

BMJ Open is committed to open peer review. As part of this commitment we make the peer review history of every article we publish publicly available.

When an article is published we post the peer reviewers' comments and the authors' responses online. We also post the versions of the paper that were used during peer review. These are the versions that the peer review comments apply to.

The versions of the paper that follow are the versions that were submitted during the peer review process. They are not the versions of record or the final published versions. They should not be cited or distributed as the published version of this manuscript.

BMJ Open is an open access journal and the full, final, typeset and author-corrected version of record of the manuscript is available on our site with no access controls, subscription charges or pay-per-view fees (<u>http://bmjopen.bmj.com</u>).

If you have any questions on BMJ Open's open peer review process please email <u>info.bmjopen@bmj.com</u>

BMJ Open

BMJ Open

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

Journal:	BMJ Open
Manuscript ID	bmjopen-2022-061772
Article Type:	Original research
Date Submitted by the Author:	07-Feb-2022
Complete List of Authors:	Nygård, Henriette; Norwegian Institute of Public Health, Health; University of Tromso Department of Community Medicine Nguyen, Lien; Norwegian Institute of Public Health Berg, Rigmor C; Norwegian Institute of Public Health; University of Tromso Department of Community Medicine
Keywords:	Telemedicine < BIOTECHNOLOGY & BIOINFORMATICS, Dialysis < NEPHROLOGY, End stage renal failure < NEPHROLOGY, Adult nephrology < NEPHROLOGY, Chronic renal failure < NEPHROLOGY, Health informatics < BIOTECHNOLOGY & BIOINFORMATICS

SCH	OL	AR	Ο	N	E	
M	an	uso	ri	pt	S	



I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our <u>licence</u>.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which <u>Creative Commons</u> licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

reliez oni

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Title

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

Corresponding author

Henriette Tyse Nygård, Buggemyra 1, 5378 Klokkarvik, Norway. hettny@gmail.com

Authors

Henriette Tyse Nygård, Norwegian Institute of Public Health, Oslo, Norway, University of Tromsø, Tromsø, Norway, and Haukeland University Hospital, Bergen, Norway

Lien H. Nguyen, Norwegian Institute of Public Health, Oslo, Norway

Rigmor C Berg, Norwegian Institute of Public Health, Oslo, Norway, and University of Tromsø, Tromsø, Norway

Acknowledgements: We are grateful to Elisabet Hafstad, Norwegian Institute of Public Health, for peer review of the systematic search strategies

Word count: 3759

Su

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 dialysisdependent 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 incentre 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

BMJ Open

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

BMJ Open

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 inc	luded studies	(n=7)
----------	-------------	------------	---------------	-------

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

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

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 & Collins³² 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'.

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 dia	lysis 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	RR 0.97 (0.42-2.25)
Weinhandl 2018	mo)	
	Technical failure (subgroup) (11	Adj. HR 0.66 (0.50-0.86)
	mo)	
Quality of life		
Jung 2021	QoL -Patient satisfaction	Mean 75.5 in RPM group vs 73.7 in
Milan 2020	questions (6 mo)	SC group
		Median 83.3 in both groups

Table 2. Study outcomes and effect estimates

I	
2	
3	
4	
5	
6	
7	
, 8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	
5Z	
33	
34	
35	
36	
37	
38	
39	
40	
41	
42	
43	
44	
45	
46	
47	
48	
49 50	
50	
51	
52	
53	
54	
55	
56	
50	
57	

58 59 60

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

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	No. of participants	Quality of evidence (GRADE)	
	Assumed risk with control	Assumed risk with RPM	(95% CI)	(Studies)	(GRADE)	
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	that there we	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 mon	ths)		0			
		rted more peritor ections with RPM		160 (1)	⊕○○○ VERY LOW ³	
Technical failure (6-12 months)		7		
	521/2230 (23.4%)	136/786 (17.3%)	RR 0.78 (0.66 to 0.93)	2856 (3 cohort)	⊕○○○ VERY LOW ⁴	
		es (1 RCT, 2 coh es with RPM (Ta		7161 (3)		
Quality of life (6 m	onths)					
Patient satisfaction	group, 1 col	d higher QoL in ort found QoL v ups (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 in	consistency
2. Downgraded by	1 level because of imprecision		
3. Downgraded by	3 levels because of moderate risk of bias, in	consistency, i	imprecision
4. Downgraded by	1 level because of moderate risk of bias in 1	study and im	precision
5. Downgraded by	1 level because of inconsistency and imprec	ision	

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 RCT²⁶ 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 Italy³⁰ 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 RCT²⁹ 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.

Page 15 of 30

BMJ Open

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 intertwined¹⁰ and that dialysis free time and reduction of fatigue are highly valued outcomes by patients.⁹³⁶ ³⁷ This could reflect positively on quality of life.

Our results mirror two earlier systematic reviews on e-health interventions in PD patients³⁸ 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 review³⁸ 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.⁵⁴¹ 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

'This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors'.

Exclusive licence

Please confirm you agree with the following statement by ticking the box and then insert the licence statement in your manuscript file.

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a

worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in BMJ Open and any other BMJ products and to exploit all rights, as set out in our <u>licence</u>.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which <u>Creative Commons</u> licence will apply to this Work are set out in our licence referred to above.

Data availability statement

Data are available on reasonable request.

References

- 1. Chen TK, Knicely DH, Grams ME. Chronic Kidney Disease Diagnosis and Management: A Review. JAMA 2019;322(13):1294-304. doi: 10.1001/jama.2019.14745
- 2. Tonelli M, Riella M. Chronic kidney disease and the aging population. *Indian journal of nephrology* 2014;24(2):71-74. doi: 10.4103/0971-4065.127881
- Sinnakirouchenan R, Holley JL. Peritoneal dialysis versus hemodialysis: risks, benefits, and access issues. *Adv Chronic Kidney Dis* 2011;18(6):428-32. doi: 10.1053/j.ackd.2011.09.001 [published Online First: 2011/11/22]
- 4. Meld. St. 7 (2019–2020). Nasjonal helse- og sykehusplan 2020–2023: Helse- og omsorgsdepartementet; [cited 2021 12.09]. Available from: https://www.regjeringen.no/no/dokumenter/meld.-st.-7-20192020/id2678667/
- 5. Kitsiou S, Paré G, Jaana M, et al. Effectiveness of mHealth interventions for patients with diabetes: An overview of systematic reviews. *PLoS One* 2017;12(3):e0173160. doi: 10.1371/journal.pone.0173160 [published Online First: 2017/03/02]
- Widmer, R. Jay, et al. "Digital health interventions for the prevention of cardiovascular disease: a systematic review and meta-analysis." *Mayo Clinic Proceedings*. Vol. 90. No. 4. Elsevier, 2015
- 7. Helsedirektoratet. Nyresvikt dialysepasienter som får hjemmedialyse: Helsedirektoratet; 2018 [updated 2021 02.12; cited 2021 12.12]. Available from: https://www.helsedirektoratet.no/statistikk/kvalitetsindikatorer/behandling-avsykdom-og-overlevelse/andel-dialysepasienter-som-har-hjemmedialyse
- Helsedirektoratet. Handlingsplan for forebygging og behandling av kronisk nyresykdom (2011-2015) 2011 [cited 2021 11.09]. Available from:

	http://www.nephro.no/foreningsnytt/Handlingsplan_forebygging_behandling_kronisk nyresykdom.pdf.
9. Urc	uhart-Secord R, Craig JC, Hemmelgarn B, et al. Patient and Caregiver Priorities for Outcomes in Hemodialysis: An International Nominal Group Technique Study.
	American Journal of Kidney Diseases 2016;68(3):444-54. doi: https://doi.org/10.1053/j.ajkd.2016.02.037
10. M	oist LM, Bragg-Gresham JL, Pisoni RL, et al. Travel Time to Dialysis as a Predictor of Health-Related Quality of Life, Adherence, and Mortality: The Dialysis Outcomes and
	Practice Patterns Study (DOPPS). <i>American Journal of Kidney Diseases</i> 2008;51(4):641-50. doi: https://doi.org/10.1053/j.ajkd.2007.12.021
11. Bı	aut GS. Telemedisin Store medisinske leksikon [updated 2020 15.06; cited 2021 10.10]. Available from: https://sml.snl.no/telemedisin.
12. De	elVecchio A. Definition, remote patient monitoring (RPM): Tech target, Search health IT; [updated April 2019; cited 2021 10.10]. Available from:
	https://searchhealthit.techtarget.com/definition/remote-patient-monitoring-RPM
13. Ra	ijkomar A, Farrington K, Mayer A, et al. Patients' and carers' experiences of interacting with home haemodialysis technology: implications for quality and safety. <i>BMC Nephrology</i> 2014;15(1):195-95. doi: 10.1186/1471-2369-15-195
14. R <u>y</u>	gh E, Arild E, Johnsen E, et al. Choosing to live with home dialysis-patients'
	experiences and potential for telemedicine support: a qualitative study. <i>BMC</i> <i>Nephrology</i> 2012;13(1):13-13. doi: 10.1186/1471-2369-13-13
15. Vi	glino G, Neri L, Barbieri S, et al. Videodialysis: a pilot experience of telecare for assisted peritoneal dialysis. <i>J Nephrol</i> 2020;33(1):177-82. doi: 10.1007/s40620-019- 00647-6 [published Online First: 2019/09/19]
16. Fr	ançois K, Bargman JM. Evaluating the benefits of home-based peritoneal dialysis. <i>Int J</i> Nephrol Renovasc Dis 2014;7:447-55. doi: 10.2147/IJNRD.S50527
17. M	arshall MR, Polkinghorne KR, Kerr PG, et al. Temporal Changes in Mortality Risk by Dialysis Modality in the Australian and New Zealand Dialysis Population. <i>American</i> <i>Journal of Kidney Diseases</i> 2015;66(3):489-98. doi:
18 W	https://doi.org/10.1053/j.ajkd.2015.03.014 alker RC, Howard K, Morton RL. Home hemodialysis: a comprehensive review of
10. 11	patient-centered and economic considerations. <i>Clinicoecon Outcomes Res</i> 2017;9:149- 61. doi: 10.2147/CEOR.S69340
19. Hi	ggins JPT TJ, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (editors). Cochrane Handbook for Systematic Reviews of Interventions version 6.2 (updated February 2021): Cochrane; 2021 [cited 2021 12.09]. Available from:
20. PH	www.training.cochrane.org/handbook. CISMA transperant reporting of systematic reviews and meta-analyses [cited 2021 08.11]. Available from: http://www.prisma-statement.org/.
21. St	raus SE, Glasziou P, Richardson WS, et al. Evidence-based medicine E-book: How to practice and teach EBM: Elsevier Health Sciences 2018.
22. То	nelli M, Wiebe N, Guthrie B, et al. Comorbidity as a driver of adverse outcomes in people with chronic kidney disease. <i>Kidney International</i> 2015;88(4):859-66. doi: https://doi.org/10.1038/ki.2015.228
23. W	ells GA, Shea B, O'Connell D, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses: The Ottawa hospital research
	institute; [cited 2021 21.10]. Available from: http://www.ohri.ca/programs/clinical epidemiology/oxford.asp

- 24. Cochrane RevMan Cochrane Training [updated Latest verion of RevMan 5.4.1. from September 2020; cited 2021 10.10]. Available from: https://training.cochrane.org/online-learning/core-software-cochrane-reviews/revman.
- 25. GRADE: The GRADE Working Group; 2004-2021 [cited 2021 21.10]. Available from: https://www.gradeworkinggroup.org/
- 26. Cao F, Li L, Lin M, et al. Application of instant messaging software in the follow-up of patients using peritoneal dialysis, a randomised controlled trial. *Journal of Clinical Nursing* 2018;27(15-16):3001-07. doi: https://doi.org/10.1111/jocn.14487
- 27. Chaudhuri S, Han H, Muchiutti C, et al. Remote Treatment Monitoring on Hospitalization and Technique Failure Rates in Peritoneal Dialysis Patients. *Kidney360* 2020;1(3):191-202. doi: 10.34067/kid.0000302019
- 28. Corzo L, Wilkie M, Vesga JI, et al. Technique failure in remote patient monitoring program in patients undergoing automated peritoneal dialysis: A retrospective cohort study. *Perit Dial Int* 2020:896860820982223. doi: 10.1177/0896860820982223 [published Online First: 2021/01/01]
- 39. Jung HY, Jeon Y, Kim YS, et al. Outcomes of Remote Patient Monitoring for Automated Peritoneal Dialysis: A Randomized Controlled Trial. *Nephron* 2021 doi: 10.1159/000518364
- 30. Milan Manani S, Baretta M, Giuliani A, et al. Remote monitoring in peritoneal dialysis: benefits on clinical outcomes and on quality of life. *Journal of Nephrology* 2020;33(6):1301-08.
- 31. Sanabria M, Buitrago G, Lindholm B, et al. Remote Patient Monitoring Program in Automated Peritoneal Dialysis: Impact on Hospitalizations. *Perit Dial Int* 2019;39(5):472-78. doi: 10.3747/pdi.2018.00287 [published Online First: 2019/07/25]
- 32. Weinhandl ED, Collins AJ. Relative risk of home hemodialysis attrition in patients using a telehealth platform. *Hemodial Int* 2018;22(3):318-27. doi: 10.1111/hdi.12621 [published Online First: 2017/12/07]
- 33. Wong FK, Chow SK, Chan TM. Evaluation of a nurse-led disease management programme for chronic kidney disease: a randomized controlled trial. *International Journal of Nursing Studies* 2010;47(3):268-78. doi: 10.1016/j.ijnurstu.2009.07.001
- 34. Kidney Disease Quality of Life Instrument (KDQOL): The RAND Corporation; [cited 2021 14.10]. Available from: https://www.rand.org/health-care/surveys_tools/kdqol.html
- 35. Magnus M, Sikka N, Cherian T, et al. Satisfaction and Improvements in Peritoneal Dialysis Outcomes Associated with Telehealth. *Appl Clin Inform* 2017;8(1):214-25. doi: 10.4338/aci-2016-09-ra-0154 [published Online First: 2017/03/02]
- 36. Manera KE, Johnson DW, Craig JC, et al. Patient and Caregiver Priorities for Outcomes in Peritoneal Dialysis. *Multinational Nominal Group Technique Study* 2019;14(1):74-83. doi: 10.2215/cjn.05380518
- 37. Evangelidis N, Tong A, Manns B, et al. Developing a Set of Core Outcomes for Trials in Hemodialysis: An International Delphi Survey. *American Journal of Kidney Diseases* 2017;70(4):464-75. doi: 10.1053/j.ajkd.2016.11.029
- 38. Cartwright EJ, Z ZSG, Foo M, et al. eHealth interventions to support patients in delivering and managing peritoneal dialysis at home: A systematic review. *Peritoneal Dialysis International* 2021;41(1):32-41.
- Stevenson JK, Campbell ZC, Webster AC, et al. eHealth interventions for people with chronic kidney disease. *Cochrane Database of Systematic Reviews* 2019(8) doi: 10.1002/14651858.CD012379.pub2

2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
יע ו רער	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	
33	
34	
35	
36	
37	
38	
39	
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	
51	
52	
53	
54	
55	
56	
57	
58	

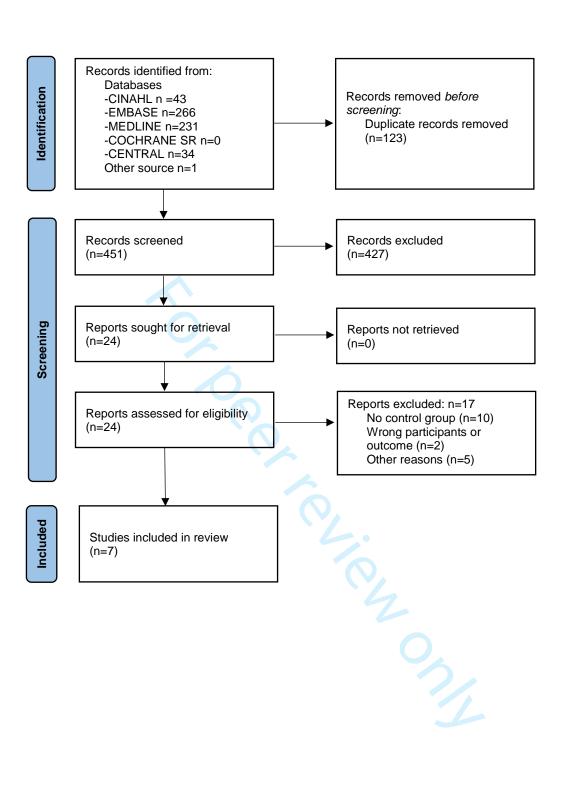
59 60

- 40. Ariza JG, Walton SM, Sanabria M, et al. Evaluating a remote patient monitoring program for automated peritoneal dialysis. Perit Dial Int 2020;40(4):377-83. doi: 10.1177/0896860819896880 [published Online First: 2020/02/18]
- 41. Sanyal C, Stolee P, Juzwishin D, et al. Economic evaluations of eHealth technologies: A systematic review. PLoS One 2018;13(6):e0198112. doi:
 - 10.1371/journal.pone.0198112 [published Online First: 2018/06/14]
- 42. Gallar P, Vigil A, Rodriguez I, et al. Two-year experience with telemedicine in the follow-up of patients in home peritoneal dialysis. Journal of Telemedicine & Telecare 2007;13(6):288-92. doi: 10.1258/135763307781644906

Figure legend:

Figure 1: Prisma flow diagram for selection of studies

i. Figure 2: Metaanalyses of outcomes disease specific hospitalisations and technical failure **BMJ** Open



