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Editorial

Medication safety through e-health technology: can we close the gaps?

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E-health technology is promoted as one of the most promising steps towards safer drug treatment. E-health solutions offer a platform for standardization and information exchange across institutions and interfaces of care, facilitate in-process controls and double checking, help to (re)structure processes and support the health care professionals during their work.

Since the late 1990s, e-health solutions for medication safety have evolved rapidly. However, a considerable fraction of evidence for these e-health solutions was gathered in only few sites in the US [1] that performed accompanying research. In Europe, research sites with a particular emphasis on medication safety are widely scattered. Hence, research collaborations across Europe may enhance knowledge exchange, bundle resources and offer the opportunity to multiply the impact of a single site. One such research co-operation was established in 2010 with a particular emphasis on medication safety and health-IT. Currently over 20 researchers from 15 institutions throughout Germany, Switzerland, and Austria exchange ideas in semi-annual meetings and organize research collaborations and scientific exchange (http://iig.umit.at/amts). The current members of the group have varying backgrounds including occupational science, bioinformatics, medical informatics, mechanical engineering, pharmacy and medicine. This colorful mix of expertise inspires joint collaborations to identify and tackle the open gaps in research on medication safety and e-health technology while the group is open for new members and interested research partners. This supplement is intended to give an overview on the groups' research focus and current 'hot topics'. Moreover, we present one strategy to foster and coordinate nation-wide research projects by developing and implementing a research memorandum that enables a focused funding of related research projects (Aly *et al*., page 1).

Medication safety is closely linked to the well-organized orderly flow of distinct events which determine the drug treatment process. This process consists of up to eleven consecutive sub-steps that ultimately determine both the desired drug effect and also adverse outcomes. Hence, a diagnosis (1) might entail a prescription of a drug (2) that has to be delivered (3) and about which the person in charge has to be informed (4) and motivated to be adherent (5). Only then the administration (6) can be carried out correctly in order to allow for appropriate pharmaceutical (7), pharmacokinetic (8) and pharmacodynamic (9) processes. The sum of these processes will finally yield the desired therapeutic effect (10), which however should be monitored (11) in order to guide subsequent treatment decisions and to detect adverse events and the frequent case of nonresponse. Hence, the treatment process is organized as a chain of consecutive events which is only as strong as its weakest link.

If any of these steps is carried out inappropriately or wrongly, the risk for adverse drug events increases and desired drug effects may vanish. In the early 1990s, the drug prescription process was identified as particularly error-prone in hospitals, and over 50% of adverse drug events have been attributed to prescription errors [2]. Since those days computerization of the drug treatment process has been a major recommendation in order to structure, standardize and guide the diverse tasks during drug treatment, and ultimately increase medication safety. Thereby, the first and most prominent advice was and still is the implementation of computerized physician order entry (CPOE) systems [3, 4].

Many studies reported potential benefits of the CPOE system and discussed potential pitfalls. Indeed, the implementation of CPOE is generally viewed essential although challenges are still considerable and beneficial effects on relevant clinical endpoints have only rarely been shown [5, 6]. One major challenge of CPOE systems is the insufficient reduction of medication errors [7]. Thereby errors that are unrelated to order structure or standardization, but result

from a lack of information or knowledge of the prescriber, are likely to persist despite electronic prescribing [8]. Hence, the implementation of a CPOE with decision-support that supports and potentially guides the user while prescribing drugs proved to be a major step forward in error prevention. These systems, however, tend to inundate the user with unsolicited information and advice not adjusted to the situation. Hence, a new disease was coined: alert-fatigue, i.e. the tiredness of physicians towards myriads of irrelevant warnings and advices that ultimately result in alert ignorance and potentially nonobservance of important information [9]. Therefore, a major challenge today's systems are facing is the need for optimization of both knowledge content and knowledge presentation.

Among the most decisive factors for the success of electronic interventions is the systems' integration in the health care setting [5]. In this setting the treatment process is usually embedded in a dense network of other processes that may be conflicting, distracting, deferring and hectic, and thus add to the complexity of health services in a given institution. Therefore, new ways of thoughtful structuring of the overall workflow and setting are crucial. In this supplement Podtschaske and co-workers (page 5) apply for the first time the theory of the medico-ergonomic six-layer model to the drug treatment process and thereby design an integrated therapy safety management system that offers a high resilience, i.e. ability to adjust for changes and disturbances. Patapovas and co-workers describe how a CDS system can be integrated in the hectic environment of an emergency department using a step-wise approach that enables a gradual access to more comprehensive information. Hence, the user himself will decide whether passive information or tooltip alerting for high risk medication is sufficient, or whether further access to structured information on drug interactions or even encyclopedic drug information is needed. Hence, this system enables the user to titrate the individual amount of decision support he considers necessary and most useful for the actual situation (page 14).

