Development of a standardized knowledge base to generate individualized medication plans automatically with drug administration recommendations

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WHAT IS ALREADY KNOWN ABOUT THIS SUBJECT

- Patients require information on how to administer drugs to prevent administration errors effectively, especially after hospital discharge.
- Standardization and categorization of written instructions improves knowledge, recall and satisfaction of patients.

WHAT THIS STUDY ADDS

- Generic grouping of brands according to their drug characteristics is generally feasible for a large drug market.
- Administration recommendations can be standardized, allocated to the generic groups and thereby dynamically integrated into distinct medication plans.

AIMS

We aimed to develop a generic knowledge base with drug administration recommendations which allows the generation of a dynamic and comprehensive medication plan and to evaluate its comprehensibility and potential benefit in a qualitative pilot study with patients and physicians.

METHODS

Based on a literature search and previously published medication plans, a prototype was developed and iteratively refined through qualitative evaluation (interviews with patients and focus group discussions with physicians). To develop the recommendations for safe administration of specific drugs we screened the summary of product characteristics (SmPC) of different exemplary brands, allocated the generated advice to groups with brands potentially requiring the same advice, and reviewed these allocations regarding applicability and appropriateness of the recommendations.

RESULTS

For the recommendations, 411 SmPCs of 140 different active ingredients including all available galenic formulations, routes of administrations except infusions, and administration devices were screened. Finally, 515 distinct administration recommendations were included in the database. In 926 different generic groups, 29 879 allocations of brands to general advice, food advice, indications, step-by-step instructions, or combinations thereof were made. Thereby, 27 216 of the preselected allocations (91.1%) were confirmed as appropriate. In total, one third of the German drug market was labelled with information.

CONCLUSIONS

Generic grouping of brands according to their active ingredient and other drug characteristics and allocation of standardized administration recommendations is feasible for a large drug market and can be integrated in a medication plan.

Introduction

One-third of medication errors leading to avoidable adverse drug events (ADEs) occur during drug administration [1] and are often caused by knowledge and handling deficits [2]. Administration errors occur during hospitalization [2], long term care [3] and frequently in ambulatory care [4, 5]. In the inpatient setting, nurses usually administer the drugs. However, in ambulatory care, drug application is mostly accomplished by the patient himself [6]. Accordingly, patients' lack of knowledge may impair the safety of drug therapy [6–12] and information deficits are indeed associated with adverse health outcomes including ADEs, increased morbidity, mortality and additional health care costs [5, 7, 8, 10–16].

Fast and efficient exchange of relevant information is a critical prerequisite for effective prevention of administration errors [14]. This is particularly relevant at interfaces of care such as hospital discharge where most changes in medication regimens occur and patients will have to become familiar with new drug application routines [17–20]. Communication between health care professionals and patients is therefore needed to ensure the continuity of care and minimize potential risks in pharmacotherapy [21, 22]. Depending on the number of drugs taken, complexity of drug handling and the patient's skills and dexterity, the amount of required information can largely vary [23]. Moreover, the way of information exchange should be tailored to the patients' needs to be effective [24–26]. Hence, any verbal education should be accompanied by written instructions [21, 25, 27, 28] to enhance recall [29, 30], which is particularly effective when written in an easy and comprehensible language [4, 6, 7, 9, 12, 23, 25, 31–33]. Adding pictograms to written instructions or a pictorial supplement to verbal information may additionally facilitate understanding [8–12, 15, 31, 33, 34] and recall [29, 35] of medication instructions. However, health care professionals and patients often understand icons differently and therefore comprehension of pictograms should be tested in the target patient population before routine use [6, 9, 15, 30, 31, 35].

