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Review

Remote patient monitoring and management in nephrology: A systematic review

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ABSTRACT

Chronic kidney disease (CKD) is a global public health problem, with adverse outcomes of kidney failure, cardiovascular disease (CVD), and premature death. According to European Kidney Health Alliance (EKHA) currently, 1 in 10 Europeans has chronic kidney disease (CKD) and it is predicted to be the fifth leading cause of death worldwide by 2040. The COVID-19, pandemic has further worsened the situation, with CKD being the number one risk factor for CKD mortality, ahead of lung and heart disease. In addition to rising mortality figures, treatments for kidney disease have not improved substantially over the past 50 years, leaving too many kidney patients with a poor quality of life and reduced life expectancy. This situation is associated with staggering aggregate annual costs amounting to €140 billion per year in Europe, more than the annual healthcare costs of cancer or diabetes.

Many studies confirm that Information and Communication Technology intervention (ICT) in nephrology can be way to tackles this issue. The increased daily use of information and communication technologies (ICT) may lead to the need for healthcare professionals to monitoring patient remotely. Remote Patient Monitoring (RPM) have the potential to improve care for patients with kidney disease.

RPM may provide a means to overcome some of the aforementioned barriers. RPM is a framework for monitoring patients at home by digital, wireless technology and extends the interactive contact of conventional clinical settings to include the patient's home. The hope is that these technologies would improve clinical outcomes through earlier recognition and

Abbreviations: ICT, information and communication technology; CKD, chronic kidney disease; DKD, diabetic kidney disease; eGFR, estimated glomerular filtration rate; ESRD, end-stage renal disease; KDIGO, kidney disease: improving global outcomes; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RCT, randomized controlled trial; RRT, renal replacement therapy; RPM, remote patient monitoring/management; PD, peritoneal dialysis; HD, hemodialysis or hemodialysis; APD, automatic peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; HHD, home hemodialysis; RTS, renal replacement therapy; TX, transplantation; RMT, remote management therapy; RTS, renal therapy services; RPM, remote patient management; EKHA, European Kidney Health Alliance; ICHD, in-center hemodialysis; THC, tele homecare; PGHD, patient-generated health data; AAKP, American Association of Kidney Patients; PAHO, Pan American Health Organization; WHO, World Health Organization.

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correction of problems. Although few studies on telehealth in the dialysis population exist, studies do support its technical feasibility, which patient acceptance of this technology is very high, and that RPM may be able to improve outcomes in other co-morbid states shared by the ESKD population.

According to Pan American Health Organization, CKD, also called kidney failure, describes the gradual loss of kidney function and is a worldwide public health problem, with adverse outcomes of kidney failure, CVD, and premature death.

This study collects the papers concerning RPM and renal patient management using ICT intervention to analyze the results from considering the bioengineer's point of view. Our focus was on technology contribution.

The aim of this study was to review and synthesize the available literature on the role of RPM in healthcare in nephrology. This systematic review was conducted to examine the content and results of publications on using RPM to improve the health care of patients with kidney disease, available to health care professionals (HCPs) and/or patients. The literature and our results confirm that in this field, RPM can allow cost reduction, improve the efficiency of healthcare resources, reduce human error, and overall improve the quality of life of kidney patients.

Monitorización y manejo remotos del paciente en Nefrología: revisión sistemática

RESUMEN

Palabras clave:
RPM en Nefrología
RPM para enfermedades renales
Revisión sistemática
Telenefrología
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ERC

La enfermedad renal crónica (ERC) es un problema de salud pública global, con resultados adversos en términos de insuficiencia renal, enfermedad cardiovascular (ECV) y muerte prematura. De acuerdo con la *European Kidney Health Alliance* (EKHA), en la actualidad uno de cada 10 europeos padece ERC y se predice que sea la quinta causa principal de muerte a nivel mundial para 2040. La pandemia de COVID-19 ha empeorado aún más la situación, siendo la ERC el factor principal de riesgo de mortalidad, por delante de las enfermedades pulmonares y cardiacas. Además de incrementar las cifras de letalidad, los tratamientos de las nefropatías no han mejorado de manera sustancial durante los últimos 50 años, lo que ha hecho que muchos pacientes renales tengan mala calidad de vida y reducción de la expectativa de esta. Tal situación está asociada a unos costes anuales agregados sorprendentes, que ascienden a 140 billones de euros por año en Europa, cifra superior a los costes sanitarios anuales relacionados con el cáncer o la diabetes.

Muchos estudios confirman que la intervención de las tecnologías de la información y la comunicación (TIC) en nefrología puede ser un modo de abordar esta cuestión. El incremento del uso diario de las TIC puede conducir a la necesidad de tratar a distancia a las personas por parte de los profesionales sanitarios. La monitorización remota del paciente (RPM) tiene el potencial de mejorar el cuidado de aquellos con enfermedad renal.

La RPM puede aportar un medio de superar alguna de las barreras anteriormente citadas. Se trata de un marco para monitorizar a los pacientes en su casa mediante tecnología digital y sin cables, lo que amplía el contacto interactivo del entorno clínico convencional, incluyendo el domicilio de la persona. La esperanza es que dichas tecnologías puedan mejorar los resultados médicos mediante un reconocimiento y una corrección más tempranos de los problemas. Aunque existen pocas investigaciones sobre telesalud en la población de diálisis, los estudios respaldan su viabilidad técnica, con una aceptación muy alta de esta tecnología por parte del paciente, pudiendo mejorar la RPM los resultados de otros estados comórbidos compartidos por la población de enfermedad renal en estado terminal.

De acuerdo con la *Pan American Health Organization*, la ERC, también denominada insuficiencia renal, describe la pérdida gradual de la función renal, y es un problema de salud pública mundial con resultados adversos en términos de fallo renal, ECV y muerte prematura.

Este estudio reúne documentos relativos a RPM y el manejo del paciente renal con el empleo de una intervención de TIC para analizar sus resultados, considerando la óptica de los bioingenieros. Nosotros nos centramos en la contribución tecnológica.

El objetivo fue revisar y sintetizar la literatura disponible sobre el rol de la RPM en la atención sanitaria nefrológica. Dicho análisis sistemático fue realizado para examinar el contenido y los resultados de las publicaciones sobre la cuestión, utilizando RPM para mejorar la atención sanitaria de los sujetos con enfermedad renal, disponible para profesionales sanitarios o pacientes. La literatura y nuestros hallazgos confirman que, en este campo, la RPM puede contribuir a reducir los costes, mejorar la eficiencia de los recursos sanitarios, reducir los errores humanos y mejorar en general la calidad de vida de los pacientes renales.

Introduction

RPM can improve the management and the quality of life of patients with chronic disease. In this study we evaluated the related paper to find possible clinical and social advantages derived from remote patient monitoring.

Home dialysis require a continuous monitoring (including peritoneal dialysis and home hemodialysis) and offers a variety of benefits over in-center hemodialysis. Studies show evidence of benefits for both peritoneal dialysis (PD) and home hemodialysis (HHD) patients related to survival, quality of life, transportation costs, increased patient autonomy and clinical benefits including enhanced blood pressure and phosphorus control.[1–5] Home dialysis is particularly advantageous in the pediatric population given the greater schedule flexibility for school and play, importance of psychosocial aspects, and the limited geographic distribution of pediatric dialysis centers. Furthermore, the cost of delivery of care of home modalities in most countries is less than that of in-center hemodialysis.[6–8]

The efficient use of RPM in Nephology requires the HCP capacitation and patient training to develop a variety of self-management skills to effectively deliver and manage their disease at home. RPM may provide the HCP with tools to better assist the patients and the patients with accessible information to develop the skills and knowledge they require to manage their treatment. This review aims to identify and evaluate RPM interventions in supporting clinicians and patients of nephrology units.

The ultimate goal of ICT interventions would be to reduce adverse events (i.e., hospitalization), and improve survival, and patient-reported outcomes such as treatment satisfaction and quality of life while reducing healthcare resources and costs.[9,10]

As this is an extremely complex disease, multidisciplinary care is needed to provide complete and continuous care. The use of RPM in Nephrology aims to improve the interventions of Health Care Professionals and the patient self-management intervention to facilitate an individual's ability to make lifestyle changes as needed.[11] The effectiveness of these interventions on patients with kidney disease is limited by the integration of these new tools into the common procedure of the Nephrology units. In this study, we applied a systematic review to investigate whether the RPM intervention improves healthcare in the Nephology units.

Due to the complexity of patients on dialysis, telehealth[12] may complement but not replace the in-person visit and provide better oversight of care with remote monitoring. It is not surprising that patients receiving peritoneal dialysis (PD) have responded positively to telehealth. Telehealth and home dialysis both foster greater home-based care, less travel time, and fewer trips to the clinic and leverage the principles of patient and care partner autonomy and self-care. Telehealth may also help facilitate patient education about home dialysis modalities, and self-care.[13]

Using technology and telemedicine to educate patients will be important in a connected world while trying to decrease face-to-face interactions.

It is important to have a system where the processes of patient care, areas of technological progress, and various issues of applied RPM are interconnected. This work is dedicated to using RPM in healthcare to support and improve the care for Patients with Kidney disease in Nephrology Units. The main problems and burdens on the way to the implementation of RPM in Nephrology have been analyzed and compiled in the column of limitations and future research in Table 1.

Following in the footsteps of the important work already accomplished by the AAKP in the United-States, the Decade of the Kidney™ will gather relevant stakeholders and partners to accelerate this change in Europe. Through a wide range of advocacy activities, the campaign will raise awareness of the challenges and unmet needs in kidney disease, with a focus on the importance of prevention, data collection and sharing, home therapies[14] personalized medicine, patient education and empowerment, and regenerative medicine.