	RPN	1	Standard	Care		Risk Ratio		Risk Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% Cl		M-H, Random, 95% Cl
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: Tau ² =	= 0.01; Chi	i ² = 1.04	4, df = 1 (P :	= 0.31);	l² = 4%		0.01	
Test for overall effect:	Z = 1.35 ((P = 0.1	8)				0.01	Favours RPM Favours Standard Care
b) Technical f	ailure							
b) Technical f	ailure	1	Standard	Care		Risk Ratio		Risk Ratio
b) Technical f Study or Subgroup		-			Weight	Risk Ratio M-H, Random, 95% Cl		Risk Ratio M-H, Random, 95% Cl
,	RPN	-			Weight 0.3%			
Study or Subgroup	RPN Events	Total	Events	Total		M-H, Random, 95% Cl		
Study or Subgroup Milan 2020	RPN Events 0	Total 35	Events 1	Total 38	0.3%	M-H, Random, 95% Cl 0.36 [0.02, 8.58]		
Study or Subgroup Milan 2020 Weinhandl 2018 Sanabria 2019	RPN Events 0 126	Total 35 606 65	Events 1 488	Total 38 1817 295	0.3% 95.7% 4.1%	M-H, Random, 95% Cl 0.36 [0.02, 8.58] 0.77 [0.65, 0.92] 0.97 [0.42, 2.25]		
Study or Subgroup Milan 2020 Weinhandl 2018	RPN Events 0 126	Total 35 606	Events 1 488	Total 38 1817 295	0.3% 95.7%	M-H, Random, 95% Cl 0.36 [0.02, 8.58] 0.77 [0.65, 0.92]		
Study or Subgroup Milan 2020 Weinhandl 2018 Sanabria 2019	RPN Events 0 126	Total 35 606 65	Events 1 488	Total 38 1817 295	0.3% 95.7% 4.1%	M-H, Random, 95% Cl 0.36 [0.02, 8.58] 0.77 [0.65, 0.92] 0.97 [0.42, 2.25]		
Milan 2020 Weinhandl 2018 Sanabria 2019 Total (95% CI)	RPN Events 0 126 6 132	Total 35 606 65 706	Events 1 488 28 517	Total 38 1817 295 2150	0.3% 95.7% 4.1% 100.0%	M-H, Random, 95% Cl 0.36 [0.02, 8.58] 0.77 [0.65, 0.92] 0.97 [0.42, 2.25]		M-H, Random, 95% Cl
Study or Subgroup Milan 2020 Weinhandl 2018 Sanabria 2019 Total (95% CI) Total events	RPN Events 0 126 6 132 = 0.00; Chi	Total 35 606 65 706 i ² = 0.5(Events 1 488 28 517), df = 2 (P	Total 38 1817 295 2150	0.3% 95.7% 4.1% 100.0%	M-H, Random, 95% Cl 0.36 [0.02, 8.58] 0.77 [0.65, 0.92] 0.97 [0.42, 2.25]	 0.01	

Chr = 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/	356402

- 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.
- 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

1

3524

3	
4	
5	
6 7	
7 8	
9	
10	
11 12	
13	
14	
15	
16 17	
18	
19	
20 21	
22	
22 23 24	
24 25	
25 26	
27	
28	
29 30	
31	
32	
33 34	
35	
36	
37 38	
30 39	
40	
41	
42 43	
44	
45	
46 47	
47	
49	
50 51	
51 52	
53	
54	
55 56	
57	
58	
59 60	
00	

13	(CAPD OF APD	01 HHDJ.u.	5524
16	or/11-15	151629	
17	10 and 16	534	
18	limit 17 to yr=2	2000-current	516
19	• •	•	rate/ or animal experiment/ or animal model/ or animal tissue/) not (human/ or normal human/ or human cell/) 6724645
20	editorial.pt.	699530	
21	18 not (19 or 2	20) 494	

- 22 limit 21 to embase 270
- 23 remove duplicates from 22 266

(CAPD or APD or HHD) ti

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.
 - 14 or/8-1369186

3
4
5
6 7
/ 8
9
10
11
12
13
14 15
16
17
18
19
20
21 22
22
24
25
26
27
28 29
30
31
32
33
34
35 36
30 37
38
39
40
41
42 43
43 44
45
46
47
48
49 50
51
52
53
54
55
56 57
57
59
60

15

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

Renal Dialysis/ 94819

Database: Cochrane Database of Systematic Review & CENTRAL

Search interface: Advanced Search > Search Manager

- #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

iez oni

#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

- #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, inCochrane Reviews 0

RY.CZ ONY

#23 #15 and #21 with Publication Year from 2000 to 2021, in Trials 34

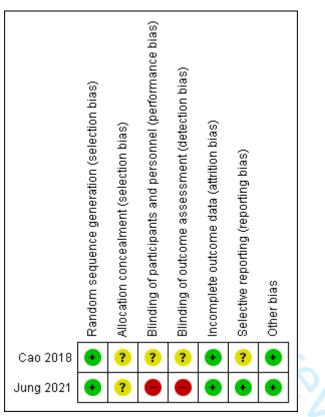
Database: CINAHL

Search interface: Advanced Search

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

BMJ Open

Risk of bias for the RCTs



Study	Selec	tion			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	ltem #	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			p. 3-4
Rationale			
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.	р. 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.	Supplemen 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.	р. 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.	р. 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.	р. 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). For peer review only - http://bmjopen.bmj.com/site/about/guidelmes.xhtml	NA

BMJ Open

 BMJ Open



PRISMA 2020 Checklist

Section and Topic	ltem #	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.	р. 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.	Supplemen 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	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	р. 9
syntheses	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 INFORMA	TION		
Registration and	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	p. 2 & 4
protocol	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. For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml	Available o request

Page 31 of 30

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 For more information, visit: <u>http://www.prisma-statement.org/</u>

For beer review only

BMJ Open

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open

BMJ Open

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

Journal:	BMJ Open
Manuscript ID	bmjopen-2022-061772.R1
Article Type:	Original research
Date Submitted by the Author:	02-May-2022
Complete List of Authors:	Nygård, Henriette; Norwegian Institute of Public Health, Health; University of Tromso Department of Community Medicine Nguyen, Lien; Norwegian Institute of Public Health Berg, Rigmor C; Norwegian Institute of Public Health; University of Tromso Department of Community Medicine
Primary Subject Heading :	Renal medicine
Secondary Subject Heading:	Health informatics, Health services research, Nursing, Patient-centred medicine, Renal medicine
Keywords:	Telemedicine < BIOTECHNOLOGY & BIOINFORMATICS, Dialysis < NEPHROLOGY, End stage renal failure < NEPHROLOGY, Adult nephrology < NEPHROLOGY, Chronic renal failure < NEPHROLOGY, Health informatics < BIOTECHNOLOGY & BIOINFORMATICS





I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our <u>licence</u>.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which <u>Creative Commons</u> licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

reliez oni

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

2		
3	1	Title
4		
5 6	2	Effect of remote patient monitoring for patients with chronic kidney disease who perform
7	2	
8	3	dialysis at home: a systematic review
9	4	
10	4	Corresponding author
11	-	
12 13	5	Henriette Tyse Nygård, Buggemyra 1, 5378 Klokkarvik, Norway. hettny@gmail.com
14		
15	6	Authors
16		
17	7	Henriette Tyse Nygård, Norwegian Institute of Public Health, Oslo, Norway, University of
18	8	Tromsø, Tromsø, Norway, and Haukeland University Hospital, Bergen, Norway
19 20	0	Tromso, Tromso, Torway, and Thackeland Oniversity Trospital, Dergen, Torway
20 21	9	Lien H. Nguyen, Norwegian Institute of Public Health, Oslo, Norway
22	9	Lien II. Nguyen, Norwegian institute of Fublic Health, Oslo, Norway
23	10	Digmor C Darg Norwagian Institute of Dublic Health Oale Norway, and University of
24	10	Rigmor C Berg, Norwegian Institute of Public Health, Oslo, Norway, and University of
25	11	Tromsø, Tromsø, Norway
26		
27 28	12	Acknowledgements: We are grateful to Elisabet Hafstad, Norwegian Institute of Public
20 29		
30	13	Health, for peer review of the systematic search strategies
31	14	
32	14	Word count: 3998
33		
34 35	15	Word count: 3998
35 36		
37	16	
38		
39		
40		
41		
42 43		
44		
45		
46		
47		
48		
49 50		
51		
52		
53		
54		
55		
56 57		
58		
59		
60		

2 3	1					
4 5	2	Abstract				
6 7	2	Abstract				
8	3	Objective: The purpose of the systematic review was to assess the effectiveness of remote				
9 10	4	patient monitoring (RPM) follow-up compared to standard care, for patients with chronic				
11 12	5	kidney disease (CKD) who perform dialysis at home.				
13 14	6	Methods: We conducted a systematic review in accordance with international guidelines. We				
15	7	performed systematic searches for publications from 2015-2021 in five databases (e.g.				
16 17	8	Medline, Cinahl, Embase) and a search for grey literature in reference lists. Included effect				
18 19	9	measures were quality of life, hospitalisation, technical failure as the cause for transfer to a				
20	10	different dialysis modality, infections, and time patients use for travel. Screening of literature,				
21 22	11	data extraction, risk of bias assessment, and certainty of evidence assessment (using the				
23 24	12	Grading of Recommendations Assessment, Development, and Evaluation approach) were				
25 26	13	done by two researchers. We conducted metaanalyses when possible.				
27 28	14	Results: Seven studies met the inclusion criteria, of which two were randomised controlled				
29	15	trials and five were retrospective cohort studies with control groups. The studies included				
30 31 32 33 34 35 36 37 38	16	9,975 participants from five countries, who were a good representation of dialysis patients in				
	17	high- and upper-middle-income countries. The patients were on peritoneal dialysis (six				
	18	studies) or home hemodialysis (one study). There was very low certainty of evidence for the				
	19	outcomes, except for hospitalisations: There was low certainty evidence from three cohort				
	20	studies for fewer hospitalisation days in the RPM group. No studies included data for time				
39 40	21	patients used for travel.				
41 42	22	Construient We found have to some how containty and that in direct them more how within				
43	22	Conclusion: We found low to very low certainty evidence that indicate there may be positive				
44 45	23	effects of RPM follow-up, in comparison to standard care only, for adult patients with CKD				
46 47	24	who perform dialysis at home. Offering RPM follow-up for home dialysis patients as an				
48	25	alternative or supplement to standard care appears to be safe and provide health benefits such				
49 50	26	as fewer hospitalisation days. Future implementation should be coupled with robust, high				
51 52	27	quality evaluations.				
53 54	28	Protocol: Pre-registered in PROSPERO (CRD42021281779).				
55 56	29	Strength and limitations of this study				
57 58	30	- To our knowledge, this is the first systematic review to assess the effectiveness and				
59 60	31	safety of remote patient monitoring follow-up for adult patients with dialysis-				
		2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2				

1 2		
2 3 4	1	dependent chronic kidney disease on home dialysis (hemodialysis and peritoneal
5	2	dialysis).
6 7	3	- Our systematic review was conducted in line with guidelines from the Cochrane and
8 9	4	GRADE working group. The researchers specialise in systematic review research, one
10	5	researcher is a registered nurse with long and diverse nephology experience, and the
11 12	6	searches were conducted by a search specialist.
13 14	7	- Due to study heterogeneity, inconsistent measurement and reporting, our ability to
15	8	conduct metaanalyses was limited.
16 17	9	
18 19	9	
20 21	10	Introduction
22	11	Chronic kidney disease (CKD) is a significant public health concern, with 8-16% of the
23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40	12	world's population affected. ¹ It is characterised by a need for close monitoring, poor health
	13	outcomes, and a high economic burden for society as well as for the individual. ² The world's
	14	population is growing older, and with CKD prevalence rising parallel with age, ² an increasing
	15	number of people will continue to need monitoring and treatment with dialysis. There are two
	16	main types of dialysis: Peritoneal dialysis (PD) and hemodialysis (HD). Both are suitable
	17	treatment options when the kidneys are unable to filter the blood sufficiently. ³
	18	With the use of technology, there are encouraging possibilities for thorough patient
	19	follow-up, and at the same time, human resource savings. ⁴⁻⁶ Both PD and HD can be
	20	performed at home. With home dialysis, the patients receive comprehensive training arranged
	21	by staff at a dialysis centre to ensure that they have the skills and knowledge required to
41 42	22	perform the treatment at home. ³⁷ While dialysis is time-consuming regardless of location,
43	23	patients on home dialysis are not dependent on hospital service hours and may experience
44 45	24	more freedom than patients receiving in-centre dialysis.89 Additionally, for patients on in-
46 47	25	centre dialysis, the burden of time spent commuting between home and hospital can be
48	26	extensive. They often also spend a substantial amount of time waiting for transport and
49 50	27	waiting to be assisted by hospital staff for connection and disconnection from HD. Research
51 52	28	shows that travel time to dialysis exceeding 60 minutes is associated with significantly
53 54	29	decreased health-related quality of life (QoL) and significantly increased mortality risk
55	30	compared to patients who travel 15 minutes or less. ¹⁰ With dialysis at home, it is reasonable to
56 57	31	expect considerable time savings for the patients as well as improved health-related QoL.
58 59		
60		

Page 5 of 34

BMJ Open

2		
3 4	1	In healthcare there is increasing interest in utilising technology-based interventions.
5	2	Telemedicine and e-health are broad terms used when medical treatment, examination, or
6 7	3	patient follow-up is done from a distance. ¹¹ Homecare telehealth is another related term, and
8 9	4	remote patient monitoring (RPM) is a subcategory thereof. RPM uses computer systems or
10	5	software application technology that transfers patient-generated data to healthcare
11 12	6	professionals. ¹² Given the intervention considered in this systematic review is internet
13 14	7	dependent, we will use the term RPM. RPM can give the patient quick access to medical
15 16	8	expertise, independent of the distance to a treatment centre, and provides healthcare teams
17	9	with valuable information about the patient's condition. Thus, RPM can be a tool to empower
18 19	10	patients in self-care and for healthcare providers to offer support from a distance. ¹¹
20 21	11	Qualitative studies from the U.K. and Norway suggest that patients on home dialysis have a
22 23	12	positive attitude towards the use of RPM and believe that this could decrease anxiety and
24	13	make it easier for more patients to choose home dialysis. ^{13 14} In a recent pilot study from Italy,
25 26	14	patients overcame physical, cognitive, and psychological barriers to PD by RPM follow-up. ¹⁵
27 28	15	Strategies to switch more patients to home dialysis may have positive impacts on the
29	16	patients' daily life, ^{14 16} decrease mortality, ¹⁷ and offer economic savings for the patients as
30 31	17	well as for society. ^{16 18} RPM holds much promise for enhancing follow up of CKD patients on
32 33	18	dialysis and it is critical to determine whether and which strategies are effective at improving
34 35	19	outcomes. RPM patient follow-up is seemingly already expanding its reach. Our Google
36	20	Scholar search in December 2021 showed that there has been a 200% increase in records
37 38	21	about e-health home dialysis from 2018 to 2021. Although interest in nephrology and e-
39 40	22	health, including RPM, is increasing, to date, there are no systematic reviews about the
41 42	23	effectiveness and safety of RPM follow-up including adult patients with dialysis-dependent
43	24	CKD on home dialysis (HD and PD). We aimed to conduct a systematic review on the
44 45	25	effectiveness of RPM follow-up compared to standard care, for adult patients with CKD who
46 47	26	perform dialysis at home.
48	27	
49 50	27	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

BMJ Open

1 Search strategy and selection

2 The reviewers (HN, RB) prepared the search strategy in collaboration with a research

- 3 librarian (LN), and a second research librarian peer-reviewed the search strategy. The
- 4 librarian (LN) conducted searches in August 2021 in CINAHL (EBSCO), EMBASE (OVID),
- 5 Medline (OVID), Cochrane Database of Systematic Reviews, and CENTRAL. The search
 - 6 included both subject headings (e.g. MeSH in Medline) and text words. Available
- 7 Supplemental Appendix 1. In addition, the two reviewers conducted hand searches in the
- 8 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.