Consequently, standardization and categorization of instructions appears to improve knowledge, recall and satisfaction of patients [23, 27, 29, 32]. However, in Germany and elsewhere, at interfaces of care, physicians often instruct their patients in a non-standardized way and most often rely on verbal information. Routine care at discharge has to be fast and often happens in a fragmentary way due to time constraints during clinical routine [36]. Additionally, because of a wide range of different routes of administration, packages, galenic formulations, application devices and distinct technical administration advice [4], physicians rarely have all important information regarding correct drug application to hand [37].

Up to now there is no common way to provide categorized and standardized instructions for patients that covers their individual medication regimen regardless of galenic formulations, route of administration and application devices. The use of a medication plan allows for integration of such information. This might be particularly promising if the medication plan is linked to the inpatient electronic prescribing system, thereby offering the chance to provide every patient with a personalized, yet standardized medication plan at discharge.

This study aimed to develop a generic knowledge base with comprehensible drug administration recommendations that readily allows for the generation of a comprehensive medication plan for patients. A qualitative study was performed with patients and physicians to evaluate comprehensibility and potential benefit of such an individualized medication plan.

Methods

Study site
The medication plan and administration recommendations were developed and evaluated at the University Hospital of Heidelberg after approval by the responsible ethics committee of the Medical Faculty of the University of Heidelberg.

Development of a medication plan layout and requested content
Pubmed was searched for publications on the provision of medication instructions for patients, especially at hospital discharge, and information included in medication plans. Search terms used for publications on medication instructions were 'discharge', 'patient education as topic', 'communication', 'comprehension', 'drug information', 'medication' and 'knowledge'. Search terms for publications on medication plans were 'medication plan', 'medication instructions', 'drug information', 'drug instructions', 'medication information', 'medication schedule', 'drug card', 'medication card', 'patient information leaflet', 'medication regimen', 'patients' and 'medication'. Furthermore, different layouts of medication plans currently in use at other hospitals or suggested by interdisciplinary organizations such as the German 'Aktionsbündnis Patientensicherheit e.V.' [38] were analyzed. A first draft of the medication plan was set up that contained information on drug name, brand name, dosage form, dose, indication, dosage schedule and administration recommendations using eight frequently prescribed drugs at the University Hospital Heidelberg with specific instructions on administration and handling (see Table 1). Moreover, already at this point, content and layout was designed to facilitate future automatic generation in an electronic prescribing system. The medication plan was qualitatively evaluated in patients (30 min interviews) and physicians (focus group discussions). To test the comprehensibility of the medication plan patients were asked explicit questions related to the content. Interviews

Table 1

List of medications with dosage form used for the first draft of the medication plan

Agent name	Dosage form
Amoxicillin	Powder for a suspension for oral use
Beclometasone dipropionate, formoterol	Metered-dose inhaler
Brinzolamide, timolol	Eye drops
Enoxaparin	Pre-filled syringe
Fentanyl	Patches
Metoclopramide	Drops
Pantoprazole	Tablet
Ramipril	Tablet

were conducted and recorded by two pharmacists after obtaining informed consent of all participants. All interviews were fully transcribed and the accuracy of each transcript was assessed by a second reviewer. A qualitative analysis of content according to Mayring was conducted [39]. Adaptation of the medication plan according to their comments and suggestions revealed the final layout of the medication plan and its contents.

Development of specific and semi-automatically generated administration recommendations

Specific administration recommendations were developed for the 140 most frequently prescribed active ingredients within our electronic prescription platform for outpatients and patients at discharge. Actual drug prescription is usually performed by drug brands, and hence, the 140 active ingredients covered >75% of all prescribed drugs. For these, all available galenic formulations, routes of administration except infusions, and administration devices were included.

