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Title

Effect of remote patient monitoring for patients with chronic kidney disease who perform dialysis at home: a systematic review

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Abstract

Objective: The purpose of the systematic review was to assess the effectiveness of remote patient monitoring (RPM) follow-up compared to standard care, for patients with chronic kidney disease (CKD) who perform dialysis at home.

Methods: We conducted a systematic review in accordance with international guidelines. We performed systematic searches for publications from 2015-2021 in five databases (e.g. Medline, Cinahl, Embase) and a search for grey literature in reference lists. Included effect measures were quality of life, hospitalisation, technical failure as the cause for transfer to a different dialysis modality, infections, and time patients use for travel. Screening of literature, data extraction, risk of bias assessment, and certainty of evidence assessment (using the Grading of Recommendations Assessment, Development, and Evaluation approach) were done by two researchers. We conducted metaanalyses when possible.

Results: Seven studies met the inclusion criteria, of which two were randomised controlled trials and five were retrospective cohort studies with control groups. The studies included 9,975 participants from five countries, who were a good representation of dialysis patients in high- and upper-middle-income countries. The patients were on peritoneal dialysis (six studies) or home hemodialysis (one study). There was low to very low certainty of evidence for all of the outcomes. No studies included data for time patients used for travel.

Conclusion: We found low to very low evidence that indicate there may be positive effects of RPM follow-up, in comparison to standard care only, for adult patients with CKD who perform dialysis at home. Offering RPM follow-up for home dialysis patients as an alternative or supplement to standard care appears to be safe and provide health benefits, but future implementation should be coupled with robust, high quality evaluations.

Protocol: Pre-registered in PROSPERO (CRD42021281779).

Strength and limitations of this study

- To our knowledge, this is the first systematic review to assess the effectiveness and safety of remote patient monitoring follow-up for adult patients with dialysis-dependent chronic kidney disease on home dialysis (hemodialysis and peritoneal dialysis).

- Our systematic review was conducted in line with guidelines from the Cochrane and Grade working group. The researchers specialise in systematic review research, one researcher is a registered nurse with long and diverse nephology experience, and the searches were conducted by a search specialist.
- Due to study heterogeneity, inconsistent measurement and reporting, our ability to conduct metaanalyses was limited.

Introduction

Chronic kidney disease (CKD) is a significant public health concern**,** with 8-16% of the world's population affected.[1] It is characterised by a need for close monitoring, poor health outcomes, and a high economic burden for society as well as for the individual.[2] The world's population is growing older, and with CKD prevalence rising parallel with age,[2] an increasing number of people will continue to need monitoring and treatment with dialysis. There are two main types of dialysis: Peritoneal dialysis (PD) and hemodialysis (HD). Both are suitable treatment options when the kidneys are unable to filter the blood sufficiently.[3]

With the use of technology, there are encouraging possibilities for thorough patient follow-up, and at the same time, human resource savings.[4-6] Both PD and HD can be performed at home. With home dialysis, the patients receive comprehensive training arranged by staff at a dialysis centre to ensure that they have the skills and knowledge required to perform the treatment at home.[3 7] While dialysis is time-consuming regardless of location, patients on home dialysis are not dependent on hospital service hours and may experience more freedom than patients receiving in-centre dialysis.[8 9] Additionally, for patients on in-centre dialysis, the burden of time spent commuting between home and hospital can be extensive. They often also spend a substantial amount of time waiting for transport and waiting to be assisted by hospital staff for connection and disconnection from HD. Research shows that travel time to dialysis exceeding 60 minutes is associated with significantly decreased health-related quality of life (QoL) and significantly increased mortality risk compared to patients who travel 15 minutes or less.[10] With dialysis at home, it is reasonable to expect considerable time savings for the patients as well as improved health-related QoL.

In healthcare there is increasing interest in utilising technology-based interventions. Telemedicine and e-health are broad terms used when medical treatment, examination, or patient follow-up is done from a distance.[11] Homecare telehealth is another related term, and

remote patient monitoring (RPM) is a subcategory thereof. RPM uses computer systems or software application technology that transfers patient-generated data to healthcare professionals.[12] Given the intervention considered in this systematic review is internet dependent, we will use the term RPM. RPM can give the patient quick access to medical expertise, independent of the distance to a treatment centre, and provides healthcare teams with valuable information about the patient's condition. Thus, RPM can be a tool to empower patients in self-care and for healthcare providers to offer support from a distance.[11] Qualitative studies from the U.K. and Norway suggest that patients on home dialysis have a positive attitude towards the use of RPM and believe that this could decrease anxiety and make it easier for more patients to choose home dialysis.[13 14] In a recent pilot study from Italy, patients overcame physical, cognitive, and psychological barriers to PD by RPM follow-up.[15]

Strategies to switch more patients to home dialysis may have positive impacts on the patients' daily life,[14 16] decrease mortality,[17] and offer economic savings for the patients as well as for society.[16 18] RPM holds much promise for enhancing follow up of CKD patients on dialysis and it is critical to determine whether and which strategies are effective at improving outcomes. RPM patient follow-up is seemingly already expanding its reach. Our Google Scholar search in December 2021 showed that there has been a 200% increase in records about e-health home dialysis from 2018 to 2021. Although interest in nephrology and e-health, including RPM, is increasing, to date, there are no systematic reviews about the effectiveness and safety of RPM follow-up including adult patients with dialysis-dependent CKD on home dialysis (HD and PD). We aimed to conduct a systematic review on the effectiveness of RPM follow-up compared to standard care, for adult patients with CKD who perform dialysis at home.

Methods

We conducted this systematic review in accordance with guidelines set forth in the Cochrane Handbook for Systematic Reviews of Interventions version 6.2.[19] The pre-specified protocol was registered in PROSPERO (CRD42021281779) and we report in line with the Preferred Reporting for Systematic Reviews and Metaanalyses (PRIMSA) statement.[20]

Search strategy and selection

The reviewers (HN, RB) prepared the search strategy in collaboration with a research librarian (LN), and a second research librarian peer-reviewed the search strategy. The librarian (LN) conducted searches in August 2021 in CINAHL (EBSCO), EMBASE (OVID), Medline (OVID), Cochrane Database of Systematic Reviews, and CENTRAL. The search

included both subject headings (e.g. MeSH in Medline) and text words. Available Supplemental Appendix 1. In addition, the two reviewers conducted hand searches in the reference lists of the included studies.

The basis for the search was the inclusion criteria. We applied the (S)PICO model, which directs attention to the study design, population, intervention, comparison, and outcomes.[21] Eligible study designs were primary intervention studies with a control group. That is, randomised controlled trials (RCTs), non-randomised controlled studies, controlled before-after studies, and cohort studies with a control group. Study participants needed to be 18 years or older, with dialysis dependent CKD who performed dialysis at home (HD or PD). The patients could perform dialysis independently or with assistance of family or other carers. CKD did not have to be the only disease of the study participant. This is because patients with CKD are known to have a higher burden of comorbidities than the average population.[22] The eligible intervention was RPM, understood as internet dependent technology used to transfer treatment data from the patient's home to a healthcare institution.[12] This included video consultations, applications installed on the patient's phone, computer, or a tablet as well as technology that transferred treatment data directly from the dialysis machine to healthcare providers.[12] RPM that was not directly treatment related was excluded. This included, but was not limited to, apps for lifestyle changes, interventions for blood pressure control, and interventions for diabetes management. The comparator was standard care, understood as patients performing dialysis in-centre or at home and having regular in-person consultations at a HD or PD centre. Included effect measures were QoL (measured with any type of QoL assessment tool), hospitalisation (all-cause, disease-specific, and number of hospitalisation days), technical failure as the cause for transfer to a different dialysis modality, hospital registered infections not requiring hospitalisation, and time patients use for travel. Lastly, studies had to be published in a Scandinavian or English language, in 2015-2021 because we wanted to identify all studies relevant to the question and today's clinical situation, being cognisant that technology is rapidly improving.

We imported all records from the searches into an EndNote library and removed all duplicate entries. Two researchers (HN, RB) independently screened all titles and abstracts from the literature searches in accordance with the predetermined inclusion and exclusion criteria. All abstracts that appeared to fit the inclusion criteria or did not provide enough information, were promoted to full text screening. At each level, we evaluated the identified records independently of one another using a pre-developed inclusion form. The final

determination to include or exclude was made together and any disagreements were solved by discussion.

Risk of bias assessment and data extraction

To assess the included studies for risk of bias (RoB) we used two different instruments: The Newcastle-Ottawa scale for cohort studies,[23] and Cochrane Risk of Bias Tool for RCTs.[19] Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed on a final RoB evaluation, with disagreements solved by discussion.

One researcher (HN) created a standard extraction form and extracted data from all included studies. The information extracted from the studies was: title, authors, publication details, study design, aim of the study, study setting (location and time the study was conducted), characteristics of included participants (age, gender etc.), characteristics of the intervention, study setting, outcomes, and results. Whenever information was available, dichotomous and continuous data for all eligible outcomes were extracted. HN contacted several authors for additional data, but did not receive a reply. RB assessed the extracted data for completeness and accuracy and any disagreements were solved by further inspection of the publication and discussion.

Analysis and assessment of the certainty of the evidence (GRADE)

We extracted crude outcome data for all eligible outcomes when postscores for both intervention and control groups were available and, when such data were available, adjusted outcome data (adjusted comparison (effect) estimates and their standard errors or 95% confidence intervals, CI). We provide dichotomous outcomes as the number of events and number of people in groups as proportions, risk ratio (RR), incident RR (IRR) or odds ratio (OR) as appropriate. Continuous outcomes are shown as mean difference (MD) and standard deviations (SD), or the most appropriate presentation based on the available data in the included studies.

We evaluated the characteristics of the studies' (S)PICO and when they were considered sufficiently similar, and data were available, we conducted metaanalyses. The judgments about whether metaanalyses were appropriate were based on recommendations in the Cochrane Handbook.[19] We used Mantel-Haenszel random effects metaanalysis for dichotomous outcomes and we presented the relative risks and their corresponding 95% CI (it was not possible to metaanalyse any continuous outcomes). We also examined between-study heterogeneity using visual inspection of CIs, the Chi-square test, and Isquare statistic,

quantifying the degree of heterogeneity as described in the Cochrane Handbook.[19] We used RevMan version 5.4, the latest version of the Cochrane metaanalysis software.[24] When the studies' (S)PICOs or results were too heterogeneous to pool statistically, or data were unavailable, we reported the results narratively, in text and tables. We planned to perform a subgroup analysis for the outcome technical failure, but this was not possible due to lack of data.

We assessed the certainty of the evidence using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework.[25]

Patient and public involvement

Due to the nature of the study (systematic review), no patients were involved.

Results

The searches returned 451 references after removal of duplicates (Figure 1). We read 24 reports in full text, including one study identified from the hand search in reference lists. The most common primary reasons for exclusion were that there was no control group or it was the wrong participants or outcomes. Seven studies published between 2018-2021 were eligible for inclusion.[26-32]

Description of the studies

The seven included studies consisted of two RCTs and five retrospective cohort studies (Table 1). They were conducted in five different countries. There were two studies each from Columbia and USA, and one study each from China, Italy, and South Korea. Three were set in a single PD centre, four took place in two or more renal care centres and the two largest studies took place in the USA with one including 55 home HD centres and another 931 Fresenius PD clinics.

Table 1: Description of the included studies (n=7)

Author, (country, setting) Study design	Population	Intervention and comparator (follow-up time)	Outcomes	Risk of bias
Cao 2018 (China: 1 PD centre) RCT	N=160, on CAPD Men 58% Mean age 52	RPM vs SC Instant messaging application (mean 11.4 mo FU)	Hospitalisations Infections Technical failure	Moderate
Chaudhuri 2020 (USA: 931 renal centres) Cohort	N=6343, on PD Men 73% Mean age 57	RPM vs SC "Patient hub" application (12 mo FU)	Hospitalisations Technical failure	Low
Corzo 2020	N=558, on APD Men 60%	RPM vs SC Cloud-based software	Technical failure	Low

(Columbia: 5 renal centres) Cohort	Mean age 54	(mean 8.3 mo FU)		
Jung 2021 (South Korea: 6 renal centres) RCT	N=57, on APD Men 60% Mean age 47	RPM vs SC Cloud-based software (6 mo FU)	QoL	Moderate
Milan 2020 (Italy: 1 PD centre) Cohort	N=73, on APD Men 75% Median age 60	RPM vs SC Cloud-based software (6 mo FU)	Hospitalisations Technical failure QoL	Low/ Moderate
Sanabria 2019 (Columbia: 28 Baxter renal care centres) Cohort	N=360, on APD Men 66% Mean age 57	RPM vs SC Cloud-based software (Mean 9 mo FU)	Hospitalisations Technical failure	Low
Weinhandl 2018 (USA: 55 HHD centres) Cohort	N=2424, on HHD Men 63% Mean age 53	RPM vs SC Nx2me telehealth platform (Mean 11 mo FU)	Technical failure	Low

Legend: APD=Automated peritoneal dialysis; CAPD=Continuous peritoneal dialysis; FU=Follow-up; HHD=Home hemodialysis; mo=Months; PD=Peritoneal dialysis; QoL=Quality of life; RCT= Randomised controlled trial; RPM=Remote patient monitoring; SC=Standard care

With respect to the population, all in all, there were 9,975 dialysis-dependent CKD patients in the studies (range 57-6343 patients). In all the studies most patients were male (range 53%-75%) and the mean age of the study participants was about 55. In all studies except one, the patients were on PD, they lived at home, and performed dialysis independently or with the assistance of a carer.

As per our inclusion criteria, the intervention was remote patient monitoring with different types of software that collected treatment data and transferred it to a treatment centre (added by the patients or automatically collected). The follow-up time ranged from 6 to 12 months. Four studies, Corzo et al.,[28] Jung et al.,[29] Milan et al.[30] and Sanabria et al.[31] used the automated PD system from Baxter: Homechoice Claria™, connected to the Sharesource platform. Milan et al.[30] additionally used the sleep-safe harmony home bridge system from Fresenius for half of the patients. Weinhandl & Collins[32] used the Nx2me telehealth platform for home HD patients. The software collects treatment data and transmits it to the healthcare providers, and the prescription can be changed 'from afar'. Chaudhuri et al.[27] used the "Patient hub" application. The PD patients can see their prescription, laboratory results, and enter treatment data, and the app transmits the patient-entered data to the healthcare providers. Cao et al.[26] used the "kidney cleaning group" instant messaging software. Technical support, nurse support, physician support, and support from fellow patients was available through chat and video. The patients were divided in smaller groups and one experienced PD patient with few complications was the group leader. Educational resources were also available in the platform. In addition, in all studies, all patients had or were likely to receive some level of standard care. This was generally described as in-person follow-up at the hospital. However,

the frequency of standard care ranged from weekly (n=1) to every three months (n=1). Most studies had or were likely to have an in-person review monthly (n=5).

Risk of bias of included studies

The RCTs had moderate risk of bias, while the retrospective cohort studies were rated fair to good methodological quality, i.e. having low to moderate risk of bias (Table 1 and Supplemental Appendix 2).

Effect of RPM versus standard care

Across the studies, there were data on four of our five pre-determined outcomes: Hospitalisation,[26 27 30 31] infections,[26] technical failure as the cause for transfer to a different dialysis modality,[26-28 30-32] and QoL.[29 30] The results are described in the text below, Table 2, and Figure 2. The GRADE assessments in Table 3 show that there was low to very low certainty of evidence for all of the outcomes. This means that the effects are largely uncertain. No publications included data for the outcome 'time patients used for travel'.

Table 2. Study outcomes and effect estimates

Study	Outcome	Result/Effect estimate (95% CI)
Hospitalisations		
Chaudhuri 2020 Milan 2020 Sanabria 2019	Hospitalisation days (12 mo) Hospitalisation days (6 mo) Hospitalisation days (9 mo)	Adj. IRR 0.68 (0.55-0.83) Median 5 days difference P 0.55 Adj. IRR 0.46 (0.23-0.92)
Cao 2018 Chaudhuri 2020 Milan 2020 Sanabria 2019	Hospitalisation all-cause (11 mo) Hospitalisation all-cause (12 mo) Hospitalisation all-cause (11 mo) Hospitalisation all-cause (9 mo)	RR 0.57 (0.17-1.88) Adj. IRR 0.74 (0.66-0.83) RR 1.33 (0.63-2.81) Adj. IRR 0.61 (0.39-0.95)
Infections		
Cao 2018	Infections (11 mo)	More peritonitis (60 in RPM group vs 40 in control group per patient month) but less exit site infections with RPM (RR= 0.45, 0.12-1.68)
Technical failure as cause for transfer to a different dialysis modality		
Cao 2018 Chaudhuri 2020 Corzo 2020	Technical failure (11 mo) Technical failure (12 mo) Technical failure (8 mo)	RR 1.00 (0.26-3.86) Adj. HR 0.79 (0.63-1.00) IRR 0.88 (0.41-1.74)
Sanabria 2019 Weinhandl 2018	Technical failure (subgroup) (9 mo) Technical failure (subgroup) (11 mo)	RR 0.97 (0.42-2.25) Adj. HR 0.66 (0.50-0.86)
Quality of life		
Jung 2021 Milan 2020	QoL -Patient satisfaction questions (6 mo)	Mean 75.5 in RPM group vs 73.7 in SC group Median 83.3 in both groups

	QoL -Patient satisfaction questions (6 mo)	
Jung 2021 Milan 2020	QoL -Dialysis staff encouragement (6 mo) QoL -Dialysis staff encouragement (6 mo)	Mean 93.1 in RPM group vs 97.1 in SC group Median 100 in both groups

Legend: Adj=Adjusted; HR=Hazard ratio; IRR=Incident rate ratio; mo=Months; QoL=Quality of life; RPM=Remote patient monitoring; RR=Relative risk; SC=Standard care

Table 3: Summary of findings (GRADE)

Population: Patients with CKD
Countries: China, Columbia, Italy, South Korea, USA

Intervention: RPM

Comparison: Standard care

Outcome, follow-up time	**Anticipated absolute effects* (95% CI)**		**Relative effect (95% CI)**	**No. of participants (Studies)**	**Quality of evidence (GRADE)**
	Assumed risk with control	Assumed risk with RPM			
Hospitalisations (6-12 months)					
Days	All 3 cohort studies showed that there were fewer hospitalization days in the RPM group (Table 2)			6,736 (3)	⊕⊕◯◯ LOW
All-cause	3 of 4 studies (1 RCT, 3 cohort) showed that there were fewer hospitalizations in the RPM group (Table 2)			6,936 (4)	⊕◯◯◯ VERY LOW[1]
Disease-specific	30/198 (15.2%)	10/110 (9.1%)	RR 0.62 (0.31 to 1.24)	308 (2 cohort)	⊕◯◯◯ VERY LOW[2]
Infections (11 months)					
	1 RCT reported more peritonitis but fewer exit site infections with RPM (Table 2)			160 (1)	⊕◯◯◯ VERY LOW[3]
Technical failure (6-12 months)					
	521/2230 (23.4%)	136/786 (17.3%)	RR 0.78 (0.66 to 0.93)	2856 (3 cohort)	⊕◯◯◯ VERY LOW[4]
	2 of 3 studies (1 RCT, 2 cohort) reported fewer failures with RPM (Table 2)			7161 (3)	
Quality of life (6 months)					
Patient satisfaction	1 RCT found higher QoL in the RPM group, 1 cohort found QoL was similar in the two groups (Table 2)			130 (2)	⊕◯◯◯ VERY LOW[5]

Dialysis staff encouragement	1 RCT found higher QoL in the RPM group, 1 cohort found QoL was similar in the two groups (Table 2)	130 (2)	⊕◯◯◯ VERY LOW[5]
Travel time	0 studies assess this outcome		No evidence

1. Downgraded by 1 level because of moderate risk of bias in 1 study and inconsistency
2. Downgraded by 1 level because of imprecision
3. Downgraded by 3 levels because of moderate risk of bias, inconsistency, imprecision
4. Downgraded by 1 level because of moderate risk of bias in 1 study and imprecision
5. Downgraded by 1 level because of inconsistency and imprecision

CI: Confidence interval; RCT: Randomised controlled study; SD: Standard deviation. *The risk in the intervention group (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).