Page 7 of 34

BMJ Open

1 Two insported in records non all statistics into an End took nonly that Netword and 2 duplicate entries. Two researches in Accordance with the predetermined inclusion and exclusion 3 from the literature searches in accordance with the predetermined inclusion and exclusion 4 eriteria. All abstracts that appeared to fit the inclusion eriteria or did not provide enough 5 information, were promoted to full text screening. At each level, we evaluated the identified 6 records independently of one another using a pre-developed inclusion form. The final 7 determination to include or exclude was made together and any disagreements were solved by 8 discussion. Excluded studies for risk of bias (RoB) we used two different instruments: The 10 To assess the included studies for risk of bias (RoB) we used two different instruments: The 11 Newcastle-Ottawa scale for othort studies. ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹ 12 Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed 13 on a final RoB evaluation, with disagreements solved by discussion. 14 One researcher (HN) created a standard extraction form and extracted data from all 15 included studies. The information extracted from the studies was: title, authors, publication 16 <th>2</th> <th></th> <th></th>	2		
3 from the literature searches in accordance with the predetermined inclusion and exclusion 4 criteria. All abstracts that appeared to fit the inclusion criteria or did not provide enough 5 information, were promoted to full text screening. At each level, we evaluated the identified 6 records independently of one another using a pre-developed inclusion form. The final 7 determination to include or exclude was made together and any disagreements were solved by 8 discussion. Excluded studies with justifications are available in Supplemental Appendix 2. 9 <i>Risk of bias assessment and data extraction</i> 10 To assess the included studies for risk of bias (RoB) we used two different instruments: The 11 Newcastle-Ottawa scale for cohort studies. ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹ 12 Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed 13 on a final RoB evaluation, with disagreements solved by discussion. 14 One researcher (HN) created a standard extraction form and extracted data from all 15 included studies. The information extracted from the studies was: title, authors, publication 16 details, study design, aim of the study, study setting (location and time the study was 17 conducted), characteristics of included participants (age, gender etc.), charac	3 4	1	We imported all records from the searches into an EndNote library and removed all
3 from the literature searches in accordance with the predetermined inclusion and exclusion 4 criteria. All abstracts that appeared to fit the inclusion criteria or did not provide enough 5 information, were promoted to full text sereening. At each level, we evaluated the identified 7 records independently of one another using a pre-developed inclusion form. The final 7 determination to include or exclude was made together and any disagreements were solved by 8 discussion. Excluded studies with justifications are available in Supplemental Appendix 2. 9 <i>Risk of bias assessment and data extraction</i> 10 To assess the included studies for risk of bias (RoB) we used two different instruments: The 11 Newcastle-Ottawa scale for cohort studies, ²³ and Cochrane Risk of Bias Tool for RCTs, ¹⁹ 12 Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed 13 on a final RoB evaluation, with disagreements solved by discussion. 14 One researcher (HN) created a standard extraction form and extracted data from all 15 included studies. The information extracted from the studies was: title, authors, publication 16 details, study design, aim of the study, study setting (location and time the study was 17 conducted), characteristics of included participants (age, gender etc.), charac		2	duplicate entries. Two researchers (HN, RB) independently screened all titles and abstracts
 criteria Aria asstates that appeared to fit the inclusion criteria of during hydro 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. <i>Risk of bias assessment and data extraction</i> 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. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> We extracted crude outcome data for all eligible outcomes when postscores for both intervention and c	7	3	from the literature searches in accordance with the predetermined inclusion and exclusion
11 11 12 11 13 12 14 12 15 12 16 records independently of one another using a pre-developed inclusion form. The final 14 12 15 12 16 discussion. Excluded studies with justifications are available in Supplemental Appendix 2. 17 12 17 0 assess the included studies for risk of bias (RoB) we used two different instruments: The 18 Newcastle-Ottawa scale for cohort studies, ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹ 17 Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed 18 on a final RoB evaluation, with disagreements solved by discussion. 19 Two researcher (HN) created a standard extraction form and extracted data from all 10 included studies. The information extracted from the studies was: title, authors, publication 16 details, study design, aim of the study, study setting (location and time the study was 17 conducted), characteristics of included participants (age, gender ctc.), characteristics of the 18 intervention, study setting, outcomes, and results. Whenever information was available, 19 dichotomous and cont		4	criteria. All abstracts that appeared to fit the inclusion criteria or did not provide enough
6 records independently of one another using a pre-developed inclusion form. The final 11 7 determination to include or exclude was made together and any disagreements were solved by 12 8 discussion. Excluded studies with justifications are available in Supplemental Appendix 2. 17 9 Risk of bias assessment and data extraction 10 To assess the included studies for risk of bias (RoB) we used two different instruments: The 11 Newcastle-Ottawa scale for cohort studies, ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹ 12 Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed 13 on a final RoB evaluation, with disagreements solved by discussion. 14 One researcher (HN) created a standard extraction form and extracted data from all 15 included studies. The information extracted from the studies was: title, authors, publication 16 details, study design, aim of the study, study setting (location and time the study was 17 conducted), characteristics of included participants (age, gender etc.), characteristics of the 18 intervention, study setting, outcomes, and results. Whenever information was available, 19 dichotomous and accuracy and any disagreements were solved by further inspection of 19 therevotinon, and assessment of th		5	information, were promoted to full text screening. At each level, we evaluated the identified
1 determination to include or exclude was made together and any disagreements were solved by 1 discussion. Excluded studies with justifications are available in Supplemental Appendix 2. 1 <i>Risk of bias assessment and data extraction</i> 10 To assess the included studies for risk of bias (RoB) we used two different instruments: The 11 Newcastle-Ottawa scale for cohort studies, ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹ 12 Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed 13 on a final RoB evaluation, with disagreements solved by discussion. 14 One researcher (HN) created a standard extraction form and extracted data from all 15 included studies. The information extracted from the studies was: title, authors, publication 16 details, study design, aim of the study, study setting (location and time the study was 17 conducted), characteristics of included participants (age, gender etc.), characteristics of the 18 intervention, study setting, outcomes, and results. Whenever information was available, 19 dichotomous and continuous data for all eligible outcomes were extracted. HN contacted 20 several authors for additional data, but did not receive a reply. RB assessed the extracted data 21 for completeness and accuracy and any disagreements were solved by fur	12	6	records independently of one another using a pre-developed inclusion form. The final
8 Biscussion: Excluded studies with justifications are available in Suppletitional Appendix 2. 9 Risk of bias assessment and data extraction 10 To assess the included studies for risk of bias (RoB) we used two different instruments: The 11 Newcastle-Ottawa scale for cohort studies, ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹ 12 Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed 13 on a final RoB evaluation, with disagreements solved by discussion. 14 One researcher (HN) created a standard extraction form and extracted data from all 15 included studies. The information extracted from the studies was: title, authors, publication 16 details, study design, aim of the study, study setting (location and time the study was 17 conducted), characteristics of included participants (age, gender etc.), characteristics of the 18 intervention, study setting, outcomes, and results. Whenever information was available, 19 dichotomous and continuous data for all eligible outcomes were extracted. HN contacted 20 several authors for additional data, but did not receive a reply. RB assessed the extracted data 21 for completeness and accuracy and any disagreements were solved by further inspection of 22 the publication and discussion. 23 <td></td> <td>7</td> <td>determination to include or exclude was made together and any disagreements were solved by</td>		7	determination to include or exclude was made together and any disagreements were solved by
9 <i>Risk of bias assessment and data extraction</i> 19 10 To assess the included studies for risk of bias (RoB) we used two different instruments: The 11 Newcastle-Ottawa scale for cohort studies, ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹ 12 Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed 13 on a final RoB evaluation, with disagreements solved by discussion. 14 One researcher (HN) created a standard extraction form and extracted data from all 15 included studies. The information extracted from the studies was: title, authors, publication 16 details, study design, aim of the study, study setting (location and time the study was 17 conducted), characteristics of included participants (age, gender etc.), characteristics of the 18 intervention, study setting, outcomes, and results. Whenever information was available, 19 dichotomous and continuous data for all eligible outcomes were extracted. HN contacted 20 several authors for additional data, but did not receive a reply. RB assessed the extracted data 21 for completeness and accuracy and any disagreements were solved by further inspection of 22 the publication and discussion. 23 Analysis and assessment of the certainty of the evidence (GRADE) 24	16	8	discussion. Excluded studies with justifications are available in Supplemental Appendix 2.
101010assess the included studies for risk of blas of blas (or blas we dided two different instutients). The11Newcastle-Ottawa scale for cohort studies, ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹ 12Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed13on a final RoB evaluation, with disagreements solved by discussion.14One researcher (HN) created a standard extraction form and extracted data from all15included studies. The information extracted from the studies was: title, authors, publication16details, study design, aim of the study, study setting (location and time the study was17conducted), characteristics of included participants (age, gender etc.), characteristics of the18intervention, study setting, outcomes, and results. Whenever information was available,19dichotomous and continuous data for all eligible outcomes were extracted. HN contacted20several authors for additional data, but did not receive a reply. RB assessed the extracted data21for completeness and accuracy and any disagreements were solved by further inspection of22the publication and discussion.23Analysis and assessment of the certainty of the evidence (GRADE)24We extracted crude outcome data for all eligible outcomes when postscores for both25intervention and control groups were available and, when such data were available, adjusted26outcome data (adjusted comparison (effect) estimates and their standard errors or 95%27confidence intervals, CI). We provide dichotomous outcomes as the number of events and <td></td> <td>9</td> <td>Risk of bias assessment and data extraction</td>		9	Risk of bias assessment and data extraction
2111Newcastle-Ottawa scale for cohort studies,23 and Cochrane Risk of Bias Tool for RCTs.1922Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed23on a final RoB evaluation, with disagreements solved by discussion.24One researcher (HN) created a standard extraction form and extracted data from all25included studies. The information extracted from the studies was: title, authors, publication26details, study design, aim of the study, study setting (location and time the study was27conducted), characteristics of included participants (age, gender etc.), characteristics of the28intervention, study setting, outcomes, and results. Whenever information was available,29dichotomous and continuous data for all eligible outcomes were extracted. HN contacted20several authors for additional data, but did not receive a reply. RB assessed the extracted data21for completeness and accuracy and any disagreements were solved by further inspection of22the publication and discussion.23Analysis and assessment of the certainty of the evidence (GRADE)24We extracted crude outcome data for all eligible outcomes when postscores for both25intervention and control groups were available and, when such data were available, adjusted24outcome data (adjusted comparison (effect) estimates and their standard errors or 95%25confidence intervals, CI). We provide dichotomous outcomes as the number of events and26number of people in groups as proportions, risk ratio (RR), incident RR (IRR) or odds ratio26(10	To assess the included studies for risk of bias (RoB) we used two different instruments: The
12Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed13on a final RoB evaluation, with disagreements solved by discussion.14One researcher (HN) created a standard extraction form and extracted data from all15included studies. The information extracted from the studies was: title, authors, publication16details, study design, aim of the study, study setting (location and time the study was17conducted), characteristics of included participants (age, gender etc.), characteristics of the18intervention, study setting, outcomes, and results. Whenever information was available,19dichotomous and continuous data for all eligible outcomes were extracted. HN contacted20several authors for additional data, but did not receive a reply. RB assessed the extracted data21for completeness and accuracy and any disagreements were solved by further inspection of22the publication and discussion.23Analysis and assessment of the certainty of the evidence (GRADE)24We extracted crude outcome data for all eligible outcomes when postscores for both25intervention and control groups were available and, when such data were available, adjusted26outcome data (adjusted comparison (effect) estimates and their standard errors or 95%27confidence intervals, CI). We provide dichotomous outcomes as the number of events and28number of people in groups as proportions, risk ratio (RR), incident RR (IRR) or odds ratio29(OR) as appropriate. Continuous outcomes are shown as mean difference (MD) and standard29deviations (21	11	Newcastle-Ottawa scale for cohort studies, ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹
13on a final RoB evaluation, with disagreements solved by discussion.14One researcher (HN) created a standard extraction form and extracted data from all15included studies. The information extracted from the studies was: title, authors, publication16details, study design, aim of the study, study setting (location and time the study was17conducted), characteristics of included participants (age, gender etc.), characteristics of the18intervention, study setting, outcomes, and results. Whenever information was available,19dichotomous and continuous data for all eligible outcomes were extracted. HN contacted20several authors for additional data, but did not receive a reply. RB assessed the extracted data21for completeness and accuracy and any disagreements were solved by further inspection of22the publication and discussion.23Analysis and assessment of the certainty of the evidence (GRADE)24We extracted crude outcome data for all eligible outcomes when postscores for both25intervention and control groups were available and, when such data were available, adjusted26outcome data (adjusted comparison (effect) estimates and their standard errors or 95%27confidence intervals, CI). We provide dichotomous outcomes as the number of events and28number of people in groups as proportions, risk ratio (RR), incident RR (IRR) or odds ratio29(OR) as appropriate. Continuous outcomes are shown as mean difference (MD) and standard29deviations (SD), or the most appropriate presentation based on the available data in the29included st	23	12	Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed
2714One researcher (HN) created a standard extraction form and extracted data from all28included studies. The information extracted from the studies was: title, authors, publication3016details, study design, aim of the study, study setting (location and time the study was31conducted), characteristics of included participants (age, gender etc.), characteristics of the33intervention, study setting, outcomes, and results. Whenever information was available,36dichotomous and continuous data for all eligible outcomes were extracted. HN contacted37several authors for additional data, but did not receive a reply. RB assessed the extracted data38for completeness and accuracy and any disagreements were solved by further inspection of41the publication and discussion.42We extracted crude outcome data for all eligible outcomes when postscores for both43intervention and control groups were available and, when such data were available, adjusted44outcome data (adjusted comparison (effect) estimates and their standard errors or 95%45confidence intervals, CI). We provide dichotomous outcomes as the number of events and46number of people in groups as proportions, risk ratio (RR), incident RR (IRR) or odds ratio47GR as appropriate. Continuous outcomes are shown as mean difference (MD) and standard48deviations (SD), or the most appropriate presentation based on the available data in the43included studies.	25	13	on a final RoB evaluation, with disagreements solved by discussion.
 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. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> 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. 	27 28 29 30 31 32 33 34 35	14	One researcher (HN) created a standard extraction form and extracted data from all
 a details, study design, ann of the study, study setting (recation and thile 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. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> 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. 		15	included studies. The information extracted from the studies was: title, authors, publication
 17 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. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> 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. 		16	details, study design, aim of the study, study setting (location and time the study was
 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. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> 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. 		17	conducted), characteristics of included participants (age, gender etc.), characteristics of the
 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. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> 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. 		18	intervention, study setting, outcomes, and results. Whenever information was available,
 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. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> 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. 		19	dichotomous and continuous data for all eligible outcomes were extracted. HN contacted
 for completeness and accuracy and any disagreements were solved by further inspection of the publication and discussion. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> 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. 	37	20	several authors for additional data, but did not receive a reply. RB assessed the extracted data
 the publication and discussion. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> 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. 	39	21	for completeness and accuracy and any disagreements were solved by further inspection of
 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. 	41	22	the publication and discussion.
 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. 	43	23	Analysis and assessment of the certainty of the evidence (GRADE)
 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. 		24	We extracted crude outcome data for all eligible outcomes when postscores for both
 48 26 outcome data (adjusted comparison (effect) estimates and their standard errors or 95% 50 27 confidence intervals, CI). We provide dichotomous outcomes as the number of events and 51 28 number of people in groups as proportions, risk ratio (RR), incident RR (IRR) or odds ratio 53 29 (OR) as appropriate. Continuous outcomes are shown as mean difference (MD) and standard 55 30 deviations (SD), or the most appropriate presentation based on the available data in the 56 31 included studies. 		25	intervention and control groups were available and, when such data were available, adjusted
 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. 	48	26	outcome data (adjusted comparison (effect) estimates and their standard errors or 95%
 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. 		27	confidence intervals, CI). We provide dichotomous outcomes as the number of events and
 ⁵³ 29 (OR) as appropriate. Continuous outcomes are shown as mean difference (MD) and standard ⁵⁵ 30 deviations (SD), or the most appropriate presentation based on the available data in the ⁵⁷ 31 included studies. 		28	number of people in groups as proportions, risk ratio (RR), incident RR (IRR) or odds ratio
 deviations (SD), or the most appropriate presentation based on the available data in the included studies. 	53	29	
56 57 31 included studies. 58	55		
58			

BMJ Open

2		
3 4	1	We evaluated the characteristics of the studies' (S)PICO and when they were
5	2	considered sufficiently similar, and data were available, we conducted metaanalyses. The
6 7	3	judgments about whether metaanalyses were appropriate were based on recommendations in
8 9	4	the Cochrane Handbook. ¹⁹ We used Mantel-Haenszel random effects metaanalysis for
10 11	5	dichotomous outcomes and we presented the relative risks and their corresponding 95% CI (it
12	6	was not possible to metaanalyse any continuous outcomes). We also examined between-study
13 14	7	heterogeneity using visual inspection of CIs, the Chi-square test, and Isquare statistic,
15 16	8	quantifying the degree of heterogeneity as described in the Cochrane Handbook. ¹⁹ We used
17	9	RevMan version 5.4, the latest version of the Cochrane metaanalysis software. ²⁴ When the
18 19	10	studies' (S)PICOs or results were too heterogeneous to pool statistically, or data were
20 21	11	unavailable, we reported the results narratively, in text and tables. We planned to perform a
22	12	subgroup analysis for the outcome technical failure, but this was not possible due to lack of
23 24	13	data.
25 26	14	We assessed the certainty of the evidence using the Grading of Recommendations
27 28	14	Assessment, Development and Evaluation (GRADE) framework. ²⁵ With regard to results that
29	15	could not be metaanalysed, we followed the Synthesis Without Meta-analysis (SWiM)
30 31	10	guideline. ²⁶
32 33	17	guidenne.
34 35	18	Results
36	19	The searches returned 451 references after removal of duplicates (Figure 1). We read 24
37 38	20	reports in full text, including one study identified from the hand search in reference lists. The
39 40	21	most common primary reasons for exclusion were that there was no control group or it was
41	22	the wrong participants or outcomes. Seven studies published between 2018-2021 were
42 43	23	eligible for inclusion. ²⁷⁻³³
44 45	24	Description of the studies
46 47	25	The seven included studies consisted of two RCTs and five retrospective cohort studies (Table
48	26	1). They were conducted in five different countries. There were two studies each from
49 50	27	Columbia and USA, and one study each from China, Italy, and South Korea. Three were set
51 52	28	in a single PD centre, four took place in two or more renal care centres and the two largest
53	29	studies took place in the USA with one including 55 home HD centres and another 931
54 55	30	Fresenius PD clinics.
56 57	31	
58 59	32	Table 1: Description of the included studies (n=7)
60		

1

Author, (country, setting) Study design	Population	Intervention and comparator (follow-up time)	Outcomes	Risk of bias
Cao 2018 ²⁷	N=160, on CAPD	RPM vs SC	Hospitalisations	Moderate
(China: 1 PD centre) RCT	Men 58% Mean age 52	Instant messaging application for support and education (mean 11.4 mo FU)	Infections Technical failure	
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

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.

BMJ Open

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 & Collins³³ 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.

⁸ 21 *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).

⁹ 27 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,
- ⁵⁶ 31 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

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

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 dialy	ysis 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	Adj. HR 0.66 (0.50-0.86)
	mo)	
Quality of life		1
Jung 2021	KDQOL -Patient satisfaction	Mean 75.5 in RPM group vs 73.7
	questions (6 mo)	in SC group, P 0.64
Milan 2020	KDQOL -Patient satisfaction	Median 83.3 in both groups, P
	questions (6 mo)	0.99
Jung 2021	KDQOL -Dialysis staff	Mean 93.1 in RPM group vs 97.
	encouragement (6 mo)	in SC group, P 0.05
Milan 2020	KDQOL -Dialysis staff	Median 100 in both groups, P
	encouragement (6 mo)	0.16

3 Table 2. Study outcomes and effect estimates

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	No. of participants	Quality of evidence (GRADE)
	Assumed risk with control	Assumed risk with RPM	(95% CI)	(Studies)	(010102)
Hospitalisations (6	-12 months)				
Days	All 3 cohort studies showed that there 6,736 (3) were fewer hospitalisation days in the RPM group (Table 2)			⊕⊕⊖⊖ LOW	
All-cause	that there we	3 of 4 studies (1 RCT, 3 cohort) showed 6,936 (4) that there were fewer hospitalisations in the RPM group (Table 2)		⊕○○○ 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 mon	ths)	<pre></pre>	0		
	-	rted more peritor ections with RPM		160 (1)	⊕○○○ VERY LOW ³
Technical failure (6-12 months)		2/	
	521/2230 (23.4%)	136/786 (17.3%)	RR 0.78 (0.66 to 0.93)	2856 (3 cohort)	⊕○○○ VERY LOW ⁴
		es (1 RCT, 2 coh es with RPM (Ta	· •	7161 (3)	
Quality of life (6 m	ionths)				
Patient satisfaction	group, 1 col	d higher QoL in nort found QoL v nps (Table 2)		130 (2)	⊕○○○ VERY LOW ⁵

2 3 4 5 6 7		Dialysis staff encouragement	1 RCT found higher QoL in the RPM130 (2)group, 1 cohort found QoL was similar inthe two groups (Table 2)	⊕○○○ VERY LOW ⁵			
8 9		Travel time	0 studies assess this outcome	No evidence			
10 11		1. Downgraded by	1 level because of moderate risk of bias in 1 study and in	nconsistency			
12 13		2. Downgraded by	1 level because of imprecision				
14 15		3. Downgraded by	3 levels because of moderate risk of bias, inconsistency,	imprecision			
16 17		4. Downgraded by	1 level because of moderate risk of bias in 1 study and ir	nprecision			
18 19		5. Downgraded by	1 level because of inconsistency and imprecision				
20 21 22 23 24		risk in the interver	terval; RCT: Randomised controlled study; SD: Standard ntion group (and its 95% confidence interval) is based on oup and the relative effect of the intervention (and its 95%	the assumed risk in			
25 26	1						
20 27 28 29	2	Hospitalisations					
	3	One RCTs and three observational studies from Italy, Colombia, China, and the USA					
30 31	4	examined the effect of RPM on hospitalisations. ^{27 28 31 32} However, the outcome was reported					
32 33 34 35	5	differently across t	he studies, as hospitalisation days/days admitted, all-caus	e hospitalisations,			
	6	and disease-specific hospitalisations (caused by overhydration, access dysfunction, and					
36	7	infections).					
37 38	8	Hospitalisation day	vs. The three observational studies, Chaudhuri et al., ²⁸ Mil	lan et al., ³¹ and			
39 40	9	Sanabria et al. ³² , al	l found fewer hospitalisation days in the RPM group than	the control group			
41 42	10	(Table 2). The resu	llts in Sanabria et al. ³² were from a matched sample, as da	ta for the whole			
43 44	11	sample was not ava	ailable. This study showed the largest effect with a differe	ence of six			
45	12	hospitalisation day	s (IRR 0.46, 0.23-0.92).				
46 47 48	13	All-cause hospitali	sations. One RCT ²⁷ and three observational studies ^{28 31 32}	had data on			
48 49	14	-					
50 51	15	less all-cause hosp	italisations than patients with standard care only, the four	th study favoured			
52 53	16	standard care (Tab	le 2).				
54 55	17	Disease-specific ho	ospitalisations. The results on disease-specific hospitalisat	tions from two			
56 57	18	observational studi	es, Milan et al., ³¹ and Sanabria et al. ³² could be pooled in	a metaanalysis			
58 59	19	(Figure 2). The nor	n-significant result suggested there were fewer disease-spe	ecific			
60	20	hospitalisations in	the RPM group than in the control group (RR 0.62, 95% o	CI 0.31-1.24).			

