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A comparison between medication reconciliation by a pharmacy technician and the use of an online personal health record by patients for identifying medication discrepancies in patients' drug lists prior to elective admissions

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ABSTRACT

Aim: Medication discrepancies (MDs), defined as unexplained differences among medication regimens, cause important public health problems with clinical and economic consequences. Medication reconciliation (MR) reduces the risk of MDs, but is time consuming and its success relies on the quality of different information sources. Online personalized health records (PHRs) may overcome these drawbacks. Therefore, the aim of this study is to determine the level of agreement of identified MDs between traditional MR and an online PHR and the correctness of the identified MDs with a PHR.

Methods: A prospective cohort study was conducted at the cardiology, neurology, internal medicine and pulmonary department of the Amphia Hospital, the Netherlands. Two weeks prior to a planned admission all patients received an invitation from a PHR to update their medication file derived from the Nationwide Medication Record System (NMRS). At admission MR was performed with all by a pharmacy technician, who created the best possible medication history (BPMH) based on the NMRS data and an interview. MDs were determined as discrepancies between the available information from the NMRS and the input and alterations patients or pharmacy technician made. The number, correctness of patients' alterations, type and severity of identified MDs were analysed.

Results: Of 488 patients approached, 155 (31.8 %) patients who both used the PHR and had received MR were included. The mean number of MDs identified with MR and PHR was 6.2 (SD 4.3) and 4.7 (SD 3.7), respectively. 82.1 % of the drug information noted by the patient in the PHR was correct compared to the BPMH and 98.6 % had no clinically relevant differences between the lists.

Conclusion: Patients who used an online PHR can relatively accurately record a list of their medication. Further research is required to explore the level of agreement and the correctness of a PHR in other (larger) hospital (departments).

1. Introduction

Transitions in healthcare are associated with a high risk of medication errors, mainly caused by poor communication of drug information at transition points [1–5]. To reduce the amount of medication errors, it is important to identify medication discrepancies (MDs), defined as unexplained differences among medication regimens [6]. Around half of the MDs have the potential to harm patients resulting in prolonged hospital stay, emergency room visits and readmissions [2,7–10]. Because all patients admitted to the hospital have at least one MD, it is important to identify harmful MDs [11–13].

Medication reconciliation (MR) has the potential to identify and reduce MDs by 68 % [14,15].The Institute of Healthcare Improvement defined MR as "the process of identifying the most accurate list of patient's current medicines including the name, dosage, frequency and route — and comparing them to the current list in use, recognizing and

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documenting any MDs, finally resulting in a complete list of medications" [16]. Although the World Health Organization (WHO) considers MR to be one of the five top strategies for ensuring patient safety, implementation of MR is hampered by the large amount of admitted patients with respect to the given time spent to perform MR (up to 30 min for each MR) [17,18]. Moreover, MR is performed according to different protocols using different resources [14,19].

Besides MR, patient empowerment, the involvement of the patient in their own care with the goal to make competent, well-informed decisions about their health and take action to support those decisions, is also an upcoming essential public health strategy to reduce medication errors [20–23]. A personalized health record (PHR), which gives patients access to personal health information, may have the ability to empower patients to manage their own medication use [24]. Recent studies explored the effect of patient empowerment in the MR process by using a PHR [25–29]. However, only one of these studies directly compared the identified MDs with a PHR to traditional MR. Buning et al. concluded that drug lists compiled by patients using a PHR ($n = 17$) were sufficiently reliable in terms of their accuracy (mean number of 1.2 deviations in the PHR per patient compared to MR) [29]. However, the level of agreement between the PHR and MR and the severity of deviations in the PHR were not investigated. Therefore, the aim of this study is to determine the level of agreement of identified MDs between traditional MR (executed by a pharmacy technician) and an online PHR (used by patients) and the correctness of the identified MDs with an online PHR.

2. Materials and methods

2.1. Study design

A prospective cohort study was conducted at the Amphia Hospital, Breda, the Netherlands. Inclusion criteria were age $\geq$ 18 years, able to read the Dutch language, had an admission at the cardiology, or neurology, or internal medicine, or pulmonary ward in the period of March or April 2019, had verified their drug list in the PHR and had received MR at admission or by telephone (at least three days before admission). Patients were excluded if no information from the Nationwide Medication Record System (NMRS), a digital nationwide network which exchanges medication dispensing data form all pharmacies in the Netherlands [30,31], was available.

The study was approved by the Medical Ethics Committee of Utrecht, the Netherlands. No informed consent of patients was needed as only data of routine procedures was collected.

2.2. Medication reconciliation

During MR, the best possible medication history (BPMH) was compiled according to the standard operating procedure of the High 5 s project of the WHO [14]. Pharmacy technicians combined the information provided by a structured interview with the patients about medication use, the information from electronic health records (EHRs) and the information (of all dispensed drugs of the past years) from the NMRS to obtain the BPMH.

2.3. Personal health record

For this study we implemented a PHR (Zorgdoc®, Eindhoven, the Netherlands) specifically developed for patients to update their own medication list. The PHR system consists of two main components: a website for patients and one for professionals. Both components contain patients' medication files one owned by the patients and one by the professionals. Both components are connected, giving the users (patients and professionals) access to the information that has been captured in the other file.