Hospitalisations

One RCTs and three observational studies from Italy, Colombia, China, and the USA examined the effect of RPM on hospitalisations.[26 27 30 31] However, the outcome was reported differently across the studies, as hospitalisation days/days admitted, all-cause hospitalisations, and disease-specific hospitalisations (caused by overhydration, access dysfunction, and infections).

Hospitalisation days. The three observational studies, Chaudhuri et al.,[27] Milan et al.,[30] and Sanabria et al.[31], all found fewer hospitalisation days in the RPM group than the control group (Table 2). The results in Sanabria et al.[31] were from a matched sample, as data for the whole sample was not available. This study showed the largest effect with a difference of six hospitalisation days (IRR 0.46, 0.23-0.92).

All-cause hospitalisations. One RCT[26] and three observational studies[27 30 31] had data on general, all-cause hospitalisations. While three of the four studies showed that RPM users had less all-cause hospitalisations than patients with standard care only, the fourth study favoured standard care (Table 2).

Disease-specific hospitalisations. The results on disease-specific hospitalisations from two observational studies, Milan et al.,[30] and Sanabria et al.[31] could be pooled in a metaanalysis (Figure 2). The non-significant result suggested there were fewer disease-specific hospitalisations in the RPM group than in the control group (RR 0.62, 95% CI 0.31-1.24).

Milan et al.[30] defined disease-specific hospitalisations as infections (peritonitis and exit site), overhydration, and access dysfunction. Sanabria et al.[31] provided numbers for hospitalisations due to peritonitis and overhydration.

Infections not requiring hospitalisation

Only one RCT, from China, examined the effectiveness of RPM follow-up for PD patients on infections.[26] The result for this outcome was inconclusive, as Cao et al. found more peritonitis but fewer exit site infections with RPM. It was not specified whether the infections were treated at home or in the hospital.

Technical failure as the cause for transfer to a different dialysis modality

One RCT from China [26] found no difference between the groups while five observational studies from the USA[27 32], Colombia[28 31], and Italy[30] consistently reported less technical failure as cause for transfer to a different dialysis modality in the RPM group compared to the control group (Table 2). Three of the cohort studies could be pooled in a metaanalysis; the result implies benefit of RPM (0.78, 95% CI 0.66, 0.92) (Figure 2). Two of the studies[31 32] gave data on novice patients with less than three months treatment duration at baseline, indicating a positive, but non-significant effect of RPM in new patients (Table 2).

Self-reported Quality of Life

Both studies, one RCT[29] and one observational study,[30] reporting on quality of life used the tool 'The short form of kidney disease quality of life' (KDQOL), which is an adaptation of SF-36.[33] All answers were transformed into pre-coded numeric values with a range from 0-100, where 100 was the highest QoL.[34] Neither studies offered an overall total score across the questions/areas, and we selected the two questions/areas that we considered most relevant (patient satisfaction and dialysis staff encouragement). For both patient satisfaction and dialysis staff encouragement, Milan et al.[30] found the same score in both groups, while Jung et al.[29] found a higher score in the RPM group than the control group concerning patient satisfaction but opposite for dialysis staff encouragement (Table 2).

Discussion

Principal findings

This systematic review advances the evidence on the effects of RPM for patients with dialysis dependent CKD on home dialysis, including home HD and PD. Our findings are in line with previous research[35 36] and document that there is no conclusive evidence, but that positive effects of RPM are indicated for clinical outcomes, technical failure, and quality of life.

The results consistently suggest that RPM reduces hospitalisations and the number of days the patient is admitted. It was especially convincing that Milan et al.[30] observed a median difference of five fewer hospitalisation days in the RPM group over six months, because the patients on RPM had a worse comorbidity score. Furthermore, except for one study that found the same number of technical failures in both groups, the other five studies found less technical failure in the RPM group. In four of the studies measuring this outcome, prescriptions could be changed from the hospital without in-person consultations. In effect, RPM allows resolving technical issues early, thus preventing progression of technical failure to the stage where the patient would need to transfer to a different dialysis modality. Research has found great advantages with the technology displaying possible causes and solutions to problems, alarm indicators showing who to contact for guidance (nurse or technician), and reminders of activities that need to be performed.[13-15] Concerning quality of life, only two studies assessed this and the results showed the scores were comparable for the patients on RPM and usual care. Encouragingly, scores for quality of life improved and patient satisfaction was higher than neutral. This is in line with a study from the U.S. that found that RPM increased patients' confidence and satisfaction with treatment because they felt more closely supported.[35] Lastly, no studies assessed time patients use for travel. However, research suggests that health-related quality of life and time patients use for travel are intertwined[10] and that dialysis free time and reduction of fatigue are highly valued outcomes by patients.[9 36 37] This could reflect positively on quality of life.

Our results mirror two earlier systematic reviews on e-health interventions in PD patients[38] and in people with CKD.[39] Both reviews, with literature searches in 2018-2019, included a wide range of patients and e-health modalities, including mobile or tablet application, text or email messages, electronic monitors, internet/websites, and video or DVD. Consequently, there was minimal overlap in included studies: Only one review[38] included two of our included studies. Both reviews concluded that the quality of evidence for the effectiveness of e-health was low with uncertain effects, but that no adverse effects were indicated. Of note, a recent modelling analysis projected that in a cohort of 100 patients on automated PD over 1 year, RPM would lead to 27 fewer hospitalisations, 518 fewer hospitalization days, 31 additional months free of complications, and six fewer peritonitis episodes.[40]

Implications

Overall, the low to very low certainty of evidence on the effects of RPM for patients with dialysis dependent CKD on home dialysis prevents strong recommendations. Given RPM seems comparable to usual care, the absence of adverse effects and promising clinical effects, it seems advisable cautiously to implement RPM while concomitantly evaluating outcomes important for patients. Prior to recommending RPM for CKD patients on home dialysis, more trials are needed to be certain of its benefits over standard care, and to establish equity and cost effectiveness. A modelling analysis from the payer perspective has found that RPM is cost effective,[40] but economic evaluations of e-health interventions are scarce and highlights an important area for further research.[5 41] Additionally, patient groups should be involved in RPM implementation and evaluation, to maximize the potential for modification and ultimately effect.

Our review highlights the need for robust, high quality research on both PD and home HD, but especially for patients on home HD and patients whose home is in a nursing home. To our knowledge, home HD in nursing homes is rare, while PD is common. It is likely that nursing home staff aided by RPM support from specialist nurses at dialysis centres could provide invaluable assistance to frail CKD patients with great need for follow-up. For such patients and others with dialysis dependent CKD on home dialysis, time used for travel and dialysis free time is a patient-important outcome that warrants further research. It is reasonable to suspect substantial time-savings when follow-up is performed from afar and evidence from video consultations in patient follow-up are positive.[15 42] We encourage research on the combined use of video consultations and cloud-based technology on outcomes such as travel time, technical failure, and hospitalisations.

Strengths and limitations

Our systematic review was conducted in line with guidelines from the Cochrane and Grade working group. The researchers specialise in systematic review research, one researcher is a registered nurse with long and diverse nephrology experience, and the searches were conducted by a search specialist. Yet, it is possible that relevant studies have been missed and relevant studies have been published after our last search. Due to study heterogeneity, inconsistent measurement and reporting, our ability to conduct metaanalyses was limited. Therefore, it was neither possible to improve precision to any great extent, nor statistically assess potential differences across groups, such as type of platform or HD and PD. We contacted several authors asking for more data, but did not receive a reply.

Conclusion

This systematic review summarises and presents low to very low evidence that indicate there may be positive effects of RPM follow-up, in comparison to standard care only, for adult patients with CKD who perform dialysis at home. Offering RPM follow-up for home dialysis patients as an alternative or supplement to standard care appears to be safe and provide health benefits, but future implementation should be coupled with robust, high quality evaluations. Despite the high interest in RPM and increasing demands for nephrology services, good quality evidence is still needed to determine their effectiveness.

Contributors

HN wrote the first draft. RB and HN contributed equally to the rest of the work. LN prepared and conducted the systematic searches and contributed with inputs on the final draft. We are grateful to [removed for blind review], for peer review of the systematic search strategies

Competing interests

'None declared'.

Ethics Approval

Patient and public involvement. Due to the nature of the study (systematic review), no patients were involved.

Funding

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Data availability statement

Data are available on reasonable request.

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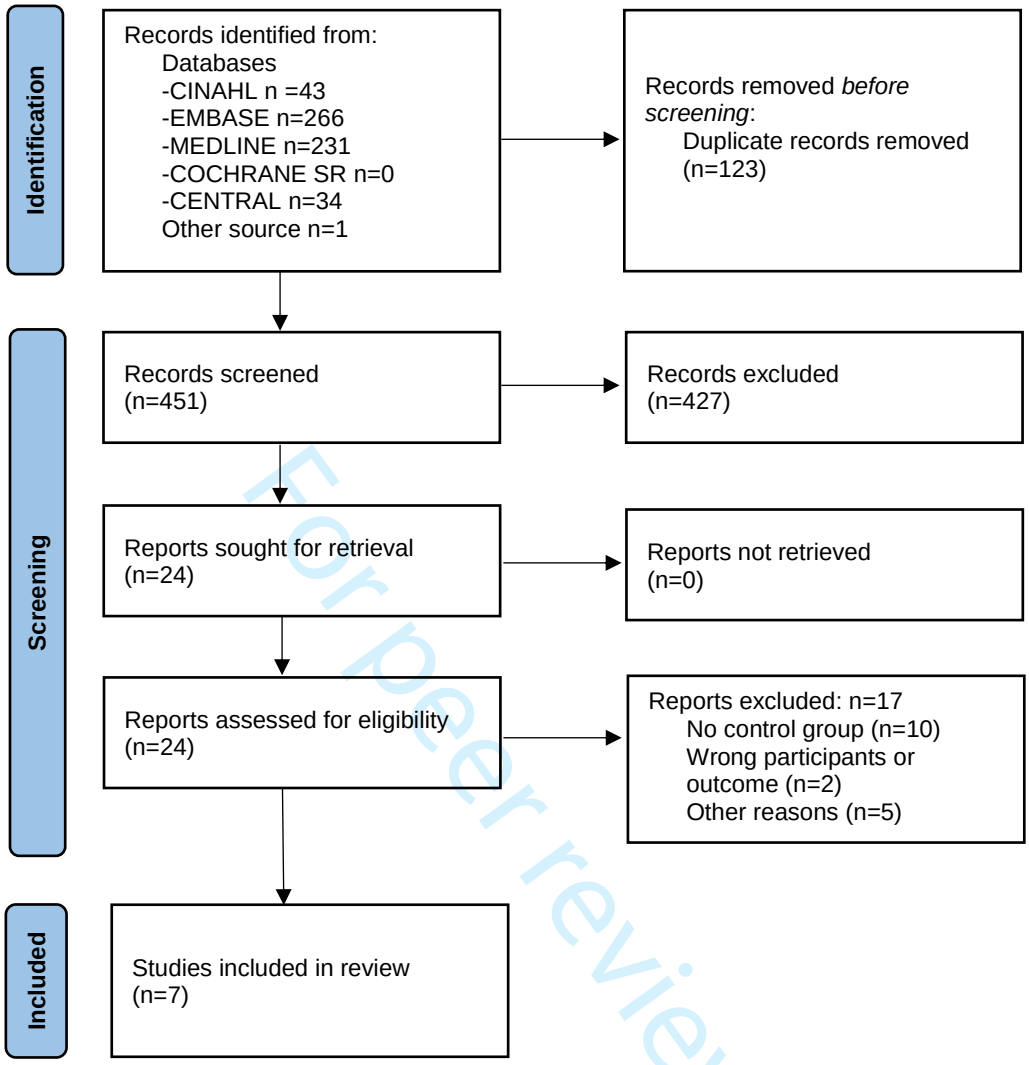
Figure legend:

Figure 1: Prisma flow diagram for selection of studies

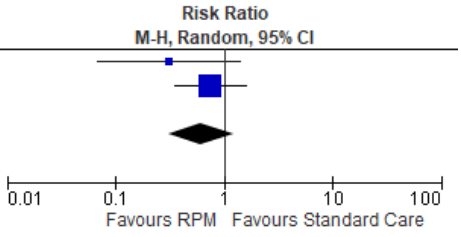
Figure 2: Metaanalyses of outcomes disease specific hospitalisations and technical failure



(a) Disease specific hospitalisations

Study or Subgroup	RPM Events	RPM Total	Standard Care Events	Standard Care Total	Weight	Risk Ratio M-H, Random, 95% CI
Milan 2020	2	35	7	38	21.3%	0.31 [0.07, 1.39]
Sanabria 2019	8	75	23	160	78.7%	0.74 [0.35, 1.58]
Total (95% CI)		**110**		**198**	**100.0%**	**0.62 [0.31, 1.24]**
Total events	10		30			

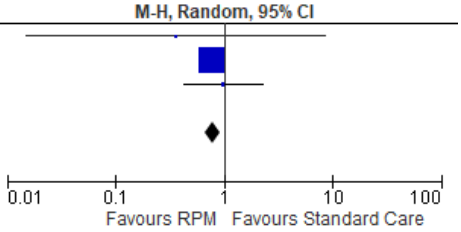
Heterogeneity: Tau² = 0.01; Chi² = 1.04, df = 1 (P = 0.31); I² = 4%
Test for overall effect: Z = 1.35 (P = 0.18)



(b) Technical failure

Study or Subgroup	RPM Events	RPM Total	Standard Care Events	Standard Care Total	Weight	Risk Ratio M-H, Random, 95% CI
Milan 2020	0	35	1	38	0.3%	0.36 [0.02, 8.58]
Weinhandl 2018	126	606	488	1817	95.7%	0.77 [0.65, 0.92]
Sanabria 2019	6	65	28	295	4.1%	0.97 [0.42, 2.25]
Total (95% CI)		**706**		**2150**	**100.0%**	**0.78 [0.66, 0.92]**
Total events	132		517			

Heterogeneity: Tau² = 0.00; Chi² = 0.50, df = 2 (P = 0.78); I² = 0%
Test for overall effect: Z = 2.88 (P = 0.004)



Supplemental Appendix 1: Search strategies

Date: 23.08.2021
Searches conducted by: Lien Nguyen
Search strategies peer reviewed by: Elisabet Hafstad

Database	Number of hits
Embase <1974 to 2021 August 20> (OVID)	266
Ovid MEDLINE(R) ALL <1946 to August 20, 2021>	231
Cochrane Library of Systematic Reviews (Cochrane Library; Wiley)	0
CENTRAL(Cochrane Library; Wiley)	34
CINAHL (EBSCO)	43
Total number of references	574
Total after duplicate removal	451

Database: Embase

Search interface: Advanced Search

1 exp telehealth/ 60896

2 exp telecommunication/ 87729

3 exp health care delivery/ 3564027

4 2 and 3 65304

5 (telecare* or teleconsult* or telefollow* or telehealth* or telehome* or telemanag* or telemedicine or telemonitor* or telenurs* or telepatient* or telesupport*).ti,ab,kw,bt. 33953

6 ((tele or telemedical* or tele medical*) adj (care* or checkup* or check up* or consult* or followup* or follow up* or health* or home* or manag* or medicine* or monitor* or nurs* or patient* or support*)).ti,ab,kw,bt. 1853

7 (ecare or econsult* or ehealth or emedicine* or enurs* or mcare or mconsult* or mhealth or mnurse or mcare or mnursing or mconsult* or mnurs*).ti,ab,kw,bt. 10706

8 ((e or m or mobile or digital) adj (care or consult* or health* or nurs*)).ti,ab,kw,bt. 15428

9 (remote adj2 (care* or checkup* or check up* or consult* or followup* or follow up* or health* or home* or manag* or medicine* or monitor* or nursing or patient* or self)).ti,ab,kw,bt. 12293

10 1 or 4 or 5 or 6 or 7 or 8 or 9 92070

11 hemodialysis/ 115843

12 exp peritoneal dialysis/ 44307

13 home dialysis/ 2966

14 (((dialysis or hemodialysis or haemodialysis) adj4 home?) or peritoneal dialysis).ti,ab,kw,bt. 37655

15	(CAPD or APD or HHD).ti.	3524
16	or/11-15	151629
17	10 and 16	534
18	limit 17 to yr=2000-current	516
19	(exp animals/ or exp invertebrate/ or animal experiment/ or animal model/ or animal tissue/ or animal cell/ or nonhuman/) not (human/ or normal human/ or human cell/)	6724645
20	editorial.pt.	699530
21	18 not (19 or 20)	494
22	limit 21 to embase	270
23	remove duplicates from 22	266

Database: OVID MEDLINE

Search interface: Advanced Search

1	Telemedicine/	29751
2	Telenursing/	232
3	Remote Consultation/	5273
4	or/1-3	34165
5	exp Telecommunications/	108428
6	(care or healthcare).hw.	1324775
7	5 and 6	19771
8	4 or 7	42042
9	(telecare* or teleconsult* or telefollow* or telehealth* or telehome* or telemanag* or telemedicine or telemonitor* or telenurs* or telepatient* or telesupport*).ti,ab,kf,bt.	26067
10	((tele or telemedical* or tele medical*) adj (care* or checkup* or check up* or consult* or followup* or follow up* or health* or home* or manag* or medicine* or monitor* or nurs* or patient* or support*)).ti,ab,kf,bt.	1020
11	(ecare or econsult* or ehealth or emedicine* or enurs* or mcare or mconsult* or mhealth or mnurse or mcare or mnursing or mconsult* or mnurs*).ti,ab,kf,bt.	10618
12	((e or m or mobile or digital) adj (care or consult* or health* or nurs*)).ti,ab,kf,bt.	13372
13	(remote adj2 (care* or checkup* or check up* or consult* or followup* or follow up* or health* or home* or manag* or medicine* or monitor* or nursing or patient* or self)).ti,ab,kf,bt.	8231
14	or/8-13	69186