BMJ Open

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

3 due to peritonitis and overhydration.

4 <u>Infections</u>

 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

8 treated at home or in the hospital.

9 <u>Technical failure as the cause for transfer to a different dialysis modality</u>

10 One RCT from China²⁷ found no difference between the groups while five observational

11 studies from the USA^{28 33}, Colombia^{29 32}, and Italy³¹ consistently reported less technical

²³ ²⁴ 12 failure as cause for transfer to a different dialysis modality in the RPM group compared to the

²⁵ 13 control group (Table 2). Three of the cohort studies could be pooled in a metaanalysis; the

27 14 result implies benefit of RPM (0.78, 95% CI 0.66, 0.92) (Figure 2). Two of the studies^{32 33}

29 15 gave data on novice patients with less than three months treatment duration at baseline,

 $\frac{30}{31}$ 16 indicating a positive, but non-significant effect of RPM in new patients (Table 2).

3233 17 <u>Self-reported Quality of Life</u>

Both studies, one RCT³⁰ 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).

27 Discussion

28 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

- $\frac{58}{59}$ 31 previous research^{36 37} and document that there is no conclusive evidence, but that positive
- 60 32 effects of RPM are indicated for clinical outcomes, technical failure, and quality of life.

Page 15 of 34

1 2

BMJ Open

2	
3 4	
5	
6	
7	
8	
9 10	
11	
12	
13	
14	
15 16	
17	
18	
19]
20	1
21 22	1
23]
23 24	1
25 26	1
26 27	1
28 29	1
30	
31]
32 33	1
33 34	1
35]
36	2
37	
38 39	2
40	
41	_
42	4
43 44	2
45	~
46	4
47	2
48 49	2
50	2
51	4
52 53	2
53 54	2
55	-
56	-
57	
58 59	
60	

1 The results consistently suggest that RPM reduces hospitalisations and the number of 2 days the patient is admitted. It was especially convincing that Milan et al.³¹ observed a median 3 difference of five fewer hospitalisation days in the RPM group over six months, because the 4 patients on RPM had a worse comorbidity score. Furthermore, except for one study that found 5 the same number of technical failures in both groups, the other five studies found less 6 technical failure in the RPM group. In four of the studies measuring this outcome, 7 prescriptions could be changed from the hospital without in-person consultations. In effect, 8 RPM allows resolving technical issues early, thus preventing progression of technical failure 9 to the stage where the patient would need to transfer to a different dialysis modality. Research 10 has found great advantages with the technology displaying possible causes and solutions to 11 problems, alarm indicators showing who to contact for guidance (nurse or technician), and 12 reminders of activities that need to be performed.¹⁴⁻¹⁶ Concerning quality of life, only two 13 studies assessed this and the results showed the scores were comparable for the patients on 14 RPM and usual care. Encouragingly, scores for quality of life improved slightly and patient 15 satisfaction was higher than neutral. This is in line with a study from the U.S. that found that 16 RPM increased patients' confidence and satisfaction with treatment because they felt more 17 closely supported.³⁶ Lastly, no studies assessed time patients use for travel. However, research 18 suggests that health-related quality of life and time patients use for travel are intertwined¹¹ 19 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. 20

Our results mirror two earlier systematic reviews on e-health interventions in PD 21 patients³⁹ and in people with CKD.⁴⁰ Both reviews, with literature searches in 2018-2019, 22 23 included a wide range of patients and e-health modalities, including mobile or tablet 24 application, text or email messages, electronic monitors, internet/websites, and video or DVD. Consequently, there was minimal overlap in included studies: Only one review³⁹ included two 25 26 of our included studies. Both reviews concluded that the quality of evidence for the 27 effectiveness of e-health was low with uncertain effects, but that no adverse effects were 28 indicated. Of note, a recent modelling analysis projected that in a cohort of 100 patients on 29 automated PD over 1 year, RPM would lead to 27 fewer hospitalisations, 518 fewer 30 hospitalization days, 31 additional months free of complications, and six fewer peritonitis episodes.41 31

1 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.⁶⁴² 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.¹⁶⁴³ 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

47 26 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

BMJ Open

3	
4	
5	
6	
-	
/	
8	
9	
	0
1	1
1	2
1	3
	4
1	5
1	5
1	
1	7
1	8
	9
	0
2	1
2	2
2	3
	4
	5
2	6
2	7
	8
	9
	0
3	1
3	2
3	
	4
3	5
3	6
3	
	8
3	9
4	0
4	
4	
4	3
4	4
4	5
4	
4	
	8
4	9
5	
-	
5	
5	3
5	4
-	

1 reporting, our ability to conduct metaanalyses was limited. Therefore, it was neither possible 2 to improve precision to any great extent, nor statistically assess potential differences across 3 groups, such as type of platform or HD and PD. We contacted several authors asking for more 4 data, but did not receive a reply. The low number of studies meant that we were unable to 5 statistically check for publication bias. Given the modestly positive but varied results, we 6 believe the potential for publication bias is low, but we recommend future reviews of a higher 7 number of included studies to assess this potential bias. The imbalance in sample sizes across 8 the studies, with two studies having a considerably larger sample size than the other five, 9 influenced the results related to hospitalisations and technical failure. Both these two studies 10 had low risk of bias, but three other studies had moderate risk of bias.

11 Conclusion

12 This systematic review summarises and presents low to very low evidence that indicate there 13 may be positive effects of RPM follow-up, in comparison to standard care only, for adult 14 patients with CKD who perform dialysis at home. Offering RPM follow-up for home dialysis 15 patients as an alternative or supplement to standard care appears to be safe and provide health 16 benefits, but future implementation should be coupled with robust, high quality evaluations. 17 Despite the high interest in RPM and increasing demands for nephrology services, good 18 quality evidence is still needed to determine their effectiveness.

19

20 **Contributors**

21 HN wrote the first draft. RB and HN contributed equally to the rest of the work. LN prepared 22 and conducted the systematic searches and contributed with inputs on the final draft. We are 23 grateful to [removed for blind review], for peer review of the systematic search strategies

- 24 **Competing interests**
- 25 'None declared'.
- 26 Funding

55

59

27 'This research received no specific grant from any funding agency in the public, commercial 28 or not-for-profit sectors'. 56

57 29 Patient and public involvement 58

30 Due to the nature of the study (systematic review), no patients were involved. 60

Exclusive licence

Please confirm you agree with the following statement by ticking the box and then insert the licence statement in your manuscript file.

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in BMJ Open and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Data availability statement

> Data are available on reasonable request.

References

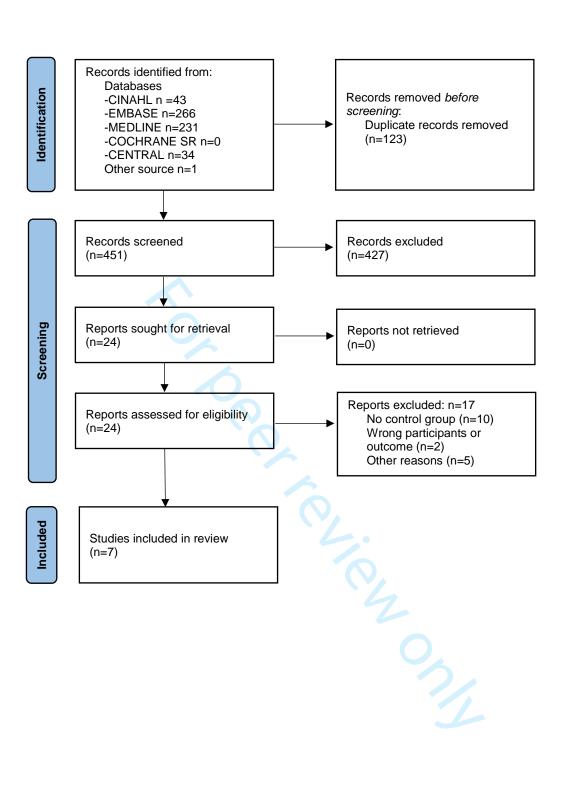
- 1. Chen TK, Knicely DH, Grams ME. Chronic Kidney Disease Diagnosis and Management: A Review. JAMA 2019;322(13):1294-304. doi: 10.1001/jama.2019.14745
- 2. Tonelli M, Riella M. Chronic kidney disease and the aging population. *Indian journal of* nephrology 2014;24(2):71-74. doi: 10.4103/0971-4065.127881
- 3. Sinnakirouchenan R, Holley JL. Peritoneal dialysis versus hemodialysis: risks, benefits, and access issues. Adv Chronic Kidney Dis 2011;18(6):428-32. doi:
 - 10.1053/j.ackd.2011.09.001 [published Online First: 2011/11/22]

1		
2		
3 4	1	4. Meld. St. 7 (2019–2020). Nasjonal helse- og sykehusplan 2020–2023: Helse- og
5	2	omsorgsdepartementet; [cited 2021 12.09]. Available from:
6	3	https://www.regjeringen.no/no/dokumenter/meldst7-20192020/id2678667/
7	4	5. Kitsiou S, Paré G, Jaana M, et al. Effectiveness of mHealth interventions for patients with
8	5	diabetes: An overview of systematic reviews. PLoS One 2017;12(3):e0173160. doi:
9	6	10.1371/journal.pone.0173160 [published Online First: 2017/03/02]
10	7	6. Widmer, R. Jay, et al. "Digital health interventions for the prevention of cardiovascular
11	8	disease: a systematic review and meta-analysis." Mayo Clinic Proceedings. Vol. 90.
12 13	9	No. 4. Elsevier, 2015
14	10	7. Helsedirektoratet. Nyresvikt - dialysepasienter som får hjemmedialyse: Helsedirektoratet;
15	11	2018 [updated 2021 02.12; cited 2021 12.12]. Available from:
16	12	https://www.helsedirektoratet.no/statistikk/kvalitetsindikatorer/behandling-av-
17	13	sykdom-og-overlevelse/andel-dialysepasienter-som-har-hjemmedialyse
18	14	8. Helsedirektoratet. Handlingsplan for forebygging og behandling av kronisk nyresykdom
19 20	15	(2011-2015) 2011 [cited 2021 11.09]. Available from:
20 21	16	http://www.nephro.no/foreningsnytt/Handlingsplan_forebygging_behandling_kronisk
21	17	_nyresykdom.pdf.
23	18	9. Urquhart-Secord R, Craig JC, Hemmelgarn B, et al. Patient and Caregiver Priorities for
24	19	Outcomes in Hemodialysis: An International Nominal Group Technique Study.
25	20	American Journal of Kidney Diseases 2016;68(3):444-54. doi:
26	21	https://doi.org/10.1053/j.ajkd.2016.02.037
27	22	10. Moist LM, Bragg-Gresham JL, Pisoni RL, et al. Travel Time to Dialysis as a Predictor of
28 29	23	Health-Related Quality of Life, Adherence, and Mortality: The Dialysis Outcomes and
29 30	24	Practice Patterns Study (DOPPS). American Journal of Kidney Diseases
31	25	2008;51(4):641-50. doi: https://doi.org/10.1053/j.ajkd.2007.12.021
32	26	11. Braut GS. Telemedisin Store medisinske leksikon [updated 2020 15.06; cited 2021 10.10].
33	27	Available from: https://sml.snl.no/telemedisin.
34	28	12. DelVecchio A. Definition, remote patient monitoring (RPM): Tech target, Search health
35	29	IT; [updated April 2019; cited 2021 10.10]. Available from:
36	30	https://searchhealthit.techtarget.com/definition/remote-patient-monitoring-RPM
37	31	13. Rajkomar A, Farrington K, Mayer A, et al. Patients' and carers' experiences of interacting
38 39	32	with home haemodialysis technology: implications for quality and safety. BMC
40	33	Nephrology 2014;15(1):195-95. doi: 10.1186/1471-2369-15-195
41	34	14. Rygh E, Arild E, Johnsen E, et al. Choosing to live with home dialysis-patients'
42	35	experiences and potential for telemedicine support: a qualitative study. <i>BMC</i>
43	36	Nephrology 2012;13(1):13-13. doi: 10.1186/1471-2369-13-13
44	37	15. Viglino G, Neri L, Barbieri S, et al. Videodialysis: a pilot experience of telecare for
45	38	assisted peritoneal dialysis. J Nephrol 2020;33(1):177-82. doi: 10.1007/s40620-019-
46 47	39	00647-6 [published Online First: 2019/09/19]
47 48	40	16. François K, Bargman JM. Evaluating the benefits of home-based peritoneal dialysis. Int J
49	40 41	Nephrol Renovasc Dis 2014;7:447-55. doi: 10.2147/IJNRD.S50527
50	41	17. Marshall MR, Polkinghorne KR, Kerr PG, et al. Temporal Changes in Mortality Risk by
51	42 43	
52		Dialysis Modality in the Australian and New Zealand Dialysis Population. American
53	44 45	Journal of Kidney Diseases 2015;66(3):489-98. doi:
54	45	https://doi.org/10.1053/j.ajkd.2015.03.014
55 56	46	18. Walker RC, Howard K, Morton RL. Home hemodialysis: a comprehensive review of
56 57	47	patient-centered and economic considerations. <i>Clinicoecon Outcomes Res</i> 2017;9:149-
58	48	61. doi: 10.2147/CEOR.S69340
59	49 50	19. Higgins JPT TJ, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (editors). Cochrane
60	50	Handbook for Systematic Reviews of Interventions version 6.2 (updated February

1 2		
3	1	2021): Cochrane; 2021 [cited 2021 12.09]. Available from:
4	2	www.training.cochrane.org/handbook.
5	3	20. PRISMA transperant reporting of systematic reviews and meta-analyses [cited 2021
6	4	08.11]. Available from: http://www.prisma-statement.org/.
7	5	21. Straus SE, Glasziou P, Richardson WS, et al. Evidence-based medicine E-book: How to
8 9	6	practice and teach EBM: Elsevier Health Sciences 2018.
10	7	22. Tonelli M, Wiebe N, Guthrie B, et al. Comorbidity as a driver of adverse outcomes in
11	8	people with chronic kidney disease. <i>Kidney International</i> 2015;88(4):859-66. doi:
12	9	https://doi.org/10.1038/ki.2015.228
13	10	23. Wells GA, Shea B, O'Connell D, et al. The Newcastle-Ottawa Scale (NOS) for assessing
14	11	the quality of nonrandomised studies in meta-analyses: The Ottawa hospital research
15 16	12	institute; [cited 2021 21.10]. Available from:
16 17	12	http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp
18	13	24. Cochrane RevMan Cochrane Training [updated Latest verion of RevMan 5.4.1. from
19	14	September 2020; cited 2021 10.10]. Available from:
20	15	https://training.cochrane.org/online-learning/core-software-cochrane-reviews/revman.
21	10	
22	17	25. GRADE: The GRADE Working Group; 2004-2021 [cited 2021 21.10]. Available from: https://www.gradeworkinggroup.org/
23 24	18	26. Campbell M, McKenzie JE, Sowden A, et al. Synthesis without meta-analysis (SWiM) in
24 25	20	systematic reviews: reporting guideline. BMJ 2020;368:16890. doi: 10.1136/bmj.16890
26	20	27. Cao F, Li L, Lin M, et al. Application of instant messaging software in the follow-up of
27	21	patients using peritoneal dialysis, a randomised controlled trial. <i>Journal of Clinical</i>
28	22	Nursing 2018;27(15-16):3001-07. doi: https://doi.org/10.1111/jocn.14487
29	23 24	
30	24 25	28. Chaudhuri S, Han H, Muchiutti C, et al. Remote Treatment Monitoring on Hospitalization and Technique Failure Rates in Peritoneal Dialysis Patients. <i>Kidney360</i>
31 32	23 26	2020;1(3):191-202. doi: 10.34067/kid.0000302019
32 33	20	29. Corzo L, Wilkie M, Vesga JI, et al. Technique failure in remote patient monitoring
34	28	program in patients undergoing automated peritoneal dialysis: A retrospective cohort
35	28 29	study. <i>Perit Dial Int</i> 2020:896860820982223. doi: 10.1177/0896860820982223
36	30	[published Online First: 2021/01/01]
37	31	30. Jung HY, Jeon Y, Kim YS, et al. Outcomes of Remote Patient Monitoring for Automated
38	32	Peritoneal Dialysis: A Randomized Controlled Trial. <i>Nephron</i> 2021 doi:
39 40	33	10.1159/000518364
41	34	31. Milan Manani S, Baretta M, Giuliani A, et al. Remote monitoring in peritoneal dialysis:
42	35	benefits on clinical outcomes and on quality of life. <i>Journal of Nephrology</i>
43	36	2020;33(6):1301-08.
44	37	32. Sanabria M, Buitrago G, Lindholm B, et al. Remote Patient Monitoring Program in
45	38	Automated Peritoneal Dialysis: Impact on Hospitalizations. <i>Perit Dial Int</i>
46 47	39	2019;39(5):472-78. doi: 10.3747/pdi.2018.00287 [published Online First: 2019/07/25]
48	40	33. Weinhandl ED, Collins AJ. Relative risk of home hemodialysis attrition in patients using
49	40	a telehealth platform. <i>Hemodial Int</i> 2018;22(3):318-27. doi: 10.1111/hdi.12621
50	42	[published Online First: 2017/12/07]
51	43	34. Wong FK, Chow SK, Chan TM. Evaluation of a nurse-led disease management
52	44	programme for chronic kidney disease: a randomized controlled trial. <i>International</i>
53 54	45	Journal of Nursing Studies 2010;47(3):268-78. doi: 10.1016/j.ijnurstu.2009.07.001
54 55	46	35. Kidney Disease Quality of Life Instrument (KDQOL): The RAND Corporation; [cited
56	47	2021 14.10]. Available from: https://www.rand.org/health-
57	48	care/surveys tools/kdqol.html
58		
59		
60		

