Development and evaluation of an eHealth self-management intervention for chronic kidney disease patients in China: protocol for a mixed-method hybrid type 2 trial

Hongxia Shen
Department of Public Health and Primary Care, Leiden University Medical Center, Leiden, Netherlands; Department of Nursing, The First Affiliated Hospital of Zhengzhou University, Zhengzhou University, Zhengzhou, China
Rianne van der Kleij
Department of Public Health and Primary Care, Leiden University Medical Center, Leiden, Netherlands; Department of Obstetrics and Gynaecology, Erasmus Medical Center, Rotterdam, Netherlands
Paul JM van der Boog
Department of Nephrology, Leiden University Medical Center, Leiden, Netherlands
Xiaoyue Song
Department of Public Health and Primary Care, Leiden University Medical Center, Leiden, Netherlands; School of Nursing and Health, Zhengzhou University, Zhengzhou, China
Wenjiao Wang
Department of Nursing, The First Affiliated Hospital of Zhengzhou University, Zhengzhou University, Zhengzhou, China
Tongtong Zhang
Department of Nursing, The First Affiliated Hospital of Zhengzhou University, Zhengzhou University, Zhengzhou, China
Zhengyan Li
Department of Nephrology, The First Affiliated Hospital of Zhengzhou University, Zhengzhou University, Zhengzhou, China
Xiaoping Lou (louxiaoping6@hotmail.com)
Niels Chavannes
Department of Public Health and Primary Care, Leiden University Medical Center, Leiden, Netherlands

Study protocol

Keywords: eHealth, Self-management, Chronic kidney disease, China, Hybrid design, Implementation

Posted Date: February 6th, 2020

DOI: https://doi.org/10.21203/rs.2.22736/v1

Abstract

Background

Chronic kidney disease (CKD) is a significant public health concern. In CKD patients, interventions that support disease self-management have shown to improve health status and quality of life. At the moment, the use of electronic health (eHealth) technology in self-management interventions is becoming more and more popular. Evidence suggests that eHealth-based self-management interventions can improve CKD patients' health-related outcomes. However, knowledge of the implementation and effectiveness of such interventions in general, and in China in specific, is still limited. This study protocol aims to develop and tailor the evidence-based Dutch 'Medical Dashboard' eHealth self-management intervention for patients suffering from CKD in China and evaluate its implementation process and effectiveness.

Methods

To develop and tailor a Medical Dashboard intervention for the Chinese context, we will use an Intervention Mapping (IM) approach. A literature review and mixed-method study will first be conducted to examine the needs, beliefs, perceptions of CKD patients and care providers towards disease (self-management) and eHealth (self-management) interventions (IM step 1). Based on the results of step 1, we will specify outcomes, performance objectives, and determinants, select theory-based methods and practical strategies. Knowledge obtained from prior results and insights from stakeholders will be combined to tailor the core interventions components of the 'Medical Dashboard' self-management intervention to the Chinese context (IM step 2-5). Then, an intervention and implementation plan will be developed. Finally, a 9-month hybrid type 2 trial design (N=60) will be employed to investigate the effectiveness of the intervention using a pilot randomized controlled trial with two parallel arms, and the implementation integrity (fidelity) and determinants of implementation (IM step 6).

Discussion

Our study will result in the delivery of a culturally tailored, standardized eHealth self-management intervention for CKD patients in China, which has the potential to optimize patients' self-management skills and improve health status and quality of life. Moreover, it will inform future research on the tailoring and translation of evidence-based eHealth self-management interventions in various contexts.

Contributions To The Literature

- Knowledge of the use of eHealth-based self-management interventions in China is still lacking. Our study will result in the delivery of a culturally tailored, standardized eHealth self-management intervention for CKD patients in China, which has the potential to optimize patients' self-management skills and improve health status and quality of life.
- This study will inform future research on the tailoring and translation of evidence-based eHealth self-management interventions in various contexts.
- This study can serve as proof of concept for the use of Intervention Mapping and a hybrid type 2 trial design to evaluate the implementation and effectiveness of eHealth self-management interventions.

Background

Prevalence and burden of chronic kidney disease

Chronic kidney disease (CKD) poses a significant threat to public health [1-3]. Globally, more than 70 million individuals are affected by CKD [4]. In China, an estimated 10.8% (119.5 million) of adults suffer from CKD [5]. CKD is defined as abnormalities of kidney structure or function, present for more than three months, with severe implications for health [6]. CKD is chronic and follows five stages of functional decline based on the estimated glomerular filtration rate (eGFR) [6]. Numerous detrimental health outcomes are linked to CKD [7]. Also, CKD increases mortality risk and hospitalization rates, and negatively impacts the quality of life [7-9]. Additionally, health-related and societal costs of CKD are considerable and constitute a substantial economic burden [10-12].

Self-Management and eHealth interventions for CKD

Interventions that support disease self-management (further referred to as 'self-management interventions') can have a significant impact on the health and quality of life of patients suffering from chronic conditions in general [13], and CKD patients in specific [14-16]. Self-management support is often defined as "*[……] improving chronic illness outcomes consisting of patient-centered attributes (involving*

patients as partners; [……]), provider attributes (possessing adequate knowledge, skills, attitudes in providing care), and organizational attributes (putting an organized system of care in place, having multidisciplinary team approach, using tangible and social support)" [17].

In the last decade, the use of electronic health (eHealth) technology in self-management interventions has become more and more popular. EHealth technology can facilitate remote patient-provider communication and exchange of (health) data and has the potential to increase healthcare accessibility and efficiency [18]. EHealth-based self-management interventions have been shown to improve health-related outcomes, such as blood pressure (BP) control and medication adherence [19, 20], and found to be feasible and acceptable for CKD patients and care professionals [19]. Hence, the use of eHealth self-management interventions for CKD patients has become increasingly popular. Knowledge of the implementation and effectivity of such interventions in China and other developing countries is, however, still lacking [21].

Medical dashboard

Researchers from the Leiden University Medical Center (LUMC) developed 'Medical Dashboard', an eHealth intervention to help support and involve CKD patients in their disease self-management. This platform is used in the Outpatient Clinic Kidney Transplant of the LUMC since February 2016. Via Medical Dashboard, patients can monitor their health from home (e.g., BP, weight), and can exchange health data with their care professionals. Moreover, during consultations in the outpatient clinic, care professionals and patients can also use Medical Dashboard to set personal health goals such as BP control and nutrition management (e.g., energy). In a randomized controlled trial (RCT), the use of "Medical Dashboard" has been shown to improve patients' adherence to sodium restriction intake and BP control [14]. Also, patients reported being highly satisfied with the online disease management system used in the platform [22]. All core intervention components of 'Medical dashboard' and their supporting evidence base are presented in Additional file 1.

Opportunities for eHealth interventions in China

There is significant support and momentum for the implementation of eHealth based self-management interventions in China. China had 731 million internet users (penetration rate 53%) and 1.3 billion mobile phone users (penetration rate of 90%) in 2016, and this number is still growing [23-26]. Furthermore, policymakers and care experts in China have recently launched the national health strategy 'Healthy China 2030'. This strategy describes eHealth technology as an essential pillar to improve disease self-management as well as the accessibility and cost-effectiveness of care in rural areas. Moreover, it views eHealth technology as the preferred medium to reach one of the main goals: '*enable everyone to be involved in health, share health, and be responsible for health*' [27, 28]. Also, the prevalence rate and severe adverse health outcomes of CKD have put it high on the public health agenda in China.