Examples of such technologies include home-based point-of-care labs based on finger sticks and home-based diagnostics and care. As such, we must continue to make it better; we must continue to make it easier; and we must continue to make it available to anyone and everyone in need of care by addressing technology literacy, and infrastructure.[15]

The challenges to appropriately utilize home modalities have been multifold, including low start rates, high attrition rates, and inadequate infrastructure in all facets of medical service providers to care for the home dialysis patient[16] (e.g., nursing facilities, trained access operators, transition to home, etc.).

CKD, especially end-stage renal failure (ESRF), represents a major public health problem in developed and developing countries. Healthcare statistics in mainland China show that ESRF has become one of the major health problems in the adult Chinese population. PD is a kind of renal replacement therapy (RRT) that is often presented as an easier and less cumbersome dialysis modality. However, long-term PD impacts the patient's physical, psychological, and social well-being, leading to fre-

Table 1 – Characteristics of studies included in the systematic review.

#	Title and aim	First author	Country/years/ref.	ICT tools/RRT modality	Sample size/duration (weeks)	Findings/outcomes/results	Limitations and future research
01	Remote patient Management in peritoneal dialysis	Ronco C et al.	China and Canada (2019) [1]	RPM/PD	300 Patients/for 24 weeks	Lower hospitalization and emergency visits. Diagnosis of infections by videoconferencing or pictures. Improving adherence Facilitate patients as active participants in their own care. Improve outcomes and therapy confidence and treatment satisfaction. Patients can identify changes in their health status. The survey confirms that the patients are satisfied or completely satisfied with the RPM system.	Prevention targeted via RPM needs improvement. Future studies of RPM technology among PD patients should include both qualitative and quantitative evaluations of patients' reported outcomes. RPM will be an important adjunct in shaping the expansion of telemedicine and "tele-nephrology".
02	Design and evaluation of a mobile application to assist in the self-monitoring of chronic kidney disease in developing countries	Alvaro Sobrinho et al.	Brazil (2018) [2]	mHealth/CKD	30 Patients	A mHealth app for risk evaluation and stratification of CKD can benefit both patients and physicians in managing and monitoring the disease, and in identifying a possible risk before critical health stages	Some functionalities need improvement, for instance, some patients may be discouraged to use the CDA-sharing functionalities of the app due to confidentiality concerns. More study is needed to overcome this challenge regarding users' confidence and acceptance.
03	'My Home Hemo' app – a new telehealth tool for remote monitoring of patients on home hemodialysis	Mary Ann Nicdao et al.	Australia (2016) [3]	RPM, app, web Portal and Telehealth/HD	74 patients during 21 weeks	Patients with HHD are exposed to the same health risks as other dialysis patients. The HHD-RMS (My Home Hemo app) enabled nurses to monitor patients in multiple locations from the dialysis unit. Led to savings associated with patient and nursing time related to travel, enhanced patients' clinical decision-making, and improved patient and staff satisfaction. Health benefits to patients and cost savings to health services	Patients may feel isolated and discouraged to continue with the modality due to limited contact with clinical staff.

Table 1 (*Continued*)

#	Title and aim	First author	Country/years/ref.	ICT tools/RRT modality	Sample size/duration (weeks)	Findings/outcomes/results	Limitations and future research
04	Exploring the utility and scalability of a tele homecare intervention for patients with chronic kidney disease undergoing peritoneal dialysis – a study protocol	Lianne Jeffs et al.	Canada (2017) [4]	Tele home-care/CKD/PD	200 Patients during 96 weeks	Enhancing CKD patients undergoing PD outcomes and experiences. Aid PD patients in performing continuous ambulatory PD exchanges. Increased real-time communication between the patient and the dialysis center that is ongoing between face-to-face visits. Improved outcomes and decreased complications through real-time monitoring as well as safety prompts that are built into the flow of the application, increased ability to extend PD uptake of patients that may live far from a dialysis center. Increased sense of security from the patients, ability to rapidly change prescription and diagnosis problems in response to data that is monitored throughout the month. Allow patients to remain at home without the need for routine monthly face-to-face visits. Patients find the system useful and do obtain an increased sense of security and connectivity using the application. Can improve outcomes such as blood pressure control	Sustain and spread the tele homecare application that will be useful to guide the development, implementation, and evaluation of future virtual care applications aimed at improving the quality-of-care outcomes and experiences of patients. Potential to contribute to accelerating knowledge by producing a comprehensive dataset on how remote telemonitoring can improve health care outcomes of peritoneal dialysis patients
05	Telemonitoring system for patients with chronic kidney disease undergoing peritoneal dialysis	J.R. Cuevas et al.	Mexico (2016) [5]	Web mobile & RPM/PD (APD&CAPD)	Not reported	This service allows for establishing the minimum and maximum values of biomedical ranges such as hematocrit, sodium, potassium, albumin, and ultrafiltration for patients with APD. This service allows the HCP to view the treatment register by the patient and generate reports The service also allows the HCP to send notifications to the patients	Data mining to extract relevant information from the data collected from the treatments

Table 1 (*Continued*)

#	Title and aim	First author	Country/years/ref.	ICT tools/RRT modality	Sample size/duration (weeks)	Findings/outcomes/results	Limitations and future research
06	Remote patient management in peritoneal dialysis: an answer to an unmet clinical need	John Oommen et al.	UK (2019) [6]	RPM/PD	Not reported	Transfer medical information from the patient for the delivery of clinical and educational services with an aim to improve health outcomes. Transmission of parameters from multiple sources to the system in real time. Efficient and Sustainable Self-Care PD patients, spend a significant amount of time in self-care tasks. Augmented Communication between Patients and Healthcare Delivery. User-Generated Clinical Data and Non-Invasive Monitoring of Clinical Parameters. Automated Clinical Decision Support System, Patient Education, Support System, and Electronic Prescription Management Facilitating Personalized Therapy in Real-Time. Remote health management offers a promising alternative to optimally utilize information and communication technologies for remote diagnosis, monitoring, and delivery of care	Studies have shown that addressing social isolation and catering to the emotional needs of users is a major challenge to emerging telemonitoring and innovative technologies that deliver care remotely.
07	Smart sensors for real-time monitoring of patients on dialysis	Fokko Wieringa et al.	Netherland (2020) [7]	RPM/PD and HD	Not reported	Unobtrusive wearable and/or ubiquitous smart monitoring may therefore make 4P medicine (that is, predictive, precise, preventive, and personalized), individualize treatments, and improve patient outcomes. Monitoring, therefore, represents a key opportunity to optimize treatment efficacy and patient care. That real-time monitoring of clinical parameters could help to individualize treatments for patients	Longitudinal data might help clinicians to diagnose earlier and monitor disease progression, and perhaps help patients adopt a healthier lifestyle.

Table 1 (*Continued*)

#	Title and aim	First author	Country/years/ref.	ICT tools/RRT modality	Sample size/duration (weeks)	Findings/outcomes/results	Limitations and future research
08	Use of sharesource in remote patient management in peritoneal dialysis: A UK nurse's perspective	Michelle Blaauw	UK (2019) [8]	RPM/PD	Not reported	Patient clinical data are available on system. The time invested into monitoring data from PD treatment was found to be more effective and the result is more individualized prescriptions for patients. RPM has enabled more proactive nursing practice, more personalized PD prescriptions, and more proactive nurse care. Reduce PD glucose exposure, patient drop-off, hospitalization, and peritonitis rates.	Very little research, carried out to date, on the impact of RPM on PD patient outcomes.
09	The utility of remote patient management in peritoneal dialysis. Running Head: RPM on patients with PD	Haci Yeter et al.	Italy and Turkey (2021) [9]	RPM/PD	130 Patients during 44 weeks	Facilitating treatment intervention, increasing adherence; and one of the main advantages of integrating RPM into APD is increased treatment adherence, and it is known that non-adherence to treatment is associated with more frequent peritonitis episodes, so RPM programs are associated with favorable clinical outcomes and could lead to a reduction in health expenses. Health cost Hospital visit Hospitalization Decreased health cost and hospital visit	The most important limitation of home-based dialysis therapies is the lack of contact between the clinician and the patient. The success of innovations in the PD field will depend on its simplicity, degree of automation, biocompatibility, comfort, efficiency, and safety. In this context, wearable PD technology. Technology to generate dialysate in miniaturized portable systems.
10	Telemonitoring system for patients with chronic kidney disease undergoing peritoneal dialysis: usability assessment based on a case study	Marcos Garcia et al.	Mexico (2018) [10]	RPM dialysis/PD	24 Patients during 172 weeks	PD exchange registration service, alerts to inform the doctor, notifications, and reminders to the several risk situations were immediately detected and good acceptance by the nephrology staff	Several risk situations were immediately detected, such as fluid retention, dehydration, and peritonitis

Table 1 (*Continued*)