Administration recommendations were categorized as (i) advice (i.e. 'Shake well before use') or (ii) step-by-step instruction (i.e. 'How to use a turbohaler'). Step-by-step instructions referred to a complex sequence of actions such as the preparation of oral suspensions or the use of inhalers and were written as a separate instruction that was added to the medication plan as an optional appendix. Each advice was written as a clear statement not exceeding 130 characters to allow smooth integration into the layout of the medication plan (using a font size of 10 points). Each advice was allocated to one of the following information classes: (i) time of food intake, (ii) stability of the drug, (iii) storage of the drug, (iv) handling of the drug before, (v) during and (vi) directly after administration and (vii) handling of the drug during the whole therapy. Additionally, indications in a language understandable for patients were defined. The wording of each advice or indication was developed in a three step process:

1 Analysis of the summary of product characteristics (SmPC) of the originator brand whenever possible (e.g. of a specific active ingredient, galenic formulation and route of administration) to extract administration recommendations and indications.

2 Generic grouping of all brands that potentially required the same advice or step-by-step instruction. For the generic grouping all drug characteristics (anchors) listed in Table 2 or combinations of them with the possibility to include and exclude a specific characteristic were employed. The characteristics were either provided by MMI (Medizinische Medien Informations GmbH, Neu-Isenburg, Germany; e.g. ATC code and active ingredient) [40], allocated to each brand according to a previously specified local knowledge base (e.g. route of administration, drug release, basic form of presentation, mode of administration, basic form of administration, administration device, site of administration and container) [41], or could be extracted from the individual medication regimen (e.g. dosage schedule and drug dose) in the electronic prescribing system. If an advice was very generic like the advice to dissolve effervescent tablets before use, brands with an active ingredient not included in the initial list of the top 140 active ingredients could also be labelled because then only the anchor of 'effervescent tablet' irrespective of the active ingredient would be used. Obviously, one brand could be included in several groups, depending on the applicable administration recommendations.

3 Verification of applicability of the assigned administration recommendations. Correct allocation was verified in each SmPC and differences between allocation and SmPC information were documented. In that case, new (sub-)groups were generated (i.e. stability of the same active ingredient in a comparable dosage form was indicated differently in distinct brands). This step was intended to be performed only once for the first evaluation of feasibility to assess the positive predictive value of step 2 and should not be necessary for future updates of the knowledge base.

All administration recommendations were entered via an electronic tool, reviewed and double-checked. Moreover, all recommendations but not indications were partially enhanced with pictograms to improve comprehensibility and recall.

Results

Qualitative evaluation of the medication plan

Study population Six patients from three different clinics of the hospital were included in the qualitative evaluation (54.7 years, range 31–69 years). The interviews lasted on average 29 min (range 16–45 min). In the 40 min focus

Table 2

Specifications (anchors) of drug brands used to generate a generic group of brands and to link administration recommendations

Anchor	Example	Example drug
Route of administration	Per oral	Amoxicillin tablet
Drug release	Extended release	Budesonide extended-release capsule
Basic form of presentation	Powder	Cefuroxime powder
Mode of administration	To be swallowed	Betamethasone solution
Basic form of administration	Suspension	Ibuprofen suspension
Administration device	Metered-dose inhaler	Salbutamol metered-dose inhaler
Site of administration	Administration on the eye	Aciclovir eye salve
Container	Pre-filled syringe	Insulin pre-filled syringe
ATC code	R03AC02	Salbutamol
Active ingredient	Dipyrone	Dipyrone drops
Dosage schedule	Twice daily	Clonidine tablet
Drug dose	70 mg	Alendronic acid tablet

group discussion three physicians with at least 1 year of professional experience participated (two females).

Comprehensibility and potential use of the medication plan All participants approved the layout of the plan as clear and straightforward and almost all participants indicated that they understood the texts of the recommendations (six patients and two physicians) and terms (i.e. 'high blood pressure' as indication; five patients, three physicians). Questions related to the content of the medication plan were mainly answered correctly by the patients and *vice versa*, all physicians valued the medication plan as comprehensible for patients. Almost all participants (five patients, three physicians) agreed that patients would benefit from this medication plan. However, in response to the comments of the patients the final layout and content of the medication plan was adapted. A separate column specifying food restrictions and information about drug storage was added, the separate column for drug strength was removed and the strength was located next to the drug name and the dose unit next to the dose value (Figure 1).

Generation of administration recommendations

Considering that each of the top 140 active ingredients might be marketed in different dosage forms and different routes of application, 411 SmPCs were initially screened leading to 205 different administration recommendations (153 texts for general advice, 24 for food advice, and 28 step-by-step instructions) and 102 indications (step 1).

Based on this screening, all brands containing at least one of the 140 active ingredients were firstly assigned to 857 different generic groups, of which 264 groups (30.8%) contained general advice, 304 (35.5%) food advice, 261 (30.5%) indications and 28 (3.3%) step-by-step instructions (step 2). Step 2 allocated 29 879 brands to one or more generic groups according to their drug specifications (one

brand could be allocated to several groups, Table 2). The SmPCs of all brands that potentially met the criteria of a group were checked for correct allocation (step 3). Thereby, several issues became evident: (i) the initial grouping was not specific enough and creation of further groups (i.e. because food advice differed between some brands with the same active ingredient) or additional anchors were necessary (i.e. because food advice for the same active ingredient differed due to different drug release mechanisms); (ii) some of the administration recommendations generated during the initial screening were not transferable to all brands and thus additional recommendations were phrased (i.e. to give instructions for patients with difficulties in swallowing or if shelf life differed between brands); (iii) some groups could be combined so that different active ingredients with the same advice became one group (i.e. 'Shake well before use' or 'Dissolve in one glass of water before use'); finally, (iv) a group for general advice could also contain food advice further reducing existing groups. Hence, in the end, 926 different generic groups containing general advice [394 groups (+49.2%)], food advice [253 groups (−16.8%)], step-by-step instructions [33 groups (+17.9%)], indications [237 groups (−9.2%)], or combinations of those (nine groups (all new)) were defined. Thereby, 355 distinct administration recommendations (+73.2%) were included in the database of which 280 gave general advice, 42 food advice, 33 represented step-by-step instructions and 160 were indications (+56.9%) (Figure 2).

The verification of each distinct SmPC (step 3) confirmed 27 216 of the preselected allocations (91.1%) as appropriate. Reasons for not including a preselection in a group were (i) unavailable SmPC (762, 28.6%), (ii) missing statement in the SmPC (1177, 44.2%), (iii) incorrect preselection (178, 6.5%) and (iv) redundant labelling because the brand was already included in another group with the same advice (546, 20.7%). Thereby, reasons and number of excluded preselected allocations in a group differed with
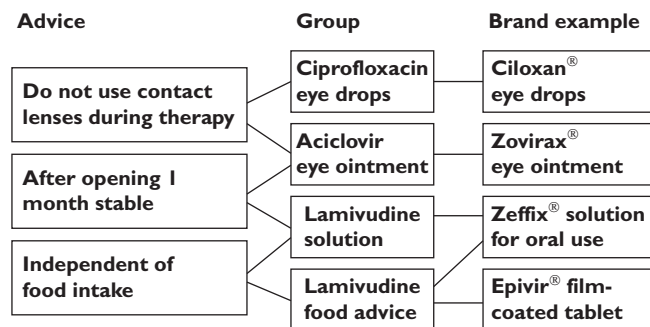
Medication plan

University Hospital Heidelberg

For: John Doe, born on 01.01.1980

Heidelberg, 22.03.12

Active ingredient with strength Brand example	Reason for administration	Morning	Noon	Evening	Night	Before/with/after food	Administration recommendations
Amoxicillin (50 mg/ml) e.g. *AmoxiHEXAL® Saft, 250 mg/5 ml Pulver z. Herstell. e. Suspens. z. Einnehmen*	Bacterial infection	**20 ml**	**20 ml**	**20 ml**	**0**	Independent	• Shake well before use • Take every 8 hour • Suspension is stable for 14 days 🕐 See appendix
			Intake till 26.03.12				
Enoxaparin (2000 IE) e.g. *Clexane® 20 mg 0.2ml Fertigspritze*	Thrombosis prophylaxis	**1 Syringe**	**0**	**0**	**0**	Independent	🕐 See appendix
Beclometasone (100 μg), Formoterol (6 μg) e.g. *INUVAIR® 100/6 Mikrogramm Druckgasinhalation, Lösung*	Asthma	**1 Puff**	**0**	**1 Puff**	**0**	Before food	• After inspiration: Rinse out the mouth, brush teeth, or eat something • Use within 5 months 🕐 See appendix
Brinzolamide (10 mg/ml), Timolol (5 mg/ml) e.g. *AZARGA® 10 mg/ml + 5 mg/ml Augentropfensuspension*	Glaucoma	**1 Drop**	**0**	**1 Drop**	**0**	Independent	• Shake well before use • Insert soft contact lenses earliest 15 min after administration • 4 weeks stable after first use 🕐 See appendix
Fentanyl (8.4 mg) e.g. *Durogesic® SMAT 50 μg/h, transdermales Pflaster*	Pain	**-**	**-**	**-**	**-**	Independent	• Avoid exposition of pathces to direct sunlight/heat 🕐 See appendix
			Change patch every 3 days				
Pantoprazole (40 mg) e.g. *Pantozol® 40 mg, magensaftres.Tbl.*	Reduction of stomach acid	**0**	**1 Tablet**	**0**	**0**	1 h before food	• Do no split, crush, or chew the tablet
Ramipril (5 mg) e.g. *Delix® 5 mgTbl.*	High blood pressure	**1/2 Tablet**	**0**	**1/2 Tablet**	**0**	Independent	
Metoclopramide (4 mg/ml) e.g. *Paspertin® Tropf.*	Nausea	**-**	**-**	**-**	**-**	Before food	• Hold bottle vertically during use • 6 months stable after first use 🕐 See appendix
		In case of nausea take 30 drops Do not take above 120 drops daily!					

Figure 1

Final version of the medication plan with integrated administration recommendations of the listed drugs

respect to group type. From all preselected indications, 98.4% (9960) were correct. The most frequent reasons for exclusion were a missing SmPC (72.0%) and potential redundant labelling (26.8%). Only 1.3% (two brands) were incorrectly preselected, of which one had a false ATC code (anchor) allocated and the other was an infusion. In groups containing food advice 90.2% (7025) were correct. The majority (59.3%) of rejected preselections were already labelled in other groups. In 39.3% of the remaining cases the SmPC was unavailable and 1.4% (11 brands) had no statement in their SmPC regarding food intake. While generally the absence of such a statement in the SmPC would be labelled as independent of food intake, the 11 brands mentioned above are known to be taken before food and therefore no advice was given. Allocations giving general advice were correct in 81.1% (7504) cases. In most of the remaining cases preselected allocations were not included because of missing statements in the SmPC (66.8%), unavailable SmPC (20.1%) or incorrect preselection (9.8%).

Only 3.3% were already labelled in other groups. In total, 692 preselections were rejected because of missing SmPCs. Hence, if rejected preselections due to missing SmPCs and correct preselection rejected because they were already labelled in other groups were not considered, step 3 confirmed 95.0% of the preselected allocations as appropriate.

For the grouping of brands, anchors were used in different numbers and combinations. Grouping for general advice statements most often used the active ingredient ($n = 385$ groups, 97.7%) and the basic form of administration ($n = 128$ groups, 32.5%) whereas the most frequent anchors for food advice were active ingredient ($n = 253$ groups; 100.0%) and route of administration ($n = 188$ groups, 74.3%). For indications ATC code was the only anchor used. From all allocated brands, 14 330 (52.7%) were linked to one anchor, 10 453 (38.4%) used two, 2109 (7.7%) three and 324 (1.2%) required four anchors (Table 3). In general, one group contained a median of seven brands (25% quartile = 2, 75% quartile = 7) with a large range between 1–1479 brands and 1.2 ± 0.7 administration recommendations (range 1–8, Table 4) per group.

Overall, 98 different pictograms were developed to illustrate administration recommendations. Because pictograms could be used in more than one group, overall 147 groups (15.9%) were complemented with at least one pictogram, of which 28 groups (19.0%) contained general advice, 107 (72.8%) food advice and 12 (8.2%) step-by-step instructions. Step-by-step instructions (36.4% with pictograms) were most richly illustrated containing on average 4.5 ± 1.4 pictograms (range 2–6 pictograms) to illustrate the often complex sequence of actions.

In total, 12 595 drug brands were labelled with at least one administration recommendation or indication (of roughly 34 000 brands available on the German drug

Figure 2

Examples illustrating how recommendations, groups and brands were linked in the database

Table 3

Number of anchors required to establish groups for semi-automated allocation of recommendations for proper administration of brands

Group type	Required anchors (n)	Groups (n)	Preselected allocations (n)	Confirmed allocations (n)	%
General advice	1	76	3 089	2 966	39.5
	2	209	4 377	3 430	45.7
	3	106	1 650	1 046	13.9
	4	12	133	62	0.8
					99.9*
Food advice	1	43	1 028	946	13.5
	2	169	5 931	5 279	75.1
	3	35	560	538	7.7
	4	6	267	262	3.7
					100.0
Indications	1	237	10 117	9 960	100.0
					100.0
Step-by-step instructions	1	17	458	458	16.8
	2	11	1 744	1 744	64.0
	3	5	525	525	19.3
					100.1*

*Deviation from 100.0% due to rounding.

Table 4

Average quantity and range of confirmed allocated brands and integrated administration recommendations per group

Group type	Average quantity of brands (n)	Range of brands (n)	Average quantity of administration recommendations (n ± SD)	Range of administration recommendations (n)
General advice	19	1–596	1.1 ± 0.4	1–4
Food advice	28	1–479	1.0 ± 0.0	1
Indications	42	1–1479	1.7 ± 1.1	1–8
Step-by-step instructions	94	1–959	1.0 ± 0.0	1

market). Brands had information about indications most often (n = 9745), followed by food advice (n = 7053), general advice (n = 5264) and step-by-step instructions (n = 2727). Not every brand was labelled with each class of advice or an indication. Indications were allocated only to brands containing at least one of the 140 selected active ingredients and food advice only to brands, which are administered orally or where food is an issue (i.e. insulin). Step-by-step instructions and general advice were allocated to dosage forms that needed specific additional recommendations or a detailed drug administration instruction.

Discussion

Patient discharge from hospital is generally a hectic process that frequently fails to provide patients with sufficient information and often leaves them unsatisfied with their knowledge on future drug treatment [4, 13, 18, 23, 36]. Moreover, the communication is mostly verbal, although enrichment of drug information with texts and pictures would substantially increase recall [8–12, 15, 21, 25, 27–31, 33–35]. However, such a time-consuming, standardized, and comprehensive approach is difficult to implement in the current setting without electronic support.

Hence, one intriguing option is to issue a written medication plan tailored to the needs of the individual patient. Currently such plans usually contain only the drug name, strength, dosage and, if at all, free text information on drug administration. This study describes the development and proof-of-concept evaluation of a knowledge base that uses generic linkage of administration recommendations to groups of drugs and thereby automatically selects the appropriate advice for an individualized medication plan from a standardized pool of administration recommendations. Based on the 140 most frequently prescribed active ingredients, 355 different administration recommendations and 160 indications were defined and allocated to 12 595 brands covering about one third of the rather large German drug market. Thereby, the generic approach enables an easy update process of the database. Fluctuation in the drug market is large and in Germany every month roughly 300 brands are added to the drug market.

Most of them are generics that contain active ingredients that are already available on the market. The high rate of correct preselection (95.0% without taking unavailable SmPCs and already labelled brands into consideration) suggests that the existing recommendations can easily be transferred to new brands with the same ingredients and comparable drug characteristics. Furthermore an extension of the administration recommendations to new texts is easily feasible thus increasing transferability to further brands containing other active ingredients. In addition, standardized texts will allow future developments like automatic translation into other languages which enables physicians to inform patients even when they do not speak the same language.

The process of verification of the preselected allocations (step 3) was very efficient as >90% of the automatic allocations were appropriate. Reasons and number of inappropriately preselected allocations differed between groups. While almost all preselections in groups containing indications (98.4%) were appropriate, the ratio was smaller in groups containing food advice (90.2%) or general advice (81.1%). The major part (59.3%) of rejected preselections for food advice was correct albeit already labelled in other groups. This depended mostly on preparations containing combinations of two or more of the 140 active ingredients included in this study. In groups with general advice statements, preselected allocations were most often not included because of an inaccurate preselection (66.8% missing statements in the SmPC and 9.8% incorrect preselection). This relatively high ratio is due to the fact that information displayed in SmPCs of comparable drugs is often not harmonized and sometimes even contradictory [42–44]. Hence, harmonization and machine-readable structuring of SmPCs would also stimulate the generation of patient information [45]. General advice like cleaning instructions of inhalers or general instructions after administration of a drug (i.e. hand washing) are mentioned only sporadically in SmPCs. Moreover, some actions are brand-related and only included in the label of some drugs, such as the allowance to open a capsule when swallowing is difficult. Hence, for some aspects, brand-related labelling is required if displayed information is intended to be in-label information. Therefore quality assurance measures of an automated allocation process should particularly focus on

combination products and appropriateness of general advice covering brand-related statements.

This work has several limitations. A prerequisite for generic grouping is detailed information on the brands that is not provided in commercially available databases. For example, from the 926 different generated groups only 327 (35.3%) can be built using information from commercially available databases (in our case MMI [40]). While it is possible to allocate 100% of the indications with the provided characterization, the provided information in these databases enables the allocation of only 13.5% of the general advice statements, 14.6% of those related to food intake and none of the step-by-step instructions. For the development of the database and the tool only a small fraction of drugs ($n = 140$) was considered, but it was enough to cover one third of the entire German drug market and is thus likely sizeable enough for a prospective evaluation of its impact on patients' satisfaction, adherence, safety or even clinical end points. However, to include also recommendation advice for specific drugs that are frequently prescribed in patient populations that were not in the focus of this trial, the database will be continuously enlarged and updated to achieve nearly full coverage of the German drug market. Because drug administration is a key element of safe drug treatment it would also be worth to discuss whether information should be structured during drug authorization to be readily available in a computer readable format when the drug enters the market [45]. The qualitative assessment of the plan included only very few patients and physicians. However, the qualitative assessment in this project was conducted as a preliminary pilot study to gather information on a suitable layout of the medication plan during the development process to confirm the validity of the general approach. In a second step, the plan will now be thoroughly assessed in a prospective study assessing acceptance, potential benefit and areas for improvement in a large patient population.

In conclusion, generic grouping of brands according to their drug characteristics and semi-automated allocation of standardized administration recommendations is feasible for a large drug market and yields patient-specific information on drug administration that can be integrated in a printable medication plan. It has thus the potential to facilitate easy and rapid information for patients concerning drug administration and might be an essential basis for enabling secure administration of the prescribed drugs.

Competing Interests

All authors have completed the Unified Competing Interest form at http://www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare no support from any organization for the submitted work, no financial relationships with any organizations that might have an interest in the submitted work in the previous 3 years and no other relationships or activities that could appear to have influenced the submitted work.

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