Study aims and research methods

In conclusion, eHealth self-management interventions have the potential to fundamentally improve the quality of life and health outcomes of patients suffering from CKD in China. Therefore, we aim to tailor the evidence-based Dutch intervention 'Medical Dashboard' to the Chinese context and evaluate its implementation process and effectiveness. To this end, we will use an intervention mapping (IM) approach comprising six steps: (1) a needs assessment, (2) preparation of change objectives matrices, (3) selection of theory-informed intervention methods and strategies, (4) development of a tailored 'Medical Dashboard' based intervention plan, (5) development of an implementation - and (6) evaluation plan.

In correspondence with the steps of IM [29], we aim to:

- ***Phase 1: Needs, beliefs and perceptions (Step 1 of IM)***

Examine the needs, beliefs, perceptions of CKD patients and care providers towards disease self-management and eHealth interventions;

- ***Phase 2: Intervention and implementation development & planning (Step 2-5 of IM)***

Tailor the core components of the 'Medical Dashboard' self-management intervention for CKD patients to the Chinese context;

- ***Phase 3: Intervention evaluation (Step 6 of IM)***

Employ a hybrid type 2 trial to:

- Evaluate the effectiveness of the intervention using a pilot RCT with two parallel arms;
- Evaluate implementation integrity (fidelity) and determinants of implementation.

Methods

The study has been approved by the Ethics Committee of the First Affiliated Hospital of Zhengzhou University (reference number 2019-KY-52).

Study setting

All study phases are (to be) conducted in the First Affiliated Hospital of Zhengzhou University in the Henan province in China. Henan is one of the biggest provinces of China, and it accounts for 9% of the rural Chinese population. An estimated 16.4% (12 million) of adults suffer from CKD in rural areas in Henan [30]. The Department of Nephrology of the First Affiliated Hospital of Zhengzhou University has five sub-units with approximately 276 beds; more than 60,000 CKD patients visit the Outpatient Clinic of Department of Nephrology each year.

Overview Of Study Design

An overview of the study flow following the six steps of IM is displayed in Table 1.

Phase 1

Aim

Preliminary evidence suggests that both patients' and care providers' needs, beliefs (i.e., an idea or principle judged to be true) and perceptions (i.e., the organized cognitive representations that individuals have about a subject) of disease (self-management) can influence their display of health behaviors and uptake of (self-management) interventions [31-34]. Therefore, following step 1 of IM, we will first conduct a needs assessment and examine the needs, beliefs, perceptions of CKD patients and care providers towards disease (self-management) and the use of eHealth interventions.

Design

Intervention monitoring group

First, a multi-disciplinary intervention monitoring group including both Dutch and Chinese experts will be established. This group will consist of five members: two researchers, one nephrologist, and two experts in chronic disease care. This expert group has ample experience with CKD care and the implementation of (eHealth) self-management interventions. The intervention monitoring group will meet monthly throughout all IM steps to discuss progress and the execution of major deliverables such as the needs assessment (e.g. program goals), intervention development (e.g. intervention content, delivery strategies), and evaluation planning (e.g. inclusion, outcome choice, analysis).

Literature review

A scoping literature review will be conducted to identify relevant evidence on CKD patients' and care providers' needs toward disease management. The search strategy is already developed in collaboration with a certified librarian (see Additional file 2).

Mixed-method study

We will conduct a mixed-method study to gain insight into the needs, beliefs, perceptions of CKD patients, and care providers towards disease (self-management) and the use of eHealth (self-management) interventions. This study will include face to face interviews, focus group discussions, observations, and survey research. Methods will build on an adapted version of the theoretical framework on beliefs and perceptions towards chronic lung disease used in FRESH AIR (Brakema et al., submitted). This adapted framework combines the Health Belief Model [35] and the Theory of Planned Behavior [36] and focuses on individuals' beliefs and perceptions as well as the sociocultural context in which the individual resides (see Fig. 1).

We will explore CKD patients' and care providers': (1) beliefs and perceptions towards CKD and disease self-management, (2) needs towards CKD self-management, and (3) needs, beliefs, perceptions towards the use of eHealth interventions in disease self-management. The survey will consist of three validated measures: (1) 'The Brief Illness Perception Questionnaire' (BIPQ) [37], (2) 'Chronic Kidney Disease Self-management instrument' (CKD-SM) [38], and (3) 'Chinese eHealth Literacy Scale' (C-eHEALS) [39]. For the qualitative part, following principles of "purposive and convenience sampling" [40], the inclusion of participants will be based on opportunity, willingness to participate, and creation of diversity (e.g., age, gender) in our sample. We will also use snowball sampling [41], in which participants will be asked if they know any other individuals who could participate in the study. As there are no defined rules for calculating sample size in

qualitative studies, data collection will continue until no new themes are identified from the data. For the quantitative part, as a rule of thumb, the sample size should be 5-10 times the number of items in the questionnaires [42]. Therefore, our aim is to recruit at least 230 patients. Eligibility criteria are detailed in Table 2.

The methods to be used differ between care providers and patients following the relevant group- and context characteristics (see details in Table 3). For instance, focus groups cannot be held with care providers as they (1) cannot be of duty all at the same time, and (2) work with a tight schedule, and finding a time slot that suits all care providers is very difficult. Moreover, we feel that CKD patients would be comfortable discussing their needs towards eHealth self-management interventions in a focus group setting, but not their needs and beliefs towards their disease in general. Hence, we will plan to discuss this topic in face-to-face interviews. More details on the methods use and relevant research materials used are presented in Additional file 3.

Phase 2

Aim

Following step 2-5 of IM, we aim to tailor the core interventions components of the 'Medical Dashboard' self-management intervention to the Chinese context following the results of the needs assessment performed in Phase I.

Design

All the IM concepts used in the steps below are operationalized and further detailed in Table 4 and Figure 2.

Step 2: Preparing matrices of change objectives

First, we will formulate *program outcomes* [29] on all levels as defined in the socio-ecological model [43]. This model will help us to understand the complex interplay between individual, interpersonal, community, and societal outcomes. Second, we will subdivide program outcomes into *performance objectives* [29]. Third, as each performance objective can only be reached if matching behavioral determinants are addressed, we will break each performance objective down into *key underlying determinants* [29]. We will use the Theoretical Domains Framework (TDF) to support the identification and selection of relevant determinants of behavior [44]. Two researchers will independently identify the determinants, and discrepancies will be resolved through discussions. Also, the intervention monitoring group will evaluate the determinants selected based on relevance and changeability, using the four possible consensus-based recommendation levels proposed by Michie et al.[44]. Finally, based on the determinants identified, we will specify *change objectives* [29].

Step 3: Selecting theory-informed intervention methods and practical strategies

We will first review the literature and identify relevant *theoretical methods* that can potentially induce a change in the determinants identified in step 2 [29]. Second, we will match the selected methods with specific change objectives. Third, the selected methods will be translated into practical strategies to target each determinant. Finally, the intervention monitoring group will rank the practical strategies per method [44] and ensure that these methods and practical strategies match with the program goals.