#	Title and aim	First author	Country/years/ref.	ICT tools/RRT modality	Sample size/duration (weeks)	Findings/outcomes/results	Limitations and future research
11	Effects of a self-management program on patients with early-stage chronic kidney disease: a pilot study	Chiu-Chu Lin et al.	Taiwan (2013) [11]	CKD self-management program based on video (training)	37 Patients over 12 weeks	Significant improvement in subjects, and improved physiological outcomes. Effect on preventing the deterioration of CKD. More Information will guide the self-management strategies to reach desired outcomes. Healthcare providers should motivate patients with early-stage CKD to self-manage their disease by learning the strategies of self-regulation to prevent CKD progression. Theory base intervention is feasible and has potential efficacy in retarding CKD progression	A large-scale longitudinal randomized controlled trial is needed. Further work on mechanisms of effect is warranted, these findings, alongside evidence that interventions to change professional behavior to support self-management are of limited benefit, suggest that better outcomes may be achieved by placing more effort and resources in communities and that more research should be directed towards determining ways and means of embedding health management activities into everyday life.
12	Remote patient management for home dialysis patients	Eric Wallace et al.	USA (2017) [12]	RPM/Home Dialysis (HD and PD)	Not reported	Remote patient management has exciting potential to improve home dialysis patient care and home modalities uptake. Improve the quality of life and reduce cost. RPM can help reduce the burden of travel, and improve the process of managing PD supplies. Additionally, the ability to receive vital patient information in real-time allows the physician to directly impact a patient's care sooner and hopefully lead to fewer complications.	Further, RCT and large registry-based studies focused on how and what to monitor are needed to guide the most efficacious use of telehealth as it applies to the dialysis patient and provider.
13	Telehealth for home dialysis in COVID-19 and beyond: a perspective from the American Society of Nephrology COVID-19 Home Dialysis Subcommittee	Susie Q. Lew et al.	USA (2020) [13]	Telehealth/home dialysis	30 Patients	Urban communities are intuitively thought to have greater access to home dialysis, home dialysis facilities allow the patient to safely isolate at home during the COVID-19 pandemic	Many dialysis units are unable to provide home dialysis; challenges remain in the implementation and widespread use of telehealth. The future landscape for advancing telehealth usage in home dialysis depends on integrating technology with an efficient home program workflow, addressing internet infrastructure, technology literacy, and socioeconomic determinants of health.

Table 1 (*Continued*)

#	Title and aim	First author	Country/years/ref.	ICT tools/RRT modality	Sample size/duration (weeks)	Findings/outcomes/results	Limitations and future research
14	Clinical and social advantages of remote patient monitoring in home dialysis	Massimo Morosetti	Italia (2020) [14]	RPM using Doctor Plus Nephro/Home Dialysis – CKD	16 Patients during 80 weeks	Was a reduction of systolic pressure in 69% of the patients and of diastolic pressure in 62.5%. The mean heart rate decreased from 69.4 bpm to 68.8 bpm The perceived health status of all patients had improved. The number of patients accessing emergency services also decreased. Doctor Plus® Nephro could improve access to home treatment; the results of this study show it to be a useful tool for Nephrological Centers to monitor patients undergoing home dialysis	Not reported
15	Effectiveness of a Web-Based eHealth Portal for Delivery of Care to Home Dialysis Patients: A Single-Arm Pilot Study	James Kiberd et al.	Canada (2018) [15]	Home dialysis (HD and PD)	41 Patients during 16 weeks	Patients had a positive experience with the care and communication provided by their nephrologist. The portal was found to have a neutral or mildly positive impact on patient management of several domains of their dialysis care (including reductions in stress, improved understanding of medications, increased personal independence, and access to a kidney specialist). Was a small but statistically significant reduction in patient telephone usage after the adoption of the eHealth portal. Patients found the portal easy to use and were satisfied with the portal. The portal was found to have a neutral or mildly positive impact on patient management of several domains of their dialysis care. Reductions in stress, improved understanding of medications, increased personal independence, and access to a kidney specialist. ICT has been shown to improve self-management and satisfaction of care in various settings, with evidence of improved health outcomes in chronic disease populations. ICT has spread to the dialysis population with the advent of online self-management support tools and advances in telemedicine technologies	The study is limited by the small sample size. High rate of patient dropout, Limited response rate, In this study of home dialysis patients, we identified that eHealth communication did not lead to significant improvements in patient experience with home dialysis care. A larger, multicenter trial is needed to evaluate the utility and feasibility of online communication portals more rigorously for home dialysis patients.

Table 1 (*Continued*)

#	Title and aim	First author	Country/years/ref.	ICT tools/RRT modality	Sample size/duration (weeks)	Findings/outcomes/results	Limitations and future research
16	Remote monitoring of automated peritoneal dialysis improves personalization of dialytic prescription and patient's independence/To determine if an eHealth portal is effective at improving home dialysis	Sabrina Manani et al.	USA (2018) [16]	Home dialysis (PD) RM-APD	37 Patients during 48 weeks	For RM-APD the prescriptions were modified more frequently, reducing presence visits for emergencies, RM allows efficient use of healthcare resources, helping to improve the personalization of APD prescriptions, and helping to intervene early with "troubleshooting". Make changes in the PD prescription in a timelier and cost-effective manner. RM can be an effective management strategy to increase patient independence from the PD center.	It is a small study, single-center study, potentially insufficient time to detect real long-term effects of the RM program. Future new studies will need to focus on the longer-term use, acceptance, and outcomes of RM
17	Effects of post-discharge nurse-led telephone supportive care for patients with chronic kidney disease undergoing peritoneal dialysis in China	Juan Li et al.	China (2014) [17]	Mobile phone/PD	135 Patients during 72 weeks	Post-discharge nurse-led telephone support is helpful for some aspects of quality of life and reducing re-administration and clinic visits of PD patients in Guangdong. Helpful for China to develop accessible healthcare services, obtaining the right services at the right time to promote improved health outcomes.	Further studies will be performed on patient's compliance with the medication and the relationship to the clinic conditions and quality of life in PD patients and other chronic patients.
18	Telemedicine and remote monitoring: supporting the patient on peritoneal dialysis	Nayak et al.	USA, India and Italy (2016) [18]	Telemedicine and RPM/PD	246 Patients	Can allow for the assessment of the patient's home environment, adherence to the prescribed technique, observation, and correction of potential or real hazards that may increase the risk of infection. Reinforcement of patient confidence in self-care by providing support and encouragement. Home-visit programs coupled with telemedicine surveillance encourage a closer relationship between patient and their caregivers. Telemedicine, once widely used, with a high load of patients and their data maintenance, might suffer from high maintenance and service expenses, severe capability limitations, lack of experienced professionals, and interoperability issues. A larger number of patients to a telemedicine intervention is needed. What is currently clear is that the technology is available and may become part of standard PD care, if proven effective.	Although we do not have such in-depth evidence at present, we know that telemedicine in PD shows great promise.

Table 1 (*Continued*)

#	Title and aim	First author	Country/years/ref.	ICT tools/RRT modality	Sample size/duration (weeks)	Findings/outcomes/results	Limitations and future research
19	Evaluation of the experience with the use of telemedicine in a home dialysis program – a qualitative and quantitative study	Raquel Scofano et al.	Brazil (2022) [19]	Telemedicine/HHD	17 Patients 12 Nurses during 24 weeks	Patients and nurses had positive experiences with telemonitoring, highlighted feelings of being cared for, and improved confidence. Telemonitoring is a useful tool to increase satisfaction with and confidence in home hemodialysis, experiences with telemedicine were positive mainly because it increased their confidence and sense of care during HHD. Telemedicine could be considered a valuable tool for coping with distancing while providing HHD health professionals expressed their confidence in and acceptance of this delivery method	Users indicated that telemonitoring does not replace face-to-face visits. The initial resistance of nurses was probably greater than that of patients due to the possibility of evaluating their care performance, creating a feeling of discomfort. Telemedicine was deemed an acceptable way to receive health care but was regarded as complementary to face-to-face visits with the doctor. Further studies are needed to show the impact of telemedicine on physicians, nurses, social workers, and dieticians participating in an HHD program.
20	Telemedicine: Development of a distance care system for pre-dialysis chronic kidney disease patients	Natália Maria Fernandes et al.	Brazil (2014) [20]	Telemedicine/Pre-dialysis stage	Not reported	This tool will enable to increase the coverage area of nephrologists. Reduce costs, and bring the patient closer to the primary care physician. When available and used as an alternative to face-to-face consultation, this tool will help expand nephrology care coverage for stable patients. This will help expand the coverage area of nephrologists.	As future papers to be carried out, we can say that: a study to investigate the effectiveness of electronic consultation when compared to face-to-face in the case of stable pre-dialysis CKD (already in progress)
21	Two-year experiences with telemedicine in the follow-up of patients in home peritoneal dialysis	Paloma Gallar et al.	Spain (2007) [21]	Telemedicine/PD (at Home & CPDA & APD)	25 + 32 Patients During 96 weeks	Home telemedicine appears to be clinically useful in the long-term follow-up of stable patients undergoing peritoneal dialysis. The costs and savings seem to be encouraging, with good image quality and adequate sound. Patients perceived teleconsultation as being like hospital consultation. Improvement in quality of life with telemedicine, the time spent was shorter than in the hospital, there were time savings for both patients (because they did not need transport) and staff, Was less use of outpatient clinic premises. Telemedicine allowed knowledge of the exact patient treatment, visualizing dialysis graphics, and arterial pressure measurements with electronic devices or glucose control at home. Telemedicine also made it possible to evaluate the social and healthcare aspects of each patient, thus avoiding nurse home visits.	Some patients refused to participate. Connection difficulties in 20% of teleconsultations presumably because of telephone network overload. There is little evidence of its cost-effectiveness. There is little evidence of its cost-effectiveness. Connection difficulties in 20% of teleconsultations presumably because of telephone network overload. Older patients tended to refuse Telemedicine.

