, APD with cloud-based software was also associated with several challenges. Three studies reported unfavorable findings related to clinical effectiveness, particularly for some PD outcomes. Possible explanations included insufficient follow-up by the clinical team and problems related to data transmission (Yeter, Karacalik, et al., 2020). In addition, healthcare teams may initially require additional time to learn, adapt to, and implement the technology, potentially affecting the time available for routine patient review (Alipour & Hayavi-Haghighi, 2021). The clinical team was required to initially invest some time to learn, adapt, and implement the technology, consequently leading to less time for routine patient review (Wood et al., 2019). These findings highlight that the availability of technological infrastructure alone may not be sufficient to achieve the intended benefits of RM; implementation processes, staff adaptation, and clinical workflows may also influence its effectiveness.

Telephone monitoring was reported with several challenges, particularly within the clinical effectiveness and organizational domains. The two studies addressing this approach reported limitations related to the absence of visual assessment, insufficient training of healthcare professionals and patients, and potential delays in obtaining medical evaluation (Nerbass et al., 2023; Tabuti et al., 2022). Organizational challenges included limitations in conducting specific assessments through telephone communication

and the need for appropriate training structures (Nerbass et al., 2023; Tabuti et al., 2022). These findings suggest that telephone-based RM may have limitations when clinical assessment requires direct observation or measurement of physical parameters. However, the evidence mapped in this review does not support a conclusion that telephone monitoring is inherently less safe or less effective than other RM modalities.

The safety-related challenges reported for telephone monitoring were primarily related to limitations in obtaining comprehensive clinical information. Without visual or physical assessment, healthcare professionals may have less information available when evaluating patients' conditions (Nerbass et al., 2023; Tabuti et al., 2022). This limitation may be particularly relevant when patients develop symptoms requiring assessment beyond information that can be communicated verbally. Nevertheless, these findings should be understood as implementation challenges reported in the included studies rather than evidence of comparative safety between telephone monitoring and other RM approaches.

Despite these limitations, telephone monitoring was also associated with opportunities related to the patient perspective. Some studies described telephone communication as a feasible approach for supporting patient participation and monitoring clinical parameters, particularly among older patients or those experiencing social or technological barriers (Nerbass et al., 2023; Tabuti et al., 2022). The relatively low technological requirements of telephone communication may also make it a practical option in settings where reliable internet connectivity, high-performance computers, or specialized software are not readily available (Boikanyo et al., 2023). Telephone monitoring may therefore remain a relevant option when video conferencing or more technologically advanced remote patient monitoring systems are unavailable or infeasible (Shah et al., 2021; Tabuti et al., 2022). Its role should, however, be considered in relation to the type of clinical information that needs to be assessed and the resources available in the local healthcare setting.

Unlike most types of RM that demonstrate considerable in clinical effectiveness domain, RBM notably excels in the domain of patient

perspectives. This can be attributed to the satisfaction experienced by patients with RBM, as evidenced by the significant increase in their satisfaction levels (WHO, 2016b). Additionally, patients perceive the utilization of RBM as straightforward due to its automated recording of data (Tabuti et al., 2022). However, acquiring essential equipment and technology for biometric monitoring and secure data transmission required for RBM has been associated with an initial upfront cost (García et al., 2018).

Contrary to RBM, mobile device applications had the highest number of challenges in the domain of patient perspective, although it did have the most opportunities for the clinical effectiveness domain. The major criticism of this approach was the need for automated data entry into the application, with patients preferring to include vital signs without manually entering these values (Harrington et al., 2014). Other challenges noted in the implementation of mobile devices included insufficient training due to the lack of time and manpower, no prompt access to medical staff, and the risk of system failure during emergencies (Latif et al., 2017; Rezaee et al., 2022). The limited availability of wireless internet connectivity for some patients had also become a potential barrier. Missed entries/non-compliance were mainly due to problems with Wi-Fi connectivity at the patient's location or server connectivity (Harrington et al., 2014). Mobile devices should be able to connect to the internet even in areas without access to internet providers and should be capable of working offline and synchronizing data once an internet connection is available (John & Jha, 2019).

Utilizing instant messaging applications for RM provides several opportunities for clinical effectiveness and organizational aspects. RM through instant messaging enhances clinical effectiveness and organizational aspects by shifting traditional medical approaches. This method encourages the medical staff to actively participate in patient treatment, aligning with "patient-centered" hospital practices (Cao et al., 2018; Polanco et al., 2021). Implementing instant messaging for follow-up creates an expansive scientific database, fostering collaborative development within hospital platforms (Cao et al., 2018).

Conclusion and Recommendation

This scoping review mapped the implementation of RM in PD and identified reported opportunities and challenges across different RM approaches. Opportunities and challenges were reported across multiple MAST domains, with clinical effectiveness being the most frequently represented. However, the findings should be interpreted in light of the heterogeneity of the available evidence and the unequal representation of RM modalities, which limits direct comparison between approaches. Several domains, particularly safety, organizational, sociocultural, ethical, and legal aspects, were also less frequently reported. These gaps highlight the need for more comprehensive and standardized evaluations of RM in PD that consider clinical outcomes alongside patient perspectives, safety, organizational requirements, economic aspects, and sociocultural, ethical, and legal considerations. The findings may inform healthcare professionals and stakeholders in considering RM implementation while recognizing the limitations of the current evidence base.

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Declaration of conflict of interest

The authors declare no competing interests.

Declaration on the Use of AI

Artificial intelligence (AI)-assisted tools were used solely to improve the language, grammar, and readability of the manuscript. The authors reviewed and approved all content and remain fully responsible for the accuracy, integrity, and originality of the manuscript.

Data Availability Statement

Data sharing is not applicable to this article.

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