When the verification flow is initiated (usually triggered by an upcoming hospital visit), the hospital update their own patient medication file by retrieving medication related data from the EHR and NMRS. About two weeks before hospital admission, an invitation was sent to the patient by mail or via SMS.

During the verification process, the PHR presents the combined information from both the professionals and the patient file in an simple and understandable drug list (Supplemental file 1). After a seven-step tutorial on how to verify their drug list, patients were asked to verify the shown medication information and to update it if necessary. If there was a difference between the listed drugs and how patients actually used the drugs, patients noted the correct dose, formulation, frequency, route of administration and/or strength in their PHR. Patients were also able to stop medication that was no longer in use and add new medication.

When the patient finished the verification process, the hospital validated the information patients entered in the PHR. The PHR indicates MDs and requests the professional to confirm the correctness of the final drug list. The results of the validation are then stored in both the patient's and professional's files.

2.4. Outcome measures

The primary outcome of this study was the level of agreement in the number of identified MDs between MR performed by a pharmacy technician and the use of an online PHR by a patient. A MD was defined as a difference between the NMRS and the final drug list, either achieved by changes patients made in their PHRs or MR. The level of agreement was determined by a pharmacist (DN) who directly compared the amount of MDs identified with the PHR to the amount of identified MDs with MR. The correctness of the identified MDs with the PHR was also assessed by a pharmacist (DN) who directly compared the drug list made by the patient in the PHR with the drug list derived from MR. Deviations in the drug list of PHR were classified as incorrect, under the assumption that the process of MR results in the BPMH. Drugs with an identified MD were categorized according to their Anatomical Therapeutic Chemical (ATC) classification [32]. The secondary outcomes were the type and severity of the MDs. The type of MDs were divided into: commission (where the drug was taken incorrectly), omission (where a drug was not taken), duplication (two identical drugs with the same strength were taken together), wrong doses, wrong duration of medication treatment, wrong formulation, wrong frequency, wrong strength, wrong time of admission (where the drug was taken in the wrong period or at the wrong time of the day) and commission and omission related to over-the-counter (OTC) medication, defined as drugs which are sold to patients without a doctor's prescription [33–35].

The severity of MDs was classified according to the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) Index [36,37]. This index consists of nine categories ranged from A to I, in which A represents no harm and I patient's death [36]. MDs categorized in category E and higher were classified as clinically relevant MDs (CRMDs) because MDs in these categories may harm patients [38]. Types and severity of MDs were independently determined by two researchers (DN, MT). In the case of disagreement in the type and severity of the MDs, a third person (HO) was consulted.

2.5. Data collection

Patient characteristics were extracted from the EHR. The following patient characteristics were collected: patient's age, patient's gender, number of (high-risk) drugs, known comorbidities in the EHR, number of outpatient visits in the last 12 months, usage of different outpatient pharmacies in the last 6 months, type of care before admission, and use of an individual multi-dose packaging [39]. Medication were classified as high risk medication according to the Institute For Safe Medication Practices list of high-alert drugs and the Narrow Therapeutic Index list of the Royal Dutch Pharmacists Association [40,41]. All data were treated according to the European General Data Protection Regulation and the

Amphia Hospital privacy regulations [42].

2.6. Statistical analysis

The number of (CR)MDs between the PHR and MR were compared using a Bland-Altman plot. Differences between the PHR and MR regarding the amount of identified MDs within ATC-classes were analysed using a McNemar test. First, drugs classified to one ATC-class were selected (this was performed for each ATC-class consecutively) and subsequently within this ATC-class the number of identified MDs with the PHR was compared to the number of identified MDs with MR. In the same manner, the McNemar test was used to analyse differences within the different types and severities of MDs. Descriptive analysis were performed to determine the level of agreement between the PHR and MR, the correctness of the PHR and the amount, type and ATC-classification of identified MDs and deviations. Descriptive statistics were provided using mean (± standard deviation (SD)) or median (interquartile range (IQR)) values depending on the (non-)parametric distribution of measured variables. Results were considered statistically significant at $p < 0.05$. Data were analysed using IBM SPSS Statistics software version 25.

3. Results

3.1. Study sample

Among 488 patients initially invited, 217 patients responded of which 155 met the inclusion criteria. Almost half of the non-responders (48 %) had an explanation why they did not use the PHR (Fig. 1).

Table 1 shows the characteristics of the study sample. Patients who used the PHR (mean age 63.8 +/- 13.1 years, 69.0 % male), used a median number of 7.0 (IQR: 3.0–10.0) drugs and were home living (98.7 %). MR was mostly performed by telephone (96.1 %) and most patients (90.3 %) were admitted at the cardiology department.

3.2. Identified medication discrepancies

The total number of MDs detected by MR and the PHR were 954 and 731 respectively. The mean number of MDs per patient identified with the PHR was 4.7 (SD 3.7) compared to 6.2 (SD 4.3) identified by MR ($p < 0.001$). The Bland-Altman plot (Fig. 2A) shows that MR identified on average 1.4 (SD 2.1) more MDs compared to the PHR, with consistent variability (94.2 % within the limits of agreement (mean $^{+}$/- 1.96 SD) of -2.8 to 5.5).