15	Renal Dialysis/	94819
16	Hemodialysis, Home/	2013
17	exp Peritoneal Dialysis/	26840
18	(((dialysis or hemodialysis or haemodialysis) adj4 home?) or peritoneal dialysis).ti,ab,kf,bt.	28202
19	(CAPD or APD or HHD).ti.	2685
20	or/15-19	121750
21	14 and 20	271
22	limit 21 to yr=2000-current	243
23	exp animals/ not humans/	4877030
24	(news or editorial or comment).pt.	1512750
25	22 not (23 or 24)	231
26	remove duplicates from 25	231

Database: Cochrane Database of Systematic Review & CENTRAL

Search interface: Advanced Search > Search Manager

ID	Search	Hits
#1	[mh ^telemedicine]	2414
#2	[mh ^telenursing]	31
#3	[mh ^"remote consultation"]	381
#4	#1 or #2 or #3	2777
#5	[mh telecommunications]	7362
#6	[mh ^"delivery of health care"]	806
#7	[mh ^"health services"]	458
#8	#5 and (#6 or #7)	139
#9	#4 or #8	2838
#10	(telecare* or teleconsult* or telefollow* or telehealth* or telehome* or telemanag* or telemedicine or telemonitor* or telenurs* or telepatient* or telesupport*):ti,ab,kw	7370
#11	((tele or telemedical* or tele-medical*) NEXT (care* or checkup* or check-up* or consult* or followup* or follow-up* or health* or home* or manag* or medicine* or monitor* or nurs* or patient* or support*)):ti,ab,kw	446

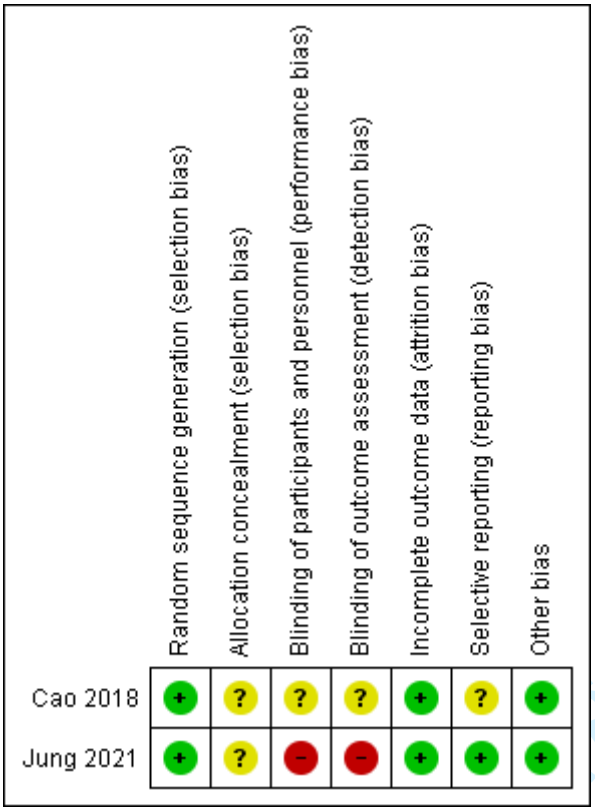
#12	(ecare or econsult* or ehealth or emedicine* or enurs* or mcare or mconsult* or mhealth or mnurse or mcare or mnursing or mconsult* or mnurs*):ti,ab,kw	2547
#13	((e or m or mobile or digital) NEXT (care or consult* or health* or nurs*)):ti,ab,kw	3725
#14	(remote NEAR/2 (care* or checkup* or check-up* or consult* or followup* or follow-up* or health* or home* or manag* or medicine* or monitor* or nursing or patient* or self)):ti,ab,kw	1743
#15	{or #9-#14}	11340
#16	[mh ^"Renal Dialysis"]	4322
#17	[mh ^"hemodialysis, home"]	43
#18	[mh "Peritoneal Dialysis"]	900
#19	(((dialysis or hemodialysis or haemodialysis) NEAR/4 home?) or "peritoneal dialysis"):ti,ab,kw	2491
#20	(CAPD or APD or HHD):ti	409
#21	{or #16-#20}	6775
#22	#15 and #21 with Cochrane Library publication date Between Jan 2000 and Aug 2021, in Cochrane Reviews	0
#23	#15 and #21 with Publication Year from 2000 to 2021, in Trials	34

Database: CINAHL

Search interface: Advanced Search

Supplemental Appendix 2: Description of the studies' risk of bias

Risk of bias for the RCTs



Risk of bias for the retrospective cohort studies

Study	Selection				Comparability	Outcome			Stars: Quality
	1	2	3	4		1	2	3	
Chaudhuri 2020	1b*	2a*	3a*	4b	1ab**	1b*	2a*	3d	7: Good
Corzo 2020	1b*	2a*	3a*	4b	1ab**	1b*	2a*	3b*	9: Good
Milan 2020	1c	2a*	3a*	4b	1-	1b*	2a*	3b*	6: Fair
Sanabrina 2019	1b*	2a*	3a*	4b	1ab	1b*	2a*	3b*	9: Good
Weinhandl 2018	1b*	2a*	3a*	4b	1ab**	1b*	2a*	3d	7: Good

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	p. 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	p. 2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	p. 3-4
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	p. 4
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	p. 4-6
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	p. 4 & supplement file 1
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Supplement file 1
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	p. 5
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	p. 6
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	p. 5-6
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	p. 6
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	p. 5-6
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	p. 6
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	p. 6
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	NA
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	p. 6
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	p. 6
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	NA
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	NA
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	NA

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	p. 6
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Figure 1 & p. 7
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	p. 7
Study characteristics	17	Cite each included study and present its characteristics.	Table 1 & p. 7
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Supplement file 2
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Figure 2 & table 2
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	p. 9
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	p. 9 & Figure 2
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	NA
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	NA
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	NA
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Table 3
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	p. 10-11
	23b	Discuss any limitations of the evidence included in the review.	p. 11-12
	23c	Discuss any limitations of the review processes used.	p. 11-12
	23d	Discuss implications of the results for practice, policy, and future research.	p. 11
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	p. 2 & 4
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	p. 2 & 4
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	p. 6
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	No support for review
Competing interests	26	Declare any competing interests of review authors.	No conflicts to declare
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Available on request

PRISMA 2020 Checklist

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

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Effect of remote patient monitoring for patients with chronic kidney disease who perform dialysis at home: a systematic review

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Title

Effect of remote patient monitoring for patients with chronic kidney disease who perform dialysis at home: a systematic review

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Word count: 3998

Abstract

Objective: The purpose of the systematic review was to assess the effectiveness of remote patient monitoring (RPM) follow-up compared to standard care, for patients with chronic kidney disease (CKD) who perform dialysis at home.

Methods: We conducted a systematic review in accordance with international guidelines. We performed systematic searches for publications from 2015-2021 in five databases (e.g. Medline, Cinahl, Embase) and a search for grey literature in reference lists. Included effect measures were quality of life, hospitalisation, technical failure as the cause for transfer to a different dialysis modality, infections, and time patients use for travel. Screening of literature, data extraction, risk of bias assessment, and certainty of evidence assessment (using the Grading of Recommendations Assessment, Development, and Evaluation approach) were done by two researchers. We conducted metaanalyses when possible.

Results: Seven studies met the inclusion criteria, of which two were randomised controlled trials and five were retrospective cohort studies with control groups. The studies included 9,975 participants from five countries, who were a good representation of dialysis patients in high- and upper-middle-income countries. The patients were on peritoneal dialysis (six studies) or home hemodialysis (one study). There was very low certainty of evidence for the outcomes, except for hospitalisations: There was low certainty evidence from three cohort studies for fewer hospitalisation days in the RPM group. No studies included data for time patients used for travel.

Conclusion: We found low to very low certainty evidence that indicate there may be positive effects of RPM follow-up, in comparison to standard care only, for adult patients with CKD who perform dialysis at home. Offering RPM follow-up for home dialysis patients as an alternative or supplement to standard care appears to be safe and provide health benefits such as fewer hospitalisation days. Future implementation should be coupled with robust, high quality evaluations.

Protocol: Pre-registered in PROSPERO (CRD42021281779).

Strength and limitations of this study

- To our knowledge, this is the first systematic review to assess the effectiveness and safety of remote patient monitoring follow-up for adult patients with dialysis-

dependent chronic kidney disease on home dialysis (hemodialysis and peritoneal dialysis).

- Our systematic review was conducted in line with guidelines from the Cochrane and GRADE working group. The researchers specialise in systematic review research, one researcher is a registered nurse with long and diverse nephology experience, and the searches were conducted by a search specialist.
- Due to study heterogeneity, inconsistent measurement and reporting, our ability to conduct metaanalyses was limited.

Introduction

Chronic kidney disease (CKD) is a significant public health concern**,** with 8-16% of the world's population affected.[1] It is characterised by a need for close monitoring, poor health outcomes, and a high economic burden for society as well as for the individual.[2] The world's population is growing older, and with CKD prevalence rising parallel with age,[2] an increasing number of people will continue to need monitoring and treatment with dialysis. There are two main types of dialysis: Peritoneal dialysis (PD) and hemodialysis (HD). Both are suitable treatment options when the kidneys are unable to filter the blood sufficiently.[3]

With the use of technology, there are encouraging possibilities for thorough patient follow-up, and at the same time, human resource savings.[4-6] Both PD and HD can be performed at home. With home dialysis, the patients receive comprehensive training arranged by staff at a dialysis centre to ensure that they have the skills and knowledge required to perform the treatment at home.[3 7] While dialysis is time-consuming regardless of location, patients on home dialysis are not dependent on hospital service hours and may experience more freedom than patients receiving in-centre dialysis.[8 9] Additionally, for patients on in-centre dialysis, the burden of time spent commuting between home and hospital can be extensive. They often also spend a substantial amount of time waiting for transport and waiting to be assisted by hospital staff for connection and disconnection from HD. Research shows that travel time to dialysis exceeding 60 minutes is associated with significantly decreased health-related quality of life (QoL) and significantly increased mortality risk compared to patients who travel 15 minutes or less.[10] With dialysis at home, it is reasonable to expect considerable time savings for the patients as well as improved health-related QoL.

In healthcare there is increasing interest in utilising technology-based interventions. Telemedicine and e-health are broad terms used when medical treatment, examination, or patient follow-up is done from a distance.[11] Homecare telehealth is another related term, and remote patient monitoring (RPM) is a subcategory thereof. RPM uses computer systems or software application technology that transfers patient-generated data to healthcare professionals.[12] Given the intervention considered in this systematic review is internet dependent, we will use the term RPM. RPM can give the patient quick access to medical expertise, independent of the distance to a treatment centre, and provides healthcare teams with valuable information about the patient's condition. Thus, RPM can be a tool to empower patients in self-care and for healthcare providers to offer support from a distance.[11] Qualitative studies from the U.K. and Norway suggest that patients on home dialysis have a positive attitude towards the use of RPM and believe that this could decrease anxiety and make it easier for more patients to choose home dialysis.[13 14] In a recent pilot study from Italy, patients overcame physical, cognitive, and psychological barriers to PD by RPM follow-up.[15]

Strategies to switch more patients to home dialysis may have positive impacts on the patients' daily life,[14 16] decrease mortality,[17] and offer economic savings for the patients as well as for society.[16 18] RPM holds much promise for enhancing follow up of CKD patients on dialysis and it is critical to determine whether and which strategies are effective at improving outcomes. RPM patient follow-up is seemingly already expanding its reach. Our Google Scholar search in December 2021 showed that there has been a 200% increase in records about e-health home dialysis from 2018 to 2021. Although interest in nephrology and e-health, including RPM, is increasing, to date, there are no systematic reviews about the effectiveness and safety of RPM follow-up including adult patients with dialysis-dependent CKD on home dialysis (HD and PD). We aimed to conduct a systematic review on the effectiveness of RPM follow-up compared to standard care, for adult patients with CKD who perform dialysis at home.

Methods

We conducted this systematic review in accordance with guidelines set forth in the Cochrane Handbook for Systematic Reviews of Interventions version 6.2.[19] The pre-specified protocol was registered in PROSPERO (CRD42021281779) and we report in line with the Preferred Reporting for Systematic Reviews and Metaanalyses (PRIMSA) statement.[20]

Search strategy and selection

The reviewers (HN, RB) prepared the search strategy in collaboration with a research librarian (LN), and a second research librarian peer-reviewed the search strategy. The librarian (LN) conducted searches in August 2021 in CINAHL (EBSCO), EMBASE (OVID), Medline (OVID), Cochrane Database of Systematic Reviews, and CENTRAL. The search included both subject headings (e.g. MeSH in Medline) and text words. Available Supplemental Appendix 1. In addition, the two reviewers conducted hand searches in the reference lists of the included studies.

The basis for the search was the inclusion criteria. We applied the (S)PICO model, which directs attention to the study design, population, intervention, comparison, and outcomes.[21] Eligible study designs were primary intervention studies with a control group. That is, randomised controlled trials (RCTs), non-randomised controlled studies, controlled before-after studies, and cohort studies with a control group. Study participants needed to be 18 years or older, with dialysis dependent CKD who performed dialysis at home (HD or PD). The patients could perform dialysis independently or with assistance of family or other carers. CKD did not have to be the only disease of the study participant. This is because patients with CKD are known to have a higher burden of comorbidities than the average population.[22] The eligible intervention was RPM, understood as internet dependent technology used to transfer treatment data from the patient's home to a healthcare institution.[12] This included video consultations, applications installed on the patient's phone, computer, or a tablet as well as technology that transferred treatment data directly from the dialysis machine to healthcare providers.[12] RPM that was not directly treatment related was excluded. This included, but was not limited to, apps for lifestyle changes, interventions for blood pressure control, and interventions for diabetes management. The comparator was standard care, understood as patients performing dialysis in-centre or at home and having regular in-person consultations at a HD or PD centre. Included effect measures were QoL (measured with any type of QoL assessment tool), hospitalisation (all-cause, disease-specific, and number of hospitalisation days), technical failure as the cause for transfer to a different dialysis modality, hospital registered infections not requiring hospitalisation, and time patients use for travel. Lastly, studies had to be published in a Scandinavian or English language, in 2015-2021 because we wanted to identify all studies relevant to the question and today's clinical situation, being cognisant that technology is rapidly improving.

We imported all records from the searches into an EndNote library and removed all duplicate entries. Two researchers (HN, RB) independently screened all titles and abstracts from the literature searches in accordance with the predetermined inclusion and exclusion criteria. All abstracts that appeared to fit the inclusion criteria or did not provide enough information, were promoted to full text screening. At each level, we evaluated the identified records independently of one another using a pre-developed inclusion form. The final determination to include or exclude was made together and any disagreements were solved by discussion. Excluded studies with justifications are available in Supplemental Appendix 2.

Risk of bias assessment and data extraction

To assess the included studies for risk of bias (RoB) we used two different instruments: The Newcastle-Ottawa scale for cohort studies,[23] and Cochrane Risk of Bias Tool for RCTs.[19] Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed on a final RoB evaluation, with disagreements solved by discussion.

One researcher (HN) created a standard extraction form and extracted data from all included studies. The information extracted from the studies was: title, authors, publication details, study design, aim of the study, study setting (location and time the study was conducted), characteristics of included participants (age, gender etc.), characteristics of the intervention, study setting, outcomes, and results. Whenever information was available, dichotomous and continuous data for all eligible outcomes were extracted. HN contacted several authors for additional data, but did not receive a reply. RB assessed the extracted data for completeness and accuracy and any disagreements were solved by further inspection of the publication and discussion.

Analysis and assessment of the certainty of the evidence (GRADE)

We extracted crude outcome data for all eligible outcomes when postscores for both intervention and control groups were available and, when such data were available, adjusted outcome data (adjusted comparison (effect) estimates and their standard errors or 95% confidence intervals, CI). We provide dichotomous outcomes as the number of events and number of people in groups as proportions, risk ratio (RR), incident RR (IRR) or odds ratio (OR) as appropriate. Continuous outcomes are shown as mean difference (MD) and standard deviations (SD), or the most appropriate presentation based on the available data in the included studies.

We evaluated the characteristics of the studies' (S)PICO and when they were considered sufficiently similar, and data were available, we conducted metaanalyses. The judgments about whether metaanalyses were appropriate were based on recommendations in the Cochrane Handbook.[19] We used Mantel-Haenszel random effects metaanalysis for dichotomous outcomes and we presented the relative risks and their corresponding 95% CI (it was not possible to metaanalyse any continuous outcomes). We also examined between-study heterogeneity using visual inspection of CIs, the Chi-square test, and Isquare statistic, quantifying the degree of heterogeneity as described in the Cochrane Handbook.[19] We used RevMan version 5.4, the latest version of the Cochrane metaanalysis software.[24] When the studies' (S)PICOs or results were too heterogeneous to pool statistically, or data were unavailable, we reported the results narratively, in text and tables. We planned to perform a subgroup analysis for the outcome technical failure, but this was not possible due to lack of data.

We assessed the certainty of the evidence using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework.[25] With regard to results that could not be metaanalysed, we followed the Synthesis Without Meta-analysis (SWiM) guideline.[26]

Results

The searches returned 451 references after removal of duplicates (Figure 1). We read 24 reports in full text, including one study identified from the hand search in reference lists. The most common primary reasons for exclusion were that there was no control group or it was the wrong participants or outcomes. Seven studies published between 2018-2021 were eligible for inclusion.[27-33]

Description of the studies

The seven included studies consisted of two RCTs and five retrospective cohort studies (Table 1). They were conducted in five different countries. There were two studies each from Columbia and USA, and one study each from China, Italy, and South Korea. Three were set in a single PD centre, four took place in two or more renal care centres and the two largest studies took place in the USA with one including 55 home HD centres and another 931 Fresenius PD clinics.