Besides drug prescription the process of drug administration proved to be particularly error-prone. Thereby, many e-health solutions that aim at preventing administration errors most often focus on process-related issues, e.g. wrong-time or wrong-patient errors and hence include documentation software such as barcode-assisted or closed-loop electronic medication records [10, 11]. However, also the administration process itself may become limiting and therefore need careful consideration (page 25). Thus far, only few systems have been implemented to prevent particular errors during application itself – a scope for future developments. Many studies on administration errors have been performed in the hospital setting, where about one in three medication errors resulting in adverse drug events occurred during the drug administration step [2]. However, this ratio might be even higher in ambulatory care with drug administration being a task for patients and family carers, i.e. lay people with less experience and knowledge than trained health care professionals [12]. The first step to correct drug administration is information on the treatment regimen. This information is frequently provided on a paper medication plan which, however, often lacks detailed information on drug administration [13, 14]. Send and co-workers describe the successful approach of development of a large database containing drug administration advices that can be linked to an individualized medication plan in an electronic prescribing system and printed out for the patient. Their methodology of grouping brands according to, for example, their galenic properties and generic attribution of standardized advices might allow for covering large drug markets (page 37).

Accidental non-adherence of patients is often linked with forgotten drug intake [15]. Over the last years many automated reminders have been developed that may alert the patient when a drug should be taken [15, 16]. However, these reminders are not linked to the actual drug intake and similar to classical CDS systems, they may tend to over-alerting and poorer response rates than more sophisticated approaches [17, 18]. Brath and co-workers now describe in their work the introduction and evaluation of an e-blister-based alerting system to increase adherence. After drug removal from the e-blister, patients transmitted the information via a remote telemonitoring service to the physician. Hence, only if the drug was not removed or data were not transmitted, a reminder for drug intake or data transfer was issued. This approach could improve adherence for diabetes medication in elderly patient with cardiovascular diseases while being generally well accepted by the patients (page 47).

The last – and maybe again first – step in the circuit of drug treatment refers to treatment monitoring. Thereby both beneficial and adverse effect monitoring is important to assess the benefit-risk ratio of drug treatment in an individual patient. Thereby, many different definitions are applied on what actually an adverse drug event is (in comparison with an adverse drug reaction and a medication error), and indeed in observational trials ratios of reported adverse drug events vary largely. Bürkle and co-workers now suggest that such variation might not only be explained by different settings and patient populations but rather by the inherent complexity of the drug treatment process and the clinical case. This fact, however, is not captured by current concepts and definitions for adverse drug events. Because the number of adverse drug events is frequently used as an endpoint to compare the effectiveness of different approaches in improving medication safety, comparability of the measured outcomes is essential. The authors draw a distinct map of how medication errors (i.e. actions and decisions) may interfere with disease symptoms, adverse drug events,

and adverse drug reactions (as events) and outline complex situations that must be kept in mind when assessing adverse event rates in order to derive a new counting mechanism of adverse drug events (page 56). A common tool to detect adverse drug events is the analysis of patient charts or electronic health records – a laborious and time-consuming task, if it is done manually. Hence, many trigger tools have been developed (e.g. the Institute for Healthcare Improvement trigger tool [19]) that may alert prospectively or retrospectively if clinical notes in electronic health records suggest the occurrence of an adverse drug event (e.g. increased INR, prescription of antidotes). Neubert and co-workers present now the linkage of symptoms (i.e. abnormal lab values) with the potential adverse drug events and automatically check the list of prescribed drugs whether any of these drugs is known to cause such adverse drug events. Such linkage might guide and prospectively warn physicians of potential drug-related events (page 69). This approach might be taken even further, if frequently occurring adverse drug events in a particular setting are displayed to the people working in this surrounding in order to sensitize them for particular adverse drug events. Hackl and co-workers present the evaluation of so-called adverse drug event-scorecards in a hospital setting. These scorecards present automatically detected, department-specific cases of adverse drug events to physicians, nurses, and pharmacists. They report a positive feedback from the health care team that found the scorecards useful to increase patient safety (page 78).

Hence, improvement of medication safety is a complex responsibility of all professionals involved, and often combinations of different approaches and interventions are necessary to achieve a positive result. E-health solutions however may play an important role both at the level of distinct sub-steps of the drug treatment process. Moreover, they may bridge interfaces, facilitate communication between persons involved and may thus help standardizing and structuring the overall treatment process.

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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