1		
2 3	1	
4	1	36. Magnus M, Sikka N, Cherian T, et al. Satisfaction and Improvements in Peritoneal
5	2	Dialysis Outcomes Associated with Telehealth. <i>Appl Clin Inform</i> 2017;8(1):214-25.
6	3	doi: 10.4338/aci-2016-09-ra-0154 [published Online First: 2017/03/02]
7	4	37. Manera KE, Johnson DW, Craig JC, et al. Patient and Caregiver Priorities for Outcomes
8	5	in Peritoneal Dialysis. Multinational Nominal Group Technique Study 2019;14(1):74-
9	6	83. doi: 10.2215/cjn.05380518
10	7	38. Evangelidis N, Tong A, Manns B, et al. Developing a Set of Core Outcomes for Trials in
11 12	8	Hemodialysis: An International Delphi Survey. American Journal of Kidney Diseases
12	9	2017;70(4):464-75. doi: 10.1053/j.ajkd.2016.11.029
14	10	39. Cartwright EJ, Z ZSG, Foo M, et al. eHealth interventions to support patients in delivering
15	11	and managing peritoneal dialysis at home: A systematic review. Peritoneal Dialysis
16	12	International 2021;41(1):32-41.
17	13	40. Stevenson JK, Campbell ZC, Webster AC, et al. eHealth interventions for people with
18	14	chronic kidney disease. Cochrane Database of Systematic Reviews 2019(8) doi:
19 20	15	10.1002/14651858.CD012379.pub2
20 21	16	41. Ariza JG, Walton SM, Sanabria M, et al. Evaluating a remote patient monitoring program
22	17	for automated peritoneal dialysis. Perit Dial Int 2020;40(4):377-83. doi:
23	18	10.1177/0896860819896880 [published Online First: 2020/02/18]
24	19	42. Sanyal C, Stolee P, Juzwishin D, et al. Economic evaluations of eHealth technologies: A
25	20	systematic review. PLoS One 2018;13(6):e0198112. doi:
26	21	10.1371/journal.pone.0198112 [published Online First: 2018/06/14]
27	22	43. Gallar P, Vigil A, Rodriguez I, et al. Two-year experience with telemedicine in the
28	23	follow-up of patients in home peritoneal dialysis. Journal of Telemedicine & Telecare
29 30	24	2007;13(6):288-92. doi: 10.1258/135763307781644906
31	25	44. SONG. Standardised outcomes in nephrology [cited 2022 23.04]. Available from:
32	26	https://songinitiative.org/
33	27	
34		
35	28	Figure legend:
36	-0	
37 38	20	
39	29	Figure 1: Prisma flow diagram for selection of studies
40		
41	20	Figure 2. Metaanalyzaa of autoomaa digaaga graatific hagnitaligations and tachnical failure
42	30	Figure 2: Metaanalyses of outcomes disease specific hospitalisations and technical failure
43		
44	31	
45 46		
40 47	32	
48		
49		
50		
51		
52		
53 54		
54 55		
56		
57		
58		
59		
60		

BMJ Open



	RPN	1	Standard Care			Risk Ratio	Risk Ratio M-H, Random, 95% Cl				
Study or Subgroup	Events	Total	Weight	M-H, Random, 95% Cl							
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: Tau ² =	= 0.01; Chi	i ² = 1.04	4, df = 1 (P	= 0.31);	l² = 4%						
Test for overall effect							0.01	0.1 1 10 100			
restion overall ellect	:Z=1.35((P = 0.1	8)					Favours RPM Favours Standard Care			
	:2=1.35((P = 0.1	8)					Favours RPM Favours Standard Care			
	: Z = 1.35 ((P = 0.1	8)					Favours RPM Favours Standard Care			
		(P = 0.1	8)					Favours RPM Favours Standard Care			
	failure			Care		Risk Ratio					
		1	Standard		Weight	Risk Ratio M-H, Random, 95% Cl		Favours RPM Favours Standard Care Risk Ratio M-H, Random, 95% Cl			
b) Technical f	failure RPN	1	Standard		Weight 0.3%			Risk Ratio			
b) Technical f	failure RPN Events	I Total	Standard Events	Total	-	M-H, Random, 95% Cl		Risk Ratio			
b) Technical f <u>Study or Subgroup</u> Milan 2020	failure RPN Events	I Total 35	Standard Events 1	Total 38	0.3%	M-H, Random, 95% Cl 0.36 [0.02, 8.58]		Risk Ratio			
(b) Technical f <u>Study or Subgroup</u> Milan 2020 Weinhandl 2018	Failure RPN Events 0 126	1 <u>Total</u> 35 606	Standard Events 1 488	Total 38 1817	0.3% 95.7%	M-H, Random, 95% Cl 0.36 [0.02, 8.58] 0.77 [0.65, 0.92]		Risk Ratio			
b) Technical f <u>study or Subgroup</u> Milan 2020 Weinhandl 2018	Failure RPN Events 0 126	1 <u>Total</u> 35 606	Standard Events 1 488	Total 38 1817 295	0.3% 95.7%	M-H, Random, 95% Cl 0.36 [0.02, 8.58] 0.77 [0.65, 0.92]		Risk Ratio			
b) Technical f <u>Study or Subgroup</u> Milan 2020 Weinhandl 2018 Sanabria 2019	Failure RPN Events 0 126	1 Total 35 606 65	Standard Events 1 488	Total 38 1817 295	0.3% 95.7% 4.1%	M-H, Random, 95% Cl 0.36 (0.02, 8.58) 0.77 (0.65, 0.92) 0.97 (0.42, 2.25)		Risk Ratio			
(b) Technical f <u>Study or Subgroup</u> Milan 2020	failure RPN Events	I Total 35	Standard Events 1	Total 38	0.3%	M-H, Random, 95% Cl 0.36 [0.02, 8.58]		Risk Ratio			
(b) Technical f <u>Study or Subgroup</u> Milan 2020 Weinhandl 2018 Sanabria 2019	Failure RPN Events 0 126	1 Total 35 606 65	Standard Events 1 488	Total 38 1817 295	0.3% 95.7% 4.1%	M-H, Random, 95% Cl 0.36 (0.02, 8.58) 0.77 (0.65, 0.92) 0.97 (0.42, 2.25)		Risk Ratio			

Chr = 0.004)

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

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/	356402

- 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.
- 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

16

17

18

19

20

21

22

23

1

2

3

4

5

6

7

8

9

10

11

12

13

14

(CAPD or APD or HHD).ti.

limit 17 to yr=2000-current

151629

699530

494

270

534

or/11-15

10 and 16

editorial.pt.

Database: OVID MEDLINE

Telenursing/

or/1-3 34165

5 and 6 19771

4 or 7 42042

self)).ti,ab,kf,bt.

or/8-1369186

18 not (19 or 20)

limit 21 to embase

Search interface: Advanced Search

Telemedicine/ 29751

232

or patient* or support*)).ti,ab,kf,bt.

Remote Consultation/ 5273

exp Telecommunications/

(care or healthcare).hw.

remove duplicates from 22

1

(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

3524

516

266

108428

1324775

mnurse or mcare or mnursing or mconsult* or mnurs*).ti,ab,kf,bt.

8231

(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

(ecare or econsult* or ehealth or emedicine* or enurs* or mcare or mconsult* or mhealth or

10618

13372

((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*

1020

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

health* or home* or manag* or medicine* or monitor* or nursing or patient* or

(remote adj2 (care* or checkup* or check up* or consult* or followup* or follow up* or

2	
4 5	
6 7	
8	
9 10	
11 12	
13	
14 15	
16 17	
18	
19 20 21	
22	
23 24	
25	
26 27	
28 29	
30 31	
32	
33 34	
35 36	
37	
38 39	
40 41	
42 43	
44	
45 46	
47 48	
49	
50 51 52	
52 53	
54 55	
56	
57 58	
59 60	
50	

3
4
5
6
7
8
9
10
11
12
13
14
15
16 17
17
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38 39
39 40
40 41
41
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59 60
60

15

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							

Renal Dialysis/ 94819

Database: Cochrane Database of Systematic Review & CENTRAL

Search interface: Advanced Search > Search Manager

- #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

iez oni

#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

- #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, inCochrane Reviews 0

RY.CZ ONY

#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

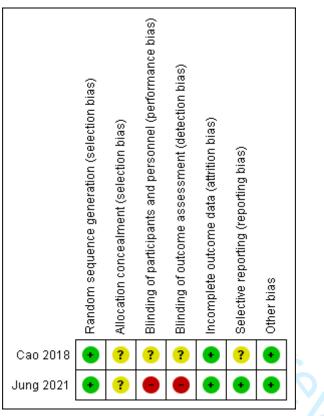
Excluded studies read in full text (n=17)	Justifications for exclusion
Dey V, Jones A, Spalding EM. Telehealth: Acceptability, clinical interventions and quality of life in peritoneal dialysis. SAGE Open Med. 2016;4:2050312116670188.	No control group
El Shamy O, Tran H, Sharma S, Ronco C, Narayanan M, 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 outcome
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	No pre-intervention
patient management in peritoneal dialysis on haemodynamic and volume control.	assessment
Nephrology. 2020;25(11):856-64.	

for peer teriew only

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

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

Variables adjusted for in the analyses

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."

of th . employs

PRISMA 2020 Checklist

Section and Topic	ltem #	Checklist item	Location where item is reported
TITLE	1		
Title	1	Identify the report as a systematic review.	p. 1
ABSTRACT	1		
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.	р. 3-4
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	p. 4
METHODS	1		
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.	р. 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). For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml	NA

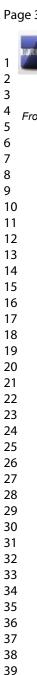
BMJ Open



PRISMA 2020 Checklist

Section and Topic	ltem #	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.	р. 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	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	р. 9
syntheses	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 INFORM	TION		
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. For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml	Available or request

Page 35 of 34



45 46 47

PRISMA 2020 Checklist

.a. The PRISMA 2020 s. 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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open

BMJ Open

BMJ Open

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

Journal:	BMJ Open
Manuscript ID	bmjopen-2022-061772.R2
Article Type:	Original research
Date Submitted by the Author:	07-Oct-2022
Complete List of Authors:	Nygård, Henriette; Norwegian Institute of Public Health, Health; University of Tromso Department of Community Medicine Nguyen, Lien; Norwegian Institute of Public Health Berg, Rigmor C; Norwegian Institute of Public Health; University of Tromso Department of Community Medicine
Primary Subject Heading :	Renal medicine
Secondary Subject Heading:	Health informatics, Health services research, Nursing, Patient-centred medicine, Renal medicine
Keywords:	Telemedicine < BIOTECHNOLOGY & BIOINFORMATICS, Dialysis < NEPHROLOGY, End stage renal failure < NEPHROLOGY, Adult nephrology < NEPHROLOGY, Chronic renal failure < NEPHROLOGY, Health informatics < BIOTECHNOLOGY & BIOINFORMATICS





I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our <u>licence</u>.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which <u>Creative Commons</u> licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

reliez oni

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

2		
3	1	Title
4		
5 6	2	Effect of remote patient monitoring for patients with chronic kidney disease who perform
7	2	
8	3	dialysis at home: a systematic review
9	4	
10	4	Corresponding author
11	-	
12 13	5	Henriette Tyse Nygård, Buggemyra 1, 5378 Klokkarvik, Norway. hettny@gmail.com
14		
15	6	Authors
16		
17	7	Henriette Tyse Nygård, Norwegian Institute of Public Health, Oslo, Norway, University of
18	8	Tromsø, Tromsø, Norway, and Haukeland University Hospital, Bergen, Norway
19 20	0	Tromso, Tromso, Torway, and Thackeland Oniversity Trospital, Dergen, Torway
20 21	9	Lien H. Nguyen, Norwegian Institute of Public Health, Oslo, Norway
22	9	Lien II. Nguyen, Norwegian institute of Fublic Health, Oslo, Norway
23	10	Digmor C Darg Norwagian Institute of Dublic Health Oale Norway, and University of
24	10	Rigmor C Berg, Norwegian Institute of Public Health, Oslo, Norway, and University of
25	11	Tromsø, Tromsø, Norway
26		
27 28	12	Acknowledgements: We are grateful to Elisabet Hafstad, Norwegian Institute of Public
20 29		
30	13	Health, for peer review of the systematic search strategies
31	14	
32	14	Word count: 3998
33		
34 35	15	Word count: 3998
35 36		
37	16	
38		
39		
40		
41		
42 43		
44		
45		
46		
47		
48		
49 50		
51		
52		
53		
54		
55		
56 57		
58		
59		
60		

2 3	1			
4 5	2	Abstract		
6 7	2	Abstract		
8	3	Objective: The purpose of the systematic review was to assess the effectiveness of remote		
9 10	4	patient monitoring (RPM) follow-up compared to standard care, for patients with chronic		
11 12	5	kidney disease (CKD) who perform dialysis at home.		
13 14	6	Methods: We conducted a systematic review in accordance with international guidelines. We		
15	7	performed systematic searches for publications from 2015-2021 in five databases (e.g.		
16 17	8	Medline, Cinahl, Embase) and a search for grey literature in reference lists. Included effect		
18 19	9	measures were quality of life, hospitalisation, technical failure as the cause for transfer to a		
20	10	different dialysis modality, infections, and time patients use for travel. Screening of literature,		
21 22	11	data extraction, risk of bias assessment, and certainty of evidence assessment (using the		
23 24	12	Grading of Recommendations Assessment, Development, and Evaluation approach) were		
25 26	13	done by two researchers. We conducted metaanalyses when possible.		
27 28	14	Results: Seven studies met the inclusion criteria, of which two were randomised controlled		
29	15	trials and five were retrospective cohort studies with control groups. The studies included		
30 31 32 33	16	9,975 participants from five countries, who were a good representation of dialysis patients in		
	17	high- and upper-middle-income countries. The patients were on peritoneal dialysis (six		
34 35	18	studies) or home hemodialysis (one study). There was very low certainty of evidence for the		
36	19	outcomes, except for hospitalisations: There was low certainty evidence from three cohort		
37 38	20	studies for fewer hospitalisation days in the RPM group. No studies included data for time		
39 40	21	patients used for travel.		
41 42	22	Construient We found have to some how containty and that in direct them more how within		
43	22	Conclusion: We found low to very low certainty evidence that indicate there may be positive		
44 45	23	effects of RPM follow-up, in comparison to standard care only, for adult patients with CKD		
46 47	24	who perform dialysis at home. Offering RPM follow-up for home dialysis patients as an		
48	25	alternative or supplement to standard care appears to be safe and provide health benefits such		
49 50	26	as fewer hospitalisation days. Future implementation should be coupled with robust, high		
51 52	27	quality evaluations.		
53 54	28	Protocol: Pre-registered in PROSPERO (CRD42021281779).		
55 56	29	Strength and limitations of this study		
57 58	30	- To our knowledge, this is the first systematic review to assess the effectiveness and		
59 60	31	safety of remote patient monitoring follow-up for adult patients with dialysis-		
		2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2		

1 2		
2 3 4	1	dependent chronic kidney disease on home dialysis (hemodialysis and peritoneal
5	2	dialysis).
6 7	3	- Our systematic review was conducted in line with guidelines from the Cochrane and
8 9	4	GRADE working group. The researchers specialise in systematic review research, one
10	5	researcher is a registered nurse with long and diverse nephology experience, and the
11 12	6	searches were conducted by a search specialist.
13 14	7	- Due to study heterogeneity, inconsistent measurement and reporting, our ability to
15	8	conduct metaanalyses was limited.
16 17	9	
18 19	9	
20 21	10	Introduction
22	11	Chronic kidney disease (CKD) is a significant public health concern, with 8-16% of the
23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40	12	world's population affected. ¹ It is characterised by a need for close monitoring, poor health
	13	outcomes, and a high economic burden for society as well as for the individual. ² The world's
	14	population is growing older, and with CKD prevalence rising parallel with age, ² an increasing
	15	number of people will continue to need monitoring and treatment with dialysis. There are two
	16	main types of dialysis: Peritoneal dialysis (PD) and hemodialysis (HD). Both are suitable
	17	treatment options when the kidneys are unable to filter the blood sufficiently. ³
	18	With the use of technology, there are encouraging possibilities for thorough patient
	19	follow-up, and at the same time, human resource savings. ⁴⁻⁶ Both PD and HD can be
	20	performed at home. With home dialysis, the patients receive comprehensive training arranged
	21	by staff at a dialysis centre to ensure that they have the skills and knowledge required to
41 42	22	perform the treatment at home. ³⁷ While dialysis is time-consuming regardless of location,
43	23	patients on home dialysis are not dependent on hospital service hours and may experience
44 45	24	more freedom than patients receiving in-centre dialysis.89 Additionally, for patients on in-
46 47	25	centre dialysis, the burden of time spent commuting between home and hospital can be
48	26	extensive. They often also spend a substantial amount of time waiting for transport and
49 50	27	waiting to be assisted by hospital staff for connection and disconnection from HD. Research
51 52	28	shows that travel time to dialysis exceeding 60 minutes is associated with significantly
53 54	29	decreased health-related quality of life (QoL) and significantly increased mortality risk
55	30	compared to patients who travel 15 minutes or less. ¹⁰ With dialysis at home, it is reasonable to
56 57	31	expect considerable time savings for the patients as well as improved health-related QoL.
58 59		
60		