Table 1: Description of the included studies (n=7)

Author, (country, setting) Study design	Population	Intervention and comparator (follow-up time)	Outcomes	Risk of bias
Cao 2018[27] (China: 1 PD centre) RCT	N=160, on CAPD Men 58% Mean age 52	RPM vs SC Instant messaging application for support and education (mean 11.4 mo FU)	Hospitalisations Infections Technical failure	Moderate
Chaudhuri 2020[28] (USA: 931 renal centres) Cohort	N=6343, on PD Men 73% Mean age 57	RPM vs SC "Patient hub" application - patients add and access treatment data (12 mo FU)	Hospitalisations Technical failure	Low
Corzo 2020[29] (Columbia: 5 renal centres) Cohort	N=558, on APD Men 60% Mean age 54	RPM vs SC Cloud-based software - prescriptions can be changed remotely (mean 8.3 mo FU)	Technical failure	Low
Jung 2021[30] (South Korea: 6 renal centres) RCT	N=57, on APD Men 60% Mean age 47	RPM vs SC Cloud-based software - prescriptions can be changed remotely (6 mo FU)	QoL	Moderate
Milan 2020[31] (Italy: 1 PD centre) Cohort	N=73, on APD Men 75% Median age 60	RPM vs SC Cloud-based software - prescriptions can be changed remotely (6 mo FU)	Hospitalisations Technical failure QoL	Low/ Moderate
Sanabria 2019[32] (Columbia: 28 Baxter renal care centres) Cohort	N=360, on APD Men 66% Mean age 57	RPM vs SC Cloud-based software - prescriptions can be changed remotely (Mean 9 mo FU)	Hospitalisations Technical failure	Low
Weinhandl 2018[33] (USA: 55 HHD centres) Cohort	N=2424, on HHD Men 63% Mean age 53	RPM vs SC Nx2me telehealth platform - staff can do remote 'troubleshooting' during HHD (Mean 11 mo FU)	Technical failure	Low

Legend: APD=Automated peritoneal dialysis; CAPD=Continuous peritoneal dialysis; FU=Follow-up; HHD=Home hemodialysis; mo=Months; PD=Peritoneal dialysis; QoL=Quality of life; RCT= Randomised controlled trial; RPM=Remote patient monitoring; SC=Standard care

With respect to the population, all in all, there were 9,975 dialysis-dependent CKD patients in the studies. The range was 57-6343 patients, thus there was imbalance in sample sizes across the studies. The two largest studies, cohorts from the USA, made up 88% of the total number of study participants. In all the studies most patients were male (range 53%-75%) and the mean age of the study participants was about 55. In all studies except one, the patients were on PD, they lived at home, and performed dialysis independently or with the assistance of a carer.

As per our inclusion criteria, the intervention was remote patient monitoring with different types of software that collected treatment data and transferred it to a treatment centre (added by the patients or automatically collected). The specific type of RPM varied across the studies. Four studies, Corzo et al.,[29] Jung et al.,[30] Milan et al.[31] and Sanabria et al.[32] used the automated PD system from Baxter: Homechoice Claria™, connected to the Sharesource platform. Milan et al.[31] additionally used the sleep-safe harmony home bridge system from Fresenius for half of the patients. Weinhandl & Collins[33] used the Nx2me telehealth platform for home HD patients. The software collects treatment data and transmits it to the healthcare providers, and the prescription can be changed 'from afar'. Chaudhuri et al.[28] used the "Patient hub" application. The PD patients can see their prescription, laboratory results, and enter treatment data, and the app transmits the patient-entered data to the healthcare providers. Cao et al.[27] used the "kidney cleaning group" instant messaging software. Technical support, nurse support, physician support, and support from fellow patients was available through chat and video. The patients were divided in smaller groups and one experienced PD patient with few complications was the group leader. Educational resources were also available in the platform. In addition, in all studies, all patients had or were likely to receive some level of standard care. This was generally described as in-person follow-up at the hospital. However, the frequency of standard care ranged from weekly (n=1) to every three months (n=1). Most studies had or were likely to have an in-person review monthly (n=5). The follow-up time ranged from 6 to 12 months.

Risk of bias of included studies

The RCTs had moderate risk of bias, while the retrospective cohort studies were rated fair to good methodological quality, i.e. having low to moderate risk of bias (Table 1 and Supplemental Appendix 3). With respect to the studies' sources of funding, three of the observational studies received financial support from the provider of the intervention (Supplemental Appendix 3).

Effect of RPM versus standard care

Across the studies, there were data on four of our five pre-determined outcomes: Hospitalisation,[27 28 31 32] infections,[27] technical failure as the cause for transfer to a different dialysis modality,[27-29 31-33] and QoL.[30 31] Due to the inconsistent measurement of outcomes, and inconsistent and incomplete reporting of outcome results in the studies, our ability to synthesise data was limited. The results are described in the text below, Table 2, and Figure 2. The GRADE assessments in Table 3 show that there was low to very low certainty of

evidence for all of the outcomes. This means that the effects are largely uncertain. No publications included data for the outcome 'time patients used for travel'.

Table 2. Study outcomes and effect estimates

Study	Outcome	Result/Effect estimate (95% CI)
Hospitalisations		
Chaudhuri 2020 Milan 2020 Sanabria 2019	Hospitalisation days (12 mo) Hospitalisation days (6 mo) Hospitalisation days (9 mo)	Adj. IRR 0.68 (0.55-0.83) Median 5 days difference P 0.55 Adj. IRR 0.46 (0.23-0.92)
Cao 2018 Chaudhuri 2020 Milan 2020 Sanabria 2019	Hospitalisation all-cause (11 mo) Hospitalisation all-cause (12 mo) Hospitalisation all-cause (11 mo) Hospitalisation all-cause (9 mo)	RR 0.57 (0.17-1.88) Adj. IRR 0.74 (0.66-0.83) RR 1.33 (0.63-2.81) Adj. IRR 0.61 (0.39-0.95)
Infections		
Cao 2018	Infections (11 mo)	More peritonitis (60 in RPM group vs 40 in control group per patient month) but less exit site infections with RPM (RR= 0.45, 0.12-1.68)
Technical failure as cause for transfer to a different dialysis modality		
Cao 2018 Chaudhuri 2020 Corzo 2020	Technical failure (11 mo) Technical failure (12 mo) Technical failure (8 mo)	RR 1.00 (0.26-3.86) Adj. HR 0.79 (0.63-1.00) IRR 0.88 (0.41-1.74)
Sanabria 2019 Weinhandl 2018	Technical failure (subgroup) (9 mo) Technical failure (subgroup) (11 mo)	RR 0.97 (0.42-2.25) Adj. HR 0.66 (0.50-0.86)
Quality of life		
Jung 2021 Milan 2020	KDQOL -Patient satisfaction questions (6 mo) KDQOL -Patient satisfaction questions (6 mo)	Mean 75.5 in RPM group vs 73.7 in SC group, P 0.64 Median 83.3 in both groups, P 0.99
Jung 2021 Milan 2020	KDQOL -Dialysis staff encouragement (6 mo) KDQOL -Dialysis staff encouragement (6 mo)	Mean 93.1 in RPM group vs 97.1 in SC group, P 0.05 Median 100 in both groups, P 0.16

Legend: Adj=Adjusted (listed in Supplemental Appendix 3); HR=Hazard ratio; IRR=Incident rate ratio (compares the incidence rates between two different groups and shows if exposure to something increases or decreases the rate of some incidence -- if IRR is 1 then there is no difference); mo=Months; KDQOL=kidney disease quality of life; RPM=Remote patient monitoring; RR=Relative risk; SC=Standard care

Table 3: Summary of findings (GRADE)

Population: Patients with CKD
Countries: China, Columbia, Italy, South Korea, USA

Intervention: RPM

Comparison: Standard care

Outcome, follow-up time	**Anticipated absolute effects* (95% CI)**		**Relative effect (95% CI)**	**No. of participants (Studies)**	**Quality of evidence (GRADE)**
	Assumed risk with control	Assumed risk with RPM			
Hospitalisations (6-12 months)					
Days	All 3 cohort studies showed that there were fewer hospitalisation days in the RPM group (Table 2)			6,736 (3)	⊕⊕◯◯ LOW
All-cause	3 of 4 studies (1 RCT, 3 cohort) showed that there were fewer hospitalisations in the RPM group (Table 2)			6,936 (4)	⊕◯◯◯ VERY LOW[1]
Disease-specific	30/198 (15.2%)	10/110 (9.1%)	RR 0.62 (0.31 to 1.24)	308 (2 cohort)	⊕◯◯◯ VERY LOW[2]
Infections (11 months)					
	1 RCT reported more peritonitis but fewer exit site infections with RPM (Table 2)			160 (1)	⊕◯◯◯ VERY LOW[3]
Technical failure (6-12 months)					
	521/2230 (23.4%)	136/786 (17.3%)	RR 0.78 (0.66 to 0.93)	2856 (3 cohort)	⊕◯◯◯ VERY LOW[4]
	2 of 3 studies (1 RCT, 2 cohort) reported fewer failures with RPM (Table 2)			7161 (3)	
Quality of life (6 months)					
Patient satisfaction	1 RCT found higher QoL in the RPM group, 1 cohort found QoL was similar in the two groups (Table 2)			130 (2)	⊕◯◯◯ VERY LOW[5]

Dialysis staff encouragement	1 RCT found higher QoL in the RPM group, 1 cohort found QoL was similar in the two groups (Table 2)	130 (2)	⊕◯◯◯ VERY LOW[5]
Travel time	0 studies assess this outcome		No evidence

1. Downgraded by 1 level because of moderate risk of bias in 1 study and inconsistency
2. Downgraded by 1 level because of imprecision
3. Downgraded by 3 levels because of moderate risk of bias, inconsistency, imprecision
4. Downgraded by 1 level because of moderate risk of bias in 1 study and imprecision
5. Downgraded by 1 level because of inconsistency and imprecision

CI: Confidence interval; RCT: Randomised controlled study; SD: Standard deviation. *The risk in the intervention group (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).

Hospitalisations

One RCTs and three observational studies from Italy, Colombia, China, and the USA examined the effect of RPM on hospitalisations.[27 28 31 32] However, the outcome was reported differently across the studies, as hospitalisation days/days admitted, all-cause hospitalisations, and disease-specific hospitalisations (caused by overhydration, access dysfunction, and infections).

Hospitalisation days. The three observational studies, Chaudhuri et al.,[28] Milan et al.,[31] and Sanabria et al.[32], all found fewer hospitalisation days in the RPM group than the control group (Table 2). The results in Sanabria et al.[32] were from a matched sample, as data for the whole sample was not available. This study showed the largest effect with a difference of six hospitalisation days (IRR 0.46, 0.23-0.92).

All-cause hospitalisations. One RCT[27] and three observational studies[28 31 32] had data on general, all-cause hospitalisations. While three of the four studies showed that RPM users had less all-cause hospitalisations than patients with standard care only, the fourth study favoured standard care (Table 2).

Disease-specific hospitalisations. The results on disease-specific hospitalisations from two observational studies, Milan et al.,[31] and Sanabria et al.[32] could be pooled in a metaanalysis (Figure 2). The non-significant result suggested there were fewer disease-specific hospitalisations in the RPM group than in the control group (RR 0.62, 95% CI 0.31-1.24).

Milan et al.[31] defined disease-specific hospitalisations as infections (peritonitis and exit site), overhydration, and access dysfunction. Sanabria et al.[32] provided numbers for hospitalisations due to peritonitis and overhydration.

Infections

Only one RCT, from China, examined the effectiveness of RPM follow-up for PD patients on infections.[27] The result for this outcome was inconclusive, as Cao et al. found more peritonitis but fewer exit site infections with RPM. It was not specified whether the infections were treated at home or in the hospital.

Technical failure as the cause for transfer to a different dialysis modality

One RCT from China [27] found no difference between the groups while five observational studies from the USA[28 33], Colombia[29 32], and Italy[31] consistently reported less technical failure as cause for transfer to a different dialysis modality in the RPM group compared to the control group (Table 2). Three of the cohort studies could be pooled in a metaanalysis; the result implies benefit of RPM (0.78, 95% CI 0.66, 0.92) (Figure 2). Two of the studies[32 33] gave data on novice patients with less than three months treatment duration at baseline, indicating a positive, but non-significant effect of RPM in new patients (Table 2).

Self-reported Quality of Life

Both studies, one RCT[30] and one observational study,[31] reporting on quality of life used the tool 'The short form of kidney disease quality of life' (KDQOL), which is an adaptation of SF-36.[34] All answers were transformed into pre-coded numeric values with a range from 0-100, where 100 was the highest QoL.[35] Neither studies offered an overall total score across the questions/areas, and we selected the two questions/areas that we considered most relevant (patient satisfaction and dialysis staff encouragement). For both patient satisfaction and dialysis staff encouragement, Milan et al.[31] found the same score in both groups, while Jung et al.[30] found a higher score in the RPM group than the control group concerning patient satisfaction, but opposite for dialysis staff encouragement (Table 2).

Discussion

Principal findings

This systematic review advances the evidence on the effects of RPM for patients with dialysis dependent CKD on home dialysis, including home HD and PD. Our findings are in line with previous research[36 37] and document that there is no conclusive evidence, but that positive effects of RPM are indicated for clinical outcomes, technical failure, and quality of life.

The results consistently suggest that RPM reduces hospitalisations and the number of days the patient is admitted. It was especially convincing that Milan et al.[31] observed a median difference of five fewer hospitalisation days in the RPM group over six months, because the patients on RPM had a worse comorbidity score. Furthermore, except for one study that found the same number of technical failures in both groups, the other five studies found less technical failure in the RPM group. In four of the studies measuring this outcome, prescriptions could be changed from the hospital without in-person consultations. In effect, RPM allows resolving technical issues early, thus preventing progression of technical failure to the stage where the patient would need to transfer to a different dialysis modality. Research has found great advantages with the technology displaying possible causes and solutions to problems, alarm indicators showing who to contact for guidance (nurse or technician), and reminders of activities that need to be performed.[14-16] Concerning quality of life, only two studies assessed this and the results showed the scores were comparable for the patients on RPM and usual care. Encouragingly, scores for quality of life improved slightly and patient satisfaction was higher than neutral. This is in line with a study from the U.S. that found that RPM increased patients' confidence and satisfaction with treatment because they felt more closely supported.[36] Lastly, no studies assessed time patients use for travel. However, research suggests that health-related quality of life and time patients use for travel are intertwined[11] and that dialysis free time and reduction of fatigue are highly valued outcomes by patients.[10 37 38] This could reflect positively on quality of life.

Our results mirror two earlier systematic reviews on e-health interventions in PD patients[39] and in people with CKD.[40] Both reviews, with literature searches in 2018-2019, included a wide range of patients and e-health modalities, including mobile or tablet application, text or email messages, electronic monitors, internet/websites, and video or DVD. Consequently, there was minimal overlap in included studies: Only one review[39] included two of our included studies. Both reviews concluded that the quality of evidence for the effectiveness of e-health was low with uncertain effects, but that no adverse effects were indicated. Of note, a recent modelling analysis projected that in a cohort of 100 patients on automated PD over 1 year, RPM would lead to 27 fewer hospitalisations, 518 fewer hospitalization days, 31 additional months free of complications, and six fewer peritonitis episodes.[41]

Implications

Overall, the low to very low certainty of evidence on the effects of RPM for patients with dialysis dependent CKD on home dialysis prevents strong recommendations. Given RPM seems comparable to usual care, the absence of adverse effects and promising clinical effects, it seems advisable cautiously to implement RPM while concomitantly evaluating outcomes important for patients. Prior to recommending RPM for CKD patients on home dialysis, more trials are needed to be certain of its benefits over standard care, and to establish equity and cost effectiveness. A modelling analysis from the payer perspective has found that RPM is cost effective,[41] but economic evaluations of e-health interventions are scarce and highlights an important area for further research.[6 42] Additionally, patient groups should be involved in RPM implementation and evaluation, to maximize the potential for modification and ultimately effect.

Our review highlights the need for robust, high quality research on both PD and home HD, but especially for patients on home HD and patients whose home is in a nursing home. To our knowledge, home HD in nursing homes is rare, while PD is common. It is likely that nursing home staff aided by RPM support from specialist nurses at dialysis centres could provide invaluable assistance to frail CKD patients with great need for follow-up. For such patients and others with dialysis dependent CKD on home dialysis, time used for travel and dialysis free time is a patient-important outcome that warrants further research. It is reasonable to suspect substantial time-savings when follow-up is performed from afar and evidence from video consultations in patient follow-up are positive.[16 43] We encourage research on the combined use of video consultations and cloud-based technology on outcomes such as travel time, technical failure, and hospitalisations. Standardised outcomes in nephrology (SONG) have identified and prioritised outcomes for both HD and PD patients and can be a useful tool when planning outcomes in future research.[44]

Strengths and limitations

Our systematic review was conducted in line with guidelines from the Cochrane and GRADE working group. The outcome selection was in alignment with core outcomes recommended by the SONG initiative.[44] The researchers specialise in systematic review research, one researcher is a registered nurse with long and diverse nephrology experience, and the searches were conducted by a search specialist. Yet, it is possible that relevant studies have been missed and relevant studies have been published after our last search. Due to study heterogeneity, variability in intervention characteristics, inconsistent measurement and

reporting, our ability to conduct metaanalyses was limited. Therefore, it was neither possible to improve precision to any great extent, nor statistically assess potential differences across groups, such as type of platform or HD and PD. We contacted several authors asking for more data, but did not receive a reply. The low number of studies meant that we were unable to statistically check for publication bias. Given the modestly positive but varied results, we believe the potential for publication bias is low, but we recommend future reviews of a higher number of included studies to assess this potential bias. The imbalance in sample sizes across the studies, with two studies having a considerably larger sample size than the other five, influenced the results related to hospitalisations and technical failure. Both these two studies had low risk of bias, but three other studies had moderate risk of bias.

Conclusion

This systematic review summarises and presents low to very low evidence that indicate there may be positive effects of RPM follow-up, in comparison to standard care only, for adult patients with CKD who perform dialysis at home. Offering RPM follow-up for home dialysis patients as an alternative or supplement to standard care appears to be safe and provide health benefits, but future implementation should be coupled with robust, high quality evaluations. Despite the high interest in RPM and increasing demands for nephrology services, good quality evidence is still needed to determine their effectiveness.

Contributors

HN wrote the first draft. RB and HN contributed equally to the rest of the work. LN prepared and conducted the systematic searches and contributed with inputs on the final draft. We are grateful to [removed for blind review], for peer review of the systematic search strategies

Competing interests

'None declared'.

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Patient and public involvement

Due to the nature of the study (systematic review), no patients were involved.

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Data availability statement

Data are available on reasonable request.

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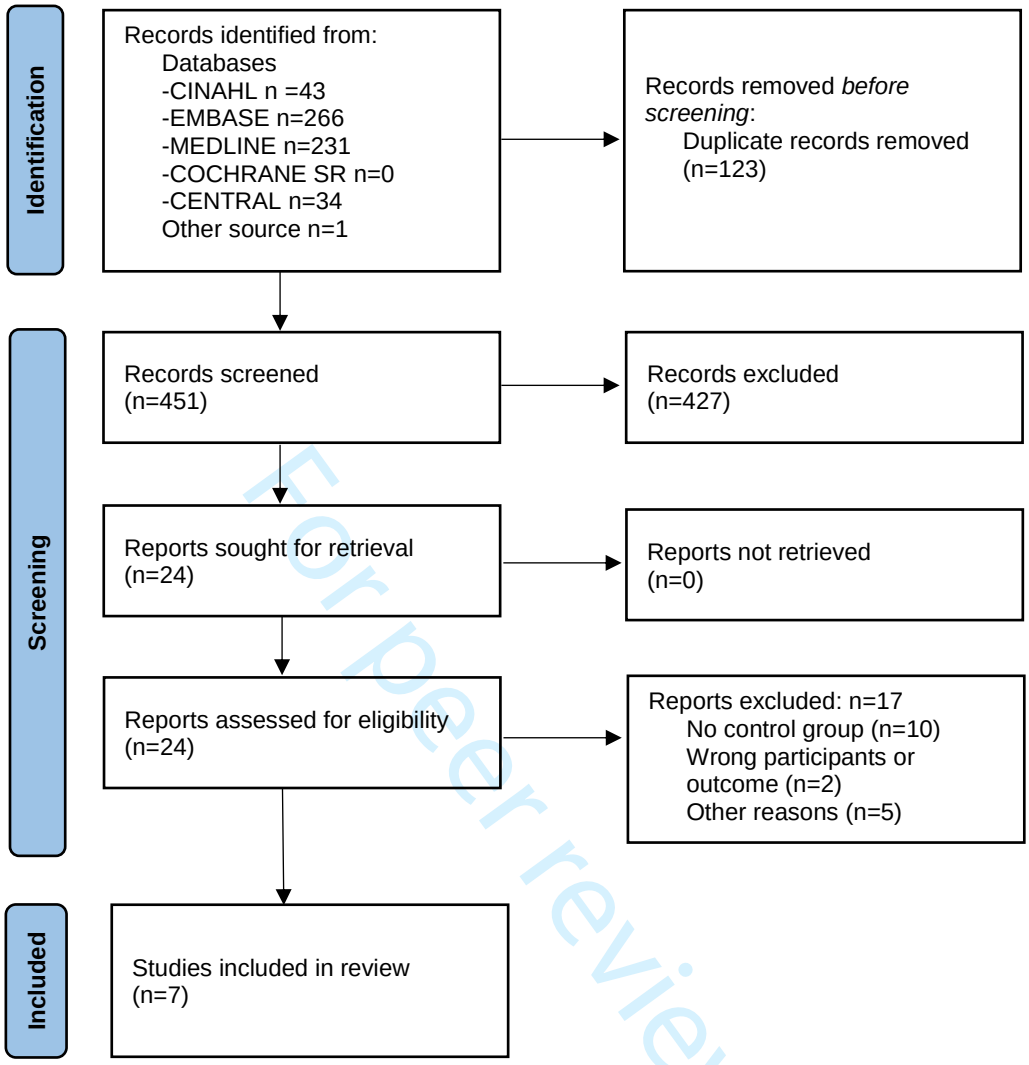
Figure legend:

Figure 1: Prisma flow diagram for selection of studies

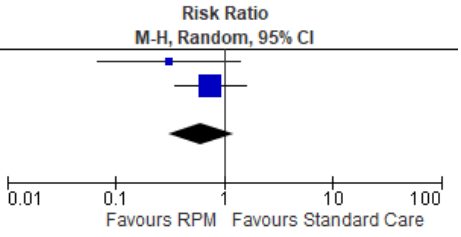
Figure 2: Metaanalyses of outcomes disease specific hospitalisations and technical failure



(a) Disease specific hospitalisations

Study or Subgroup	RPM Events	RPM Total	Standard Care Events	Standard Care Total	Weight	Risk Ratio M-H, Random, 95% CI
Milan 2020	2	35	7	38	21.3%	0.31 [0.07, 1.39]
Sanabria 2019	8	75	23	160	78.7%	0.74 [0.35, 1.58]
Total (95% CI)		**110**		**198**	**100.0%**	**0.62 [0.31, 1.24]**
Total events	10		30			

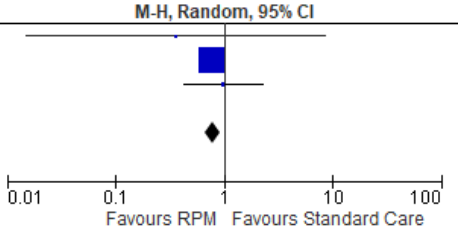
Heterogeneity: Tau² = 0.01; Chi² = 1.04, df = 1 (P = 0.31); I² = 4%
Test for overall effect: Z = 1.35 (P = 0.18)



(b) Technical failure

Study or Subgroup	RPM Events	RPM Total	Standard Care Events	Standard Care Total	Weight	Risk Ratio M-H, Random, 95% CI
Milan 2020	0	35	1	38	0.3%	0.36 [0.02, 8.58]
Weinhandl 2018	126	606	488	1817	95.7%	0.77 [0.65, 0.92]
Sanabria 2019	6	65	28	295	4.1%	0.97 [0.42, 2.25]
Total (95% CI)		**706**		**2150**	**100.0%**	**0.78 [0.66, 0.92]**
Total events	132		517			

Heterogeneity: Tau² = 0.00; Chi² = 0.50, df = 2 (P = 0.78); I² = 0%
Test for overall effect: Z = 2.88 (P = 0.004)



Supplemental Appendix 1: Search strategies

Date: 23.08.2021
Searches conducted by: Lien Nguyen
Search strategies peer reviewed by: Elisabet Hafstad

Database	Number of hits
Embase <1974 to 2021 August 20> (OVID)	266
Ovid MEDLINE(R) ALL <1946 to August 20, 2021>	231
Cochrane Library of Systematic Reviews (Cochrane Library; Wiley)	0
CENTRAL(Cochrane Library; Wiley)	34
CINAHL (EBSCO)	43
Total number of references	574
Total after duplicate removal	451

Database: Embase

Search interface: Advanced Search

1 exp telehealth/ 60896

2 exp telecommunication/ 87729

3 exp health care delivery/ 3564027

4 2 and 3 65304

5 (telecare* or teleconsult* or telefollow* or telehealth* or telehome* or telemanag* or telemedicine or telemonitor* or telenurs* or telepatient* or telesupport*).ti,ab,kw,bt. 33953

6 ((tele or telemedical* or tele medical*) adj (care* or checkup* or check up* or consult* or followup* or follow up* or health* or home* or manag* or medicine* or monitor* or nurs* or patient* or support*)).ti,ab,kw,bt. 1853

7 (ecare or econsult* or ehealth or emedicine* or enurs* or mcare or mconsult* or mhealth or mnurse or mcare or mnursing or mconsult* or mnurs*).ti,ab,kw,bt. 10706

8 ((e or m or mobile or digital) adj (care or consult* or health* or nurs*)).ti,ab,kw,bt. 15428

9 (remote adj2 (care* or checkup* or check up* or consult* or followup* or follow up* or health* or home* or manag* or medicine* or monitor* or nursing or patient* or self)).ti,ab,kw,bt. 12293

10 1 or 4 or 5 or 6 or 7 or 8 or 9 92070

11 hemodialysis/ 115843

12 exp peritoneal dialysis/ 44307

13 home dialysis/ 2966

14 (((dialysis or hemodialysis or haemodialysis) adj4 home?) or peritoneal dialysis).ti,ab,kw,bt. 37655

15	(CAPD or APD or HHD).ti.	3524
16	or/11-15	151629
17	10 and 16	534
18	limit 17 to yr=2000-current	516
19	(exp animals/ or exp invertebrate/ or animal experiment/ or animal model/ or animal tissue/ or animal cell/ or nonhuman/) not (human/ or normal human/ or human cell/)	6724645
20	editorial.pt.	699530
21	18 not (19 or 20)	494
22	limit 21 to embase	270
23	remove duplicates from 22	266

Database: OVID MEDLINE

Search interface: Advanced Search

1	Telemedicine/	29751
2	Telenursing/	232
3	Remote Consultation/	5273
4	or/1-3	34165
5	exp Telecommunications/	108428
6	(care or healthcare).hw.	1324775
7	5 and 6	19771
8	4 or 7	42042
9	(telecare* or teleconsult* or telefollow* or telehealth* or telehome* or telemanag* or telemedicine or telemonitor* or telenurs* or telepatient* or telesupport*).ti,ab,kf,bt.	26067
10	((tele or telemedical* or tele medical*) adj (care* or checkup* or check up* or consult* or followup* or follow up* or health* or home* or manag* or medicine* or monitor* or nurs* or patient* or support*)).ti,ab,kf,bt.	1020
11	(ecare or econsult* or ehealth or emedicine* or enurs* or mcare or mconsult* or mhealth or mnurse or mcare or mnursing or mconsult* or mnurs*).ti,ab,kf,bt.	10618
12	((e or m or mobile or digital) adj (care or consult* or health* or nurs*)).ti,ab,kf,bt.	13372
13	(remote adj2 (care* or checkup* or check up* or consult* or followup* or follow up* or health* or home* or manag* or medicine* or monitor* or nursing or patient* or self)).ti,ab,kf,bt.	8231
14	or/8-13	69186

15	Renal Dialysis/	94819
16	Hemodialysis, Home/	2013
17	exp Peritoneal Dialysis/	26840
18	(((dialysis or hemodialysis or haemodialysis) adj4 home?) or peritoneal dialysis).ti,ab,kf,bt.	28202
19	(CAPD or APD or HHD).ti.	2685
20	or/15-19	121750
21	14 and 20	271
22	limit 21 to yr=2000-current	243
23	exp animals/ not humans/	4877030
24	(news or editorial or comment).pt.	1512750
25	22 not (23 or 24)	231
26	remove duplicates from 25	231

Database: Cochrane Database of Systematic Review & CENTRAL

Search interface: Advanced Search > Search Manager

ID	Search	Hits
#1	[mh ^telemedicine]	2414
#2	[mh ^telenursing]	31
#3	[mh ^"remote consultation"]	381
#4	#1 or #2 or #3	2777
#5	[mh telecommunications]	7362
#6	[mh ^"delivery of health care"]	806
#7	[mh ^"health services"]	458
#8	#5 and (#6 or #7)	139
#9	#4 or #8	2838
#10	(telecare* or teleconsult* or telefollow* or telehealth* or telehome* or telemanag* or telemedicine or telemonitor* or telenurs* or telepatient* or telesupport*):ti,ab,kw	7370
#11	((tele or telemedical* or tele-medical*) NEXT (care* or checkup* or check-up* or consult* or followup* or follow-up* or health* or home* or manag* or medicine* or monitor* or nurs* or patient* or support*)):ti,ab,kw	446

#12	(ecare or econsult* or ehealth or emedicine* or enurs* or mcare or mconsult* or mhealth or mnurse or mcare or mnursing or mconsult* or mnurs*):ti,ab,kw	2547
#13	((e or m or mobile or digital) NEXT (care or consult* or health* or nurs*)):ti,ab,kw	3725
#14	(remote NEAR/2 (care* or checkup* or check-up* or consult* or followup* or follow-up* or health* or home* or manag* or medicine* or monitor* or nursing or patient* or self)):ti,ab,kw	1743
#15	{or #9-#14}	11340
#16	[mh ^"Renal Dialysis"]	4322
#17	[mh ^"hemodialysis, home"]	43
#18	[mh "Peritoneal Dialysis"]	900
#19	(((dialysis or hemodialysis or haemodialysis) NEAR/4 home?) or "peritoneal dialysis"):ti,ab,kw	2491
#20	(CAPD or APD or HHD):ti	409
#21	{or #16-#20}	6775
#22	#15 and #21 with Cochrane Library publication date Between Jan 2000 and Aug 2021, in Cochrane Reviews	0
#23	#15 and #21 with Publication Year from 2000 to 2021, in Trials	34

Database: CINAHL

Search interface: Advanced Search

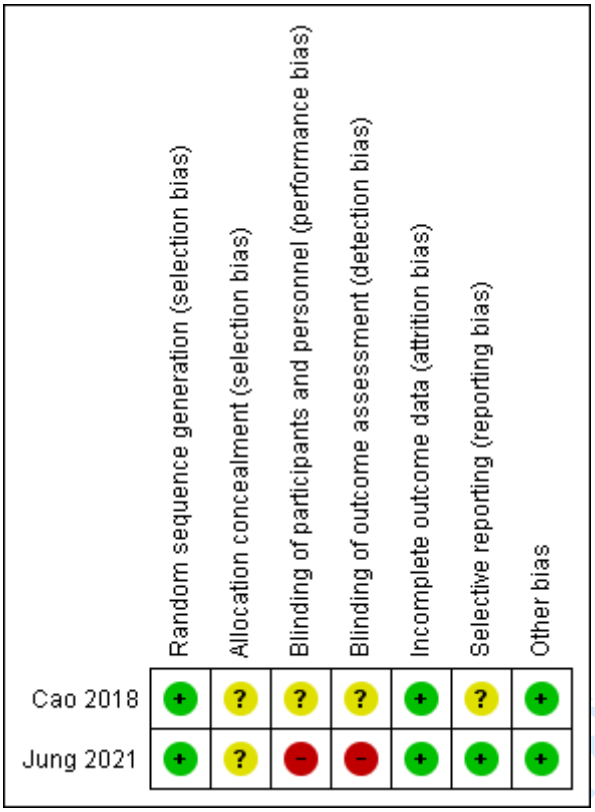
Supplemental Appendix 2: Excluded studies read in full text

Excluded studies read in full text (n=17)	Justifications for exclusion
Dey V, Jones A, Spalding EM. Telehealth: Acceptability, clinical interventions and quality of life in peritoneal dialysis. SAGE Open Med. 2016;4:2050312116670188.	No control group
El Shamy O, Tran H, Sharma S, Ronco C, Narayanan M, Uribarri J, et al. Telenephrology with Remote Peritoneal Dialysis Monitoring during Coronavirus Disease 19. Karger AG; 2020. p. 480-2.	Letter about Covid-19 and the impact in kidney care/review
Harnett P, Jones M, Almond M, Ballasubramaniam G, Kunnath V. A virtual clinic to improve long-term outcomes in chronic kidney disease. Clinical Medicine, Journal of the Royal College of Physicians of London. 2018;18(5):356-63.	Not home dialysis patients
Huang R, Liu N, Nicdao MA, Mikaheal M, Baldacchino T, Albeos A, et al. Emotion sharing in remote patient monitoring of patients with chronic kidney disease. J Am Med Inform Assoc. 2020;27(2):185-93.	No control group and wrong outcome
Kiberd J, Khan U, Stockman C, Radhakrishnan A, Phillips M, Kiberd BA, et al. Effectiveness of a Web-Based eHealth Portal for Delivery of Care to Home Dialysis Patients: A Single-Arm Pilot Study. Can J Kidney Health Dis. 2018;5:2054358118794415.	No control group
Milan Manani S, Crepaldi C, Giuliani A, Virzi GM, Garzotto F, Riello C, et al. Remote Monitoring of Automated Peritoneal Dialysis Improves Personalization of Dialytic Prescription and Patient's Independence. Blood Purification. 2018;46(2):111-7.	No control group
Milan Manani S, Rosner MH, Virzì GM, Giuliani A, Berti S, Crepaldi C, et al. Longitudinal Experience with Remote Monitoring for Automated Peritoneal Dialysis Patients. Nephron. 2019;142(1):1-9.	No control group
Musso CG, Plazzotta F, Otero C, Aguilera J, Campos F, Diez GR, et al. Informatic nephrology: 17 years of one-center experience. International Urology and Nephrology. 2015;47(9):1587-8.	Letter (not empirical study)
Nayak KS, Ronco C, Karopadi AN, Rosner MH. Telemedicine and Remote Monitoring: Supporting the Patient on Peritoneal Dialysis. Perit Dial Int. 2016;36(4):362-6.	No control group: summary from three different studies
Patterson P. Telehealth for Home Dialysis Therapies. Nephrol Nurs J. 2017;44(6):545-8.	An interview with a doctor
Polanco E, Aquey M, Collado J, Campos E, Guzman J, Cuevas-Budhart MA, et al. A COVID-19 pandemic-specific, structured care process for Peritoneal Dialysis patients facilitated by Telemedicine: therapy continuity, prevention and complications management. Therapeutic apheresis and dialysis : official peer-reviewed journal of the International Society for Apheresis, the Japanese Society for Apheresis, the Japanese Society for Dialysis Therapy. 2021.	No control group
Ronco C, Manani SM, Giuliani A, Tantillo I, Reis T, Brown EA. Remote patient management of peritoneal dialysis during COVID-19 pandemic. Perit Dial Int. 2020;40(4):363-7.	Review
Scarpioni R, Manini A, Chiappini P. Remote patient monitoring in peritoneal dialysis helps reduce risk of hospitalization during Covid-19 pandemic. J Nephrol. 2020;33(6):1123-4.	There are patients with RPM and without, but they are not compared
Tangaro S, Fanizzi A, Amoroso N, Corciulo R, Garuccio E, Gesualdo L, et al. Computer aided detection system for prediction of the malaise during hemodialysis. Computational and Mathematical Methods in Medicine. 2016;2016 (no pagination).	No control group without TM
Viglino G, Neri L, Barbieri S, Tortone C. Videodialysis: a pilot experience of telecare for assisted peritoneal dialysis. J Nephrol. 2020;33(1):177-82.	No relevant outcomes
Wood E, McCarthy K, Roper M. Remote monitoring of peritoneal dialysis: evaluating the impact of the Claria Sharesource system. Journal of Kidney Care. 2019;4(1):16-24.	No control group

Yeter HH, Karacalik C, Eraslan E, Akcay OF, Derici U, Ronco C. Effect of remote patient management in peritoneal dialysis on haemodynamic and volume control. Nephrology. 2020;25(11):856-64.	No pre-intervention assessment

Supplemental Appendix 3: Description of the studies' risk of bias, variables adjusted for in the analyses and sources of funding

Risk of bias for the RCTs



Risk of bias for the retrospective cohort studies

Study	Selection				Comparability	Outcome			Stars: Quality
	1	2	3	4		1	2	3	
Chaudhuri 2020	1b*	2a*	3a*	4b	1ab**	1b*	2a*	3d	7: Good
Corzo 2020	1b*	2a*	3a*	4b	1ab**	1b*	2a*	3b*	9: Good
Milan 2020	1c	2a*	3a*	4b	1-	1b*	2a*	3b*	6: Fair
Sanabrina 2019	1b*	2a*	3a*	4b	1ab	1b*	2a*	3b*	9: Good
Weinhandl 2018	1b*	2a*	3a*	4b	1ab**	1b*	2a*	3d	7: Good