PHR and MR both identified the greatest proportions of MDs associated with drugs classified to the ATC-classes 'anti-infective for systemic use', 'nervous system', 'sensory organs' and 'systematic hormonal preparations, excluding sex hormones and insulins' and 'various' (Table 2). Drugs classified as 'blood and blood forming organs', 'cardiovascular system' and 'genito urinary system and sex hormones' had the smallest proportion of identified MDs. Compared to the PHR, MR identified significantly more MDs by drugs classified to the ATC-classes 'alimentary tract and metabolism', 'anti-infective for systemic use', 'blood and blood forming organs', 'cardiovascular system', 'dermatologicals', 'musculo-skeletal system', 'nervous system', 'respiratory system' and 'sensory organs' ($p < 0.05$).

There was a statistically significant difference in the type of identified MDs between the PHR and MR, $p < 0.001$ (Table 3). The most revealed type of MD for both methods was commission (64.3 % for MR and 77.2 % for the PHR; $p < 0.05$). On the other hand, MR identified significantly more omission (of OTC medication), wrong doses, wrong durations, wrong frequencies and wrong strengths ($p < 0.05$).

When the PHR was directly compared to MR, 37 (23.9 %) patients had a drug list which was completely the same as the drug list of MR. Each patient had on average 2.0 (IQR: 1.0–3.0) deviations in their PHR. 315 out of 1756 of the used drugs (17.9 %) deviated in the PHR. 19 drugs had two deviations, resulted in a total of 334 deviations in the PHR compared to MR. 89.5 % of the drugs with two deviations had both a wrong frequency and wrong dose. These drugs were mostly classified to the ATC-class 'nervous system' (36.8 %) and 'respiratory system' (26.3

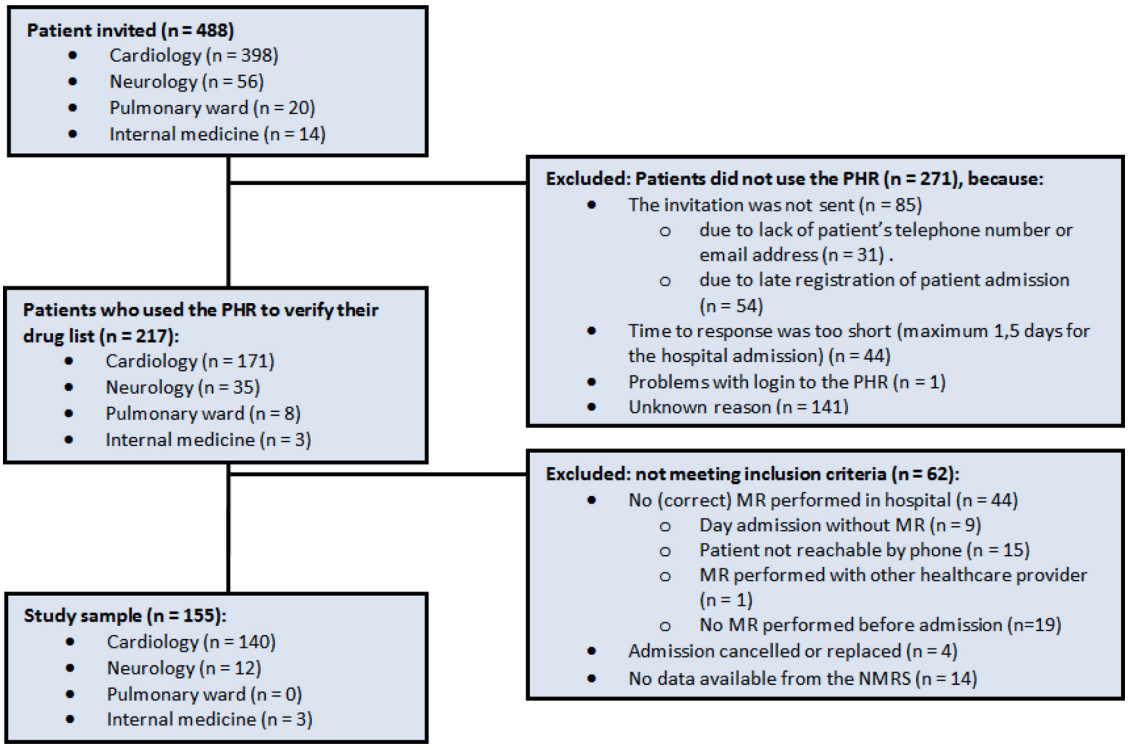

Fig. 1. Flowchart of the sample selection. The flowchart displays the number of patients per admitted department and the reasons of exclusion. At the end of the study 155 patients were included. Abbreviations: PHR, personal health record; MR, medication reconciliation; NMRS, Nationwide Medication Record System.

Table 1
Patient, setting and drug related characteristics of the study sample (n = 155). The number of (high-risk) drugs was extracted from the BPMH. Drugs were classified as high-risk drugs according to the Institute For Safe Medication Practices (ISMP) high-alert medications list and the narrow therapeutic index list of the Royal Dutch Pharmacists Association (KNMP) [40,41]. To determine the proportion of high-risk drugs in each Anatomical Therapeutic Chemical (ATC)-class the number of high-risk drugs in an ATC-class was divided by the total number of drugs classified to that ATC-class. The known comorbidities were extracted from the problem list of the EHR composed by doctors according to the International Classification of Diseases (ICD)-10. All diagnoses in the patient's past which were reported by the doctors as 'current' were taken into account. To make sure that the list was complete and correct, the information was checked and supplemented with comorbidities based on drug information of the BPMH.