Page 5 of 34

BMJ Open

2		
3 4	1	In healthcare there is increasing interest in utilising technology-based interventions.
5	2	Telemedicine and e-health are broad terms used when medical treatment, examination, or
6 7	3	patient follow-up is done from a distance. ¹¹ Homecare telehealth is another related term, and
8 9	4	remote patient monitoring (RPM) is a subcategory thereof. RPM uses computer systems or
10	5	software application technology that transfers patient-generated data to healthcare
11 12	6	professionals. ¹² Given the intervention considered in this systematic review is internet
13 14	7	dependent, we will use the term RPM. RPM can give the patient quick access to medical
15 16	8	expertise, independent of the distance to a treatment centre, and provides healthcare teams
17	9	with valuable information about the patient's condition. Thus, RPM can be a tool to empower
18 19	10	patients in self-care and for healthcare providers to offer support from a distance. ¹¹
20 21	11	Qualitative studies from the U.K. and Norway suggest that patients on home dialysis have a
22 23	12	positive attitude towards the use of RPM and believe that this could decrease anxiety and
24	13	make it easier for more patients to choose home dialysis. ^{13 14} In a recent pilot study from Italy,
25 26	14	patients overcame physical, cognitive, and psychological barriers to PD by RPM follow-up. ¹⁵
27 28	15	Strategies to switch more patients to home dialysis may have positive impacts on the
29	16	patients' daily life, ^{14 16} decrease mortality, ¹⁷ and offer economic savings for the patients as
30 31	17	well as for society. ^{16 18} RPM holds much promise for enhancing follow up of CKD patients on
32 33	18	dialysis and it is critical to determine whether and which strategies are effective at improving
34 35	19	outcomes. RPM patient follow-up is seemingly already expanding its reach. Our Google
36	20	Scholar search in December 2021 showed that there has been a 200% increase in records
37 38	21	about e-health home dialysis from 2018 to 2021. Although interest in nephrology and e-
39 40	22	health, including RPM, is increasing, to date, there are no systematic reviews about the
41 42	23	effectiveness and safety of RPM follow-up including adult patients with dialysis-dependent
43	24	CKD on home dialysis (HD and PD). We aimed to conduct a systematic review on the
44 45	25	effectiveness of RPM follow-up compared to standard care, for adult patients with CKD who
46 47	26	perform dialysis at home.
48	27	
49 50	27	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

BMJ Open

1 Search strategy and selection

2 The reviewers (HN, RB) prepared the search strategy in collaboration with a research

- 3 librarian (LN), and a second research librarian peer-reviewed the search strategy. The
- 4 librarian (LN) conducted searches in August 2021 in CINAHL (EBSCO), EMBASE (OVID),
- 5 Medline (OVID), Cochrane Database of Systematic Reviews, and CENTRAL. The search
 - 6 included both subject headings (e.g. MeSH in Medline) and text words. Available
- 7 Supplemental Appendix 1. In addition, the two reviewers conducted hand searches in the
- 8 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.

Page 7 of 34

BMJ Open

1 Two insported in records non all statistics into an End took nonly that Netword and 2 duplicate entries. Two researches in Accordance with the predetermined inclusion and exclusion 3 from the literature searches in accordance with the predetermined inclusion and exclusion 4 eriteria. All abstracts that appeared to fit the inclusion eriteria or did not provide enough 5 information, were promoted to full text screening. At each level, we evaluated the identified 6 records independently of one another using a pre-developed inclusion form. The final 7 determination to include or exclude was made together and any disagreements were solved by 8 discussion. Excluded studies for risk of bias (RoB) we used two different instruments: The 10 To assess the included studies for risk of bias (RoB) we used two different instruments: The 11 Newcastle-Ottawa scale for othort studies. ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹ 12 Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed 13 on a final RoB evaluation, with disagreements solved by discussion. 14 One researcher (HN) created a standard extraction form and extracted data from all 15 included studies. The information extracted from the studies was: title, authors, publication 16 <th>2</th> <th></th> <th></th>	2		
3 from the literature searches in accordance with the predetermined inclusion and exclusion 4 criteria. All abstracts that appeared to fit the inclusion criteria or did not provide enough 5 information, were promoted to full text screening. At each level, we evaluated the identified 6 records independently of one another using a pre-developed inclusion form. The final 7 determination to include or exclude was made together and any disagreements were solved by 8 discussion. Excluded studies with justifications are available in Supplemental Appendix 2. 9 <i>Risk of bias assessment and data extraction</i> 10 To assess the included studies for risk of bias (RoB) we used two different instruments: The 11 Newcastle-Ottawa scale for cohort studies. ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹ 12 Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed 13 on a final RoB evaluation, with disagreements solved by discussion. 14 One researcher (HN) created a standard extraction form and extracted data from all 15 included studies. The information extracted from the studies was: title, authors, publication 16 details, study design, aim of the study, study setting (location and time the study was 17 conducted), characteristics of included participants (age, gender etc.), charac	3 4	1	We imported all records from the searches into an EndNote library and removed all
3 from the literature searches in accordance with the predetermined inclusion and exclusion 4 criteria. All abstracts that appeared to fit the inclusion criteria or did not provide enough 5 information, were promoted to full text sereening. At each level, we evaluated the identified 7 records independently of one another using a pre-developed inclusion form. The final 7 determination to include or exclude was made together and any disagreements were solved by 8 discussion. Excluded studies with justifications are available in Supplemental Appendix 2. 9 <i>Risk of bias assessment and data extraction</i> 10 To assess the included studies for risk of bias (RoB) we used two different instruments: The 11 Newcastle-Ottawa scale for cohort studies, ²³ and Cochrane Risk of Bias Tool for RCTs, ¹⁹ 12 Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed 13 on a final RoB evaluation, with disagreements solved by discussion. 14 One researcher (HN) created a standard extraction form and extracted data from all 15 included studies. The information extracted from the studies was: title, authors, publication 16 details, study design, aim of the study, study setting (location and time the study was 17 conducted), characteristics of included participants (age, gender etc.), charac		2	duplicate entries. Two researchers (HN, RB) independently screened all titles and abstracts
 criteria Aria asstates that appeared to fit the inclusion criteria of during hydro 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. <i>Risk of bias assessment and data extraction</i> 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. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> We extracted crude outcome data for all eligible outcomes when postscores for both intervention and c	7	3	from the literature searches in accordance with the predetermined inclusion and exclusion
11 11 12 11 13 12 14 12 15 12 16 records independently of one another using a pre-developed inclusion form. The final 14 12 15 12 16 discussion. Excluded studies with justifications are available in Supplemental Appendix 2. 17 12 17 0 assess the included studies for risk of bias (RoB) we used two different instruments: The 18 Newcastle-Ottawa scale for cohort studies, ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹ 17 Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed 18 on a final RoB evaluation, with disagreements solved by discussion. 19 Two researcher (HN) created a standard extraction form and extracted data from all 10 included studies. The information extracted from the studies was: title, authors, publication 16 details, study design, aim of the study, study setting (location and time the study was 17 conducted), characteristics of included participants (age, gender ctc.), characteristics of the 18 intervention, study setting, outcomes, and results. Whenever information was available, 19 dichotomous and cont		4	criteria. All abstracts that appeared to fit the inclusion criteria or did not provide enough
6 records independently of one another using a pre-developed inclusion form. The final 11 7 determination to include or exclude was made together and any disagreements were solved by 12 8 discussion. Excluded studies with justifications are available in Supplemental Appendix 2. 17 9 Risk of bias assessment and data extraction 10 To assess the included studies for risk of bias (RoB) we used two different instruments: The 11 Newcastle-Ottawa scale for cohort studies, ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹ 12 Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed 13 on a final RoB evaluation, with disagreements solved by discussion. 14 One researcher (HN) created a standard extraction form and extracted data from all 15 included studies. The information extracted from the studies was: title, authors, publication 16 details, study design, aim of the study, study setting (location and time the study was 17 conducted), characteristics of included participants (age, gender etc.), characteristics of the 18 intervention, study setting, outcomes, and results. Whenever information was available, 19 dichotomous and accuracy and any disagreements were solved by further inspection of 19 therevotinon, and assessment of th		5	information, were promoted to full text screening. At each level, we evaluated the identified
1 determination to include or exclude was made together and any disagreements were solved by 1 discussion. Excluded studies with justifications are available in Supplemental Appendix 2. 1 <i>Risk of bias assessment and data extraction</i> 10 To assess the included studies for risk of bias (RoB) we used two different instruments: The 11 Newcastle-Ottawa scale for cohort studies, ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹ 12 Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed 13 on a final RoB evaluation, with disagreements solved by discussion. 14 One researcher (HN) created a standard extraction form and extracted data from all 15 included studies. The information extracted from the studies was: title, authors, publication 16 details, study design, aim of the study, study setting (location and time the study was 17 conducted), characteristics of included participants (age, gender etc.), characteristics of the 18 intervention, study setting, outcomes, and results. Whenever information was available, 19 dichotomous and continuous data for all eligible outcomes were extracted. HN contacted 20 several authors for additional data, but did not receive a reply. RB assessed the extracted data 21 for completeness and accuracy and any disagreements were solved by fur	12	6	records independently of one another using a pre-developed inclusion form. The final
8 Biscussion: Excluded studies with justifications are available in Suppletitional Appendix 2. 9 Risk of bias assessment and data extraction 10 To assess the included studies for risk of bias (RoB) we used two different instruments: The 11 Newcastle-Ottawa scale for cohort studies, ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹ 12 Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed 13 on a final RoB evaluation, with disagreements solved by discussion. 14 One researcher (HN) created a standard extraction form and extracted data from all 15 included studies. The information extracted from the studies was: title, authors, publication 16 details, study design, aim of the study, study setting (location and time the study was 17 conducted), characteristics of included participants (age, gender etc.), characteristics of the 18 intervention, study setting, outcomes, and results. Whenever information was available, 19 dichotomous and continuous data for all eligible outcomes were extracted. HN contacted 20 several authors for additional data, but did not receive a reply. RB assessed the extracted data 21 for completeness and accuracy and any disagreements were solved by further inspection of 22 the publication and discussion. 23 <td></td> <td>7</td> <td>determination to include or exclude was made together and any disagreements were solved by</td>		7	determination to include or exclude was made together and any disagreements were solved by
9 <i>Risk of bias assessment and data extraction</i> 19 10 To assess the included studies for risk of bias (RoB) we used two different instruments: The 11 Newcastle-Ottawa scale for cohort studies, ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹ 12 Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed 13 on a final RoB evaluation, with disagreements solved by discussion. 14 One researcher (HN) created a standard extraction form and extracted data from all 15 included studies. The information extracted from the studies was: title, authors, publication 16 details, study design, aim of the study, study setting (location and time the study was 17 conducted), characteristics of included participants (age, gender etc.), characteristics of the 18 intervention, study setting, outcomes, and results. Whenever information was available, 19 dichotomous and continuous data for all eligible outcomes were extracted. HN contacted 20 several authors for additional data, but did not receive a reply. RB assessed the extracted data 21 for completeness and accuracy and any disagreements were solved by further inspection of 22 the publication and discussion. 23 Analysis and assessment of the certainty of the evidence (GRADE) 24	16	8	discussion. Excluded studies with justifications are available in Supplemental Appendix 2.
101010assess the included studies for risk of blas of blas (or blas we dided two different instutients). The11Newcastle-Ottawa scale for cohort studies, ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹ 12Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed13on a final RoB evaluation, with disagreements solved by discussion.14One researcher (HN) created a standard extraction form and extracted data from all15included studies. The information extracted from the studies was: title, authors, publication16details, study design, aim of the study, study setting (location and time the study was17conducted), characteristics of included participants (age, gender etc.), characteristics of the18intervention, study setting, outcomes, and results. Whenever information was available,19dichotomous and continuous data for all eligible outcomes were extracted. HN contacted20several authors for additional data, but did not receive a reply. RB assessed the extracted data21for completeness and accuracy and any disagreements were solved by further inspection of22the publication and discussion.23Analysis and assessment of the certainty of the evidence (GRADE)24We extracted crude outcome data for all eligible outcomes when postscores for both25intervention and control groups were available and, when such data were available, adjusted26outcome data (adjusted comparison (effect) estimates and their standard errors or 95%27confidence intervals, CI). We provide dichotomous outcomes as the number of events and <td></td> <td>9</td> <td>Risk of bias assessment and data extraction</td>		9	Risk of bias assessment and data extraction
2111Newcastle-Ottawa scale for cohort studies,23 and Cochrane Risk of Bias Tool for RCTs.1922Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed23on a final RoB evaluation, with disagreements solved by discussion.24One researcher (HN) created a standard extraction form and extracted data from all25included studies. The information extracted from the studies was: title, authors, publication26details, study design, aim of the study, study setting (location and time the study was27conducted), characteristics of included participants (age, gender etc.), characteristics of the28intervention, study setting, outcomes, and results. Whenever information was available,29dichotomous and continuous data for all eligible outcomes were extracted. HN contacted20several authors for additional data, but did not receive a reply. RB assessed the extracted data21for completeness and accuracy and any disagreements were solved by further inspection of22the publication and discussion.23Analysis and assessment of the certainty of the evidence (GRADE)24We extracted crude outcome data for all eligible outcomes when postscores for both25intervention and control groups were available and, when such data were available, adjusted24outcome data (adjusted comparison (effect) estimates and their standard errors or 95%25confidence intervals, CI). We provide dichotomous outcomes as the number of events and26number of people in groups as proportions, risk ratio (RR), incident RR (IRR) or odds ratio26(10	To assess the included studies for risk of bias (RoB) we used two different instruments: The
12Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed13on a final RoB evaluation, with disagreements solved by discussion.14One researcher (HN) created a standard extraction form and extracted data from all15included studies. The information extracted from the studies was: title, authors, publication16details, study design, aim of the study, study setting (location and time the study was17conducted), characteristics of included participants (age, gender etc.), characteristics of the18intervention, study setting, outcomes, and results. Whenever information was available,19dichotomous and continuous data for all eligible outcomes were extracted. HN contacted20several authors for additional data, but did not receive a reply. RB assessed the extracted data21for completeness and accuracy and any disagreements were solved by further inspection of22the publication and discussion.23Analysis and assessment of the certainty of the evidence (GRADE)24We extracted crude outcome data for all eligible outcomes when postscores for both25intervention and control groups were available and, when such data were available, adjusted26outcome data (adjusted comparison (effect) estimates and their standard errors or 95%27confidence intervals, CI). We provide dichotomous outcomes as the number of events and28number of people in groups as proportions, risk ratio (RR), incident RR (IRR) or odds ratio29(OR) as appropriate. Continuous outcomes are shown as mean difference (MD) and standard29deviations (21	11	Newcastle-Ottawa scale for cohort studies, ²³ and Cochrane Risk of Bias Tool for RCTs. ¹⁹
13on a final RoB evaluation, with disagreements solved by discussion.14One researcher (HN) created a standard extraction form and extracted data from all15included studies. The information extracted from the studies was: title, authors, publication16details, study design, aim of the study, study setting (location and time the study was17conducted), characteristics of included participants (age, gender etc.), characteristics of the18intervention, study setting, outcomes, and results. Whenever information was available,19dichotomous and continuous data for all eligible outcomes were extracted. HN contacted20several authors for additional data, but did not receive a reply. RB assessed the extracted data21for completeness and accuracy and any disagreements were solved by further inspection of22the publication and discussion.23Analysis and assessment of the certainty of the evidence (GRADE)24We extracted crude outcome data for all eligible outcomes when postscores for both25intervention and control groups were available and, when such data were available, adjusted26outcome data (adjusted comparison (effect) estimates and their standard errors or 95%27confidence intervals, CI). We provide dichotomous outcomes as the number of events and28number of people in groups as proportions, risk ratio (RR), incident RR (IRR) or odds ratio29(OR) as appropriate. Continuous outcomes are shown as mean difference (MD) and standard29deviations (SD), or the most appropriate presentation based on the available data in the29included st	23	12	Two researchers (HN, RB) conducted independent risk of bias assessments and then agreed
2714One researcher (HN) created a standard extraction form and extracted data from all28included studies. The information extracted from the studies was: title, authors, publication3016details, study design, aim of the study, study setting (location and time the study was31conducted), characteristics of included participants (age, gender etc.), characteristics of the33intervention, study setting, outcomes, and results. Whenever information was available,36dichotomous and continuous data for all eligible outcomes were extracted. HN contacted37several authors for additional data, but did not receive a reply. RB assessed the extracted data38for completeness and accuracy and any disagreements were solved by further inspection of41the publication and discussion.42We extracted crude outcome data for all eligible outcomes when postscores for both43intervention and control groups were available and, when such data were available, adjusted44outcome data (adjusted comparison (effect) estimates and their standard errors or 95%45confidence intervals, CI). We provide dichotomous outcomes as the number of events and46number of people in groups as proportions, risk ratio (RR), incident RR (IRR) or odds ratio47GR as appropriate. Continuous outcomes are shown as mean difference (MD) and standard48deviations (SD), or the most appropriate presentation based on the available data in the43included studies.	25	13	on a final RoB evaluation, with disagreements solved by discussion.
 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. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> 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. 	27	14	One researcher (HN) created a standard extraction form and extracted data from all
 a details, study design, ann of the study, study setting (recation and thile 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. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> 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. 	29 30 31 32 33 34 35	15	included studies. The information extracted from the studies was: title, authors, publication
 17 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. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> 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. 		16	details, study design, aim of the study, study setting (location and time the study was
 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. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> 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. 		17	conducted), characteristics of included participants (age, gender etc.), characteristics of the
 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. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> 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. 		18	intervention, study setting, outcomes, and results. Whenever information was available,
 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. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> 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. 		19	dichotomous and continuous data for all eligible outcomes were extracted. HN contacted
 for completeness and accuracy and any disagreements were solved by further inspection of the publication and discussion. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> 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. 	37	20	several authors for additional data, but did not receive a reply. RB assessed the extracted data
 the publication and discussion. <i>Analysis and assessment of the certainty of the evidence (GRADE)</i> 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. 	39	21	for completeness and accuracy and any disagreements were solved by further inspection of
 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. 	41	22	the publication and discussion.
 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. 	43	23	Analysis and assessment of the certainty of the evidence (GRADE)
 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. 		24	We extracted crude outcome data for all eligible outcomes when postscores for both
 48 26 outcome data (adjusted comparison (effect) estimates and their standard errors or 95% 50 27 confidence intervals, CI). We provide dichotomous outcomes as the number of events and 51 28 number of people in groups as proportions, risk ratio (RR), incident RR (IRR) or odds ratio 53 29 (OR) as appropriate. Continuous outcomes are shown as mean difference (MD) and standard 55 30 deviations (SD), or the most appropriate presentation based on the available data in the 56 31 included studies. 		25	intervention and control groups were available and, when such data were available, adjusted
 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. 	48	26	outcome data (adjusted comparison (effect) estimates and their standard errors or 95%
 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. 		27	confidence intervals, CI). We provide dichotomous outcomes as the number of events and
 ⁵³ 29 (OR) as appropriate. Continuous outcomes are shown as mean difference (MD) and standard ⁵⁵ 30 deviations (SD), or the most appropriate presentation based on the available data in the ⁵⁷ 31 included studies. 		28	number of people in groups as proportions, risk ratio (RR), incident RR (IRR) or odds ratio
 deviations (SD), or the most appropriate presentation based on the available data in the included studies. 	53	29	
56 57 31 included studies. 58	55		
58			