Variables adjusted for in the analyses

	Hospitalisations	Technical failure	QoL
Chaudhuri 2020	User group, Age, Gender, Race/ethnicity, Comorbidity, Laboratory measures, Education, Alcohol dependency, Urbanicity	User group, Age, Gender, Race/ethnicity, Comorbidity, Laboratory measures, Education, Alcohol dependency, Urbanicity	
Corzo 2020		Death, Kidney transplant	
Jung 2021			Age, Diabetes, Serum albumin concentrations
Sanabria 2019	Age, Gender, Education, CKD cause, Comorbidity index, Hemoglobin, Albumin, Phosphorus, Diuresis, Peritoneal equilibration test %, City, Follow-up time, Cause of censure		
Weinhandl 2018		Age, Sex, Race, Vascular access modality	

Sources of funding

Cao 2018: *"This project is supported by the 2014 Appropriate Technology Promotion Funding Plan for primary organizations and cities by the Fujian Provincial Health and Family Planning Commission and key Clinical Specialty Discipline Construction Program of Fujian, P.R.C."*

Jung 2021: *"This research was supported by a grant from the Korea Health Technology R&D Project through the Korea Health Industry Development Institute, funded by the Ministry of Health & Welfare, Republic of Korea (HC15Cll29). The sponsor of this study had no role in the study design collection, data management, data analysis, interpretation of data, writing of the report, and the decision to submit the report for publication"*

Chaudhuri 2020: "*Analysis was supported by Fresenius Medical Care"*

Corzo 2020: *"This work was funded by Renal Therapy Services, Colombia"*

Milan 2020: *"The authors did not use funding sources"*

Sanabria 2019: *"The study was supported by Baxter Renal Care Services Colombia, an independent entity owned by Baxter International, Inc. Funding to support the preparation of this manuscript was provided by Baxter Healthcare Corporation, Deerfield, Illinois. Baxter Healthcare Corporation participated in reviewing the manuscript for scientific accuracy"*

Weinhandl 2018: *"Conflict of Interest: Dr Weinhandl and Dr Collins are both employees of NxStage Medical. Disclosure of grants or other funding: The authors are solely responsible for the design of the study and the content of the manuscript. The content of the manuscript was reviewed by other NxStage Medical employees only for the verification of compliance with product labeling."*

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	p. 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	p. 2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	p. 3-4
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	p. 4
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	p. 4-6
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	p. 4 & supplement file 1
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Supplement file 1
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	p. 5
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	p. 6
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	p. 5-6
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	p. 6
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	p. 5-6
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	p. 6
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	p. 6
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	NA
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	p. 6
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	p. 6
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	NA
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	NA
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	NA

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	p. 6
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Figure 1 & p. 7
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	p. 7
Study characteristics	17	Cite each included study and present its characteristics.	Table 1 & p. 7
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Supplement file 2
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Figure 2 & table 2
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	p. 9
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	p. 9 & Figure 2
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	NA
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	NA
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	NA
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Table 3
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	p. 10-11
	23b	Discuss any limitations of the evidence included in the review.	p. 11-12
	23c	Discuss any limitations of the review processes used.	p. 11-12
	23d	Discuss implications of the results for practice, policy, and future research.	p. 11
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	p. 2 & 4
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	p. 2 & 4
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	p. 6
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	No support for review
Competing interests	26	Declare any competing interests of review authors.	No conflicts to declare
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Available on request

PRISMA 2020 Checklist

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

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Effect of remote patient monitoring for patients with chronic kidney disease who perform dialysis at home: a systematic review

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Title

Effect of remote patient monitoring for patients with chronic kidney disease who perform dialysis at home: a systematic review

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Word count: 3998

Abstract

Objective: The purpose of the systematic review was to assess the effectiveness of remote patient monitoring (RPM) follow-up compared to standard care, for patients with chronic kidney disease (CKD) who perform dialysis at home.

Methods: We conducted a systematic review in accordance with international guidelines. We performed systematic searches for publications from 2015-2021 in five databases (e.g. Medline, Cinahl, Embase) and a search for grey literature in reference lists. Included effect measures were quality of life, hospitalisation, technical failure as the cause for transfer to a different dialysis modality, infections, and time patients use for travel. Screening of literature, data extraction, risk of bias assessment, and certainty of evidence assessment (using the Grading of Recommendations Assessment, Development, and Evaluation approach) were done by two researchers. We conducted metaanalyses when possible.

Results: Seven studies met the inclusion criteria, of which two were randomised controlled trials and five were retrospective cohort studies with control groups. The studies included 9,975 participants from five countries, who were a good representation of dialysis patients in high- and upper-middle-income countries. The patients were on peritoneal dialysis (six studies) or home hemodialysis (one study). There was very low certainty of evidence for the outcomes, except for hospitalisations: There was low certainty evidence from three cohort studies for fewer hospitalisation days in the RPM group. No studies included data for time patients used for travel.

Conclusion: We found low to very low certainty evidence that indicate there may be positive effects of RPM follow-up, in comparison to standard care only, for adult patients with CKD who perform dialysis at home. Offering RPM follow-up for home dialysis patients as an alternative or supplement to standard care appears to be safe and provide health benefits such as fewer hospitalisation days. Future implementation should be coupled with robust, high quality evaluations.

Protocol: Pre-registered in PROSPERO (CRD42021281779).

Strength and limitations of this study

- To our knowledge, this is the first systematic review to assess the effectiveness and safety of remote patient monitoring follow-up for adult patients with dialysis-

dependent chronic kidney disease on home dialysis (hemodialysis and peritoneal dialysis).

- Our systematic review was conducted in line with guidelines from the Cochrane and GRADE working group. The researchers specialise in systematic review research, one researcher is a registered nurse with long and diverse nephology experience, and the searches were conducted by a search specialist.
- Due to study heterogeneity, inconsistent measurement and reporting, our ability to conduct metaanalyses was limited.

Introduction

Chronic kidney disease (CKD) is a significant public health concern**,** with 8-16% of the world's population affected.[1] It is characterised by a need for close monitoring, poor health outcomes, and a high economic burden for society as well as for the individual.[2] The world's population is growing older, and with CKD prevalence rising parallel with age,[2] an increasing number of people will continue to need monitoring and treatment with dialysis. There are two main types of dialysis: Peritoneal dialysis (PD) and hemodialysis (HD). Both are suitable treatment options when the kidneys are unable to filter the blood sufficiently.[3]

With the use of technology, there are encouraging possibilities for thorough patient follow-up, and at the same time, human resource savings.[4-6] Both PD and HD can be performed at home. With home dialysis, the patients receive comprehensive training arranged by staff at a dialysis centre to ensure that they have the skills and knowledge required to perform the treatment at home.[3 7] While dialysis is time-consuming regardless of location, patients on home dialysis are not dependent on hospital service hours and may experience more freedom than patients receiving in-centre dialysis.[8 9] Additionally, for patients on in-centre dialysis, the burden of time spent commuting between home and hospital can be extensive. They often also spend a substantial amount of time waiting for transport and waiting to be assisted by hospital staff for connection and disconnection from HD. Research shows that travel time to dialysis exceeding 60 minutes is associated with significantly decreased health-related quality of life (QoL) and significantly increased mortality risk compared to patients who travel 15 minutes or less.[10] With dialysis at home, it is reasonable to expect considerable time savings for the patients as well as improved health-related QoL.

In healthcare there is increasing interest in utilising technology-based interventions. Telemedicine and e-health are broad terms used when medical treatment, examination, or patient follow-up is done from a distance.[11] Homecare telehealth is another related term, and remote patient monitoring (RPM) is a subcategory thereof. RPM uses computer systems or software application technology that transfers patient-generated data to healthcare professionals.[12] Given the intervention considered in this systematic review is internet dependent, we will use the term RPM. RPM can give the patient quick access to medical expertise, independent of the distance to a treatment centre, and provides healthcare teams with valuable information about the patient's condition. Thus, RPM can be a tool to empower patients in self-care and for healthcare providers to offer support from a distance.[11] Qualitative studies from the U.K. and Norway suggest that patients on home dialysis have a positive attitude towards the use of RPM and believe that this could decrease anxiety and make it easier for more patients to choose home dialysis.[13 14] In a recent pilot study from Italy, patients overcame physical, cognitive, and psychological barriers to PD by RPM follow-up.[15]

Strategies to switch more patients to home dialysis may have positive impacts on the patients' daily life,[14 16] decrease mortality,[17] and offer economic savings for the patients as well as for society.[16 18] RPM holds much promise for enhancing follow up of CKD patients on dialysis and it is critical to determine whether and which strategies are effective at improving outcomes. RPM patient follow-up is seemingly already expanding its reach. Our Google Scholar search in December 2021 showed that there has been a 200% increase in records about e-health home dialysis from 2018 to 2021. Although interest in nephrology and e-health, including RPM, is increasing, to date, there are no systematic reviews about the effectiveness and safety of RPM follow-up including adult patients with dialysis-dependent CKD on home dialysis (HD and PD). We aimed to conduct a systematic review on the effectiveness of RPM follow-up compared to standard care, for adult patients with CKD who perform dialysis at home.

Methods

We conducted this systematic review in accordance with guidelines set forth in the Cochrane Handbook for Systematic Reviews of Interventions version 6.2.[19] The pre-specified protocol was registered in PROSPERO (CRD42021281779) and we report in line with the Preferred Reporting for Systematic Reviews and Metaanalyses (PRIMSA) statement.[20]

Search strategy and selection

The reviewers (HN, RB) prepared the search strategy in collaboration with a research librarian (LN), and a second research librarian peer-reviewed the search strategy. The librarian (LN) conducted searches in August 2021 in CINAHL (EBSCO), EMBASE (OVID), Medline (OVID), Cochrane Database of Systematic Reviews, and CENTRAL. The search included both subject headings (e.g. MeSH in Medline) and text words. Available Supplemental Appendix 1. In addition, the two reviewers conducted hand searches in the reference lists of the included studies.

The basis for the search was the inclusion criteria. We applied the (S)PICO model, which directs attention to the study design, population, intervention, comparison, and outcomes.[21] Eligible study designs were primary intervention studies with a control group. That is, randomised controlled trials (RCTs), non-randomised controlled studies, controlled before-after studies, and cohort studies with a control group. Study participants needed to be 18 years or older, with dialysis dependent CKD who performed dialysis at home (HD or PD). The patients could perform dialysis independently or with assistance of family or other carers. CKD did not have to be the only disease of the study participant. This is because patients with CKD are known to have a higher burden of comorbidities than the average population.[22] The eligible intervention was RPM, understood as internet dependent technology used to transfer treatment data from the patient's home to a healthcare institution.[12] This included video consultations, applications installed on the patient's phone, computer, or a tablet as well as technology that transferred treatment data directly from the dialysis machine to healthcare providers.[12] RPM that was not directly treatment related was excluded. This included, but was not limited to, apps for lifestyle changes, interventions for blood pressure control, and interventions for diabetes management. The comparator was standard care, understood as patients performing dialysis in-centre or at home and having regular in-person consultations at a HD or PD centre. Included effect measures were QoL (measured with any type of QoL assessment tool), hospitalisation (all-cause, disease-specific, and number of hospitalisation days), technical failure as the cause for transfer to a different dialysis modality, hospital registered infections not requiring hospitalisation, and time patients use for travel. Lastly, studies had to be published in a Scandinavian or English language, in 2015-2021 because we wanted to identify all studies relevant to the question and today's clinical situation, being cognisant that technology is rapidly improving.

We imported all records from the searches into an EndNote library and removed all duplicate entries. Two researchers (HN, RB) independently screened all titles and abstracts from the literature searches in accordance with the predetermined inclusion and exclusion criteria. All abstracts that appeared to fit the inclusion criteria or did not provide enough information, were promoted to full text screening. At each level, we evaluated the identified records independently of one another using a pre-developed inclusion form. The final determination to include or exclude was made together and any disagreements were solved by discussion. Excluded studies with justifications are available in Supplemental Appendix 2.

Risk of bias assessment and data extraction

To assess the included studies for risk of bias (RoB) we used two different instruments: The Newcastle-Ottawa scale for cohort studies,[23] and Cochrane Risk of Bias Tool for RCTs.[19] Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed on a final RoB evaluation, with disagreements solved by discussion.

One researcher (HN) created a standard extraction form and extracted data from all included studies. The information extracted from the studies was: title, authors, publication details, study design, aim of the study, study setting (location and time the study was conducted), characteristics of included participants (age, gender etc.), characteristics of the intervention, study setting, outcomes, and results. Whenever information was available, dichotomous and continuous data for all eligible outcomes were extracted. HN contacted several authors for additional data, but did not receive a reply. RB assessed the extracted data for completeness and accuracy and any disagreements were solved by further inspection of the publication and discussion.

Analysis and assessment of the certainty of the evidence (GRADE)

We extracted crude outcome data for all eligible outcomes when postscores for both intervention and control groups were available and, when such data were available, adjusted outcome data (adjusted comparison (effect) estimates and their standard errors or 95% confidence intervals, CI). We provide dichotomous outcomes as the number of events and number of people in groups as proportions, risk ratio (RR), incident RR (IRR) or odds ratio (OR) as appropriate. Continuous outcomes are shown as mean difference (MD) and standard deviations (SD), or the most appropriate presentation based on the available data in the included studies.

We evaluated the characteristics of the studies' (S)PICO and when they were considered sufficiently similar, and data were available, we conducted metaanalyses. The judgments about whether metaanalyses were appropriate were based on recommendations in the Cochrane Handbook.[19] We used Mantel-Haenszel random effects metaanalysis for dichotomous outcomes and we presented the relative risks and their corresponding 95% CI (it was not possible to metaanalyse any continuous outcomes). We also examined between-study heterogeneity using visual inspection of CIs, the Chi-square test, and Isquare statistic, quantifying the degree of heterogeneity as described in the Cochrane Handbook.[19] We used RevMan version 5.4, the latest version of the Cochrane metaanalysis software.[24] When the studies' (S)PICOs or results were too heterogeneous to pool statistically, or data were unavailable, we reported the results narratively, in text and tables. We planned to perform a subgroup analysis for the outcome technical failure, but this was not possible due to lack of data.

We assessed the certainty of the evidence using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework.[25] With regard to results that could not be metaanalysed, we followed the Synthesis Without Meta-analysis (SWiM) guideline.[26]

Patient and public involvement

Due to the nature of the study (systematic review), no patients were involved.

Results

The searches returned 451 references after removal of duplicates (Figure 1). We read 24 reports in full text, including one study identified from the hand search in reference lists. The most common primary reasons for exclusion were that there was no control group or it was the wrong participants or outcomes. Seven studies published between 2018-2021 were eligible for inclusion.[27-33]

Description of the studies

The seven included studies consisted of two RCTs and five retrospective cohort studies (Table 1). They were conducted in five different countries. There were two studies each from Columbia and USA, and one study each from China, Italy, and South Korea. Three were set in a single PD centre, four took place in two or more renal care centres and the two largest studies took place in the USA with one including 55 home HD centres and another 931 Fresenius PD clinics.

Table 1: Description of the included studies (n=7)

Author, (country, setting) Study design	Population	Intervention and comparator (follow-up time)	Outcomes	Risk of bias
Cao 2018[27] (China: 1 PD centre) RCT	N=160, on CAPD Men 58% Mean age 52	RPM vs SC Instant messaging application for support and education (mean 11.4 mo FU)	Hospitalisations Infections Technical failure	Moderate
Chaudhuri 2020[28] (USA: 931 renal centres) Cohort	N=6343, on PD Men 73% Mean age 57	RPM vs SC "Patient hub" application - patients add and access treatment data (12 mo FU)	Hospitalisations Technical failure	Low
Corzo 2020[29] (Columbia: 5 renal centres) Cohort	N=558, on APD Men 60% Mean age 54	RPM vs SC Cloud-based software - prescriptions can be changed remotely (mean 8.3 mo FU)	Technical failure	Low
Jung 2021[30] (South Korea: 6 renal centres) RCT	N=57, on APD Men 60% Mean age 47	RPM vs SC Cloud-based software - prescriptions can be changed remotely (6 mo FU)	QoL	Moderate
Milan 2020[31] (Italy: 1 PD centre) Cohort	N=73, on APD Men 75% Median age 60	RPM vs SC Cloud-based software - prescriptions can be changed remotely (6 mo FU)	Hospitalisations Technical failure QoL	Low/ Moderate
Sanabria 2019[32] (Columbia: 28 Baxter renal care centres) Cohort	N=360, on APD Men 66% Mean age 57	RPM vs SC Cloud-based software - prescriptions can be changed remotely (Mean 9 mo FU)	Hospitalisations Technical failure	Low
Weinhandl 2018[33] (USA: 55 HHD centres) Cohort	N=2424, on HHD Men 63% Mean age 53	RPM vs SC Nx2me telehealth platform - staff can do remote 'troubleshooting' during HHD (Mean 11 mo FU)	Technical failure	Low

Legend: APD=Automated peritoneal dialysis; CAPD=Continuous peritoneal dialysis; FU=Follow-up; HHD=Home hemodialysis; mo=Months; PD=Peritoneal dialysis; QoL=Quality of life; RCT= Randomised controlled trial; RPM=Remote patient monitoring; SC=Standard care

With respect to the population, all in all, there were 9,975 dialysis-dependent CKD patients in the studies. The range was 57-6343 patients, thus there was imbalance in sample sizes across the studies. The two largest studies, cohorts from the USA, made up 88% of the total number of study participants. In all the studies most patients were male (range 53%-75%) and the mean age of the study participants was about 55. In all studies except one, the

patients were on PD, they lived at home, and performed dialysis independently or with the assistance of a carer.

As per our inclusion criteria, the intervention was remote patient monitoring with different types of software that collected treatment data and transferred it to a treatment centre (added by the patients or automatically collected). The specific type of RPM varied across the studies. Four studies, Corzo et al.,[29] Jung et al.,[30] Milan et al.[31] and Sanabria et al.[32] used the automated PD system from Baxter: Homechoice Claria™, connected to the Sharesource platform. Milan et al.[31] additionally used the sleep-safe harmony home bridge system from Fresenius for half of the patients. Weinhandl & Collins[33] used the Nx2me telehealth platform for home HD patients. The software collects treatment data and transmits it to the healthcare providers, and the prescription can be changed 'from afar'. Chaudhuri et al.[28] used the "Patient hub" application. The PD patients can see their prescription, laboratory results, and enter treatment data, and the app transmits the patient-entered data to the healthcare providers. Cao et al.[27] used the "kidney cleaning group" instant messaging software. Technical support, nurse support, physician support, and support from fellow patients was available through chat and video. The patients were divided in smaller groups and one experienced PD patient with few complications was the group leader. Educational resources were also available in the platform. In addition, in all studies, all patients had or were likely to receive some level of standard care. This was generally described as in-person follow-up at the hospital. However, the frequency of standard care ranged from weekly (n=1) to every three months (n=1). Most studies had or were likely to have an in-person review monthly (n=5). The follow-up time ranged from 6 to 12 months.

Risk of bias of included studies

The RCTs had moderate risk of bias, while the retrospective cohort studies were rated fair to good methodological quality, i.e. having low to moderate risk of bias (Table 1 and Supplemental Appendix 3). With respect to the studies' sources of funding, three of the observational studies received financial support from the provider of the intervention (Supplemental Appendix 3).

Effect of RPM versus standard care

Across the studies, there were data on four of our five pre-determined outcomes: Hospitalisation,[27 28 31 32] infections,[27] technical failure as the cause for transfer to a different dialysis modality,[27-29 31-33] and QoL.[30 31] Due to the inconsistent measurement of outcomes, and inconsistent and incomplete reporting of outcome results in the studies, our ability to

synthesise data was limited. The results are described in the text below, Table 2, and Figure 2. The GRADE assessments in Table 3 show that there was low to very low certainty of evidence for all of the outcomes. This means that the effects are largely uncertain. No publications included data for the outcome 'time patients used for travel'.

Table 2. Study outcomes and effect estimates

Study	Outcome	Result/Effect estimate (95% CI)
Hospitalisations		
Chaudhuri 2020	Hospitalisation days (12 mo)	Adj. IRR 0.68 (0.55-0.83)
Milan 2020	Hospitalisation days (6 mo)	Median 5 days difference P 0.55
Sanabria 2019	Hospitalisation days (9 mo)	Adj. IRR 0.46 (0.23-0.92)
Cao 2018	Hospitalisation all-cause (11 mo)	RR 0.57 (0.17-1.88)
Chaudhuri 2020	Hospitalisation all-cause (12 mo)	Adj. IRR 0.74 (0.66-0.83)
Milan 2020	Hospitalisation all-cause (11 mo)	RR 1.33 (0.63-2.81)
Sanabria 2019	Hospitalisation all-cause (9 mo)	Adj. IRR 0.61 (0.39-0.95)
Infections		
Cao 2018	Infections (11 mo)	More peritonitis (60 in RPM group vs 40 in control group per patient month) but less exit site infections with RPM (RR= 0.45, 0.12-1.68)
Technical failure as cause for transfer to a different dialysis modality		
Cao 2018	Technical failure (11 mo)	RR 1.00 (0.26-3.86)
Chaudhuri 2020	Technical failure (12 mo)	Adj. HR 0.79 (0.63-1.00)
Corzo 2020	Technical failure (8 mo)	IRR 0.88 (0.41-1.74)
Sanabria 2019	Technical failure (subgroup) (9 mo)	RR 0.97 (0.42-2.25)
Weinhandl 2018	Technical failure (subgroup) (11 mo)	Adj. HR 0.66 (0.50-0.86)
Quality of life		
Jung 2021	KDQOL -Patient satisfaction questions (6 mo)	Mean 75.5 in RPM group vs 73.7 in SC group, P 0.64
Milan 2020	KDQOL -Patient satisfaction questions (6 mo)	Median 83.3 in both groups, P 0.99
Jung 2021	KDQOL -Dialysis staff encouragement (6 mo)	Mean 93.1 in RPM group vs 97.1 in SC group, P 0.05
Milan 2020	KDQOL -Dialysis staff encouragement (6 mo)	Median 100 in both groups, P 0.16

Legend: Adj=Adjusted (listed in Supplemental Appendix 3); HR=Hazard ratio; IRR=Incident rate ratio (compares the incidence rates between two different groups and shows if exposure to something increases or decreases the rate of some incidence -- if IRR is 1 then there is no difference); mo=Months; KDQOL=kidney disease quality of life; RPM=Remote patient monitoring; RR=Relative risk; SC=Standard care

Table 3: Summary of findings (GRADE)

Population: Patients with CKD
Countries: China, Columbia, Italy, South Korea, USA

Intervention: RPM

Comparison: Standard care

Outcome, follow-up time	**Anticipated absolute effects* (95% CI)**		**Relative effect (95% CI)**	**No. of participants (Studies)**	**Quality of evidence (GRADE)**
	Assumed risk with control	Assumed risk with RPM			
Hospitalisations (6-12 months)					
Days	All 3 cohort studies showed that there were fewer hospitalisation days in the RPM group (Table 2)			6,736 (3)	⊕⊕◯◯ LOW
All-cause	3 of 4 studies (1 RCT, 3 cohort) showed that there were fewer hospitalisations in the RPM group (Table 2)			6,936 (4)	⊕◯◯◯ VERY LOW[1]
Disease-specific	30/198 (15.2%)	10/110 (9.1%)	RR 0.62 (0.31 to 1.24)	308 (2 cohort)	⊕◯◯◯ VERY LOW[2]
Infections (11 months)					
	1 RCT reported more peritonitis but fewer exit site infections with RPM (Table 2)			160 (1)	⊕◯◯◯ VERY LOW[3]
Technical failure (6-12 months)					
	521/2230 (23.4%)	136/786 (17.3%)	RR 0.78 (0.66 to 0.93)	2856 (3 cohort)	⊕◯◯◯ VERY LOW[4]
	2 of 3 studies (1 RCT, 2 cohort) reported fewer failures with RPM (Table 2)			7161 (3)	
Quality of life (6 months)					
Patient satisfaction	1 RCT found higher QoL in the RPM group, 1 cohort found QoL was similar in the two groups (Table 2)			130 (2)	⊕◯◯◯ VERY LOW[5]

Dialysis staff encouragement	1 RCT found higher QoL in the RPM group, 1 cohort found QoL was similar in the two groups (Table 2)	130 (2)	⊕◯◯◯ VERY LOW[5]
Travel time	0 studies assess this outcome		No evidence

1. Downgraded by 1 level because of moderate risk of bias in 1 study and inconsistency
2. Downgraded by 1 level because of imprecision
3. Downgraded by 3 levels because of moderate risk of bias, inconsistency, imprecision
4. Downgraded by 1 level because of moderate risk of bias in 1 study and imprecision
5. Downgraded by 1 level because of inconsistency and imprecision

CI: Confidence interval; RCT: Randomised controlled study; SD: Standard deviation. *The risk in the intervention group (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).

Hospitalisations

One RCTs and three observational studies from Italy, Colombia, China, and the USA examined the effect of RPM on hospitalisations.[27 28 31 32] However, the outcome was reported differently across the studies, as hospitalisation days/days admitted, all-cause hospitalisations, and disease-specific hospitalisations (caused by overhydration, access dysfunction, and infections).

Hospitalisation days. The three observational studies, Chaudhuri et al.,[28] Milan et al.,[31] and Sanabria et al.[32], all found fewer hospitalisation days in the RPM group than the control group (Table 2). The results in Sanabria et al.[32] were from a matched sample, as data for the whole sample was not available. This study showed the largest effect with a difference of six hospitalisation days (IRR 0.46, 0.23-0.92).

All-cause hospitalisations. One RCT[27] and three observational studies[28 31 32] had data on general, all-cause hospitalisations. While three of the four studies showed that RPM users had less all-cause hospitalisations than patients with standard care only, the fourth study favoured standard care (Table 2).

Disease-specific hospitalisations. The results on disease-specific hospitalisations from two observational studies, Milan et al.,[31] and Sanabria et al.[32] could be pooled in a metaanalysis (Figure 2). The non-significant result suggested there were fewer disease-specific hospitalisations in the RPM group than in the control group (RR 0.62, 95% CI 0.31-1.24).

Milan et al.[31] defined disease-specific hospitalisations as infections (peritonitis and exit site), overhydration, and access dysfunction. Sanabria et al.[32] provided numbers for hospitalisations due to peritonitis and overhydration.

Infections

Only one RCT, from China, examined the effectiveness of RPM follow-up for PD patients on infections.[27] The result for this outcome was inconclusive, as Cao et al. found more peritonitis but fewer exit site infections with RPM. It was not specified whether the infections were treated at home or in the hospital.

Technical failure as the cause for transfer to a different dialysis modality

One RCT from China [27] found no difference between the groups while five observational studies from the USA[28 33], Colombia[29 32], and Italy[31] consistently reported less technical failure as cause for transfer to a different dialysis modality in the RPM group compared to the control group (Table 2). Three of the cohort studies could be pooled in a metaanalysis; the result implies benefit of RPM (0.78, 95% CI 0.66, 0.92) (Figure 2). Two of the studies[32 33] gave data on novice patients with less than three months treatment duration at baseline, indicating a positive, but non-significant effect of RPM in new patients (Table 2).

Self-reported Quality of Life

Both studies, one RCT[30] and one observational study,[31] reporting on quality of life used the tool 'The short form of kidney disease quality of life' (KDQOL), which is an adaptation of SF-36.[34] All answers were transformed into pre-coded numeric values with a range from 0-100, where 100 was the highest QoL.[35] Neither studies offered an overall total score across the questions/areas, and we selected the two questions/areas that we considered most relevant (patient satisfaction and dialysis staff encouragement). For both patient satisfaction and dialysis staff encouragement, Milan et al.[31] found the same score in both groups, while Jung et al.[30] found a higher score in the RPM group than the control group concerning patient satisfaction, but opposite for dialysis staff encouragement (Table 2).

Discussion

Principal findings

This systematic review advances the evidence on the effects of RPM for patients with dialysis dependent CKD on home dialysis, including home HD and PD. Our findings are in line with previous research[36 37] and document that there is no conclusive evidence, but that positive effects of RPM are suggested for clinical outcomes, technical failure, and quality of life.

The results consistently suggest that RPM reduces hospitalisations and the number of days the patient is admitted. It was especially convincing that Milan et al.[31] observed a median difference of five fewer hospitalisation days in the RPM group over six months, because the patients on RPM had a worse comorbidity score. Furthermore, except for one study that found the same number of technical failures in both groups, the other five studies found less technical failure in the RPM group. In four of the studies measuring this outcome, prescriptions could be changed from the hospital without in-person consultations. In effect, RPM allows resolving technical issues early, thus preventing progression of technical failure to the stage where the patient would need to transfer to a different dialysis modality. Research has found great advantages with the technology displaying possible causes and solutions to problems, alarm indicators showing who to contact for guidance (nurse or technician), and reminders of activities that need to be performed.[13-15] Concerning quality of life, only two studies assessed this and the results showed the scores were comparable for the patients on RPM and usual care. Encouragingly, scores for quality of life improved slightly and patient satisfaction was higher than neutral. This is in line with a study from the U.S. that found that RPM increased patients' confidence and satisfaction with treatment because they felt more closely supported.[38] Lastly, no studies assessed time patients use for travel. However, research suggests that health-related quality of life and time patients use for travel are intertwined[10] and that dialysis free time and reduction of fatigue are highly valued outcomes by patients.[9 39 40] This could reflect positively on quality of life.

Our results mirror two earlier systematic reviews on e-health interventions in PD patients[36] and in people with CKD.[37] Both reviews, with literature searches in 2018-2019, included a wide range of patients and e-health modalities, including mobile or tablet application, text or email messages, electronic monitors, internet/websites, and video or DVD. Consequently, there was minimal overlap in included studies: Only one review[36] included two of our included studies. Both reviews concluded that the quality of evidence for the effectiveness of e-health was low with uncertain effects, but that no adverse effects were indicated. Of note, a recent modelling analysis projected that in a cohort of 100 patients on automated PD over 1 year, RPM would lead to 27 fewer hospitalisations, 518 fewer hospitalization days, 31 additional months free of complications, and six fewer peritonitis episodes.[41]

Implications

Overall, the low to very low certainty of evidence on the effects of RPM for patients with dialysis dependent CKD on home dialysis prevents strong recommendations. Given RPM seems comparable to usual care, the absence of adverse effects and promising clinical effects, it seems advisable cautiously to implement RPM while concomitantly evaluating outcomes important for patients. Prior to recommending RPM for CKD patients on home dialysis, more trials are needed to be certain of its benefits over standard care, and to establish equity and cost effectiveness. A modelling analysis from the payer perspective has found that RPM is cost effective,[41] but economic evaluations of e-health interventions are scarce and highlights an important area for further research.[5 42] Additionally, patient groups should be involved in RPM implementation and evaluation, to maximize the potential for modification and ultimately effect.

Our review highlights the need for robust, high quality research on both PD and home HD, but especially for patients on home HD and patients whose home is in a nursing home. To our knowledge, home HD in nursing homes is rare, while PD is common. It is likely that nursing home staff aided by RPM support from specialist nurses at dialysis centres could provide invaluable assistance to frail CKD patients with great need for follow-up. For such patients and others with dialysis dependent CKD on home dialysis, time used for travel and dialysis free time is a patient-important outcome that warrants further research. It is reasonable to suspect substantial time-savings when follow-up is performed from afar and evidence from video consultations in patient follow-up are positive.[15 43] We encourage research on the combined use of video consultations and cloud-based technology on outcomes such as travel time, technical failure, and hospitalisations. Standardised outcomes in nephrology (SONG) have identified and prioritised outcomes for both HD and PD patients and can be a useful tool when planning outcomes in future research.[44]

Strengths and limitations

Our systematic review was conducted in line with guidelines from the Cochrane and GRADE working group. The outcome selection was in alignment with core outcomes recommended by the SONG initiative.[44] The researchers specialise in systematic review research, one researcher is a registered nurse with long and diverse nephrology experience, and the searches were conducted by a search specialist. Yet, it is possible that relevant studies have been missed and relevant studies have been published after our last search. Due to study heterogeneity, variability in intervention characteristics, inconsistent measurement and

reporting, our ability to conduct metaanalyses was limited. Therefore, it was neither possible to improve precision to any great extent, nor statistically assess potential differences across groups, such as type of platform or HD and PD. We contacted several authors asking for more data, but did not receive a reply. The low number of studies meant that we were unable to statistically check for publication bias. Given the modestly positive but varied results, we believe the potential for publication bias is low, but we recommend future reviews of a higher number of included studies to assess this potential bias. The imbalance in sample sizes across the studies, with two studies having a considerably larger sample size than the other five, influenced the results related to hospitalisations and technical failure. Both these two studies had low risk of bias, but three other studies had moderate risk of bias.

Conclusion

This systematic review summarises and presents low to very low evidence that indicate there may be positive effects of RPM follow-up, in comparison to standard care only, for adult patients with CKD who perform dialysis at home. Offering RPM follow-up for home dialysis patients as an alternative or supplement to standard care appears to be safe and provide health benefits, but future implementation should be coupled with robust, high quality evaluations. Despite the high interest in RPM and increasing demands for nephrology services, good quality evidence is still needed to determine their effectiveness.

Contributors

HN wrote the first draft. RB and HN contributed equally to the rest of the work. LN prepared and conducted the systematic searches and contributed with inputs on the final draft. We are grateful to [removed for blind review], for peer review of the systematic search strategies

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'None declared'.

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Not applicable

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Data availability statement

Data are available on reasonable request.

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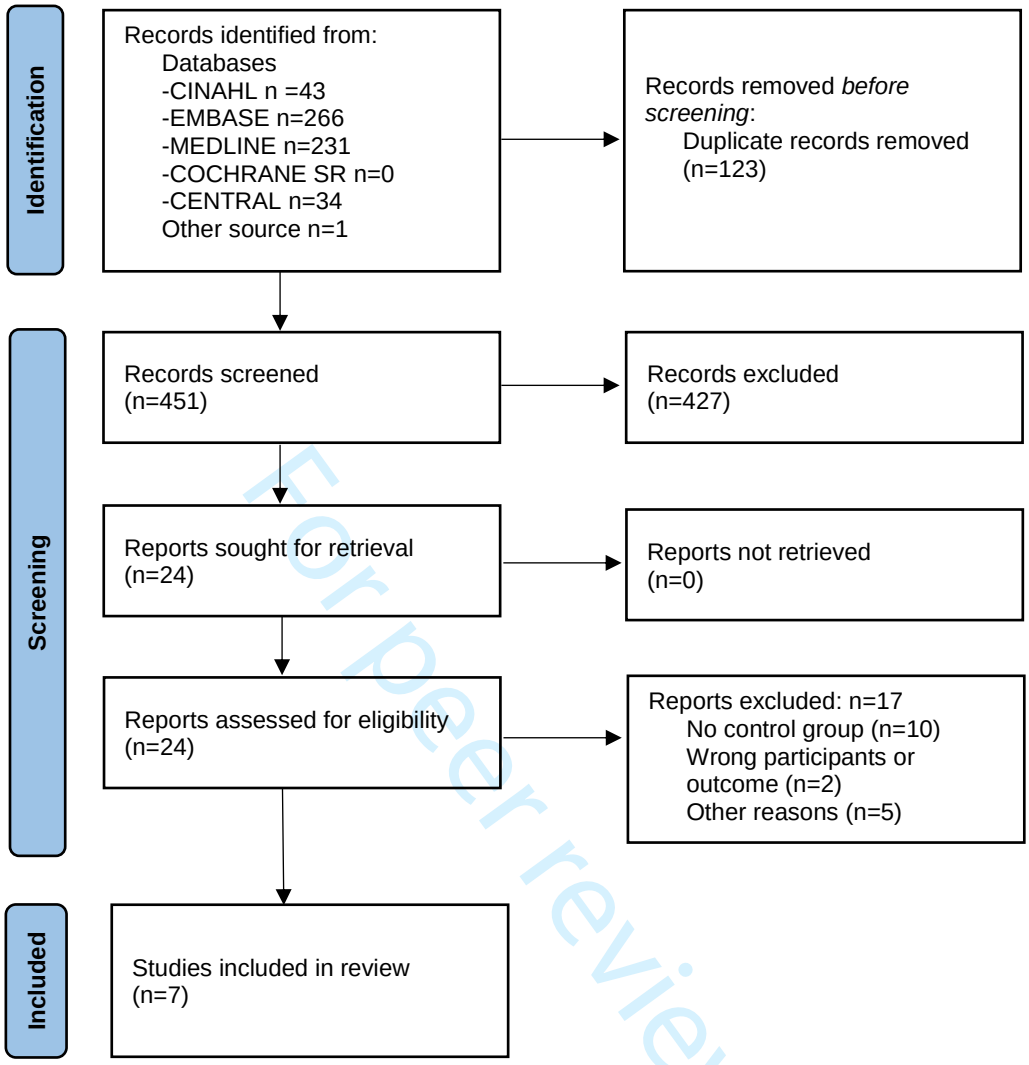
Figure legend:

Figure 1: Prisma flow diagram for selection of studies

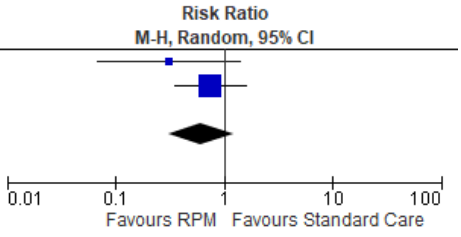
Figure 2: Metaanalyses of outcomes disease specific hospitalisations and technical failure



(a) Disease specific hospitalisations

Study or Subgroup	RPM Events	RPM Total	Standard Care Events	Standard Care Total	Weight	Risk Ratio M-H, Random, 95% CI
Milan 2020	2	35	7	38	21.3%	0.31 [0.07, 1.39]
Sanabria 2019	8	75	23	160	78.7%	0.74 [0.35, 1.58]
Total (95% CI)		**110**		**198**	**100.0%**	**0.62 [0.31, 1.24]**
Total events	10		30			

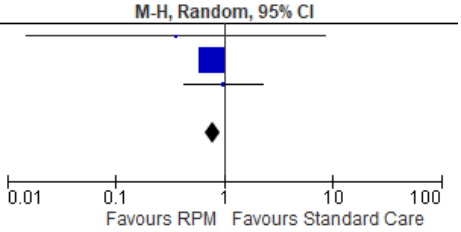
Heterogeneity: Tau² = 0.01; Chi² = 1.04, df = 1 (P = 0.31); I² = 4%
Test for overall effect: Z = 1.35 (P = 0.18)



(b) Technical failure

Study or Subgroup	RPM Events	RPM Total	Standard Care Events	Standard Care Total	Weight	Risk Ratio M-H, Random, 95% CI
Milan 2020	0	35	1	38	0.3%	0.36 [0.02, 8.58]
Weinhandl 2018	126	606	488	1817	95.7%	0.77 [0.65, 0.92]
Sanabria 2019	6	65	28	295	4.1%	0.97 [0.42, 2.25]
Total (95% CI)		**706**		**2150**	**100.0%**	**0.78 [0.66, 0.92]**
Total events	132		517			

Heterogeneity: Tau² = 0.00; Chi² = 0.50, df = 2 (P = 0.78); I² = 0%
Test for overall effect: Z = 2.88 (P = 0.004)



Supplemental Appendix 1: Search strategies

Date: 23.08.2021
Searches conducted by: Lien Nguyen
Search strategies peer reviewed by: Elisabet Hafstad

Database	Number of hits
Embase <1974 to 2021 August 20> (OVID)	266
Ovid MEDLINE(R) ALL <1946 to August 20, 2021>	231
Cochrane Library of Systematic Reviews (Cochrane Library; Wiley)	0
CENTRAL(Cochrane Library; Wiley)	34
CINAHL (EBSCO)	43
Total number of references	574
Total after duplicate removal	451

Database: Embase

Search interface: Advanced Search

1 exp telehealth/ 60896

2 exp telecommunication/ 87729

3 exp health care delivery/ 3564027

4 2 and 3 65304

5 (telecare* or teleconsult* or telefollow* or telehealth* or telehome* or telemanag* or telemedicine or telemonitor* or telenurs* or telepatient* or telesupport*).ti,ab,kw,bt. 33953

6 ((tele or telemedical* or tele medical*) adj (care* or checkup* or check up* or consult* or followup* or follow up* or health* or home* or manag* or medicine* or monitor* or nurs* or patient* or support*)).ti,ab,kw,bt. 1853

7 (ecare or econsult* or ehealth or emedicine* or enurs* or mcare or mconsult* or mhealth or mnurse or mcare or mnursing or mconsult* or mnurs*).ti,ab,kw,bt. 10706

8 ((e or m or mobile or digital) adj (care or consult* or health* or nurs*)).ti,ab,kw,bt. 15428

9 (remote adj2 (care* or checkup* or check up* or consult* or followup* or follow up* or health* or home* or manag* or medicine* or monitor* or nursing or patient* or self)).ti,ab,kw,bt. 12293

10 1 or 4 or 5 or 6 or 7 or 8 or 9 92070

11 hemodialysis/ 115843

12 exp peritoneal dialysis/ 44307

13 home dialysis/ 2966

14 (((dialysis or hemodialysis or haemodialysis) adj4 home?) or peritoneal dialysis).ti,ab,kw,bt. 37655

15	(CAPD or APD or HHD).ti.	3524
16	or/11-15	151629
17	10 and 16	534
18	limit 17 to yr=2000-current	516
19	(exp animals/ or exp invertebrate/ or animal experiment/ or animal model/ or animal tissue/ or animal cell/ or nonhuman/) not (human/ or normal human/ or human cell/)	6724645
20	editorial.pt.	699530
21	18 not (19 or 20)	494
22	limit 21 to embase	270
23	remove duplicates from 22	266

Database: OVID MEDLINE

Search interface: Advanced Search

1	Telemedicine/	29751
2	Telenursing/	232
3	Remote Consultation/	5273
4	or/1-3	34165
5	exp Telecommunications/	108428
6	(care or healthcare).hw.	1324775
7	5 and 6	19771
8	4 or 7	42042
9	(telecare* or teleconsult* or telefollow* or telehealth* or telehome* or telemanag* or telemedicine or telemonitor* or telenurs* or telepatient* or telesupport*).ti,ab,kf,bt.	26067
10	((tele or telemedical* or tele medical*) adj (care* or checkup* or check up* or consult* or followup* or follow up* or health* or home* or manag* or medicine* or monitor* or nurs* or patient* or support*)).ti,ab,kf,bt.	1020
11	(ecare or econsult* or ehealth or emedicine* or enurs* or mcare or mconsult* or mhealth or mnurse or mcare or mnursing or mconsult* or mnurs*).ti,ab,kf,bt.	10618
12	((e or m or mobile or digital) adj (care or consult* or health* or nurs*)).ti,ab,kf,bt.	13372
13	(remote adj2 (care* or checkup* or check up* or consult* or followup* or follow up* or health* or home* or manag* or medicine* or monitor* or nursing or patient* or self)).ti,ab,kf,bt.	8231
14	or/8-13	69186

15	Renal Dialysis/	94819
16	Hemodialysis, Home/	2013
17	exp Peritoneal Dialysis/	26840
18	(((dialysis or hemodialysis or haemodialysis) adj4 home?) or peritoneal dialysis).ti,ab,kf,bt.	28202
19	(CAPD or APD or HHD).ti.	2685
20	or/15-19	121750
21	14 and 20	271
22	limit 21 to yr=2000-current	243
23	exp animals/ not humans/	4877030
24	(news or editorial or comment).pt.	1512750
25	22 not (23 or 24)	231
26	remove duplicates from 25	231

Database: Cochrane Database of Systematic Review & CENTRAL

Search interface: Advanced Search > Search Manager

ID	Search	Hits
#1	[mh ^telemedicine]	2414
#2	[mh ^telenursing]	31
#3	[mh ^"remote consultation"]	381
#4	#1 or #2 or #3	2777
#5	[mh telecommunications]	7362
#6	[mh ^"delivery of health care"]	806
#7	[mh ^"health services"]	458
#8	#5 and (#6 or #7)	139
#9	#4 or #8	2838
#10	(telecare* or teleconsult* or telefollow* or telehealth* or telehome* or telemanag* or telemedicine or telemonitor* or telenurs* or telepatient* or telesupport*):ti,ab,kw	7370
#11	((tele or telemedical* or tele-medical*) NEXT (care* or checkup* or check-up* or consult* or followup* or follow-up* or health* or home* or manag* or medicine* or monitor* or nurs* or patient* or support*)):ti,ab,kw	446

#12	(ecare or econsult* or ehealth or emedicine* or enurs* or mcare or mconsult* or mhealth or mnurse or mcare or mnursing or mconsult* or mnurs*):ti,ab,kw	2547
#13	((e or m or mobile or digital) NEXT (care or consult* or health* or nurs*)):ti,ab,kw	3725
#14	(remote NEAR/2 (care* or checkup* or check-up* or consult* or followup* or follow-up* or health* or home* or manag* or medicine* or monitor* or nursing or patient* or self)):ti,ab,kw	1743
#15	{or #9-#14}	11340
#16	[mh ^"Renal Dialysis"]	4322
#17	[mh ^"hemodialysis, home"]	43
#18	[mh "Peritoneal Dialysis"]	900
#19	(((dialysis or hemodialysis or haemodialysis) NEAR/4 home?) or "peritoneal dialysis"):ti,ab,kw	2491
#20	(CAPD or APD or HHD):ti	409
#21	{or #16-#20}	6775
#22	#15 and #21 with Cochrane Library publication date Between Jan 2000 and Aug 2021, in Cochrane Reviews	0
#23	#15 and #21 with Publication Year from 2000 to 2021, in Trials	34

Database: CINAHL

Search interface: Advanced Search

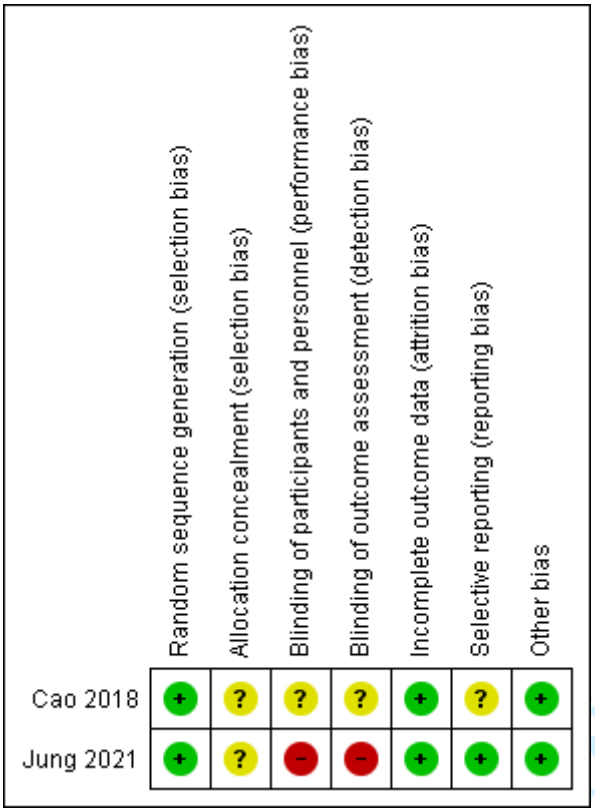
Supplemental Appendix 2: Excluded studies read in full text

Excluded studies read in full text (n=17)	Justifications for exclusion
Dey V, Jones A, Spalding EM. Telehealth: Acceptability, clinical interventions and quality of life in peritoneal dialysis. SAGE Open Med. 2016;4:2050312116670188.	No control group
El Shamy O, Tran H, Sharma S, Ronco C, Narayanan M, Uribarri J, et al. Telenephrology with Remote Peritoneal Dialysis Monitoring during Coronavirus Disease 19. Karger AG; 2020. p. 480-2.	Letter about Covid-19 and the impact in kidney care/review
Harnett P, Jones M, Almond M, Ballasubramaniam G, Kunnath V. A virtual clinic to improve long-term outcomes in chronic kidney disease. Clinical Medicine, Journal of the Royal College of Physicians of London. 2018;18(5):356-63.	Not home dialysis patients
Huang R, Liu N, Nicdao MA, Mikaheal M, Baldacchino T, Albeos A, et al. Emotion sharing in remote patient monitoring of patients with chronic kidney disease. J Am Med Inform Assoc. 2020;27(2):185-93.	No control group and wrong outcome
Kiberd J, Khan U, Stockman C, Radhakrishnan A, Phillips M, Kiberd BA, et al. Effectiveness of a Web-Based eHealth Portal for Delivery of Care to Home Dialysis Patients: A Single-Arm Pilot Study. Can J Kidney Health Dis. 2018;5:2054358118794415.	No control group
Milan Manani S, Crepaldi C, Giuliani A, Virzi GM, Garzotto F, Riello C, et al. Remote Monitoring of Automated Peritoneal Dialysis Improves Personalization of Dialytic Prescription and Patient's Independence. Blood Purification. 2018;46(2):111-7.	No control group
Milan Manani S, Rosner MH, Virzì GM, Giuliani A, Berti S, Crepaldi C, et al. Longitudinal Experience with Remote Monitoring for Automated Peritoneal Dialysis Patients. Nephron. 2019;142(1):1-9.	No control group
Musso CG, Plazzotta F, Otero C, Aguilera J, Campos F, Diez GR, et al. Informatic nephrology: 17 years of one-center experience. International Urology and Nephrology. 2015;47(9):1587-8.	Letter (not empirical study)
Nayak KS, Ronco C, Karopadi AN, Rosner MH. Telemedicine and Remote Monitoring: Supporting the Patient on Peritoneal Dialysis. Perit Dial Int. 2016;36(4):362-6.	No control group: summary from three different studies
Patterson P. Telehealth for Home Dialysis Therapies. Nephrol Nurs J. 2017;44(6):545-8.	An interview with a doctor
Polanco E, Aquey M, Collado J, Campos E, Guzman J, Cuevas-Budhart MA, et al. A COVID-19 pandemic-specific, structured care process for Peritoneal Dialysis patients facilitated by Telemedicine: therapy continuity, prevention and complications management. Therapeutic apheresis and dialysis : official peer-reviewed journal of the International Society for Apheresis, the Japanese Society for Apheresis, the Japanese Society for Dialysis Therapy. 2021.	No control group
Ronco C, Manani SM, Giuliani A, Tantillo I, Reis T, Brown EA. Remote patient management of peritoneal dialysis during COVID-19 pandemic. Perit Dial Int. 2020;40(4):363-7.	Review
Scarpioni R, Manini A, Chiappini P. Remote patient monitoring in peritoneal dialysis helps reduce risk of hospitalization during Covid-19 pandemic. J Nephrol. 2020;33(6):1123-4.	There are patients with RPM and without, but they are not compared
Tangaro S, Fanizzi A, Amoroso N, Corciulo R, Garuccio E, Gesualdo L, et al. Computer aided detection system for prediction of the malaise during hemodialysis. Computational and Mathematical Methods in Medicine. 2016;2016 (no pagination).	No control group without TM
Viglino G, Neri L, Barbieri S, Tortone C. Videodialysis: a pilot experience of telecare for assisted peritoneal dialysis. J Nephrol. 2020;33(1):177-82.	No relevant outcomes
Wood E, McCarthy K, Roper M. Remote monitoring of peritoneal dialysis: evaluating the impact of the Claria Sharesource system. Journal of Kidney Care. 2019;4(1):16-24.	No control group

Yeter HH, Karacalik C, Eraslan E, Akcay OF, Derici U, Ronco C. Effect of remote patient management in peritoneal dialysis on haemodynamic and volume control. Nephrology. 2020;25(11):856-64.	No pre-intervention assessment

Supplemental Appendix 3: Description of the studies' risk of bias, variables adjusted for in the analyses and sources of funding

Risk of bias for the RCTs



Risk of bias for the retrospective cohort studies

Study	Selection				Comparability	Outcome			Stars: Quality
	1	2	3	4		1	2	3	
Chaudhuri 2020	1b*	2a*	3a*	4b	1ab**	1b*	2a*	3d	7: Good
Corzo 2020	1b*	2a*	3a*	4b	1ab**	1b*	2a*	3b*	9: Good
Milan 2020	1c	2a*	3a*	4b	1-	1b*	2a*	3b*	6: Fair
Sanabrina 2019	1b*	2a*	3a*	4b	1ab	1b*	2a*	3b*	9: Good
Weinhandl 2018	1b*	2a*	3a*	4b	1ab**	1b*	2a*	3d	7: Good

Variables adjusted for in the analyses

	Hospitalisations	Technical failure	QoL
Chaudhuri 2020	User group, Age, Gender, Race/ethnicity, Comorbidity, Laboratory measures, Education, Alcohol dependency, Urbanicity	User group, Age, Gender, Race/ethnicity, Comorbidity, Laboratory measures, Education, Alcohol dependency, Urbanicity	
Corzo 2020		Death, Kidney transplant	
Jung 2021			Age, Diabetes, Serum albumin concentrations
Sanabria 2019	Age, Gender, Education, CKD cause, Comorbidity index, Hemoglobin, Albumin, Phosphorus, Diuresis, Peritoneal equilibration test %, City, Follow-up time, Cause of censure		
Weinhandl 2018		Age, Sex, Race, Vascular access modality	

Sources of funding

Cao 2018: *"This project is supported by the 2014 Appropriate Technology Promotion Funding Plan for primary organizations and cities by the Fujian Provincial Health and Family Planning Commission and key Clinical Specialty Discipline Construction Program of Fujian, P.R.C."*

Jung 2021: *"This research was supported by a grant from the Korea Health Technology R&D Project through the Korea Health Industry Development Institute, funded by the Ministry of Health & Welfare, Republic of Korea (HC15Cll29). The sponsor of this study had no role in the study design collection, data management, data analysis, interpretation of data, writing of the report, and the decision to submit the report for publication"*

Chaudhuri 2020: "*Analysis was supported by Fresenius Medical Care"*

Corzo 2020: *"This work was funded by Renal Therapy Services, Colombia"*

Milan 2020: *"The authors did not use funding sources"*

Sanabria 2019: *"The study was supported by Baxter Renal Care Services Colombia, an independent entity owned by Baxter International, Inc. Funding to support the preparation of this manuscript was provided by Baxter Healthcare Corporation, Deerfield, Illinois. Baxter Healthcare Corporation participated in reviewing the manuscript for scientific accuracy"*

Weinhandl 2018: *"Conflict of Interest: Dr Weinhandl and Dr Collins are both employees of NxStage Medical. Disclosure of grants or other funding: The authors are solely responsible for the design of the study and the content of the manuscript. The content of the manuscript was reviewed by other NxStage Medical employees only for the verification of compliance with product labeling."*

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	p. 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	p. 2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	p. 3-4
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	p. 4
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	p. 4-6
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	p. 4 & supplement file 1
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Supplement file 1
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	p. 5
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	p. 6
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	p. 5-6
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	p. 6
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	p. 5-6
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	p. 6
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	p. 6
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	NA
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	p. 6
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	p. 6
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	NA
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	NA
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	NA

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	p. 6
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Figure 1 & p. 7
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	p. 7
Study characteristics	17	Cite each included study and present its characteristics.	Table 1 & p. 7
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Supplement file 2
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Figure 2 & table 2
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	p. 9
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	p. 9 & Figure 2
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	NA
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	NA
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	NA
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Table 3
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	p. 10-11
	23b	Discuss any limitations of the evidence included in the review.	p. 11-12
	23c	Discuss any limitations of the review processes used.	p. 11-12
	23d	Discuss implications of the results for practice, policy, and future research.	p. 11
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	p. 2 & 4
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	p. 2 & 4
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	p. 6
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	No support for review
Competing interests	26	Declare any competing interests of review authors.	No conflicts to declare
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Available on request

PRISMA 2020 Checklist

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

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