Characteristics	N = 155
Age (years, mean (SD))	63.8 (13.1)
Male, N (%)	107 (69.0)
Number of drugs, median (IQR)	7.0 (3.0–10.0)
Number of high-risk drugs, median (IQR)	0.0 (0.0–1.0)
Known comorbidities, median (IQR)	4.0 (2.0–7.0)
Number of outpatient visits in the last 12 months, median (IQR)	0.0 (0.0–1.0)
Usage of different outpatient pharmacies in the last 6 months, median (IQR)	1.0 (1.0–2.0)
Home living, N (%)	153 (98.7)
Use of an individual multi-dose packaging, N (%)	5.0 (3.2)
Amount of high-risk medication per ATC-class, N (%)	
Alimentary tract and metabolism	33 (10.5)
Anti-infective for systemic use	0 (0.0)
Antineoplastic and immunomodulating agents	5 (35.7)
Antiparasitic products, insecticides and repellents	0 (0.0)
Blood and blood forming organs	60 (33.1)
Cardiovascular system	45 (7.3)
Dermatologicals	1 (0.9)
Genito urinary system and sex hormones	0 (0.0)
Musculo-skeletal system	4 (6.9)
Nervous system	23 (12.8)
Respiratory system	1 (1.1)
Sensory organs	0 (0.0)
Systemic hormonal preparations, excluding sex hormones and insulins	6 (19.4)
Various	0 (0.0)
Admitted medical department, N (%)	
Neurology department	12 (7.7)
Cardiology department	140 (90.3)
Internal medicine	3 (1.9)
Pulmonary department	0 (0.0)
Years of experience of pharmacist technician, median (IQR)	5.0 (3.0–10.0)
Patient approach of medication reconciliation, N (%)	
Performed by telephone with the patient	135 (87.1)
Performed by telephone with a caregiver	14 (9.0)
Performed at bedside with a caregiver	1 (0.6)
Performed at bedside with the patient	5 (3.2)

%). Of all deviations the majority (23.1 %) were found by drugs classified to the ATC-class 'alimentary tract and metabolism' (Table 4). The most noted types of deviations were commission (25.7 %) and wrong frequency (25.1 %) (Table 3).

3.3. Severity of medication discrepancies

The majority of detected MDs by both methods did not have the potential to cause harm (NCC MERP class D or lower): 93.0 % for MR and 92.5 % for the PHR ($p > 0.05$) (Fig. 3).

The mean number of CRMDs identified with MR and the PHR was 0.43 (SD 0.70) and 0.35 (SD 0.62) respectively ($p = 0.023$). There was a high level of agreement for the identification of CRMDs between MR and PHR (mean difference (MR minus PHR) = 0.07 (SD 0.42) MDs) (Fig. 2B). The variability across the graph was consistent and 87.8 % of the patients had a result within the limits of agreement of -0.76 to 0.90.

The greatest proportion of CRMDs contained by drugs classified to ATC-class 'blood and blood forming organs' (Table 2). All these CRMDs were classified to NCC MERP class G and concerned especially the commission (67.1 %) followed by the omission (15.2 %) and duplication (10.1 %) of antithrombotic drugs. In most cases (64.6 %) these CRMDs were related to thrombocyte aggregation inhibitors.

Focusing on the clinically relevant deviations, 134 (86.5 %) patients had a drug list which was completely the same as the drug list of MR. The median number of clinically relevant deviations in the PHR compared to MR per patient was 0.0 (IQR: 0.0–0.0). The majority (92.8 %) of all deviations were clinically irrelevant (Fig. 3) which corresponds to 98.6 % of the total used drugs. Most clinically relevant deviations (37.5 %) were found in drugs of the ATC-class 'blood and blood forming organs' (Table 4) and the most noted type was omission (62.5 %) (Table 3).

4. Discussion

We examined the level of agreement of identified MDs between MR by a pharmacy technician and the use of an online PHR by the patient and assessed the correctness of the identification of MDs with an online PHR as compared to MR. Results from this study showed that although MR resulted in significantly more identified (CR)MD, more than 80 % of all drug information entered by the patient was correct, and in the case of incorrectness up to 99 % of the discrepancies between the MR and online PHR had no clinical relevance.

Although, performing MR is considered to be one of the top strategies to reduce MD, implementation in routine care is hampered by the quality of information sources and available resources. It is therefore reasonable that empowering patients to access and maintain their medication record may overcome these limitations. Indeed, several studies showed that patients were able to identify important MDs [25,27,29,43]. However, only one study directly compared the identification of MDs with a PHR to MR [29]. When compared to our study, this study was limited by the proof-of-concept design and the number of patients included (n = 17). Although Buning et al. investigated another method of updating patient's drug list in the PHR, they also concluded that the drug list compiled by patients with a PHR were sufficiently reliable in terms of their accuracy [29].

In our study MR identified significantly more (CR)MDs when compared to our PHR. For validity purposes of the PHR these differences need to be explained.

A possible cause of differences in the amount of identified MDs may be differences in baseline drug information shown in the PHR and during MR. Both methods combine drug information from the patient and the NMRS. Besides that, during MR additional drug information from the EHR was used. However, we expect that the information from the EHR has little effect on detecting more MDs, because at hospital discharge a hospital share patient's current drug list (including adjustments) with the community pharmacist who update the NMRS resulting in equal drug information in the EHR and the NMRS [33]. Another difference between the PHR and MR is that the experience and knowledge of pharmacy technicians can be used to detect abnormalities in patient's drug list which potentially resulted in more identified MDs during MR [43]. To reduce this difference in the future, the PHR might be improved by integrating drug knowledge into the system for example by adding drug monitoring signals to the system to monitor on mistakes as duplications and abnormal strength, doses and frequencies. Although challenging for patients, this might help patients to recognize potential errors, and guide them to greater medication knowledge and use.

We observed a low response rate (32 %) in our research. The reasons for this were diverse and could be subdivided into technical problems (problems with login and sending the invitation on time), practical issues (lack of patient contact data and timely registration of admission in the EHR) and unknown reasons. To increase the amount of patients who use a PHR, especially the process of sending invitations has to be improved and further research should explore patients' barriers for

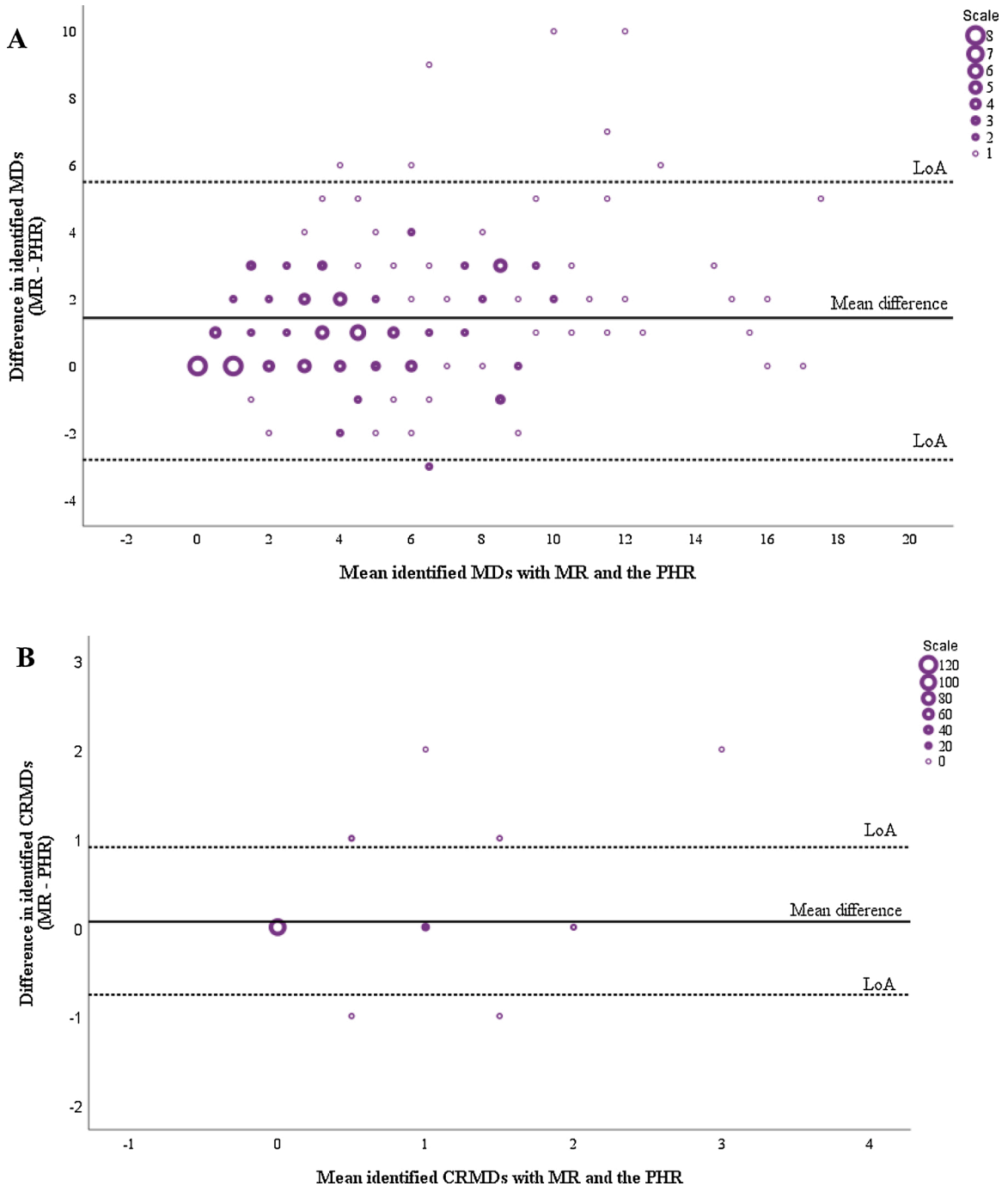

Fig. 2. Bland-Altman plot of the difference (Medication reconciliation (MR) minus the personal health record (PHR)) in (A) all identified medication discrepancies (MDs) and (B) identified clinically relevant medication discrepancies (CRMDs) against the mean identified (CR)MDs of the two methods. For each included patient both the mean number of (CR)MDs identified with both methods and the differences in identified (CR)MDs between the PHR and MR were calculated. The dots represent the results of the patients. If more patients had a certain outcome, the size of the dot is bigger (see scale). The continuous line represents the mean difference of the identified number of MDs between the methods of all included patients, which was (A) 1.4 (SD 2.1) for all MDs and (B) 0.07 (SD 0.42) for the CRMDs. This latter value was close to zero, which indicates that there was a high level of agreement between the PHR and MR for the identification of CRMDs. The dashed lines show the limits of agreement (LoA) (mean +/- 1.96 SD). The results of (A) 146 (94.2 %) patients and (B) 136 (87.8 %) patients were between the limits of agreement of -2.8 to 5.5 and -0.76 to 0.90 respectively. This indicates that the identification of MDs with MR and PHR was consistent.

using a PHR.

The greatest proportion of CRMDs were identified by drugs classified to ATC-class 'blood and blood forming organs'. It was striking that drugs classified to ATC-class 'blood and blood forming organs' had low proportions of identified MDs (with both methods), but had the greatest proportion of identified CRMDs. A high standard of usual care on the cardiology department may potentially have contributed to well-informed patients and less identified MDs. However, cardiology medication remains high-risk medication which increases the chance of having a CRMD [40,41,43]. To decrease the risk of CRMDs, further research is required to compose an algorithm which is able to calculate a risk score based on patient's characteristics and to determine a cut-off value of the risk score when MR is advised to perform whether or not in combination with the PHR.

Table 2
Number of identified (clinically relevant) medication discrepancies ((CR)MDs) with medication reconciliation (MR) and a personal health record (PHR) related to the Anatomical Therapeutic Chemical (ATC)-classification. Columns 4 and 5 show the proportion of identified MDs (reported in column 2 and 3) which was clinically relevant.

ATC-classification	MDs		CRMDs	
	MR, N (%)	PHR, N (%)	MR, N (%)	PHR, N (%)
Various	2 (100.0)	2 (100.0)	0 (0.0)	0 (0.0)
Anti-infective for systemic use*	95 (96.0)	85 (85.9)	0 (0.0)	0 (0.0)
Sensory organs*	57 (87.7)	41 (63.1)	0 (0.0)	0 (0.0)
Nervous system*	132 (73.3)	104 (57.8)	3 (2.3)	1 (1.0)
Systemic hormonal preparations, excluding sex hormones and insulins	22 (71.0)	20 (64.5)	1 (4.5)	0 (0.0)
Dermatologicals*	69 (62.2)	33 (29.7)	0 (0.0)	0 (0.0)
Respiratory system*	62 (62.0)	41 (41.0)	0 (0.0)	0 (0.0)
Musculo-skeletal system*	35 (60.3)	26 (44.8)	5 (14.3)	3 (11.5)
Antiparasitic products, insecticides and repellents	3 (60.0)	3 (60.0)	0 (0.0)	0 (0.0)
Antineoplastic and immunomodulating agents	8 (57.1)	6 (42.9)	3 (37.5)	2 (33.3)
Alimentary tract and metabolism*	170 (54.0)	122 (38.7)	1 (0.6)	2 (1.6)
Cardiovascular system*	231 (37.6)	189 (30.7)	9 (3.9)	8 (4.2)
Blood and blood forming organs*	57 (31.5)	46 (25.4)	43 (75.4)	36 (78.3)
Genito urinary system and sex hormones	11 (29.7)	13 (35.1)	2 (18.2)	3 (23.1)

* MR identified significantly more MDs by drugs classified to this ATC-class compared to the PHR ($p < 0.05$).

The results of the correctness of detecting MDs with a PHR seem confusing: 23.9 % of the patients had a drug list which was completely the same as the drug list of MR, but 82.1 % of the drug information in the PHR and MR was identical. An explanation for this might be the number of drugs a patient uses. The chance of detecting at least one MD is bigger when a patient uses more drugs. So the observed result of 23.9 % greatly depends on the length of patient's drug list. If a patient had for example one MD in a long drug list, the drug list of the patient was classified as not identical despite the correctness of the majority of the drug information noted in the PHR. So, the presence of (at least) one MD overrules the presence of correctly noted information. Because of this it is important to compare the correctness of the PHR between each drug. Furthermore, a closer look at the definition of incorrectness is necessary to determine the practical meaning of the results. A deviation was classified as incorrect and defined as a difference between the drug list made by the patient in the PHR and the drug list derived from MR. Every (small) deviation was defined as incorrect regardless of its practical meaning. There was a great chance that a patient had at least one deviation which puts the observed result of 23.9 % patients without any deviation in the PHR into perspective. The results of the clinically relevant deviations give a better indication of the correctness of the detecting of MDs with a PHR. It appeared that 86.5 % of the patients had a drug list which was identical with the drug list of MR concerning the

Table 4
Amount of drugs with a deviation in the personal health record related to the Anatomical Therapeutic Chemical (ATC)-classification: a personal health record directly compared to medication reconciliation.

ATC-classification	Amount of deviations N (%) n = 334	Amount of clinically relevant deviations N (%) n = 24
Alimentary tract and metabolism	77 (23.1)	0 (0.0)
Cardiovascular system	63 (18.9)	5 (20.8)
Nervous system	56 (16.8)	3 (12.5)
Dermatologicals	41 (12.3)	0 (0.0)
Respiratory system	28 (8.4)	0 (0.0)
Sensory organs	19 (5.7)	0 (0.0)
Anti-infective for systemic use	13 (3.9)	1 (4.2)
Blood and blood forming organs	15 (4.5)	9 (37.5)
Musculo-skeletal system	11 (3.3)	2 (8.3)
Genito urinary system and sex hormones	4 (1.2)	3 (12.5)
Systemic hormonal preparations, excluding sex hormones and insulins	3 (0.9)	1 (4.2)
Various	2 (0.6)	0 (0.0)
Antineoplastic and immunomodulating agents	2 (0.6)	0 (0.0)
Antiparasitic products, insecticides and repellents	0 (0.0)	0 (0.0)

Table 3
Types of clinically relevant medication discrepancies ((CR)MDs) identified with medication reconciliation (MR) and a personal health record (PHR). Column 1 to 4 compare the drug list of MR and the PHR to the Nationwide Medication Record System. Column 5 and 6 compares the drug list of the PHR directly to the drug list composed with MR. The most frequent type of (CR)MDs was commission defined as drugs that were taken incorrectly (mostly due to the lack of a valid doctor's prescription).

Type of MD	MR N (%)		PHR N (%)		Deviations in the PHR (n = 334) N (%)	Clinically relevant deviations in the PHR (n = 24) N (%)
	All MDs (n = 954)	CRMDs (n = 67)	All MDs (n = 731)	CRMDs (n = 55)		
Commission	613 (64.3)	39 (58.2)	564 (77.2)[a]	42 (76.4)	86 (25.7)	2 (8.3)
Wrong frequency	98 (10.3)[b]	0 (0.0)	43 (5.9)	1 (1.8)	84 (25.1)	1 (4.2)
Omission	78 (8.2)[b]	17 (25.4)	43 (5.9)	8 (14.5)	65 (19.5)	15 (62.5)
Wrong doses	56 (5.9)[b]	1 (1.5)	33 (4.5)	0 (0.0)	37 (10.2)	2 (8.3)
Over-the-counter medication commission	30 (3.1)	0 (0.0)	25 (3.4)	0 (0.0)	12 (3.6)	0 (0.0)
Over-the-counter medication omission	34 (3.6)[b]	0 (0.0)	6 (0.8)	0 (0.0)	34 (9.9)	0 (0.0)
Duplication	19 (2.0)	6 (9.0)	15 (2.1)	4 (7.3)	5 (1.5)	2 (8.3)
Wrong duration of drug treatment	11 (1.2)[b]	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.3)	0 (0.0)
Wrong strength	9 (0.9)[b]	0 (0.0)	1 (0.1)	0 (0.0)	7 (2.1)	0 (0.0)
Wrong time of admission	4 (0.4)	3 (4.5)	0 (0.0)	0 (0.0)	1 (0.3)	1 (4.2)
Wrong formulation	2 (0.2)	1 (1.5)	1 (0.1)	0 (0.0)	2 (0.6)	1 (4.2)

[a] Type of MD was significantly ($p < 0.05$) more identified with the PHR compared to MR.
[b] Type of MD was significantly ($p < 0.05$) more identified with MR compared to the PHR.

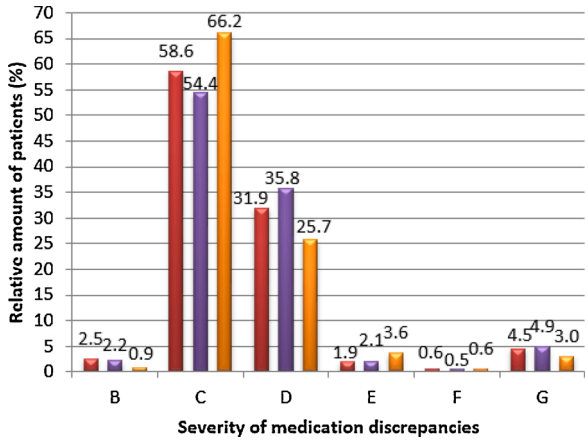

Fig. 3. Severity of medication discrepancies (MDs) identified with medication reconciliation (MR) and a personal health record (PHR) and the severity of the deviations in the PHR compared to MR. The severity is classified according to the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) Index. In our research the MDs were classified to the following categories:
B: the MD may not reach the patient;
C: the MD may reach the patient, but did not harm the patient,
D: monitoring is required to confirm that the MD resulted in no harm to the patient and/or required intervention to preclude harm.
E: the MD may contribute to or resulted in temporary harm to the patient and required intervention.
F: the MD may have contributed to or resulted in temporary harm to the patient and required initial or prolonged hospitalization.
G: the MD may contributed to or resulted in permanent patient harm [36].
Most identified MDs and deviations in the PHR were clinically irrelevant (category B to D). The highest risk-class (category G) concerned mainly drugs classified to ATC-class 'blood and blood forming organs'.
Legend:
MDs identified with MR (n = 954).
MDs identified with a PHR (n = 731).
Deviations in the PHR (n = 334).

clinically relevant information and in 98.6 % of the used drugs there was no clinically relevant difference between the methods. These results may indicate that patients who used a PHR correctly identified CRMDs, but it also indicates that the PHR needs to be improved to further decrease the amount of CRMDs.