Table 1 (*Continued*)

#	Title and aim	First author	Country/years/ref.	ICT tools/RRT modality	Sample size/duration (weeks)	Findings/outcomes/results	Limitations and future research
22	The Use of a Tablet Computer Platform to Optimize the Care of Patients Receiving Peritoneal Dialysis: A Pilot Study	Daphne Harrington et al.	USA and India (2014) [22]	Telehealth (tablet (iPad®)/PD (CADP))	5 Patients during 32 weeks	Increased Patient independence, and improved quality of life However, uses a novel tablet computer-based interface to allow real-time monitoring and two-way communication to better link PD patients with a dialysis center and care providers. Increased real-time communication between the patient and the dialysis center that is ongoing between face-to-face visits, improved outcomes and decreased complications, increased ability to extend PD uptake of patients that may live far from a dialysis center, increased sense of security from the patients, ability to rapidly change prescription and diagnosis problems in response to data that is monitored throughout the month. A more long-term goal of this system would be to allow patients to remain at home without the need for routine monthly face-to-face visits, patients find the system useful and do obtain an increased sense of security and connectivity through the use of the application, demonstrates the utility of telemedicine platforms to exchange data between patient and providers and that this data exchange can improve outcomes such as blood pressure control. The investigators were able to demonstrate that the study group had fewer hospitalizations, hospital days, emergency room visits, and associated healthcare expenditures, Investigators have developed a cellular phone-based system that was useful in caring for PD patients with excellent results in patients in very remote locations.	The lack of more frequent monitoring may compromise outcomes, and decrease wider uptake of this modality. More reliable connectivity, the ability to tailor the scripted instructional steps for more experienced users, entry of physiological parameters are the next steps in the design of the system. A potential barrier to wider uptake of this application may be limited wireless internet connectivity for some patients. If the system proves to improve outcomes, it may be cost-effective for health systems to provide internet access at no charge to patients. Given the small number of subjects, we cannot determine whether outcomes and complications will be positively impacted by this system, but given the inherent factors incorporated in the system, we might expect more patients to enroll in PD, with lesser infective complications, better technique survival, and reduced comorbidities, leading to a potentially better quality of life and significant cost savings. Future design changes and larger-scale studies are in development. Investigators have also applied remote monitoring to PD with encouraging but limited results.

Table 1 (*Continued*)

#	Title and aim	First author	Country/years/ref.	ICT tools/RRT modality	Sample size/duration (weeks)	Findings/outcomes/results	Limitations and future research
23	Telehealth for non-critical Patients With Chronic Diseases During the COVID-19 Pandemic	Liu Na et al.	Australia (2020) [23]	Telehealth, RPM/CKD	5 Active patients during 20 weeks	Provide patients with more assistance and support for a positive behavioral change. Telehealth emphasizes its role in reducing hospital visits with reduced opportunities for routine clinic visits. The Copresence-enhanced design has been shown to reduce patients' anxiety and increase confidence in managing their chronic disease condition and has the potential to reduce patients' needs to engage their healthcare providers during a time when healthcare resources are stretched	We advocate for more innovative designs to be considered to enhance patients' feelings of copresence with their health care providers during this time
24	Telemedicine applied to nephrology. Another of consultation	J.R. Gómez-Martino et al.	Spain (2008) [24]	Telemedicine/CKD	52+53 Patients during 108 weeks	Telecare in nephrology is possible also promoting the approach between two welfare levels, without a decrease in the quality of assistance. Get a lower number of hospital visits, saving in sanitary transport as well as in hospital consultations.	The only reason given by the patients was preferring more direct contact with the specialist and not through a monitor
25	Telenephrology with Remote Peritoneal Dialysis Monitoring during Coronavirus Disease	Osama Shamya et al.	USA (2020) [25]	RMT (Remote Monitoring of Treatment) – (Sharesouce, a cloud-based connectivity platform)/PD	80 Patients	A cloud-based connectivity platform that shares information from the patients' dialysis cycle. Enables nephrologists and clinical staff to remotely monitor each cycle's information (fill volume and time, dwell time, drain volume and time, and ultrafiltration volume). Been an invaluable resource to get patient's information directly from home	Not reported

Table 1 (*Continued*)

#	Title and aim	First author	Country/years/ref.	ICT tools/RRT modality	Sample size/duration (weeks)	Findings/outcomes/results	Limitations and future research
26	Remote Monitoring of Automated Peritoneal Dialysis Improves Personalization of Dialytic Prescription and Patient's Independence	Sabina Manani et al.	Italy and USA (2016) [26]	RPM/APD	37 Patients	Permits the adjustment of APD-program prescription more frequently. Good maintenance of PD adequacy, enhance patients' self-management of disease at home, increases patients' independence, and improved quality of life. The number of in-person visits in incident RM-APD was reduced. Increases patient acceptance of PD as the renal replacement modality; time-saving benefits, improving adherence to follow-up, and reducing healthcare utilization Increase patient satisfaction and decrease costs	A small, single-center study, reflecting the general difficulty in performing clinical studies on PD patients. Potentially insufficient time to detect real long-term effects of the RM program Future new studies will need to focus on the longer-term use, acceptance, and outcomes of RM.
27	The COVID-19 infection in dialysis: are home-based renal replacement therapies a way to improve patient management?	Mario Cozzolino	Italia (2020) [27]	Home-Based RRT/Home Dialysis Treatment	330 HD patients and 50 PD patients	Home-based treatment – Makes it possible to limit exposure to the hospital setting. Remote counseling – A good way to avoid isolation; should integrate direct follow-up. Flexibility—empowerment – Patient empowerment is associated with better survival and better quality of life. Biochemical controls at home – Practical, reduces the need for going to a laboratory or hospital. Family involvement- Can provide important psychological support. Residual kidney function- This may be better preserved in tailored dialysis programs. Assisted home dialysis – Allows limiting exposure to the hospital setting and eliminates travel time. Reduction of travel time—lower carbon footprint – The ecologic advantages are debated but are likely to be relevant especially if patients live far from the dialysis units. The clinical results of home dialysis are usually at least competitive with hospital-based therapy.	Isolation – Acute intradialytic problems can be challenging. Fragile and elderly patients may not be able to clearly explain their problems. Patient-designed dialysis may differ from prescriptions. This can be dangerous. Standard pre- and post-dialysis controls may be difficult to organize. The burden may be heavy and create tension, monitoring may be difficult to carry out, and a slow loss of kidney function could go unnoticed. May fail to guarantee privacy, and the advantage of empowerment is usually lost, in some settings, the costs for the patients may be high. Waste management needs to be organized in advance. Home dialysis may be time-consuming for the healthcare team, in particular, if a personalized schedule is chosen

Table 1 (*Continued*)

#	Title and aim	First author	Country/years/ref.	ICT tools/RRT modality	Sample size/duration (weeks)	Findings/outcomes/results	Limitations and future research
28	The Mobile Health Readiness of People Receiving In-Center Hemodialysis and Home Dialysis	Wael Hussein et al.	Australia (2021) [28]	Mobile/HD and Home Dialysis	949 Patients (632 HD + 317 Home dialysis)	Home dialysis participants had higher proportions of younger patients, employment, and higher education and a lower proportion of Hispanic patients. The majority reported the ability to use mobile devices and to access the internet independently and were currently using or interested in using mobile health-related activities Findings suggest that even though most patients on dialysis are mobile health ready, a one-size-fits-all approach to mobile health is unlikely to be successful. Our findings that mobile health readiness is independently associated with younger age, higher education, employment, and ethnicity support previous findings in non-dialysis contexts. In people with kidney disease, Bonner et al. found that greater mobile health readiness was associated with younger age, higher education, and decreased indigeneity. Higher mobile health readiness and proficiency in our patients on home dialysis compared with patients on in-center dialysis. This important finding can stimulate the use of mobile health in home dialysis given that the vast majority of home dialysis nurses believe that its use would improve care, decrease travel time, and enhance patient-centered care in patients on home dialysis. Higher mobile health readiness and proficiency in our patients on home dialysis compared with patients on in-center dialysis. The use of mobile health for patients on in-center hemodialysis has received less attention than home dialysis, even though the technology is highly pervasive in in-center hemodialysis. The capacity to improve treatment adherence; address patient-reported symptoms in real time; and encourage the use of nutrition, activity, and mental health apps could assist in empowering patients to reverse the predominantly one-way care delivery system and place the patient on dialysis at the center of his or her own health care. The knowledge is that most users stop mobile health application usage soon after initial use. Suggests a need for additional healthcare professional education and support to help ensure that mobile health communications can lead to significant improvements in patient experience with home dialysis care	The main limitation is that this is a cross-sectional design, and we cannot propose a causal relationship between patient variables and mobile health readiness or proficiency.