Step 4: Develop a tailored 'Medical Dashboard' based intervention (plan)

First, we will review the results of the needs assessment, the initial program's logic model of change, and discuss intervention objectives, theoretical methods, and practical strategies for each level (e.g., individual, organization) specified in step 1-3. Second, the intervention monitoring group will have a meeting to amend, and if necessary, reconstruct the core components of Medical Dashboard to tailor the intervention. Also, the intervention monitoring group will create a plan for developing and testing the new version of the Medical Dashboard. Third, we will recruit five care providers and five patients to discuss the acceptability and feasibility of the intervention plan (member-check). To this end, we will use the 'think aloud' method [45], in which care providers and patients can speak aloud any words in their mind as they read through parts of the intervention plan. The think-aloud research method has been demonstrated to provide valid data on participant thinking and was successfully used in other intervention development studies [46, 47]. Based on the results obtained, further modifications will be made, resulting in a pre-tested version of the intervention plan ready for implementation in practice. The description of the intervention plan will follow the Template for Intervention Description and Replication [48].

Step 5: Develop an adoption and implementation plan

The goal of this step is to write a detailed adoption and implementation plan, containing relevant strategies to optimize intervention delivery and implementation (fidelity). First, we will discuss results obtained from step 1-4 and inventory local resources (e.g., connections

with primary care clinics) that may facilitate intervention implementation. Second, based on all results obtained from previous steps and our previous systematic review [21], the intervention monitoring group will have a meeting to pragmatically identify potential adopters and implementers. Also, this group will demonstrate program use outcomes, performance objectives and related determinants of implementation. Third, the intervention monitoring group will design the implementation plan following Figure 3 [49] based on Expert Recommendations for Implementing Change list of strategies [50]. Then, we will use the 'think aloud' method to obtain feedback from CKD patients and care providers on the implementation plan. Finally, the adoption and implementation plan will be finalized with further modifications.

Phase 3

Aim

Following step 6 of IM, we will establish an intervention evaluation plan. Our evaluation will follow a hybrid type 2 trial design, comprising of (1) a pilot RCT with two parallel arms to study effectiveness, and (2) a process evaluation to evaluate implementation integrity (fidelity) and determinants of implementation.

Design

This study will be a 9-month, two-arm, hybrid type 2 trial [51]. The trial design and corresponding study elements are detailed in Figure 4. The Standard Protocol Items: Recommendations for Interventional Trials 2013 Statement is used to report the pilot RCT protocol [52] (see Additional file 4), and the Standards for Reporting Implementation Studies will be followed for reporting the implementation study [53].

Intervention

CKD patients in the comparison group will receive usual care consisting of personalized in- and outpatient treatment based on symptoms experienced and disease severity, as outlined in the Kidney Disease Improving Global Outcomes [6]. CKD patients in the intervention group will receive the usual care plus the culturally tailored 'Medical Dashboard' based self-management intervention for nine months. Before the start of the intervention, CKD patients and care providers will receive a face-to-face training session on the use of Medical Dashboard. To avoid contamination, Medical Dashboard will only be made accessible for participants in the intervention group via a secure password-protected registration process.

Study population, recruitment & randomization

Effectiveness; Pilot RCT

CKD patients will be recruited from the First Affiliated Hospital of Zhengzhou University. Recruitment strategies, inclusion, and exclusion criteria are identical to those in phase 1 (see Table 2 and Additional file 3). In pilot studies, Sim and Lewis [54] recommend 55 or more patients in total. Thus, we aim to recruit 60 patients in total for randomization in our study. We summarize the participant flow through the study in Figure 5. The outcomes for effectiveness are presented in Table 5.

A biostatistician blind to the study conditions will complete the random allocation sequence using a computer random number generator, allocating equal numbers of patients in the intervention (group 1) and comparison group (group 2). The care providers delivering the intervention cannot be blind to the intervention, but will not collect data or analyze outcomes. Research assistants blind to group membership will perform all face to face assessments and will not be involved in intervention delivery. Those conducting statistical analyses will be blind to group allocation until the evaluation is completed.

Implementation study

CKD patients, as well as care providers in the intervention group, will participate in the process evaluation to evaluate implementation integrity (fidelity) and determinants of implementation.

Implementation outcomes on the patient level as well as care provider level will be evaluated, see the further paragraph about details of outcomes of implementation. All CKD patients in the intervention group will be invited to complete the survey. Also, following principles of "purposive and convenience sampling", CKD patients and care providers in the intervention group will be invited and interviewed either face to face or by telephone for the process evaluation. A research assistant who will not involve in the pilot RCT study will collect data within process evaluation.

Outcomes measures & data collection

Outcomes for the pilot RCT evaluating the effectiveness

We plan to evaluate:

- patients' physical outcomes including biomedical measures,
- patients' lifestyle and psychosocial functioning including self-efficacy, perceptions about CKD, quality of life, anxiety and depression status,
- hospital admission, health care utilization, and cost-benefit

A trained research assistant will conduct data collection, and the intervention monitoring group will supervise the data collection process. We will invite participants in both the intervention and comparison group to visit the Department of Nephrology at the First Affiliated Hospital of Zhengzhou University for data collection at baseline (T0), three months (T1), six months (T2) and nine months (T3) post-randomization. At baseline, we will collect demographic data, including age, race, income, education, marital status, work type of participants. To avoid dropping out of participants, if participants cannot come to the hospital, data will then be collected via telephone interview. Table 5 provides details on the proposed outcome measures and timing of the measures. The operationalization of outcomes and descriptions of the measurement tools used are detailed in Additional file 5.

Outcomes for implementation integrity (fidelity), and determinants of implementation

The process evaluation will be based on the RE-AIM framework [55]. The RE-AIM model is used to comprehensively measure the public health impact of research conducted in real-world settings [56]. Four dimensions (with the *Effectiveness* domain being applicable above)—Reach *(refers to the proportion of CKD patients reached by our program)*, Adoption *(refers to the proportion of participants who use our intervention)*, Implementation *(refer to completion as well as fidelity to the protocol)*, and Maintenance will be used to evaluate the implementation only in the intervention group. We will collect the implementation outcome measurements throughout the 9-month trial. The outcome measures for each dimension of the RE-AIM model are as described in Table 6.

We will use the Measurement Instrument for Determinants of Innovations questionnaire [57, 58] to evaluate the determinants of implementation. Also, individual interviews with stakeholders (e.g. patients, care providers) will be conducted to learn more about the usability and feasibility of Medical Dashboard, its potential for wide-scale implementation, and barriers and facilitators to implementation. We will categorize the determinants identified from this mixed-method study according to Fleuren Framework [59].

Data Analysis

Qualitative data analysis

A Framework Method [69] will be used to guide our qualitative analysis. We will structure the qualitative data in a matrix output formed by rows (cases), columns (codes), and 'cells' (summarized data). We will follow the consolidated criteria for reporting qualitative research to ensure quality and validity.