BMJ Open

1 2		
2 3 4 5	1	We evaluated the characteristics of the studies' (S)PICO and when they were
	2	considered sufficiently similar, and data were available, we conducted metaanalyses. The
6 7	3	judgments about whether metaanalyses were appropriate were based on recommendations in
8 9	4	the Cochrane Handbook. ¹⁹ We used Mantel-Haenszel random effects metaanalysis for
10	5	dichotomous outcomes and we presented the relative risks and their corresponding 95% CI (it
11 12	6	was not possible to metaanalyse any continuous outcomes). We also examined between-study
13 14	7	heterogeneity using visual inspection of CIs, the Chi-square test, and Isquare statistic,
15	8	quantifying the degree of heterogeneity as described in the Cochrane Handbook. ¹⁹ We used
16 17	9	RevMan version 5.4, the latest version of the Cochrane metaanalysis software. ²⁴ When the
18 19	10	studies' (S)PICOs or results were too heterogeneous to pool statistically, or data were
20 21	11	unavailable, we reported the results narratively, in text and tables. We planned to perform a
22	12	subgroup analysis for the outcome technical failure, but this was not possible due to lack of
23 24	13	data.
25 26 27 28 29 30 31 32 33 34 35 36 37 38 39	14	We assessed the certainty of the evidence using the Grading of Recommendations
	15	Assessment, Development and Evaluation (GRADE) framework. ²⁵ With regard to results that
	16	could not be metaanalysed, we followed the Synthesis Without Meta-analysis (SWiM)
	17	guideline. ²⁶
	18	Patient and public involvement
	19	Due to the nature of the study (systematic review), no patients were involved.
	20	Results
40 41	21	The searches returned 451 references after removal of duplicates (Figure 1). We read 24
42 43	22	reports in full text, including one study identified from the hand search in reference lists. The
44 45	23	most common primary reasons for exclusion were that there was no control group or it was
46	24	the wrong participants or outcomes. Seven studies published between 2018-2021 were
47 48	25	eligible for inclusion. ²⁷⁻³³
49 50	26	Description of the studies
51	27	The seven included studies consisted of two RCTs and five retrospective cohort studies (Table
52 53	28	1). They were conducted in five different countries. There were two studies each from
54 55	29	Columbia and USA, and one study each from China, Italy, and South Korea. Three were set
56 57	30	in a single PD centre, four took place in two or more renal care centres and the two largest
58	31	studies took place in the USA with one including 55 home HD centres and another 931
59 60	32	Fresenius PD clinics.
		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

5 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

7 patients in the studies. The range was 57-6343 patients, thus there was imbalance in sample

8 sizes across the studies. The two largest studies, cohorts from the USA, made up 88% of the

9 total number of study participants. In all the studies most patients were male (range 53%-

10 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 & Collins³³ 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.

⁴²₄₃ 23 *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).

⁵³₅₄ 29 *Effect of RPM versus standard care*

⁵⁵ 30 Across the studies, there were data on four of our five pre-determined outcomes:

57 31 Hospitalisation,^{27 28 31 32} infections,²⁷ technical failure as the cause for transfer to a different

⁵⁸ ₅₉ 32 dialysis modality,^{27-29 31-33} and QoL.^{30 31} Due to the inconsistent measurement of outcomes,

⁶⁰ 33 and inconsistent and incomplete reporting of outcome results in the studies, our ability to

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

5 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 dialy	ysis 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	Adj. HR 0.66 (0.50-0.86)
	mo)	
Quality of life		
Jung 2021	KDQOL -Patient satisfaction	Mean 75.5 in RPM group vs 73.7
	questions (6 mo)	in SC group, P 0.64
Milan 2020	KDQOL -Patient satisfaction	Median 83.3 in both groups, P
	questions (6 mo)	0.99
Jung 2021	KDQOL -Dialysis staff	Mean 93.1 in RPM group vs 97.1
	encouragement (6 mo)	in SC group, P 0.05
Milan 2020	KDQOL -Dialysis staff	Median 100 in both groups, P
	encouragement (6 mo)	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

12 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	No. of participants	Quality of evidence (GRADE)	
	Assumed risk with control	Assumed risk with RPM	(95% CI)	(Studies)	(GRADE)	
Hospitalisations (6	-12 months)					
Days	were fewer	All 3 cohort studies showed that there 6,736 (3) were fewer hospitalisation days in the RPM group (Table 2)			⊕⊕⊖⊖ LOW	
All-cause	that there we	3 of 4 studies (1 RCT, 3 cohort) showed 6,936 (4) that there were fewer hospitalisations in the RPM group (Table 2)			⊕○○○ 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 mon	ths)	<pre></pre>	0			
	-	rted more peritor ections with RPM		160 (1)	⊕○○○ VERY LOW ³	
Technical failure (6-12 months)		2,		
	521/2230 (23.4%)	136/786 (17.3%)	RR 0.78 (0.66 to 0.93)	2856 (3 cohort)	⊕○○○ VERY LOW ⁴	
		es (1 RCT, 2 coh es with RPM (Ta	· •	7161 (3)		
Quality of life (6 m	ionths)					
Patient satisfaction	group, 1 col	d higher QoL in hort found QoL v hps (Table 2)		130 (2)	⊕○○○ VERY LOW ⁵	

2 3 4 5 6 7		Dialysis staff encouragement	1 RCT found higher QoL in the RPM130 (2)group, 1 cohort found QoL was similar inthe two groups (Table 2)	⊕○○○ VERY LOW ⁵				
8 9		Travel time	0 studies assess this outcome	No evidence				
10 11		1. Downgraded by	1 level because of moderate risk of bias in 1 study and in	nconsistency				
12 13		2. Downgraded by	1 level because of imprecision					
14 15		3. Downgraded by	3 levels because of moderate risk of bias, inconsistency,	imprecision				
16 17		4. Downgraded by	1 level because of moderate risk of bias in 1 study and ir	nprecision				
18 19		5. Downgraded by	1 level because of inconsistency and imprecision					
20 21 22 23 24		risk in the interver	terval; RCT: Randomised controlled study; SD: Standard ntion group (and its 95% confidence interval) is based on oup and the relative effect of the intervention (and its 95%	the assumed risk in				
25 26	1							
27 28 29	2	Hospitalisations						
	3	One RCTs and three observational studies from Italy, Colombia, China, and the USA						
30 31	4	examined the effect of RPM on hospitalisations. ^{27 28 31 32} However, the outcome was reported						
32 33 34 35	5	differently across t	differently across the studies, as hospitalisation days/days admitted, all-cause hospitalisations,					
	6	and disease-specifi	and disease-specific hospitalisations (caused by overhydration, access dysfunction, and					
36	7	infections).						
37 38	8	Hospitalisation day	vs. The three observational studies, Chaudhuri et al., ²⁸ Mil	lan et al., ³¹ and				
39 40	9	Sanabria et al. ³² , al	l found fewer hospitalisation days in the RPM group than	the control group				
41 42	10	(Table 2). The resu	llts in Sanabria et al. ³² were from a matched sample, as da	ta for the whole				
43 44	11	sample was not ava	ailable. This study showed the largest effect with a differe	ence of six				
45	12	hospitalisation day	s (IRR 0.46, 0.23-0.92).					
46 47 48	13	All-cause hospitali	sations. One RCT ²⁷ and three observational studies ^{28 31 32}	had data on				
48 49	14	general, all-cause hospitalisations. While three of the four studies showed that RPM users h						
50 51	15	less all-cause hospitalisations than patients with standard care only, the fourth study favo						
52 53	16	standard care (Tab	le 2).					
54 55	17	Disease-specific ho	ospitalisations. The results on disease-specific hospitalisat	tions from two				
56 57	18	observational studi	es, Milan et al., ³¹ and Sanabria et al. ³² could be pooled in	a metaanalysis				
58 59	19	(Figure 2). The nor	n-significant result suggested there were fewer disease-spe	ecific				
60	20	hospitalisations in	the RPM group than in the control group (RR 0.62, 95% o	CI 0.31-1.24).				

BMJ Open

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

3 due to peritonitis and overhydration.

4 <u>Infections</u>

1 2 3

4

5 6

7 8 9

10

11 12

13 14

15

16 17 18

19 20 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

8 treated at home or in the hospital.

9 <u>Technical failure as the cause for transfer to a different dialysis modality</u>

10 One RCT from China²⁷ found no difference between the groups while five observational

11 studies from the USA^{28 33}, Colombia^{29 32}, and Italy³¹ consistently reported less technical

²³ ²⁴ 12 failure as cause for transfer to a different dialysis modality in the RPM group compared to the

²⁵ 13 control group (Table 2). Three of the cohort studies could be pooled in a metaanalysis; the

27 14 result implies benefit of RPM (0.78, 95% CI 0.66, 0.92) (Figure 2). Two of the studies^{32 33}

28 29 15 gave data on novice patients with less than three months treatment duration at baseline,

 $\frac{30}{31}$ 16 indicating a positive, but non-significant effect of RPM in new patients (Table 2).

3233 17 <u>Self-reported Quality of Life</u>

34 Both studies, one RCT³⁰ and one observational study,³¹ reporting on quality of life used the 18 35 36 tool 'The short form of kidney disease quality of life' (KDQOL), which is an adaptation of 19 37 20 SF-36.³⁴ All answers were transformed into pre-coded numeric values with a range from 0-38 39 100, where 100 was the highest QoL.³⁵ Neither studies offered an overall total score across 21 40 41 22 the questions/areas, and we selected the two questions/areas that we considered most relevant 42 43 23 (patient satisfaction and dialysis staff encouragement). For both patient satisfaction and 44 dialysis staff encouragement, Milan et al.³¹ found the same score in both groups, while Jung et 24 45 46 al.³⁰ found a higher score in the RPM group than the control group concerning patient 25 47 48 26 satisfaction, but opposite for dialysis staff encouragement (Table 2).

27 Discussion

49 50 51

52

53

28 Principal findings

This systematic review advances the evidence on the effects of RPM for patients with dialysis dependent *CKD* on home dialysis including home *UD* and *RD*. Our findings are in line with

⁵⁶ 30 dependent CKD on home dialysis, including home HD and PD. Our findings are in line with

- $_{59}^{58}$ 31 previous research^{36 37} and document that there is no conclusive evidence, but that positive
- 60 32 effects of RPM are suggested for clinical outcomes, technical failure, and quality of life.

Page 15 of 34

1 2

BMJ Open

2	
3	
4	
5	
6	
7	
8	
9	
10	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
22 23	
23 24	
24	
25	
26	
27	
28	
29	
30	
31	
32	
33	
34	
35	
36	
36	
37	
38	
39	
40	
41	
42	
43	
44	
45	
46	
47	
48	
49 50	
50	
51	
52	
53	
54	
55	
56	
57	
58	
58 59	
60	

1 The results consistently suggest that RPM reduces hospitalisations and the number of 2 days the patient is admitted. It was especially convincing that Milan et al.³¹ observed a median 3 difference of five fewer hospitalisation days in the RPM group over six months, because the 4 patients on RPM had a worse comorbidity score. Furthermore, except for one study that found 5 the same number of technical failures in both groups, the other five studies found less 6 technical failure in the RPM group. In four of the studies measuring this outcome, 7 prescriptions could be changed from the hospital without in-person consultations. In effect, 8 RPM allows resolving technical issues early, thus preventing progression of technical failure 9 to the stage where the patient would need to transfer to a different dialysis modality. Research 10 has found great advantages with the technology displaying possible causes and solutions to 11 problems, alarm indicators showing who to contact for guidance (nurse or technician), and 12 reminders of activities that need to be performed.¹³⁻¹⁵ Concerning quality of life, only two 13 studies assessed this and the results showed the scores were comparable for the patients on 14 RPM and usual care. Encouragingly, scores for quality of life improved slightly and patient 15 satisfaction was higher than neutral. This is in line with a study from the U.S. that found that 16 RPM increased patients' confidence and satisfaction with treatment because they felt more 17 closely supported.³⁸ Lastly, no studies assessed time patients use for travel. However, research 18 suggests that health-related quality of life and time patients use for travel are intertwined¹⁰ 19 and that dialysis free time and reduction of fatigue are highly valued outcomes by patients.^{9 39} 20 ⁴⁰ This could reflect positively on quality of life.

21 Our results mirror two earlier systematic reviews on e-health interventions in PD patients³⁶ and in people with CKD.³⁷ Both reviews, with literature searches in 2018-2019, 22 23 included a wide range of patients and e-health modalities, including mobile or tablet 24 application, text or email messages, electronic monitors, internet/websites, and video or DVD. 25 Consequently, there was minimal overlap in included studies: Only one review³⁶ included two 26 of our included studies. Both reviews concluded that the quality of evidence for the 27 effectiveness of e-health was low with uncertain effects, but that no adverse effects were 28 indicated. Of note, a recent modelling analysis projected that in a cohort of 100 patients on 29 automated PD over 1 year, RPM would lead to 27 fewer hospitalisations, 518 fewer 30 hospitalization days, 31 additional months free of complications, and six fewer peritonitis episodes.41 31

1 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

47 26 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

BMJ Open

3		
4		
5		
6		
7		
8		
9		
1	0	
1	1	
1		
1		
	4	
1	5	
	6	
1	7	
	8	
	9	
2	0	
2	1	
2	2	
2		
	4	
	5	
	6	
	7	
	8	
	9	
	0	
3	1	
3		
3		
	4	
	5	
	6	
3		
3		
	9	
4		
4		
4		
4		
4		
4		
4		
4		
4		
4		
5 5		
5	1 ว	
5 5		
	3 4	
5		

1 reporting, our ability to conduct metaanalyses was limited. Therefore, it was neither possible 2 to improve precision to any great extent, nor statistically assess potential differences across 3 groups, such as type of platform or HD and PD. We contacted several authors asking for more 4 data, but did not receive a reply. The low number of studies meant that we were unable to 5 statistically check for publication bias. Given the modestly positive but varied results, we 6 believe the potential for publication bias is low, but we recommend future reviews of a higher 7 number of included studies to assess this potential bias. The imbalance in sample sizes across 8 the studies, with two studies having a considerably larger sample size than the other five, 9 influenced the results related to hospitalisations and technical failure. Both these two studies 10 had low risk of bias, but three other studies had moderate risk of bias.

11 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.

19

20 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

- 6 24 **Competing interests**
- $^{\circ}_{9}$ 25 'None declared'.
- 1 26 **Ethical statement**
- 27 Not applicable
- 56 28 Funding

57

⁵⁸ 29 'This research received no specific grant from any funding agency in the public, commercial
 ⁵⁹ 30 or not-for-profit sectors'.

1 Exclusive licence

Please confirm you agree with the following statement by ticking the box and then insert thelicence statement in your manuscript file.

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in BMJ Open and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

22 Data availability statement

23 Data are available on reasonable request.

25 References

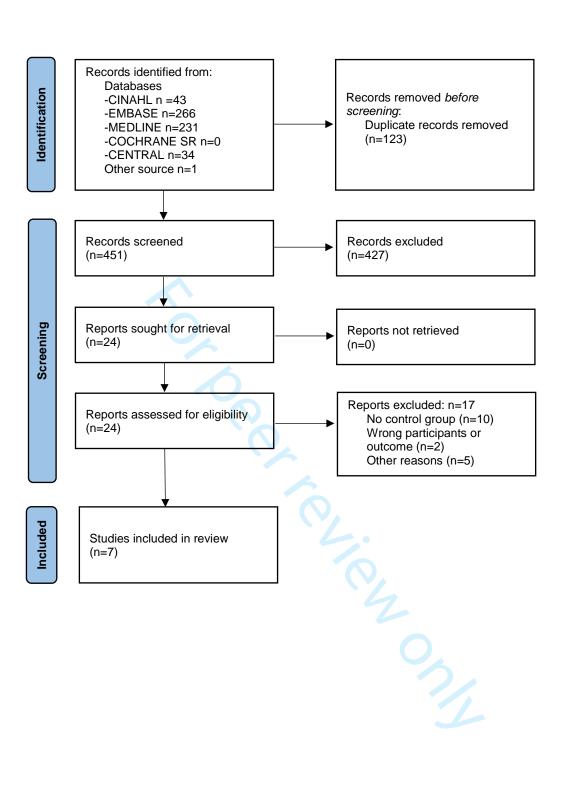
- Chen TK, Knicely DH, Grams ME. Chronic Kidney Disease Diagnosis and Management:
 A Review. JAMA 2019;322(13):1294-304. doi: 10.1001/jama.2019.14745
- 28 2. Tonelli M, Riella M. Chronic kidney disease and the aging population. *Indian journal of* 29 *nephrology* 2014;24(2):71-74. doi: 10.4103/0971-4065.127881
- 30 3. Sinnakirouchenan R, Holley JL. Peritoneal dialysis versus hemodialysis: risks, benefits,
 31 and access issues. *Adv Chronic Kidney Dis* 2011;18(6):428-32. doi:
 - 32 10.1053/j.ackd.2011.09.001 [published Online First: 2011/11/22]