Table 1 (*Continued*)

#	Title and aim	First author	Country/years/ref.	ICT tools/RRT modality	Sample size/duration (weeks)	Findings/outcomes/results	Limitations and future research
29	Patient and Clinician Perspectives on the Use of Remote Patient Monitoring in Peritoneal Dialysis	Benjamin Talbot et al.	Australia (2022) [29]	RPM/PD	14 participants (5 clinicians [2 nephrologists, 3 PD nurses] and 9 patients treated with PD).	Perceived benefits of RPM implementation. More complete data and monitoring adherence. Improved treatment oversight, more complete data capture, overcoming barriers to data documentation, and maintaining patient independence. Reduce the risks of patient disengagement.	Uncertainty regarding data governance (protection of personal data, data reliability). Reduced patient engagement, increased patient and clinician burden. The interviews were conducted in English only and with participants from a single urban dialysis unit. Concerns about increasing the burden on some patients through the use of unfamiliar technology
30	Homecare Telematics for Peritoneal Dialysis	Eleni Kaldoudi et al.	Greece (2007) [30]	Homecare Telematics/PD (APD & CAPD)	Not reported	Proven to be a low-cost solution, easy to incorporate into the daily routine of a clinic, saves time for both patients and nurses and reduces utilization of hospital facilities and hospital workload in general, telematics support has been positively received by patients on peritoneal dialysis. When patients become comfortable enough to maintain CAPD and APD without any major problems, their quality of life and that of their families, in general, is improved. A web-based portal application that provides different views of the telemetry data, according to the user.	There are some design considerations and technical limitations to existing solutions that prohibit the widespread adoption of such services
31	Use of a peritoneal dialysis remote monitoring system in India.	Aditi Nayak et al.	India (2012) [31]	RPM & PD	246 Patients (115 rural and 131 urban patients)	Patients performed well on PD and had significantly better survival rates than their urban counterparts. Monitoring strategies allow for earlier diagnosis of infectious PD complications, thus promoting prompt treatment initiation and response demonstrating the clinical advantages of communications technology in the follow-up of that patient population. PD remote monitoring tool may be a groundbreaking driving force for promoting PD as the preferred dialysis modality.	Shown poorer results in rural than in urban patients

Table 1 (*Continued*)

#	Title and aim	First author	Country/years/ref.	ICT tools/RRT modality	Sample size/duration (weeks)	Findings/outcomes/results	Limitations and future research
32	Tele-Nephrology: A Feasible Way to Improve Access to Care for Patients with Kidney Disease Who Reside in Underserved Areas	Marco Landino et al.	USA (2016) [32]	Telehealth/CKD	101 Patients	With the telenephrology clinic intervention, we were able to effectively improve BP control in patients with kidney disease who reside in underserved areas. In addition. For patients who reside in remote areas, telenephrology allows access to a renal specialist. Stabilization of the glomerular filtration rate was achieved along with control of the electrolytes. May afford potential opportunities to reduce the cost of healthcare in patients with multiple renal conditions	Not reported
33	Telehealth: Acceptability, clinical interventions and Quality of Life in peritoneal dialysis	Vishal Dey et al.	UK (2016) [33]	Telehealth/PD	22 Patients during 60 weeks	Telehealth is useful to monitor patients with renal failure on peritoneal dialysis. It is acceptable across age groups and provides an additional resource for patients to self-manage. Satisfaction scores and retention rates suggest a high level of acceptability, and time spent on teleconsultations was lower compared to hospital consultations, integrated with cellular telephone devices enabling data collection on a wide variety of parameters including exercise level and blood glucose monitoring.15 Our self-reported QUEST questionnaires demonstrate a positive experience of the use of telehealth technology, but this does not translate into an overall improvement in QOL. Issues surrounding QOL are complex and often need to be addressed by more than a single intervention.	The study is limited by the small patient numbers. Absence of a control arm and being unblended. The small and decreasing number of patients with PD in the developed world, however, makes it difficult to perform a sufficiently powered study to detect a significant difference

Table 1 (*Continued*)

#	Title and aim	First author	Country/years/ref.	ICT tools/RRT modality	Sample size/duration (weeks)	Findings/outcomes/results	Limitations and future research
34	Integrated Self-management Program Effects on hemodialysis patients: A quasi-experimental Study	OL Park et al.	South Korea (2019) [34]	Mobile Application/HD	84 HD patients + 30 additional patients	The integrated self-management program had significant effects on self-efficacy, treatment compliance, and the ratio of inter-dialytic weight gain to dry weight. This study aimed to incorporate the multifaceted characteristics of hemodialysis patients' self-management, including dietary management, exercise, medication, arteriovenous fistula management, and dialysis schedule management.	Further research is needed to develop and assess a nursing intervention program that can improve the physiological indicators of serum potassium and phosphorus levels. It is necessary to develop a nursing intervention program that involves a mobile application to improve the self-management of hemodialysis patients. Further research is needed regarding nursing interventions for hemodialysis patients to improve their self-management based on various theoretical frameworks. Self-management mobile applications that are similar to the one developed in this study should be developed by analyzing and further reflecting on hemodialysis patients' needs
35	Telehealth by an Inter-professional Team in Patients With CKD: A Randomized Controlled Trial	Ishani, Areef, et al.	USA (2016) [35]	Telehealth	451 participants during 32 weeks	Telehealth by an inter-professional team is a feasible care delivery strategy in patients with CKD	Older population, mostly men, potentially underpowered.
36	Mobile Health (mHealth) Technology: Assessment of Availability	Sarah J. Schrauben et al.	USA and India (2021) [36]	mHealth/CKD	932 Patients	Many individuals with CKD currently use the internet and smartphones, and mHealth technologies present an opportunity to engage individuals with CKD. Racial and ethnic minority groups reported greater interest in using mHealth technologies. Many Patients are interested in using mHealth in the future. Three themes regarding interest in using digital and mHealth technologies emerged: willingness, concerns, and barriers.	Few patients use mHealth apps or have adequate eHealth literacy. Further research is needed to identify strategies to overcome inadequate eHealth literacy

Table 1 (*Continued*)

#	Title and aim	First author	Country/years/ref.	ICT tools/RRT modality	Sample size/duration (weeks)	Findings/outcomes/results	Limitations and future research
37	Telehealth in nephrology care – promises and challenges	David Hailey	Australia (2016) [37]	Telehealth/CKD	Not reported	Telenephrology has been suggested as an approach to facilitate coordinated care between primary care providers and nephrologists for patients with chronic kidney disease (CKD).	Require evaluation of their safety, effectiveness, efficiency, sustainability, and influence on clinical practice.
38	Remote Patient Management in Home Dialysis: Planning Considerations for the Future	Michael Whitlow et al.	USA (2019) [38]	RPM/Home dialysis Patient/PD	Not reported	Help reduce the burden of travel. Improve the process of managing PD supplies. Receiving vital patient information in real-time allows the physician to directly impact a patient's care sooner and hopefully lead to fewer complications. This could lead to an expansion of the number of patients receiving home dialysis, improving patient education	Physicians are usually only able to obtain information regarding compliance at the monthly clinic visits. Physicians and nurses will then have to sift through large amounts of data, which own a cost burden. In the future, we should enveloped data mining tools to allow the user to extract reports or consultation with specific information
39	Health Economic Implications of Remote Patient Management	Mitchell Rosner et al.	USA (2019) [39]	RPM & Telehealth/PD &HD	300 Patients	Improve the quality of life, and increase acceptance of these modalities of renal replacement therapy. Real-time visual chat between patients and clinicians, send real-time photos or videos of their catheter. Link outcomes with a clear economic impact, and significant reductions in readmission rates. Decreased negative perceptions of PD care. Improvement in perceived autonomy and confidence. Increased level of oversight and education. Alleviates the need and associated costs of patient travel. Improve outcomes in ESKD patients. Offer patients and their care teams a set of tools that can enhance outcomes and lower costs	This address concerns that the patient may need additional oversight to ensure safety. Lack of acceptance and education among physicians, social barriers such as poor housing. Lack of family and friend support. Cognitive barriers Medical. Contraindications. Difficulty in arranging travel to the needed periodic assessments by the care team

Table 1 (*Continued*)

#	Title and aim	First author	Country/years/ref.	ICT tools/RRT modality	Sample size/duration (weeks)	Findings/outcomes/results	Limitations and future research
40	Telenephrology: Providing Healthcare to Remotely Located Patients with Chronic Kidney Disease	Judy tan et al.	USA (2018) [40]	RPM & Telehealth/PD &HD	228 Patients	Reducing clinical visit cancellation Increase appointment attending. Improve adherence. Is a promising method to provide access to care to rural CKD patients Minimize the disparity between urban and rural patients	Not reported
41	Emotion sharing in remote patient monitoring of patients with chronic kidney disease	Robin Huang et al.	Australia (2019) [41]	RPM/CKD	156 Patients	Positive nature of emotion (8% of Very HAPPY AND HAPPY)	Improvement would be to increase the accuracy of the sentiment analysis feature Limited by few amount of data Direct evaluation of patients will report best more information
42	Using information technology to improve the management of chronic disease	Branko Celler et al.	Australia (2003) [42]	Tele-Home Care/RPM	22 patients	Cost effectiveness Improve healtcare Easy to use Patient Satisfied Can be supported by multidisciplinary care teams Improve Compliance and medication management Reduce readmissions rate Facilitate patient self-management	Not reported

quent re-hospitalization and may impose a considerable burden on patients and families, which induces great demands on integrated health and social care to maintain a desirable quality of life, decrease morbidity during the course of the disease and improve health outcomes of ESRF patients.[17]

The current evidence is mainly based on disparate case reports and small observational studies. In this study, we aimed to ascertain the studies exploring the use of RPM in the context of renal health care.

The main purpose of RPM is to increase efficiency and to achieve the quality of healthcare, its modernization, and improvement.

Objective

The systematic review aims to determine that RPM can contribute to improving the healthcare for patients with kidney disease. The main purpose of RPM is to increase efficiency and to achieve the quality of healthcare, its modernization, and improvement.

Proposals and key questions

- Is RPM effective in improving care for patients with kidney disease?
- How can RPM support the Healthcare professional treating patients with kidney disease?
- Can the use of RPM contribute to improving the health care of patients with kidney disease?
- Can the use of RPM contribute to improving the quality of life of kidney disease patients?

The evidence preceding this study demonstrates that adequate early detection of kidney disease is a cornerstone of human and planetary health. RPM interventions especially in prevention, are necessary to help improve patients' quality of life and environmental goals, as well as to reduce healthcare costs from comorbidities associated with CKD.

The objective of the article should include the evaluation of any renal function replacement therapy supported by ICT.

The article should refer to ICT tools used by healthcare professionals and/or patients to support or manage kidney disease.