Stage A: Transcribing: All audio-taped interviews will be anonymized and transcribed verbatim in Chinese. Long pauses and interruptions (relevant to the study subject) will be noted within the text. Additionally, all participants' names will be replaced by an ID number. Any names mentioned during the interview will not be transcribed. One researcher will perform transcription, and another will check them to ensure content accuracy.

Stage B: Familiarization: Two researchers will independently read all transcriptions and make contextual/reflective notes to become familiar with the whole data set.

Stage C: development of an analytical framework& coding: Atlas.ti for Windows version 7.5.18 (Scientific Software development, Berlin) will be used to analyze our data. Our study includes four qualitative research parts. These are research into the (1) needs, beliefs, perceptions toward CKD and self-management (phase 1); (2) needs, beliefs, perceptions toward eHealth self-management interventions in CKD (phase 1); (3) the acceptability and usability of intervention components (phase 3); (4) determinants of implementation of eHealth self-management interventions (phase 3). Therefore, based on prior literature in which specific theoretical frameworks were used for similar research questions [70-74], we will develop four distinct initial coding trees. For the first and second research questions, we will develop two coding trees based on the adapted version of the theoretical framework of Brakema et al., (submitted) and the TDF [75]. The Technology Acceptance Model [76] will be used to develop the coding tree for evaluating the acceptability and usability of intervention components. Also, the Fleuren framework [59] will be used to develop the coding tree for determinants of implementation of eHealth self-

management interventions. The second researcher and third researcher will check the coding tree developed and make amendments if necessary. One researcher will then independently code two or three transcripts using the coding tree, and add new codes if the textual abstracts identified do not fit with the existing set of codes. Then, this researcher will meet with the second researcher and discuss the newly added codes. New codes will be added into the coding tree, and if needed, related codes will be grouped into categories. Thus, the process will be repeated until no new codes arise.

The final coding tree will be checked and approved by the second researcher and the third researcher. This coding tree will include codes and categories; all codes and categories will be operationalized, and relevant examples will be provided.

The finalized coding tree will then be applied to each transcript. One researcher will go through each transcript, highlight the meaningful textual abstracts, and assign the appropriate code from the final coding tree. Then, all codes assigned will be verified by the second researcher. All coding differences will be discussed until consensus is reached.

Stage D: Charting data into the framework matrix: Data will be charted into matrices per research question identified by two researchers using Microsoft Excel 2010. The matrix will comprise of one row per participant and one column per code. Interesting or illustrative quotations will be added to the matrices.

Stage E: Interpreting the data: Overarching themes will be generated from codes derived from the data set by reviewing the matrix and making connections within and between participants and codes. Relations, connections, and causality will be further explored and interpreted, and conclusions will be drawn.

As for data derived from observations, all checklists will be digitalized and transported to Microsoft Excel 2010. Also, all written filed notes will be digitalized and will be taken into account to triangulate data collected from other methods. For instance, observation data obtained in phase 3 will support the analysis of implementation integrity (fidelity).

Quantitative data analysis

All quantitative analyses will be performed using SPSS version 23 (IBM, Armonk, NY, USA). We will enter the quantitative data into Microsoft Excel 2010 and calculate descriptive statistics such as the mean, standard deviation, median, and range of linear variables, and frequencies and percentages of categorical variables.

To gain insight into the needs, beliefs, perceptions of CKD patients towards disease (self-management) and the use of eHealth interventions in phase 1, we will use the descriptive statistics to describe CKD patients' demographic characteristics, BIPQ scores, CKD-SM score, and C-eHEALS scores. Also, we will conduct secondary analysis using (1) independent *t*-tests for normally distributed continuous variables, (2) Mann–Whitney U-tests for nonnormally distributed variables and (3) Chi-squared or Fisher's exact tests for categorical variables to compare the difference between certain types of different groups of CKD patients (e.g., age, gender, disease stage) and BIPQ scores, CKD SM score and C-eHEALS scores. *P*-values <0.05 and odds ratios with a 95% confidence interval excluding one will be considered statistically significant.

In phase 3, one of the primary hypothesis is that the intervention group, when compared to the comparison group, will demonstrate (statistically) significant improvement in self-management behavior at 3, 6 and 9 months post-randomization. Secondary hypotheses are that the intervention group when compared to patients in the comparison group, will demonstrate (statistically) significant improvement in biomedical status, self-efficacy, illness perception, mental health, quality of life, hospital admission, healthcare utilization and cost-benefit analysis at the timing of measurement. All primary statistical analyses will be conducted using intent-to-treat methods. The primary goal of statistical analyses is to examine and compare trends over time in the primary outcome. We will replicate this analytic approach for other secondary outcomes; secondary analyses will examine trends over time for biomedical status, self-efficacy, illness perception, mental health, quality of life, hospital admission, healthcare utilization, and cost-benefit analysis. We will use longitudinal, mixed-model analyses to test the hypotheses. Exploratory analyses will assess the impact of the intervention on primary and secondary outcomes for patients.

Mixed analysis of qualitative and quantitative data by triangulation

We will conduct a combined analysis by merging the quantitative and qualitative results after separate analyses have been carried out [77]. In phase 1, the quantitative results will triangulate the qualitative results of the perception of disease, self-management behavior, and eHealth literacy. To this end, we will develop a thematic matrix [78] that includes participants' characteristics and data derived from surveys and emerging themes from our qualitative results to summarize CKD patients' illness perception, self-management behavior, and eHealth literacy. In phase 3, we will use the results collected from the qualitative interviews to help interpret the quantitative results from

the pilot trial. Qualitative results will, therefore, be used to expand upon the results of this trial to understand the implementation process as experienced by participants. For instance, the questionnaire of determinants of implementation will be matched with the qualitative research on determinants of implementation.

Discussion

Some research has shown that eHealth based self-management interventions in CKD can help to improve health-related outcomes. However, evidence on the effectiveness of CKD eHealth based self-management interventions is still inconclusive [21]. Thus, our study will gain insights into the development of theoretically based, and target population tailored implementation of eHealth based self-management interventions to improve CKD care. Our study will add knowledge on the implementation research of eHealth self-management interventions in CKD care, with fitting with the needs and priorities expressed by health care professionals and patients. Also, this study will add evidence of the effectiveness of eHealth based self-management interventions on CKD health outcomes.

There are some strengths to our research. First, we will use an innovative hybrid design to concurrently study the effectiveness and implementation of the tailored 'Medical Dashboard' self-management intervention in CKD care. The hybrid designs can test the implementation process by looking inside the so-called "black box" to see what happens in the intervention implementation and how that could affect intervention outcomes [79, 80]. Therefore, hybrid designs can provide the potential to speed the translation of intervention findings into routine practice by optimizing the implementation process [51]. In addition, the triangulation of both quantitative and qualitative results allows researchers to understand the implementation process and intervention effectiveness from multiple perspectives, different types of causal pathways, and multiple types of outcome, thereby strengthening the validity of intervention effects [77, 79, 81]. Second, the robust theory will be used to guide the process of intervention development. The IM method ensures a theory-based approach from the recognition of a need or problem to the identification of a solution and intervention testing. To translate interventions into different contexts (e.g., health care system, population), it is essential to optimize the intervention fit with the needs and priorities expressed by the target population. IM was successfully applied in the development of self-management interventions for osteoarthritis and chronic low back pain [72], and children with CKD [82, 83]. Also, the RE-AIM framework as utilized in this study provides systematic guidance on how to evaluate the intervention effect on the process and outcome level. A major limitation of this study is that we only perform the study within one hospital in China. Hence, findings may not be immediately generalizable to other health system contexts in China where the access to eHealth technology is (more) limited. Also, the transferability of developed Medical Dashboard self-management intervention to routine clinical practice in primary care may be limited and needs further exploration.