Focusing on the type of MDs, both methods identified most of the errors of commission. In literature, the most commonly noted type of MD was omission followed by commission [1,6,51–53,43–50]. Since the NMRS gives an overview of all dispensed drugs in the past year (including drugs that are already stopped), a higher frequency of errors of commission is comprehensible. We also observed that patients who used a PHR identified more errors of commission in the drug list derived from the NMRS compared to MR performed by pharmacy technicians. Two potential explanations may be that patients at home were more honest about not using a drug or patients did not recognize the drug name in the PHR. This latter is reduced during MR by discussing the drugs in layman's terms. The (wrong) identification of more errors of commission with the PHR also explained why some patients (Fig. 2) identified more MDs with the PHR compared to MR.

Omission of OTC medication, wrong strengths and wrong frequency were significantly less identified with the PHR compared to MR which corresponds to the literature [29,43,54]. Differences in the frequency of detected omission of OTC medication between both methods were explainable focusing on the procedures. During MR a pharmacy technician explicitly asked if the patient used OTC products. In the PHR patients were asked to note additional used medication not mentioned in the NMRS. Because the question was not specified on OTC products, less omissions of OTC medication were detected with the PHR. To reduce this problem, the PHR should contain additional questions focusing on the use of OTC products like vitamins and painkillers.

Our study had several limitations. First, there was an opportunity of recall bias. It is reasonable that patients know more about their medication as they checked their medication in the PHR up to a few days before the upcoming MR. Because of this, the effect of MR to identify MDs may be overestimated.

Secondly, the researchers who assessed (the severity of) the identified MDs were not blinded, nor were the MDs classified by a multidisciplinary team. This increased the risk of bias. Furthermore, the classification of the severity of MDs relied on subjective judgment of the researchers and is therefore subject to bias. The risk of bias was minimized by performing the assessment by two independent pharmacists. Furthermore, Doormaal et al. concluded that the inter-rater agreement between pharmacists is largely comparable making blinding of the pharmacists not explicitly necessary [55]. Besides that, there is no unambiguity about a preference of assessing MDs with a multidisciplinary team compared to independent pharmacists [55,56]. Besides that, the risk of bias was minimized during the process because the pharmacy technicians who performed MR were not informed about the drug information patients had entered into the PHR.

Thirdly, we assumed that there was no change in medication history between the time patients entered their medications in the PHR and the time of performing MR. This so called history effect might potentially have limited the measurements of the level of agreement between the PHR and MR and the correctness of the identified MDs with the PHR.

Fourthly, to determine the incorrectness of the PHR we used MR as reference, under the assumption that MR creates a BPMH [14]. However, in some cases the PHR may have the potential to reflect information better than MR. MR could for example detect less information when the actual visit to the hospital pressures patient's recollection of their medication use. Nevertheless, the high amount of deviations in the PHR suggests that the correctness of the PHR needs to be improved.

Fifthly, with our lower sample size rare events could not be identified. Further research in larger studies is necessary to focus more on rare events.

Sixthly, the external validity of this research might be limited as the participation rate of the study was low, the research was performed in a single hospital, and patients were mostly admitted to one department. Further research should explore the level of agreement and correctness of the PHR in other patient samples of other departments and/or hospitals.

5. Conclusions

Based on the results of this study, we conclude that patients who used an online PHR can relatively accurately record a list of their medication. Especially the identification of MDs with a PHR shows a high level of agreement with MR performed by pharmacy technicians. PHRs may have the potential to replace MR in detecting MDs, but further research is required to determine the level of agreement and the correctness of the PHR in different (larger) settings. Besides that, PHRs have to be further developed to increase the number of identified (CR)MDs and the correctness of medication lists by focusing on patients at risk for CRMDs. Algorithms identifying those patients may be subject for further research in order to ensure patients' safety.

Authors' contributions

All authors contributed to all of the following: (1) the conception and design of the research, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted. The acquisition, analysis and interpretation of data were performed by DN, MT and HO.

Author's statement

All authors (DN, MT, VH, BB and OH) contributed to all of the following: (1) the conception and design of the research, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted. The acquisition, analysis and interpretation of data were performed by DN, MT and OH.

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Declaration of Competing Interest

The authors had no competing interest.

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Appendix A. Supplementary data

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SUMMARY TABLE

What was already known about the topic:

- Medication reconciliation (MR) reduces the risk of MDs.
- MR is time consuming and its success relies on the quality of different information sources.
- Online personalized health records (PHRs) increase patient empowerment and may overcome the implementation problems of MR.

What this study added to our knowledge:

- Patients who used an online PHR can relatively accurately record a list of their medication.
- PHRs may have the potential to replace MR in detecting MDs, which brings hospitals a step closer to a more effective patient healthcare.