All articles that refer to kidney disease but do not relate it to any kind of RPM, all articles that refer to RPM but do not use it to support or manage patients with kidney disease and all type of "literature" review about RPM intervention in RRT, should be excluded.

Search strategy

We decided to perform an exhaustive search in several databases such as Web of Science, PubMed, Scopus, Science Direct, SciELO, and Cochran Library to find papers concerning RPM as TIC intervention tool to manage Nephrology patients. To refine the research, we contacted some experts in Nephrology, from Portuguese organizations of Nephrology, Spanish organizations of Nephrology, and European Kidney Health Alliance (EKHA). We also participated in several scientific events on the subject of Nephrology around the world.

RPM – Remote Patient Management Intervention in Nephrology use to be performed using several kinds of ICT interventions tools.

RPM is a subcategory associated to homecare telehealth that enables patients to use mobile-related ICTs and technology to gather patient-generated health data (PGHD) and make it available to healthcare professionals. Common physiological data that can be collected with RPM programs include vital signs, weight, blood pressure, and heart rate. Once collected, patient data is available to a physician's office through the use of a telehealth computer system or software application that can be installed on a computer, smartphone, or tablet.

RPM is frequently used to assist healthcare professionals and their patients who require chronic or acute care. By connecting high-risk patients with remote monitoring, it can notify healthcare organizations of potential health issues or keep track of patient data between visits.[18]

Telehealth and telemedicine

Telehealth is defined as the use of electronic Information and Telecommunication Technologies to support long-distance clinical health care, health-related instruction or training of patients and health professionals, public health and the administration. Technologies include video conferencing, the internet, streaming media, and both work closely to RPM.

Telehealth is different from telemedicine because it refers to a broader scope of remote healthcare services than telemedicine. While telemedicine refers specifically to remote clinical services, telehealth can refer to remote non-clinical services, such as provider training, administrative meetings, and continuing medical education, in addition to clinical services.

We identified 9 studies concerning the Telehealth and 5 studies about Telemedicine, respectively.

Home dialysis

Home dialysis means dialysis performed at home by an ESRD patient or trained caregiver who has completed an appropriate course of training. Home dialysis modalities, including home hemodialysis (HD) and peritoneal dialysis (PD), are associated with increased patient autonomy and treatment satisfaction.

We identified the following 14 studies concerning home dialysis.

Tele homecare

Tele homecare (THC) is a subfield within telehealth, so it needs the RPM intervention. It involves the delivery of healthcare services to patients at home through the use of telecommunications technologies, which enable the interaction of voice, video, and health-related data. We identified a study concerning the Tele homecare.

Self-management

Self-management is about empowering patients to control their condition to help them feel better and have a better quality of life. We need self-management as part of healthcare because someone with a chronic disease as CKD, for example – will only see healthcare professionals for a few hours every year. The rest of the time, the patient is on their own – they are self-managing. During this time alone, patients must cope with whatever their condition throws at them. That's why we are discussing self-management as part of our healthcare. Self-management intervention is a vehicle for helping patients develops skills and techniques to enhance self-care of their chronic conditions. We identified one study concerning the self-management.

Remote management therapy

Remote management of therapy, or RMT, involves monitoring and management of therapies, as the name implies. This refers to the monitoring of general medicine health categories, medication, and therapy adherence, as well as response to therapy. We identified one study concerning the RMT.

Methods

This systematic review search was conducted by searching for studies published from 2005 to May 2022 in several electronic databases as mentioned above. Randomized, Non-randomized, Qualitative and Quantitative controlled trials describing an improved intervention using RPM (e.g., Home based RRT, Telehealth, Telemedicine, Tele-nephrology. mHealth, Self-Management). RPM in patients with some stage of kidney disease were included. Studies that assessed patients and/or HCPs using RPM and/or studies that involve any life-sustaining kidney or renal replacement therapy (e.g., kidney transplantation; pre-dialysis; hemodialysis or peritoneal dialysis) were eligible.

We used as the primary search term "Remote patient monitoring and management in kidney care".

To refine the search and limit to the papers that fit our objective, we use the following specific terms:

- "RPM" AND "Kidney Disease"; "Remote patient*" AND "CKD"; "RPM" AND "RRT"; "RPM" AND "HD"; "RPM" AND "PD"; "RPM" AND "HHD"; "RPM" AND "Dialysis" "RPM" AND "Kidney Transplantation".

Nevertheless, the publications that we achieved by using those filters were not all entirely within the study scope.

Data extraction was independently performed by two reviewers that evaluate study quality and extracted characteristics, aims, outcomes, limitations, and among patients under RRT within the intervention of RPM for each trial. Reference lists from relevant review articles and reviews were also searched. Studies were first screened according to title and abstract, and the full texts of any study considered relevant according to the selection criteria were assessed for eligibility by both reviewers (AML and ARP). Disagreements between the reviewers concerning decisions to include or exclude studies were resolved by consensus, and if necessary, consultation with a third reviewer (JJSO).

Results

The search strategy yielded 2774 records (see Fig. 1). After removing 248 duplicates and excluding 2357 articles in the title and abstract screening, we assessed 86 full-text articles for eligibility, including 8 records identified from searching the reference lists of included articles. Fifty-three articles did not meet the inclusion criteria, which led to 42 articles being included in the systematic review (Table 1 in the appendix).

Forty-seven studies, met the inclusion criteria involving, comprising a total of 5323 patients at any stage of kidney disease, taking into account all known types of treatment. The number of HCPs involved was only mentioned in three studies.[19] Of those studies, some were quantitative, some used qualitative methods, and others adopted mixed methods. Most of the research originated in America (45%) and Europe (27%), the rest are from Asia (14%) and Australia (14%).

In some studies, more than one ICT Intervention is involved in RRT management. We found remote patient management (RRP) present in twenty-one studies; Telehealth in ten studies; Home Dialysis was found in ten studies as well; PC/Tablet/Mobil Phone applications in seven studies; web or Patient Portal in four studies; Telemedicine in five studies; Remote Management Therapy (RMT) in one study; Self-Management in one study; Tele homecare in two studies; and Artificial Intelligence in one study. The objective of RPM platform in all these studies was to improve healthcare for CKD patients.

Table 1 briefly lists most of these findings or outcomes, barriers, and limitations. One of the main challenges is a lack of comfort and familiarity amongst patients and nephrologists, probably due to inadequate education or information. Other common issues include a lack of trained and willing operators to place and troubleshoot dialysis accesses, as well as inadequate infrastructure to care for home dialysis patients.

We describe in the last column of Table 1 the limitations and future research to tackle these challenges and adopt strategies to overcome some of these limitations and expanded home dialysis.

The available results suggest that, overall, RPM can influence the healthcare of patients with kidney disease (e.g., improve access to healthcare services, enhance the quality of life, empower the individual to follow a healthy lifestyle, significantly reduce the rate of readmissions, decrease costs, and so forth). Despite the broad interest in the development of platforms of RPM in the clinical management of chronic diseases, only one specific investigation has been carried out on the use of RPM to prevent kidney disease and assist primary care physicians in its early detection.[20] The purpose of this study was to fill this gap by exploring this issue using a systematic review approach.

In this systematic review, the outcome measures were deliberately kept broad to include all potential outcomes of RRT described in the literature. The review included

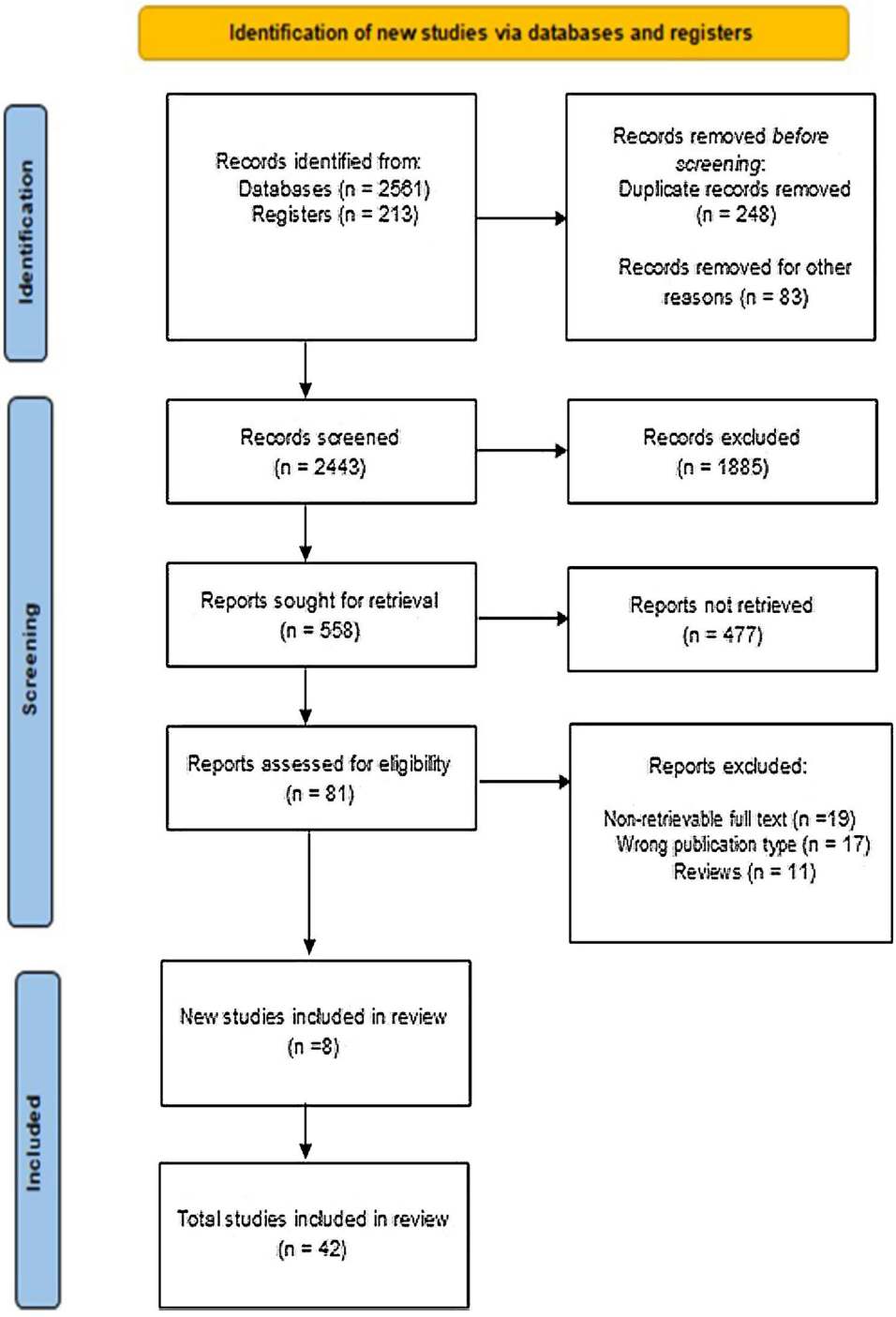

Fig. 1 – Flow chart of search and study selection process.
From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71.

qualitative studies, quantitative studies, including observational, quasi-experimental, and mixed-method study designs, as well as gray literature, and studies not written in English. Such heterogeneity is recommended against meta-analysis. Once duplicates were removed, the titles and abstracts were screened and, after that, full-text articles were assessed to establish eligibility for inclusion. Finally, verification was performed to avoid discrepancies.

Findings and types of outcomes

The included studies used RPM and its subcategory (e.g., Telehealth, mHealth, Home Dialysis, Telemedicine, Self-management), Interventions on Nephrology or RRT.

Overall, the included studies aimed to highlight the effects of using RPM to improve renal replacement therapy modalities.

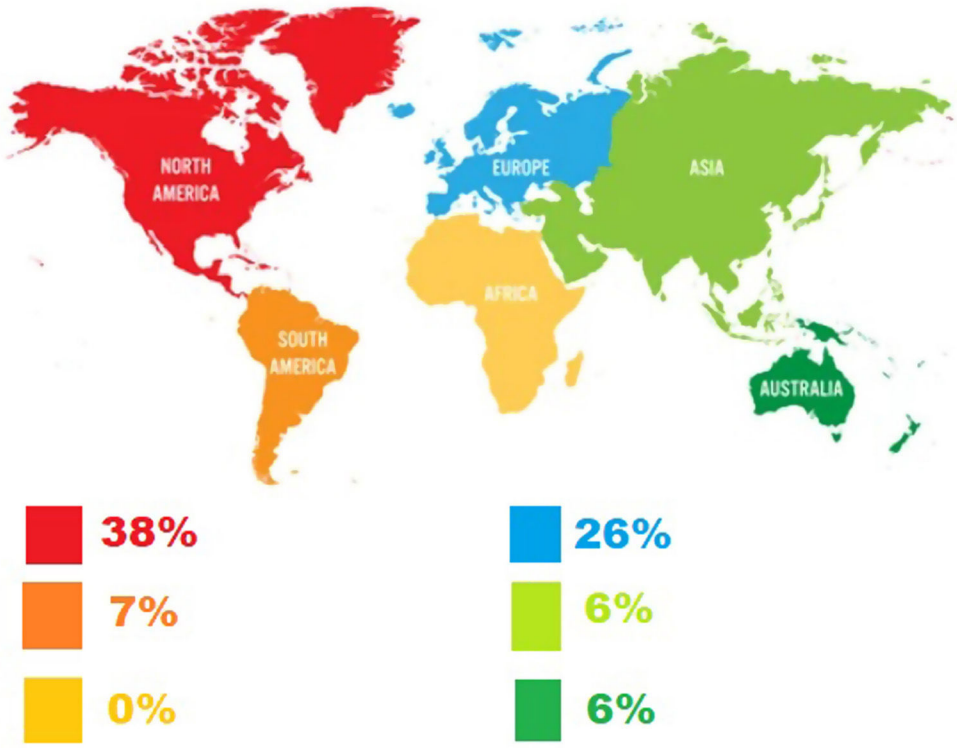

Fig. 2 – The geographic distribution of publications on world map. As some publications is shared by 2 countries, we considered 0.5 for each country sharing publication.

The types of outcomes collected from the included papers embrace the following:

Outcome improvements were found in several studies affecting important treatment issues such as subjects adherence to treatments, care, therapy confidence, quality of life, patient autonomy, patient education, patient and staff satisfaction, home care patients, supply management, patient confidence, patients' feeling of been connected with HCP, patient independence, prescription/treatment personalization.

Lower hospitalizations were mentioned as a consequence of ICT interventions in 5 studies in which the authors concluded that ICT intervention contribute to a reduction in hospitalizations, a fewer hospital consultation, and reduction of hospital workload and emergency visit.

Increase patient satisfaction and acceptance appear as outcome in the following studies in which telemedicine enable to increasing the nephrologist's coverage area and was positive mainly because it increase patient confidence and sense of care during HHD, reduces patient anxiety and increases confidence in the management of their chronic disease condition, tele-monitoring is a useful tool to increase satisfaction with and confidence in home hemodialysis, increased real-time communication between patient and the dialysis center.

Michel Rosner et al. (2019) and Paloma Gallar et al. (2007)[21] mentioned that costs associated with patient travel was referenced as alleviated using RPM or Telemedicine. Sabina Manani et al. (2016) and some other studies found that healthcare costs decreased when using RPM tools for APD[22] or mHealth for support CKD in general.[23]

RPM can improve outcomes and confidence in therapy and is useful tool to increase Satisfaction and confidence in home dialysis.[24] Vishal Dey et al. (2016) concluded that satisfaction scores and retention rates suggest a high level of acceptability in PD.[25] (Na Liu et al., 2017) come across that RPM made the HCP felt better assured with patients' status with the use of system and reported improved productivity and satisfaction with the co-presence enhancement mechanism. In studying the effectiveness of a Web-portal eHealth for deliver care to home dialysis patients, (James Kiberd et al., 2018) note that ICT has been shown to improve self-management and in care satisfaction in a variety of settings, with evidence of improved health outcomes in chronically ill populations. The telemonitoring system for CKD patients undergoing PD present some better features such as: Consistency; interactivity, clarity, feedback, applicability; satisfaction, navigability and help documentation (Marcos Antonio García et al., 2018) is the best feature.

In some studies authors detected that RPM improves adherence to follow-up and reduces healthcare utilization and in presence visits for emergency,[26] telehealth emphasizes its role in reducing hospital visits. Post discharge nurse-led telephone support is helpful for some aspect of quality of life and reducing readmission and clinic visits of patients on PD.

One of the main advantages of integrating RPM in PD is increased adherence to treatment, reduced travel time, reduced carbon footprint. The ecological advantages are debated but are likely to be relevant especially if patients live far from dialysis unit.[27]

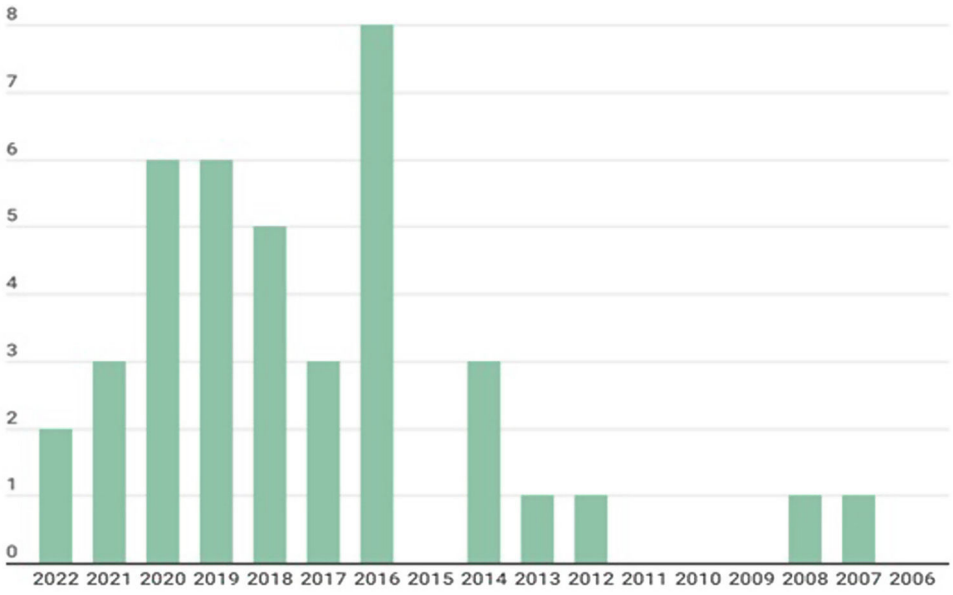

Fig. 3 – Number of publications about RPM in nephrology per year from 2005 to 2022.

Patient education was figured in some studies in which the authors concluded that the RPM increased the level of oversight and education, transferred patient medical information from the patient for the delivery of clinical and educational services with an aim to improve health outcomes. Wael Hussein et al. (2021)[28] found that the home dialysis participants had higher proportions of younger patients, employment, and higher education and a lower proportion of Hispanic patients. Aditi Nayak et al. (2012) realize that the use of RPM for PD patients clearly demonstrates the clinical advantages of ICT in monitoring that patient population.

This study also suggests the need for additional HCP training and support to help ensure that mobile health communication can lead to significant improvements in patient experience with home dialysis care. Marco Landino et al. (2016) found that Tele-Nephrology may afford potential opportunities to reduce the cost of healthcare in patients with multiple renal conditions.

Most of the studies was performed in America (45%) followed by 26% performed in Europe. Asia and Australia contribute with 14% each one (see Fig. 2).

Fig. 3 shows the evolution of publications from 2005 to 2022. The year 2016 with 8 published studies was the year with the highest scientific production in this field, followed by 2019 and 2020 with 6 publications.

PD is the RRT that experienced fastest penetration of ICT. The rapid evolution of this treatment modality has been facilitated by the development of new technology and by recent advances in prescription and monitoring. The half of includes studies (50%) is concerning RPM platforms for PD treatment and 25% is for HD (see Fig. 4).

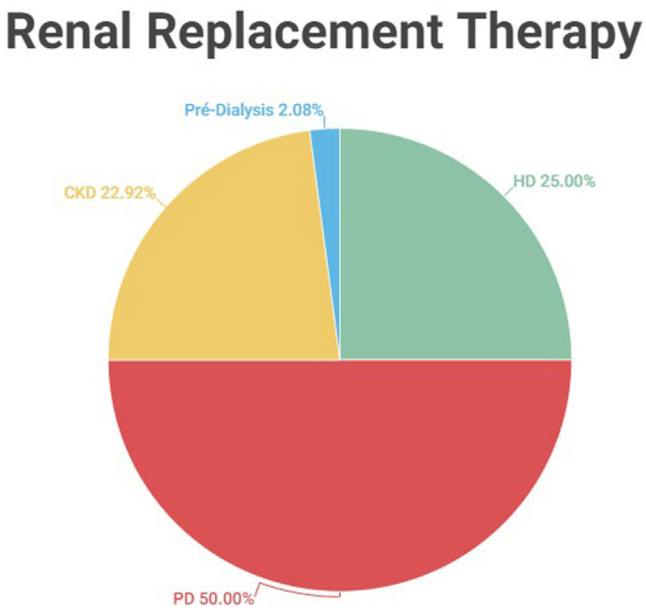

Fig. 4 – RPM penetration – the RRT supported by RPM used in the studies. We used HD for hemodialysis, PD for peritoneal dialysis; TX for transplantation; pre-dialysis and CKD for studies that involve all kind of RRT.

Discussion

Our review of the studies in the previous section finds that all research, related to the RPM intervention in Nephrology, have reached an optimal solution to improve Nephrology healthcare relying on RPM solutions to support Renal Replacement. This study shows that peritoneal dialysis is the RRT modality in which RPM impact mostly.

Table 1 shows the main characteristics of the included studies taking into account the objective, lead author, countries and year of publication, the technologies used in the RPM platforms and the RRT, sample size and duration, when reported, findings, results, and finally gaps or limitations and future research.

This systematic review summarizes the literature on RPM intervention in Nephrology. The included studies focused on the role of RPM in supporting and improving healthcare in Nephrology. The increased use of RPM is leading to the need for healthcare professionals and patients to incorporate technological competence in the practice of different RRT modalities.

Overall, the evidence suggests that RPM has the potential to bring several improvements, as indicated in the Findings, Outcomes and Results column of Table 1.

Currently, the cost of technology to improve most treatments is too high to be borne by the public health system. Therefore, the best approach for kidney disease is to delay the need for dialysis as long as possible. The great challenge is to prevent kidney failure. The economic and environmental cost will be drastically reduced if we apply efforts in the development of RPM platforms to act in the prevention of CKD.

Conclusion

Systematic reviews are the ideal method to rigorously collating, examining, and synthesizing a body of literature. Systematic review methods now exist for most questions that may arise in healthcare. This systematic review found that the ICT intervention in RRT brings many benefits and provides an overview of studies investigating ICT-based interventions to improve the care of patients in need of RRT.

We observed that many home-based tools for nephrology or Renal Replacement Therapy have been developed and widely used by health professionals and patients needed kidney care. Another inference from these studies is that the promise of better outcomes and lower costs can be realized with these tools.

RPM platform to support RRT is getting more attention in nephrology care day by day. Several types of ICT interventions contribute to improving the care of patients who need renal replacement therapy, by improving the outcomes; reducing hospitalization; improve adherence to treatment; improve quality of life. Also reduce the cost of patient travel and the consequent footprint; improve the autonomy and confidence of the patient; better adequacy of the prescription; time saving for HCP and the patient as well. All the benefits listed come from the integration of RPM in the procedures of the nephrology units. Furthermore, RPM platforms can play a very important role in patient education, CKD self-management, home dialysis, tele-nephrology, and remote care of patients, which is a key factor for an effective management strategy to increase patient independence from nephrology units.

Studying the effectiveness of an eHealth web portal in delivering care to home dialysis patients[29] note that ICTs have been shown to improve self-management and satisfaction with care in various settings, with evidence of improved health outcomes in populations with kidney disease. RPM or Telemonitoring[30] system for CKD patients undergoing PD presents some of the best characteristics such as: Consistency; interactivity, clarity, feedback, applicability; satisfaction navigability and help documentation, noticed.

This study has several strengths. In the first place, the analysis of ICT interventions on all modalities of RRT. The second is the list of all identified benefits of ICT interventions on the disease that represent a big challenge worldwide for the current decade. Many previous studies only analyze the intervention of a specific ICT tool on a specific RRT modality. Our study also listed the limitations of the ICT interventions on the RRT. We concluded that there are about 10 most common types of ICT interventions in the RRT, and this may provide a reference for the future of ICT interventions in RRT. In addition, identified several benefits that ICT interventions bring to RRT. Overall, we conclude that ICT intervention in RRT is the cornerstone of kidney disease management, and optimized RRT management is essential to control the several comorbidities of kidney disease and improving kidney disease management.[31]

The results collected through this systematic review led to the identification of different advantages concerning the use of ICT in Nephrology care. It is remarkable to conclude that more than twenty-three percent of the included studies have health cost reduction[32] as the outcome, and more than twenty-one percent present the improvement of quality of life[33] as a finding.

Surprisingly, no studies were found on the use of RPM platform targeting the prevention of kidney disease, even though the progression control only two studies was found. In future studies, there is a need to focus on prevention, to delay disease progression as much as possible with the support of ICT interventions taking in account the new version of KDIGO guidelines that was recently presented at 60th Congress of the European Renal Association (ERA) in Milan.

Future research

Our review identified several avenues research for RPM platforms to support nephrology for bioengineers interested in this field. Development of platforms to manage additional oversight to provide education, periodic assessment by care team to ensure patient safety while using the RPM, performing studies focused on longer-term use, acceptance, and outcomes of RPM. In future RPM should include data mining tools that allow the user to extract reports and consultation with specific information. Smart wearable sensors for real-time monitoring of dialysis patients are something that can help achieve 4P medicine (i.e., Predictive, Precise, Preventive and Personalized). The success of innovations in the PD field will depend on their simplicity, level of automation, biocompatibility, and miniaturized wearable/portable systems. It will be strongly recommendable to investigate the effectiveness of electronic consultation or teleconsultation when compared to face-to-face.

However, an alternative future for RPM could be the rapid development of supportive technologies that increase the number of patients that can be effectively cared for in their homes. Other future areas of study include virtual education about CKD and dialysis modalities, virtual transplantation evaluations, and virtual training for patients and caregivers as new starts dialysis or retrain after a prolonged hospitalization. Measuring and conducting research on the delivered quality of care and patient outcomes, comparing telehealth and standard care along with patient and healthcare provider satisfaction (PROMS) with telehealth will be important determinants of whether the virtual practice continues to grow after COVID-19.[34]

The future outlook for advancing telehealth usage in home dialysis depends on integrating technology with an efficient home program workflow.[35]

Self-management mobile applications should be developed by analyzing and further reflecting home hemodialysis (HHD) patients' needs. Further studies will be performed on patients' compliance with the medication and the relationship to the clinic conditions and quality of life in PD patients and other chronic patients.[36]

This systematic review showed that RPM can bring a very good contribution to the nephrology healthcare, covering all modalities of RRT improving adherence to the treatment, improving outcomes, quality of life; reducing cost; reducing the geographic burdens; save patient and HCP time, etc. But in our opinion, the best approach and future reach should be that RPM should be used successfully to manage the early stage of kidney disease and also to prevent the kidney disease. Future research should be using ICT combined with KDIGO to support the primary care clinicians detecting patients under risk of kidney disease.

In addition to the research on how RPM can improve healthcare in nephrology, we have compiled 42 studies that specifically address the use of RPM in managing CKD. These studies also demonstrate that RPM can increase the number of kidney patients utilizing peritoneal dialysis, reducing the number of HCP need to assist those patients, and improve de quality of life of CKD patients.

Ethics approval

Not applicable.

Informed consent

Not applicable.

Author contributions

AML conceived and conducted the study. JJSO and ARP reviewed and edited the manuscript and approved the final version of the manuscript. All authors contributed significantly to the study design. Material preparation, data collection and analysis were performed by AML, JJSO and ARP. The first draft of the manuscript was written by AML and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript, no other contributors assisted the authors in this work.

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Conflict of interest

The author(s) declared that there is(are) no potential conflict of interest with respect to the research, authorship and/or publication of this article.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.nefro.2024.01.005.

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