In conclusion, our study will result in the delivery of a culturally tailored, standardized eHealth self-management intervention for CKD patients in China, which has the potential to optimize patients' self-management skills and improve health status and quality of life. Also, this study can serve as proof of concept for the use of IM and a hybrid type 2 trial design to evaluate the implementation and effectiveness of eHealth self-management interventions. Moreover, it will inform future research on the tailoring and translation of evidence-based eHealth self-management interventions in various contexts.

Abbreviations

CKD: chronic kidney disease; eGFR: estimated glomerular filtration rate; eHealth: electronic health; BP: blood pressure; LUMC: Leiden University Medical Center; RCT: randomized controlled trial; IM: Intervention Mapping; BIPQ: Brief Illness Perception Questionnaire; CKD-SM: Chronic Kidney Disease Self-management instrument; C-eHEALS: Chinese eHealth Literacy Scale; TDF: Theoretical Domains Framework; CKD-SE: Chronic Kidney Disease Self-efficacy; KDQOL-36: The Kidney Disease Quality of Life 36-item short-form survey; HADS: Hospital Anxiety and Depression Scale

Declarations

Ethics approval and consent to participate

The study has been approved by the Institutional Review Boards of the First Affiliated Hospital of Zhengzhou University, reference number (2019-KY-52).

Consent for publication

Not applicable.

Availability of data and materials

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Funding

This study is funded by the China Scholarship Council.

Authors' contributions

HS led the conception and design of this study and is the main contributor in writing this manuscript. RK, PB, XS, WW, TZ, ZL, XL and NC contributed to the conception and design of the study and editing of this manuscript. All authors read and approved the final manuscript.

Acknowledgements

Not applicable.

Authors' information

[1]Department of Public Health and Primary Care, Leiden University Medical Centre, Leiden, Netherlands. [2]Department of Nursing, The First Affiliated Hospital of Zhengzhou University, Zhengzhou University, Zhengzhou, China. [3]Department of Obstetrics and Gynaecology, Erasmus Medical Center, Rotterdam, Netherlands. [4]Department of Nephrology, Leiden University Medical Centre, Leiden, Netherlands. [5]School of Nursing and Health, Zhengzhou University, Zhengzhou, China. [6]Department of Nephrology, The First Affiliated Hospital of Zhengzhou University, Zhengzhou University, Zhengzhou, China.

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Additional File

Additional file 1: Core intervention components of Medical dashboard and evidence base. (DOCX 23KB)

Additional file 2: Search strategy. (DOCX 25KB)

Additional file 3: Detailed methods and relevant materials of the mixed-method study. (DOCX 55KB)

Additional file 4: SPIRIT 2013 Statement: Defining standard protocol items for clinical trials. (DOCX 46KB)

Additional file 5: The operationalization of outcomes and descriptions of the measurement tools used in pilot RCT. (DOCX 22KB)

Tables

Table 1 Overview of study phases

Phase	IM steps	Activities
I	Step 1 Conduct needs assessment	• · Establish an intervention monitoring group • · Perform a systematic literature review • · Conduct a mixed-methods study into needs, beliefs & perceptions of chronic kidney disease patients and care providers toward chronic kidney disease (self-management) and the use of eHealth (self-management) interventions
II	Step 2 Identify outcomes, performance objectives, and determinants	• · Formulate program outcomes • · Specify performance objectives • · Specify determinants of change • · Map the performance objectives to the determinants and create a matrix of change objectives
	Step 3 Select theory-based methods and practical strategies	• · Review potentially relevant theoretical methods • · Match each determinant to the relevant method(s) • · Translate methods into practical strategies to target each determinant • · Monitoring group reaches consensus on methods and practical strategies
	Step 4 Develop a tailored 'Medical Dashboard' based intervention (plan)	• · Develop an intervention plan by tailoring the core components of the Dutch Medical Dashboard to the Chinese context • · Member check with the target population
	Step 5 Develop an adoption- and implementation plan	• · Identify potential adopters and implementers • · Specify program use outcomes and performance objectives • · Specify determinants of change • · Map the performance objectives to the determinants and create a matrix of change objectives • · Design a plan for adoption and implementation • · Member check with the target population
III	Step 6 Develop an intervention evaluation plan	• · Specify the two-arm, hybrid 2 trial design and: -Develop the effectiveness evaluation plan -Develop the implementation evaluation plan

Table 2 Eligibility criteria for chronic kidney disease patients and care providers

Category	Participant eligibility criteria
Inclusion criteria	• Patients: (1) aged over 18 years old; (2) diagnosis of chronic kidney disease; (3) Chinese speaking. • · Health care providers who work in the Department of Nephrology
Exclusion criteria	• · Individuals unable to participate due to physical or mental disabilities. • · Individuals unable to write or read.

Table 3 Field methods used for topics

Method	Care providers			Patients			Sampling
	Beliefs, perceptions, toward chronic kidney disease and self-management	Needs toward chronic kidney disease self-management	Needs, beliefs, perceptions toward eHealth self-management interventions	Beliefs, perceptions toward chronic kidney disease and self-management	Needs toward chronic kidney disease self-management	Needs, beliefs, perceptions toward eHealth self-management interventions	
Face to face interview	X	X	X	X	X	X	Purposive, Convenience
Focus group discussion						X	Purposive, Convenience
Observation	X	X	X	X	X	X	Purposive, Convenience
Survey				X	X	X	Randomly

Table 4 The concepts from Intervention Mapping step 2-5

Concept of Intervention Mapping	Definition in Bartholomew LK et al. [29]
Step 2	
Program outcome	Desired changes in the behavior and the environmental conditions
Performance objective	The required actions to accomplish the change in the behavioral and environmental outcomes
Determinant	Factors that are associated with the performance of behavior
Change objective	Specific goals stating what should change at the determinants for program outcomes in different level
Step 3	
Theoretical method	General technique or process for influencing changes in the determinants of behaviors and environmental conditions
Practical strategy	A specific technique for the practical use of theoretical methods in ways that fit with the target group and the context in which the intervention will be conducted
Step 4	
Intervention plan	A plan detailing intervention scope and sequence including delivery channels, themes, and list of the intervention materials needed
Step 5	
Implementation plan	A plan detailing how intervention adoption and implementation can be supported and maintained over time.

Table 5 Effectiveness outcomes and timing of measurements

Outcome	Outcome Indicators	Measures	Tools	Sources	Timing of measures			
					T0[a]	T1[b]	T2[c]	T3[d]
Primary Outcome								
	Self-management behavior	Survey	Chronic Kidney Disease Self-Management instrument [60, 61]	Patient	X	X	X	X
Secondary outcome								
	Biomedical status	Clinical records	Blood pressure, Bodyweight, Glomerular filtration rate, Serum albumin, Length, Serum calcium, Serum phosphate, Serum hemoglobin, Sodium and protein in 24h urine, albumin/creatinine ratio, Cholesterol, High-density lipoprotein, Low-density lipoprotein, Triglycerides, Hemoglobin A1C, Complications	Patient	X	X	X	X
	Self-efficacy	Survey	Chronic Kidney Disease Self-efficacy scale [61, 62]	Patient	X	X	X	X
	Illness perception	Survey	Brief Illness Perception Questionnaire [63, 64]	Patient	X			X
	Quality of life	Survey	The Kidney Disease Quality of Life 36-item short-form survey [65-67]	Patient	X			X
	Mental health	Survey	Hospital Anxiety and Depression Scale [68]	Patient	X	X		X
	Hospital admission	Survey	The time to first acute hospital admission with an exacerbation of CKD or death due to CKD within nine months after randomization	Patient				X
	Healthcare utilization	Survey	Number of hospitalizations and emergency room visits of patients, primary and secondary care visits	Patient		X		X
	Cost-benefit analysis	Records	All costs delivering the interventions (e.g., materials used in the interventions)	Program, intervention group		X		X
		Records	Medical cost (e.g., cost of treatment, hospitalization rates minored as monetary terms)	Patient		X		X

[a]At baseline

[b]Three months post-randomization

[c]Six months post-randomization

[d]Nine months post-randomization

Table 6 Implementation outcomes (intervention group only)

Outcome	Outcome Indicators	Measures	Tools	Sources
Reach				
	Number of patients (eligible, excluded, enrolled)	Records	The proportion of patients eligible to use our intervention program, excluded, invited, and enrolled	Patient
	Number of health care providers (eligible, excluded, enrolled)	Records	The proportion of care professionals eligible to use our intervention program, excluded, invited, and enrolled	Care provider
	Characteristics of participating patients	Records	Comparing participating patients to the target population on key clinical characteristics (e.g., disease stage)	Patient
	Qualitative assessment-reach	Interview	The barriers/facilitators to study participation	Patient
Adoption				
	Characteristics of participating care providers	Records	Comparing participating care providers to the target population on key characteristics (e.g., work type)	Care provider
	Use of program	Records	Frequency of materials or medical dashboard used	Patient, care provider
	Qualitative assessment-adoption	Interview	The appropriateness, comfort, relative advantage, and credibility of the intervention	Patient, care provider
Implementation				
	Implementation completion	Interview, observation	The implementation completion tasks will be made as a checklist, and the completion of the task and the length of time to finish will be checked.	Patient, care provider
	Acceptability and feasibility of the intervention	Interview	Experiences and perceptions of the intervention	Patients, care provider, research assistant
Maintenance				
	Follow up on the use of medical dashboard	Records	The use of intervention to assess long-term maintenance	Records
	Qualitative assessment-maintenance	Interview	Perceptions of the integration of intervention in health facilities	Patient, care provider

Figures

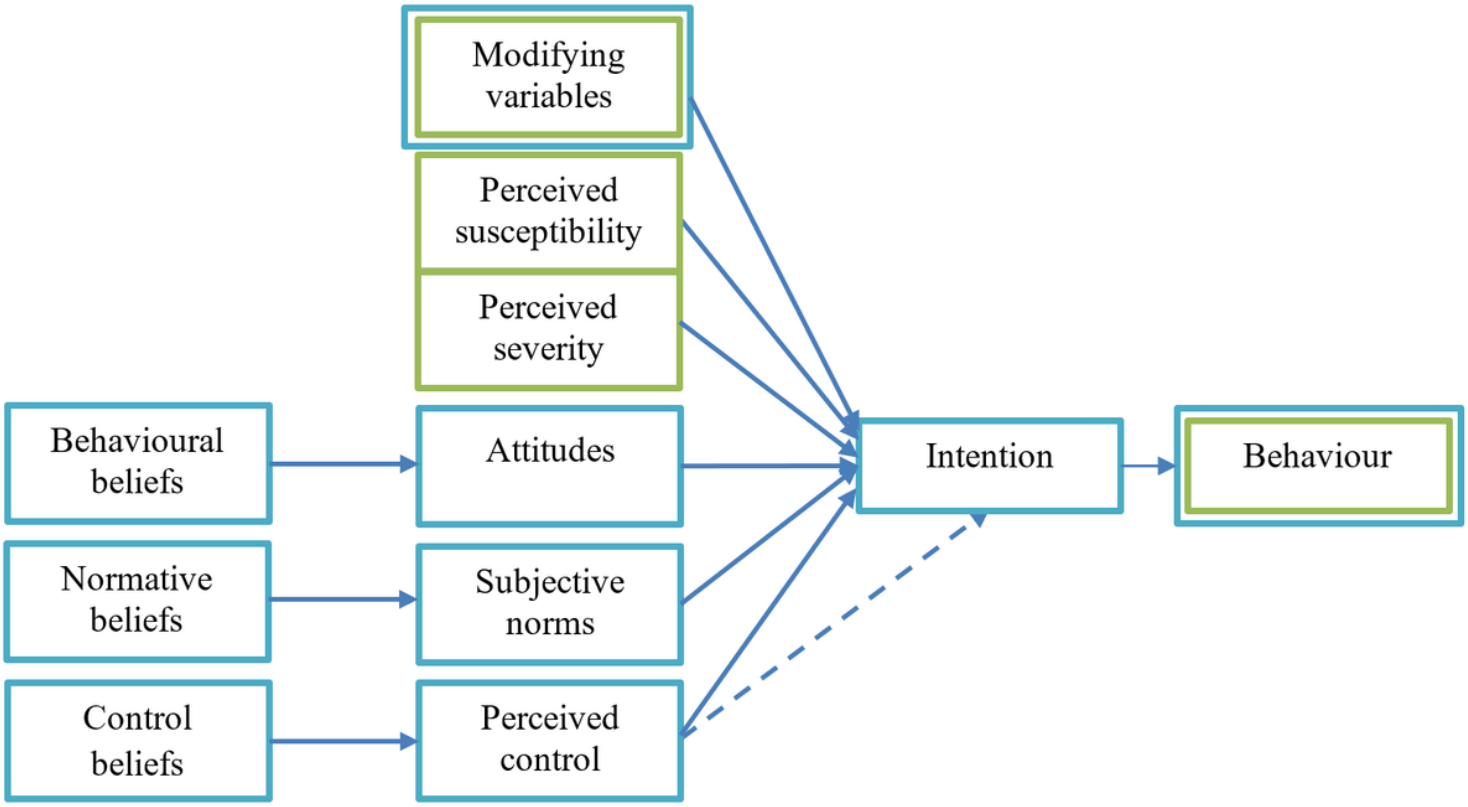

Figure 1

Adapted version of the theoretical framework of Brakema et al (submitted). A combination of concepts of the Health Beliefs Model (green) and the Theory of Planned Behavior (blue).

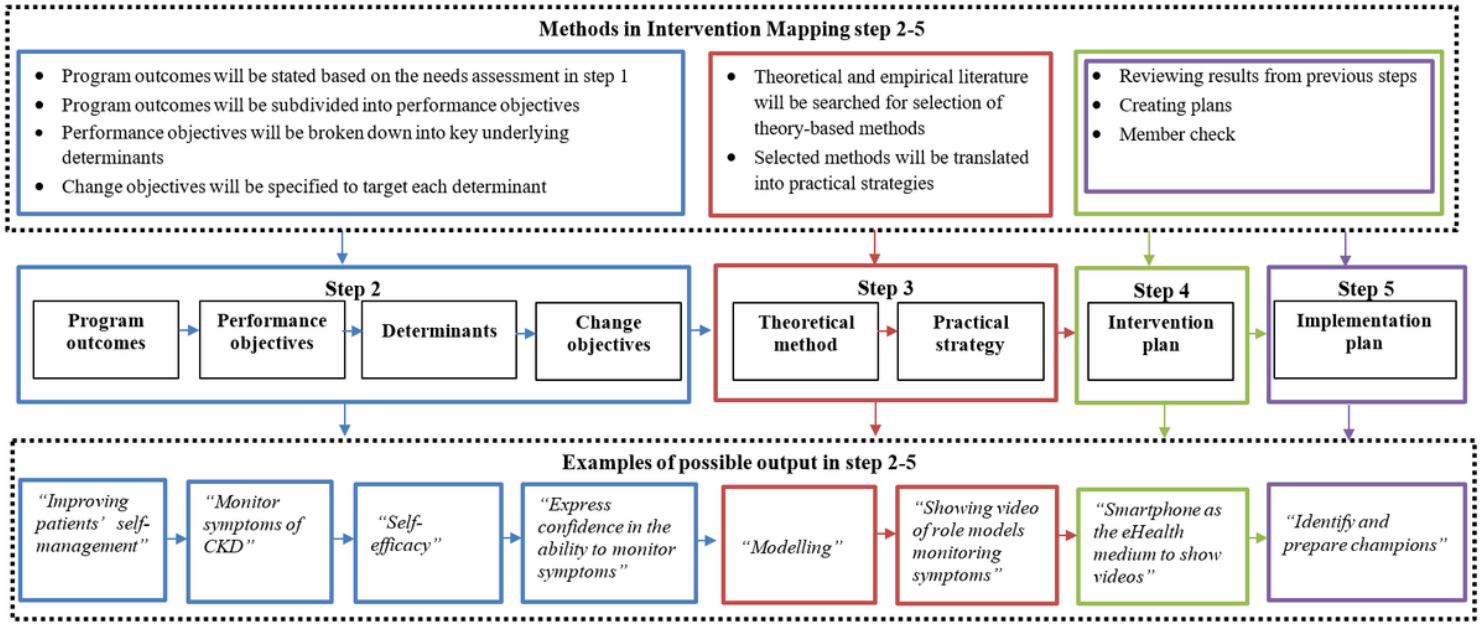

Figure 2

Methods and examples of the possible output of Intervention Mapping step 2-5. Step 2 (blue) , step 3(red), step 4(green), step 5(purple).

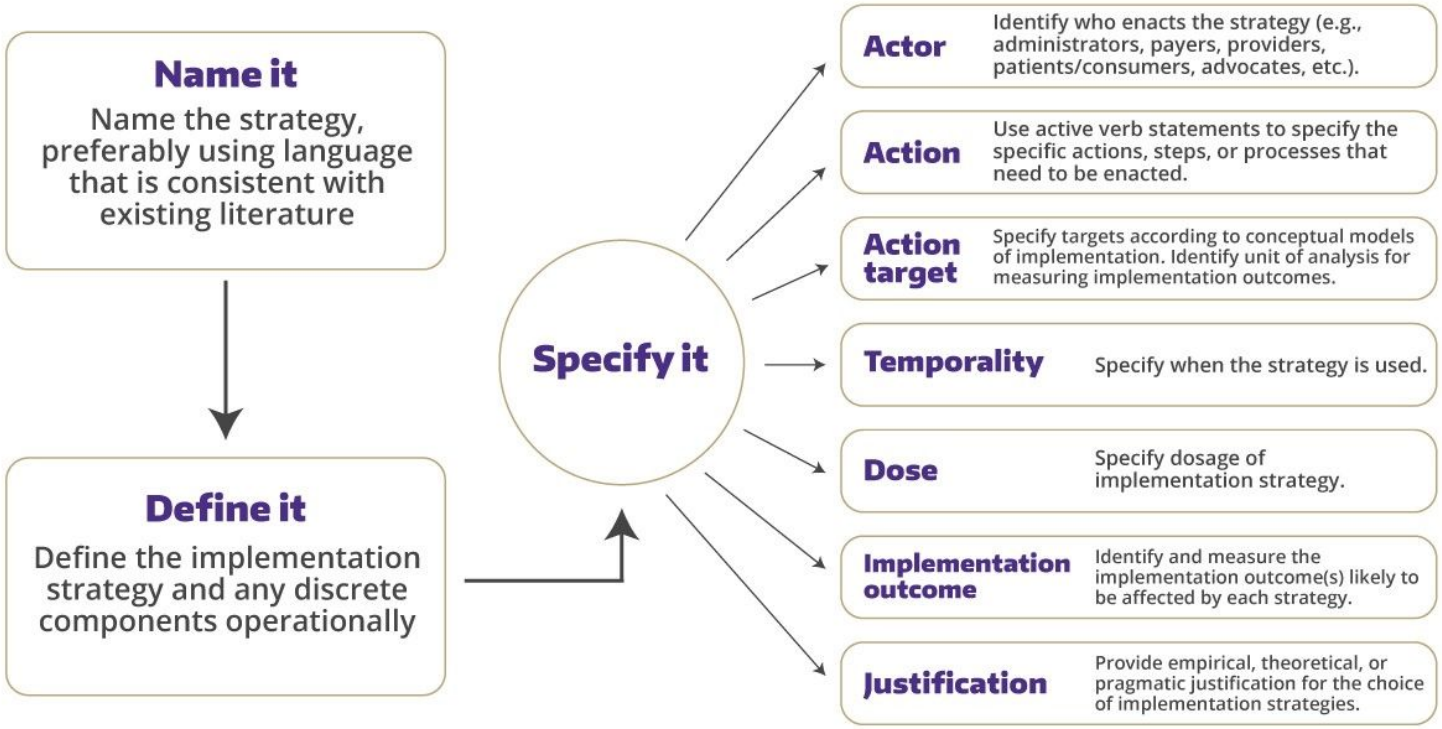

Figure 3

Guidance for specifying implementation strategies of Proctor EK et al. [49].

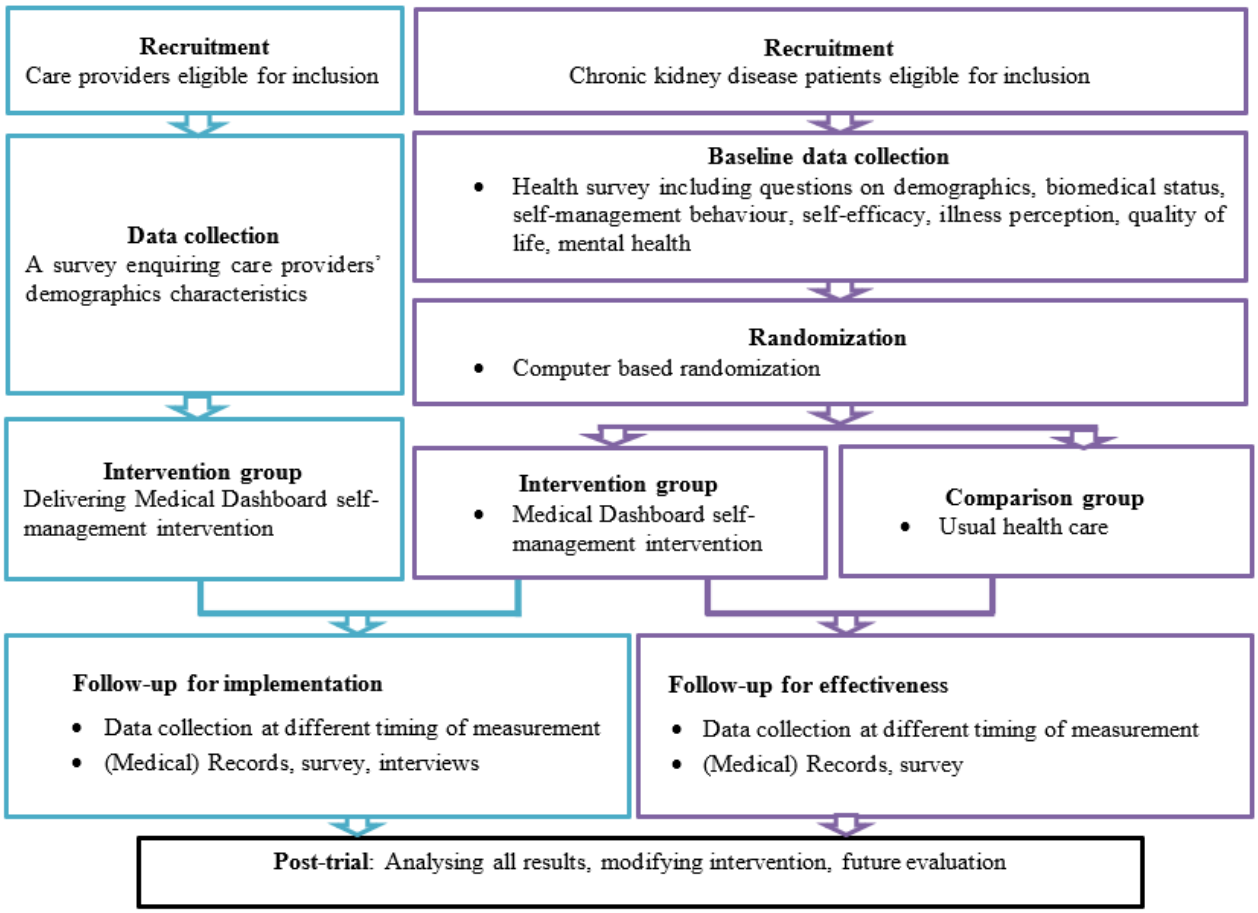

Figure 4

Study schema

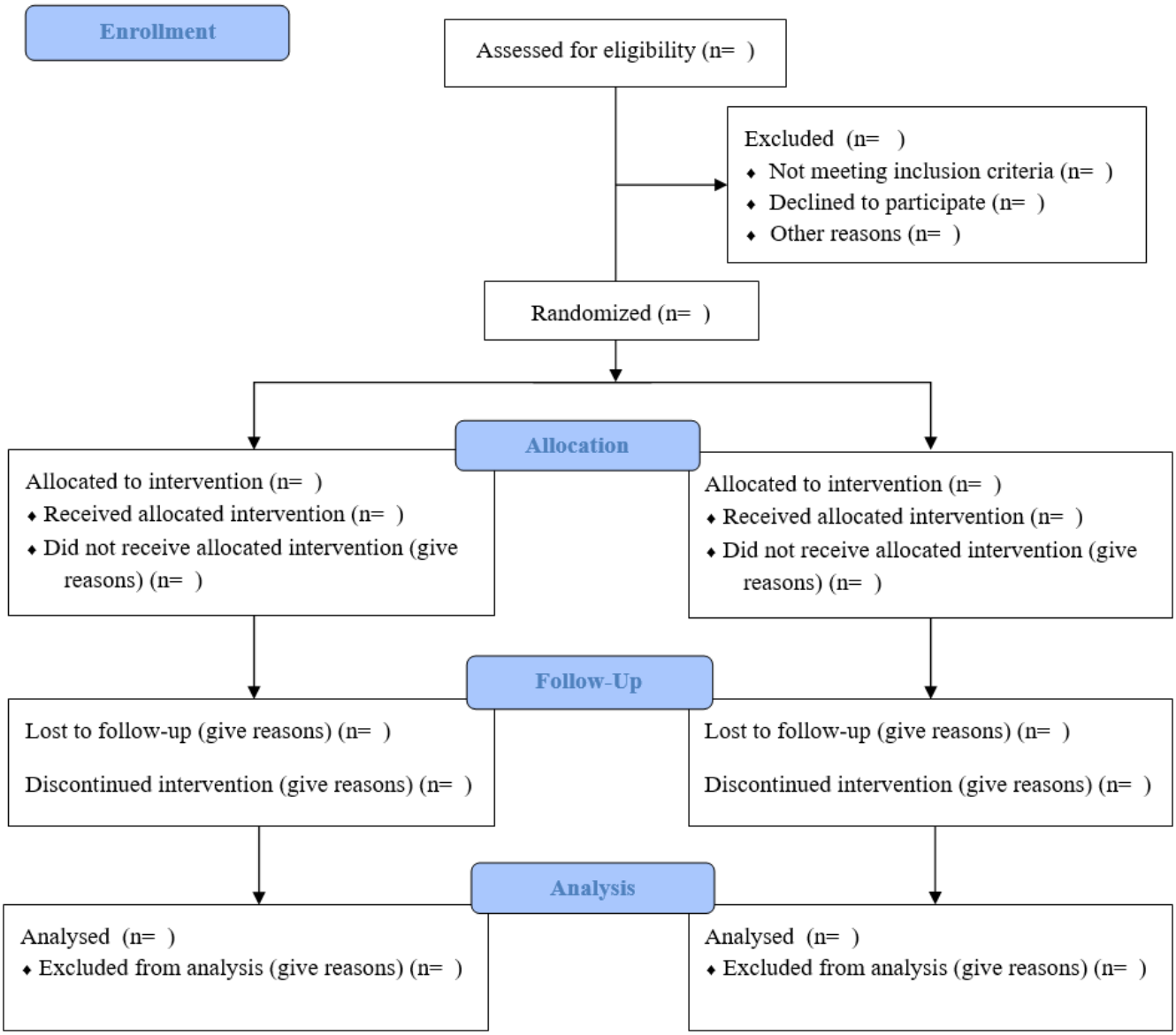

Figure 5

CONSORT flow diagram for our trial

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile4.docx
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- Additionalfile2.docx
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