1		
2		
3 4	1	4. Meld. St. 7 (2019–2020). Nasjonal helse- og sykehusplan 2020–2023: Helse- og
5	2	omsorgsdepartementet; [cited 2021 12.09]. Available from:
6	3	https://www.regjeringen.no/no/dokumenter/meldst7-20192020/id2678667/
7	4	5. Kitsiou S, Paré G, Jaana M, et al. Effectiveness of mHealth interventions for patients with
8	5	diabetes: An overview of systematic reviews. PLoS One 2017;12(3):e0173160. doi:
9	6	10.1371/journal.pone.0173160 [published Online First: 2017/03/02]
10	7	6. Widmer, R. Jay, et al. "Digital health interventions for the prevention of cardiovascular
11	8	disease: a systematic review and meta-analysis." Mayo Clinic Proceedings. Vol. 90.
12 13	9	No. 4. Elsevier, 2015
14	10	7. Helsedirektoratet. Nyresvikt - dialysepasienter som får hjemmedialyse: Helsedirektoratet;
15	11	2018 [updated 2021 02.12; cited 2021 12.12]. Available from:
16	12	https://www.helsedirektoratet.no/statistikk/kvalitetsindikatorer/behandling-av-
17	13	sykdom-og-overlevelse/andel-dialysepasienter-som-har-hjemmedialyse
18	14	8. Helsedirektoratet. Handlingsplan for forebygging og behandling av kronisk nyresykdom
19 20	15	(2011-2015) 2011 [cited 2021 11.09]. Available from:
20 21	16	http://www.nephro.no/foreningsnytt/Handlingsplan_forebygging_behandling_kronisk
21	17	_nyresykdom.pdf.
23	18	9. Urquhart-Secord R, Craig JC, Hemmelgarn B, et al. Patient and Caregiver Priorities for
24	19	Outcomes in Hemodialysis: An International Nominal Group Technique Study.
25	20	American Journal of Kidney Diseases 2016;68(3):444-54. doi:
26	21	https://doi.org/10.1053/j.ajkd.2016.02.037
27	22	10. Moist LM, Bragg-Gresham JL, Pisoni RL, et al. Travel Time to Dialysis as a Predictor of
28 29	23	Health-Related Quality of Life, Adherence, and Mortality: The Dialysis Outcomes and
29 30	24	Practice Patterns Study (DOPPS). American Journal of Kidney Diseases
31	25	2008;51(4):641-50. doi: https://doi.org/10.1053/j.ajkd.2007.12.021
32	26	11. Braut GS. Telemedisin Store medisinske leksikon [updated 2020 15.06; cited 2021 10.10].
33	27	Available from: https://sml.snl.no/telemedisin.
34	28	12. DelVecchio A. Definition, remote patient monitoring (RPM): Tech target, Search health
35	29	IT; [updated April 2019; cited 2021 10.10]. Available from:
36	30	https://searchhealthit.techtarget.com/definition/remote-patient-monitoring-RPM
37	31	13. Rajkomar A, Farrington K, Mayer A, et al. Patients' and carers' experiences of interacting
38 39	32	with home haemodialysis technology: implications for quality and safety. BMC
40	33	Nephrology 2014;15(1):195-95. doi: 10.1186/1471-2369-15-195
41	34	14. Rygh E, Arild E, Johnsen E, et al. Choosing to live with home dialysis-patients'
42	35	experiences and potential for telemedicine support: a qualitative study. <i>BMC</i>
43	36	Nephrology 2012;13(1):13-13. doi: 10.1186/1471-2369-13-13
44	37	15. Viglino G, Neri L, Barbieri S, et al. Videodialysis: a pilot experience of telecare for
45	38	assisted peritoneal dialysis. J Nephrol 2020;33(1):177-82. doi: 10.1007/s40620-019-
46 47	39	00647-6 [published Online First: 2019/09/19]
47 48	40	16. François K, Bargman JM. Evaluating the benefits of home-based peritoneal dialysis. Int J
49	40 41	Nephrol Renovasc Dis 2014;7:447-55. doi: 10.2147/IJNRD.S50527
50	41	17. Marshall MR, Polkinghorne KR, Kerr PG, et al. Temporal Changes in Mortality Risk by
51	42 43	
52		Dialysis Modality in the Australian and New Zealand Dialysis Population. American
53	44 45	Journal of Kidney Diseases 2015;66(3):489-98. doi:
54	45	https://doi.org/10.1053/j.ajkd.2015.03.014
55 56	46	18. Walker RC, Howard K, Morton RL. Home hemodialysis: a comprehensive review of
56 57	47	patient-centered and economic considerations. <i>Clinicoecon Outcomes Res</i> 2017;9:149-
58	48	61. doi: 10.2147/CEOR.S69340
59	49 50	19. Higgins JPT TJ, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (editors). Cochrane
60	50	Handbook for Systematic Reviews of Interventions version 6.2 (updated February

1 2		
3	1	2021): Cochrane; 2021 [cited 2021 12.09]. Available from:
4	2	www.training.cochrane.org/handbook.
5	3	20. PRISMA transperant reporting of systematic reviews and meta-analyses [cited 2021
6	4	08.11]. Available from: http://www.prisma-statement.org/.
7	5	21. Straus SE, Glasziou P, Richardson WS, et al. Evidence-based medicine E-book: How to
8 9	6	practice and teach EBM: Elsevier Health Sciences 2018.
10	7	22. Tonelli M, Wiebe N, Guthrie B, et al. Comorbidity as a driver of adverse outcomes in
11	8	people with chronic kidney disease. <i>Kidney International</i> 2015;88(4):859-66. doi:
12	9	https://doi.org/10.1038/ki.2015.228
13	10	23. Wells GA, Shea B, O'Connell D, et al. The Newcastle-Ottawa Scale (NOS) for assessing
14	11	the quality of nonrandomised studies in meta-analyses: The Ottawa hospital research
15 16	12	institute; [cited 2021 21.10]. Available from:
16 17	12	http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp
18	13	24. Cochrane RevMan Cochrane Training [updated Latest verion of RevMan 5.4.1. from
19	14	September 2020; cited 2021 10.10]. Available from:
20	15	https://training.cochrane.org/online-learning/core-software-cochrane-reviews/revman.
21	10	
22	17	25. GRADE: The GRADE Working Group; 2004-2021 [cited 2021 21.10]. Available from: https://www.gradeworkinggroup.org/
23 24	18	26. Campbell M, McKenzie JE, Sowden A, et al. Synthesis without meta-analysis (SWiM) in
24 25	20	systematic reviews: reporting guideline. BMJ 2020;368:16890. doi: 10.1136/bmj.16890
26	20	27. Cao F, Li L, Lin M, et al. Application of instant messaging software in the follow-up of
27	21	patients using peritoneal dialysis, a randomised controlled trial. <i>Journal of Clinical</i>
28	22	Nursing 2018;27(15-16):3001-07. doi: https://doi.org/10.1111/jocn.14487
29	23 24	
30	24 25	28. Chaudhuri S, Han H, Muchiutti C, et al. Remote Treatment Monitoring on Hospitalization and Technique Failure Rates in Peritoneal Dialysis Patients. <i>Kidney360</i>
31 32	23 26	2020;1(3):191-202. doi: 10.34067/kid.0000302019
32 33	20 27	29. Corzo L, Wilkie M, Vesga JI, et al. Technique failure in remote patient monitoring
34	28	program in patients undergoing automated peritoneal dialysis: A retrospective cohort
35	28 29	study. <i>Perit Dial Int</i> 2020:896860820982223. doi: 10.1177/0896860820982223
36	30	[published Online First: 2021/01/01]
37	31	30. Jung HY, Jeon Y, Kim YS, et al. Outcomes of Remote Patient Monitoring for Automated
38	32	Peritoneal Dialysis: A Randomized Controlled Trial. <i>Nephron</i> 2021 doi:
39 40	33	10.1159/000518364
41	34	31. Milan Manani S, Baretta M, Giuliani A, et al. Remote monitoring in peritoneal dialysis:
42	35	benefits on clinical outcomes and on quality of life. <i>Journal of Nephrology</i>
43	36	2020;33(6):1301-08.
44	37	32. Sanabria M, Buitrago G, Lindholm B, et al. Remote Patient Monitoring Program in
45	38	Automated Peritoneal Dialysis: Impact on Hospitalizations. <i>Perit Dial Int</i>
46 47	39	2019;39(5):472-78. doi: 10.3747/pdi.2018.00287 [published Online First: 2019/07/25]
48	40	33. Weinhandl ED, Collins AJ. Relative risk of home hemodialysis attrition in patients using
49	40	a telehealth platform. <i>Hemodial Int</i> 2018;22(3):318-27. doi: 10.1111/hdi.12621
50	42	[published Online First: 2017/12/07]
51	43	34. Wong FK, Chow SK, Chan TM. Evaluation of a nurse-led disease management
52	44	programme for chronic kidney disease: a randomized controlled trial. <i>International</i>
53 54	45	Journal of Nursing Studies 2010;47(3):268-78. doi: 10.1016/j.ijnurstu.2009.07.001
54 55	46	35. Kidney Disease Quality of Life Instrument (KDQOL): The RAND Corporation; [cited
56	47	2021 14.10]. Available from: https://www.rand.org/health-
57	48	care/surveys tools/kdqol.html
58		
59		
60		

1		
2		
3 4	1	36. Cartwright EJ, Z ZSG, Foo M, et al. eHealth interventions to support patients in delivering
5	2 3	and managing peritoneal dialysis at home: A systematic review. Peritoneal Dialysis
6	3	International 2021;41(1):32-41.
7	4	37. Stevenson JK, Campbell ZC, Webster AC, et al. eHealth interventions for people with
8	5	chronic kidney disease. Cochrane Database of Systematic Reviews 2019(8) doi:
9	6	10.1002/14651858.CD012379.pub2
10	7	38. Magnus M, Sikka N, Cherian T, et al. Satisfaction and Improvements in Peritoneal
11	8	Dialysis Outcomes Associated with Telehealth. <i>Appl Clin Inform</i> 2017;8(1):214-25.
12	9	doi: 10.4338/aci-2016-09-ra-0154 [published Online First: 2017/03/02]
13	10	39. Manera KE, Johnson DW, Craig JC, et al. Patient and Caregiver Priorities for Outcomes
14	10	
15		in Peritoneal Dialysis. <i>Multinational Nominal Group Technique Study</i> 2019;14(1):74-
16	12	83. doi: 10.2215/cjn.05380518
17	13	40. Evangelidis N, Tong A, Manns B, et al. Developing a Set of Core Outcomes for Trials in
18 19	14	Hemodialysis: An International Delphi Survey. American Journal of Kidney Diseases
20	15	2017;70(4):464-75. doi: 10.1053/j.ajkd.2016.11.029
20	16	41. Ariza JG, Walton SM, Sanabria M, et al. Evaluating a remote patient monitoring program
22	17	for automated peritoneal dialysis. Perit Dial Int 2020;40(4):377-83. doi:
23	18	10.1177/0896860819896880 [published Online First: 2020/02/18]
24	19	42. Sanyal C, Stolee P, Juzwishin D, et al. Economic evaluations of eHealth technologies: A
25	20	systematic review. PLoS One 2018;13(6):e0198112. doi:
26	21	10.1371/journal.pone.0198112 [published Online First: 2018/06/14]
27	22	43. Gallar P, Vigil A, Rodriguez I, et al. Two-year experience with telemedicine in the
28	23	follow-up of patients in home peritoneal dialysis. <i>Journal of Telemedicine & Telecare</i>
29		
30	24	2007;13(6):288-92. doi: 10.1258/135763307781644906
31	25	44. SONG. Standardised outcomes in nephrology [cited 2022 23.04]. Available from:
32	26	https://songinitiative.org/
33	27	
34 35		
36	28	Figure legend:
37		
38	29	Figure 1: Prisma flow diagram for selection of studies
39	29	Figure 1. Filshia now diagram for selection of studies
40		
41	30	Figure 2: Metaanalyses of outcomes disease specific hospitalisations and technical failure
42	30	Figure 2: Metaanalyses of outcomes disease specific hospitalisations and technical failure
43		
44	31	
45	• -	
46	32	
47 48	52	
40 49		
5 0		
51		
52		
53		
54		
55		
56		
57		
58		
59		
60		

BMJ Open



	RPN	1	Standard Care			Risk Ratio		Risk Ratio				
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% Cl		M-H, Random, 95% Cl				
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: Tau ² =	= 0.01; Chi	i ² = 1.04	4, df = 1 (P	= 0.31);	l² = 4%							
Test for overall effect							0.01	0.1 1 10 100				
restion overall ellect	:Z=1.35((P = 0.1	8)					Favours RPM Favours Standard Care				
	:2=1.35((P = 0.1	8)					Favours RPM Favours Standard Care				
	: Z = 1.35 ((P = 0.1	8)					Favours RPM Favours Standard Care				
		(P = 0.1	8)					Favours RPM Favours Standard Care				
	failure			Care		Risk Ratio						
		1	Standard		Weight	Risk Ratio M-H, Random, 95% Cl		Favours RPM Favours Standard Care Risk Ratio M-H, Random, 95% Cl				
b) Technical f	failure RPN	1	Standard		Weight 0.3%			Risk Ratio				
b) Technical f	failure RPN Events	I Total	Standard Events	Total	-	M-H, Random, 95% Cl		Risk Ratio				
b) Technical f <u>Study or Subgroup</u> Milan 2020	failure RPN Events	I Total 35	Standard Events 1	Total 38	0.3%	M-H, Random, 95% Cl 0.36 [0.02, 8.58]		Risk Ratio				
(b) Technical f <u>Study or Subgroup</u> Milan 2020 Weinhandl 2018	Failure RPN Events 0 126	1 <u>Total</u> 35 606	Standard Events 1 488	Total 38 1817	0.3% 95.7%	M-H, Random, 95% Cl 0.36 [0.02, 8.58] 0.77 [0.65, 0.92]		Risk Ratio				
b) Technical f <u>study or Subgroup</u> Milan 2020 Weinhandl 2018	Failure RPN Events 0 126	1 <u>Total</u> 35 606	Standard Events 1 488	Total 38 1817 295	0.3% 95.7%	M-H, Random, 95% Cl 0.36 [0.02, 8.58] 0.77 [0.65, 0.92]		Risk Ratio				
b) Technical f <u>Study or Subgroup</u> Milan 2020 Weinhandl 2018 Sanabria 2019	Failure RPN Events 0 126	1 Total 35 606 65	Standard Events 1 488	Total 38 1817 295	0.3% 95.7% 4.1%	M-H, Random, 95% Cl 0.36 (0.02, 8.58) 0.77 (0.65, 0.92) 0.97 (0.42, 2.25)		Risk Ratio				
(b) Technical f <u>Study or Subgroup</u> Milan 2020	failure RPN Events	I Total 35	Standard Events 1	Total 38	0.3%	M-H, Random, 95% Cl 0.36 [0.02, 8.58]		Risk Ratio				
(b) Technical f <u>Study or Subgroup</u> Milan 2020 Weinhandl 2018 Sanabria 2019	Failure RPN Events 0 126	1 Total 35 606 65	Standard Events 1 488	Total 38 1817 295	0.3% 95.7% 4.1%	M-H, Random, 95% Cl 0.36 (0.02, 8.58) 0.77 (0.65, 0.92) 0.97 (0.42, 2.25)		Risk Ratio				

Chr = 0.004)

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

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/	356402

- 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.
- 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

16

17

18

19

20

21

22

23

1

2

3

4

5

6

7

8

9

10

11

12

13

14

(CAPD or APD or HHD).ti.

limit 17 to yr=2000-current

151629

699530

494

270

534

or/11-15

10 and 16

editorial.pt.

Database: OVID MEDLINE

Telenursing/

or/1-3 34165

5 and 6 19771

4 or 7 42042

self)).ti,ab,kf,bt.

or/8-1369186

18 not (19 or 20)

limit 21 to embase

Search interface: Advanced Search

Telemedicine/ 29751

232

or patient* or support*)).ti,ab,kf,bt.

Remote Consultation/ 5273

exp Telecommunications/

(care or healthcare).hw.

remove duplicates from 22

1

(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

3524

516

266

108428

1324775

mnurse or mcare or mnursing or mconsult* or mnurs*).ti,ab,kf,bt.

8231

(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

(ecare or econsult* or ehealth or emedicine* or enurs* or mcare or mconsult* or mhealth or

10618

13372

((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*

1020

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

health* or home* or manag* or medicine* or monitor* or nursing or patient* or

(remote adj2 (care* or checkup* or check up* or consult* or followup* or follow up* or

2	
4 5	
6 7	
8	
9 10	
11 12	
13	
14 15	
16 17	
18	
19 20 21	
22	
23 24	
25	
26 27	
28 29	
30 31	
32	
33 34	
35 36	
37	
38 39	
40 41	
42 43	
44	
45 46	
47 48	
49	
50 51 52	
52 53	
54 55	
56	
57 58	
59 60	
50	

3
4
5
6
7
8
9
10
11
12
13
14
15
16 17
17
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38 39
39 40
40 41
41
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59 60
60

15

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							

Renal Dialysis/ 94819

Database: Cochrane Database of Systematic Review & CENTRAL

Search interface: Advanced Search > Search Manager

- #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

iez oni

#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

- #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, inCochrane Reviews 0

RY.CZ ONY

#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

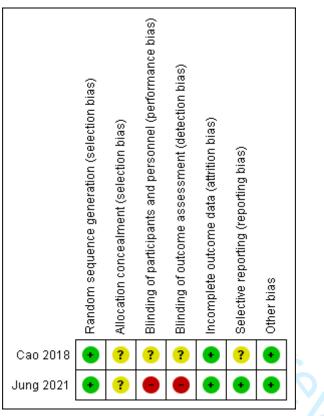
Excluded studies read in full text (n=17)	Justifications for exclusion
Dey V, Jones A, Spalding EM. Telehealth: Acceptability, clinical interventions and quality of life in peritoneal dialysis. SAGE Open Med. 2016;4:2050312116670188.	No control group
El Shamy O, Tran H, Sharma S, Ronco C, Narayanan M, 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 outcome
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	No pre-intervention
patient management in peritoneal dialysis on haemodynamic and volume control.	assessment
Nephrology. 2020;25(11):856-64.	

for peer teriew only

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

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

Variables adjusted for in the analyses

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."

of th . employs

PRISMA 2020 Checklist

Section and Topic	ltem #	Checklist item	Location where item is reported
TITLE	1		
Title	1	Identify the report as a systematic review.	p. 1
ABSTRACT	1		
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.	р. 3-4
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	p. 4
METHODS	1		
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.	р. 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). For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml	NA

BMJ Open

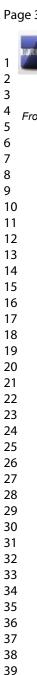
BMJ Open



PRISMA 2020 Checklist

Section and Topic	ltem #	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	·		
-	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
syntheses 20 20	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	р. 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 INFORM	ATION		
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. For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml	Available or request

Page 35 of 34



45 46 47

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 For more information, visit: <u>http://www.prisma-statement.org/</u>

For beer review only

BMJ Open

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml