# Patient-centred medication management: How to enhance patient safety and reduce the work burden for medical staff by digitalised closed-loop cabinets

Received (in revised form): 27th August, 2022


## Maximilian C. von Eiff

St. Josef Hospital, Clinic for Urology and Uro-Gynaecology, Germany


Dr med. Maximilian C. von Eiff, Assistant Physician Urology, studied human medicine at the University of Pécs Hungary (dr med in neurology) and completed a doctorate in orthopaedics and traumatology at the University of Leipzig, Germany. His main research areas are digitalisation in healthcare, health technology assessment, cost-benefit analyses of clinical processes and the impact of the healing environment approach on medical quality, patient outcome, length of stay and costs. Dr Maximilian completed a Six Sigma Training and worked on different studies aiming at process optimisation and quality improvement.


Richard-Wagner-Straße 7, 48165 Münster, Germany
Tel: +491701623478; E-mail: maximilian@voneiff.me



## Wilfried von Eiff

Center for Hospital Management, Germany


Univ.-Prof. Dr Wilfried von Eiff (Münster) is Professor of Health Care Management and Regulation at HHL Leipzig Graduate School of Management and Director of the Center for Hospital Management, a research institute linked to the University of Muenster (Germany). Both institutions are well known for their international and national research, consulting and government advisory activities in various fields of healthcare and hospital management as well as health service research. Dr Wilfried's research focuses on the international benchmarking of hospitals and healthcare systems. He holds two doctoral degrees, one from the faculty of medicine (University of Gießen) and the other from the faculty of business administration (University of Tübingen). In the clinical field he works as a member of the board of directors of Kerckhoff Clinic Heart and Lung Center, Bad Nauheim (Germany). Dr Wilfried chairs the special interest group on international best practices and process optimisation, an initiative of the EHMA European Health Management Association (Brussels). He was previously managing director and member of the board of the University Clinic of Giessen. He is co-editor of *International Best Practices in Health Care Management* (Emerald Books 2015) and *Boundaryless Hospital* (Springer 2016).


Center for Hospital Management, Brandhoveweg 104, D-48167 Münster, Germany
Tel: +49 174 3987132; E-mail: von.eiff@uni-muenster.de



## Mohamed Ghanem

Senior Consultant of Orthopaedic Surgery, Department for Orthopaedics, Traumatology and Plastic Surgery University Hospital Leipzig, Germany


Priv-Doz Dr med Mohamed Ghanem, MBA (Leipzig, Germany), is Senior Consultant of Orthopaedic Surgery in the Department for Orthopaedics, Traumatology and Plastic Surgery and Chairman of the Department of Physical Therapy and Rehabilitation, University Hospital Leipzig. Dr Mohamed graduated from the Medical School of Cairo University and went on to do his postgraduate studies and practice at the University hospital of Paris as well as at the University hospital of Leipzig. He completed his studies in business administration at the HHL Leipzig Graduate School of Management in 2010 and later continued his scientific contributions at the HHL Graduate School of Management as visiting lecturer for international healthcare management.


Clinic for Orthopaedics, Traumatology and Plastic Surgery, Liebigstraße 20, 04103 Leipzig, Germany
Tel: +493419723878; E-mail: mohamed.ghanem@medizin.uni-leipzig.de

**Abstract** Medication management is both an economic challenge and a patient safety issue. In German hospitals between 19 per cent and 35 per cent of all failures causing harm to patients are attributable to medication errors. As a consequence, an estimated 15,000 patients die each year. In addition, about 14 per cent of the average length of stay is assignable to unplanned drug interactions. Independent of patient risks, health impairments and outcome deficits, every non-fatal medication error leads to additional costs totalling €3,000 on average. Nurses, in particular, who typically suffer from work overload, are affected by error-prone medication logistics. Between 26 per cent and 44 per cent of all failures occurring in the medication administration process result from activities in which nurses are substantially involved. International best-in-class hospitals like the Mayo Clinic (Phoenix), Scripps (San Diego), OLVG (Amsterdam) and Guy's and St. Thomas' (London) have been using automated dispensing systems (smart cabinets) for medication safety reasons for many years. Moreover, in the USA, automated medication dispensing cabinets are ubiquitous in various types of hospitals and have an implementation rate of 89 per cent. But in German hospitals, this technology is still nowhere to be seen. In 2020, the German government, via legal act, decided that all hospitals must implement a closed-loop medication administration system in combination with a unit dose drug delivery by January 2025 in order to minimise medication errors. Otherwise, a penalty of 2 per cent of the total hospital revenue would have to be paid. Derived from best-practice reports in the literature, this paper explores the benefits of smart cabinets in terms of economic efficiency, patient safety, reduced work burden and employee acceptance. Furthermore, the reasons why many German hospital decision makers refuse to implement smart cabinets are presented and analysed. Finally, based on all this information, a generic medication administration process has been developed to provide a blueprint for a successful implementation of smart cabinets as an electronically based backbone in a closed-loop medication administration system.

KEYWORDS: adverse drug events, automated dispensing cabinets, closed-loop medication administration, medication errors, medication logistics, patient safety, smart cabinets

## INTRODUCTION

Reducing healthcare costs has become a crucial concern for hospitals as well as for health politicians and payers. Pharmaceuticals are identified as an important cost driver in all developed healthcare systems. In Germany the expenditure on drug-related therapies totalled €41 billion in 2019.[1] A second area that drives costs for hospitals relates to preventable adverse drug events (ADEs). In German hospitals, between 19 per cent and 35 per cent of all failures causing harm to patients are attributable to medication errors, causing an estimated 15,000 patients to die.[2] In addition, about 14 per cent of the average length of stay in German hospitals is attributable to unplanned drug interactions, and 6.5 per cent of all admissions to emergency departments are prompted by adverse drug reactions.[3] About 4.5 per cent of acute care patients are victims of an ADE,[4] and between 30 per cent and 55 per cent of these ADEs are considered avoidable.[5]

When admitted to hospital, 34 per cent of patients suffer from side effects of their drug therapy, only 29 per cent of which were classified as 'inevitable', the remaining 71 per cent being the consequence of medication errors.[6] Several studies have shown that drug-related hospitalisations account for

between 2.4 per cent and 6.2 per cent of all medical admissions.[7–9]

The consequences for patients range from nausea and vomiting to temporary health impairment, undergoing additional therapies and an extended length of stay, along with an increasing risk of nosocomial infection. In the worst case, the patient suffers sustainable health impairments or dies.

Independent of patient risks, health impairment and outcome deficits, every non-fatal medication error leads to additional costs averaging €3,000. Per case the LOS extension ranges from 1.7 and 8.5 days. This leads to opportunity costs in the form of lost contribution margins between €7,000 and €15,000, depending on the type of interventions (eg total knee arthroplasty, coronary artery bypass graft and transfemoral valve intervention).[10] The total costs of treatment necessitated by medication failures are estimated to range between €800 million and €1.2 billion per year in Germany.[11]

## CAUSES OF MEDICATION ERRORS: PRODUCT AND PROCESS COMPLEXITY

In Germany, more than 100,000 different drugs are approved, of which 56,000 are prescription drugs. Furthermore, 2,400 active ingredients and more than 6,600 known ingredient interactions make medication therapy a highly complicated and risky decision-making process.

Also, the entire medication process from drug anamnesis at admission until the drug therapy decision at discharge is a complex and highly collaborative workflow with many opportunities for failure: these include prescription errors made by the physician, improper storage, deficient monitoring of drug expiration dates, confusion of drugs, look-alike and sound-alike errors, wrong drug composition for the patient and failures relating to administering the drugs to the patient (see Figure 1). An important additional source of failure is an increasing work burden for physicians and nurses accompanied by time pressure and, as a consequence, growing stress levels.

Nurses, in particular, who typically suffer from work overload, are affected by error-prone medication logistics. Between 26 per cent and 44 per cent of all failures occurring in the medication administration process emerge through activities in which nurses are substantially involved.[12,13]

Even the nursing workload has increased significantly owing to a gradual economisation of health care: from 2005 to 2017, the number of treatment cases has grown by 12 per cent, while, at the same time, the number of beds decreased by 9.4 per cent and the length of stay shortened from 8.4 to 7.3 days. The accumulated nursing overtime in German hospitals alone is equivalent to 17,800 full-time employees.[14]

During the coronavirus crisis the working situation, especially for nurses facilitating patients ventilated on the intensive care unit, has deteriorated dramatically: additional overtime, high patient mortality, resource-intensive and stressful care requirements lead to prostration and mental exhaustion.

As a consequence of this tremendous work burden for nurses and physicians during the pandemic, up to 30 per cent of these occupational groups complained about inadequate working conditions and expressed their intention to quit their jobs.

The complaints were essentially about a lack of digitalised equipment that would contribute to a safer and more stress-resistant working environment.

In most of the German hospitals, a medication management organisation can be observed that is far removed from closed-loop safety requirements.[15]

- In 61 per cent of hospitals, the pharmacy delivers the necessary drugs in packets to the stock on the ward. From this stock, the nurse allocates the medication according to patient needs and physician prescriptions.

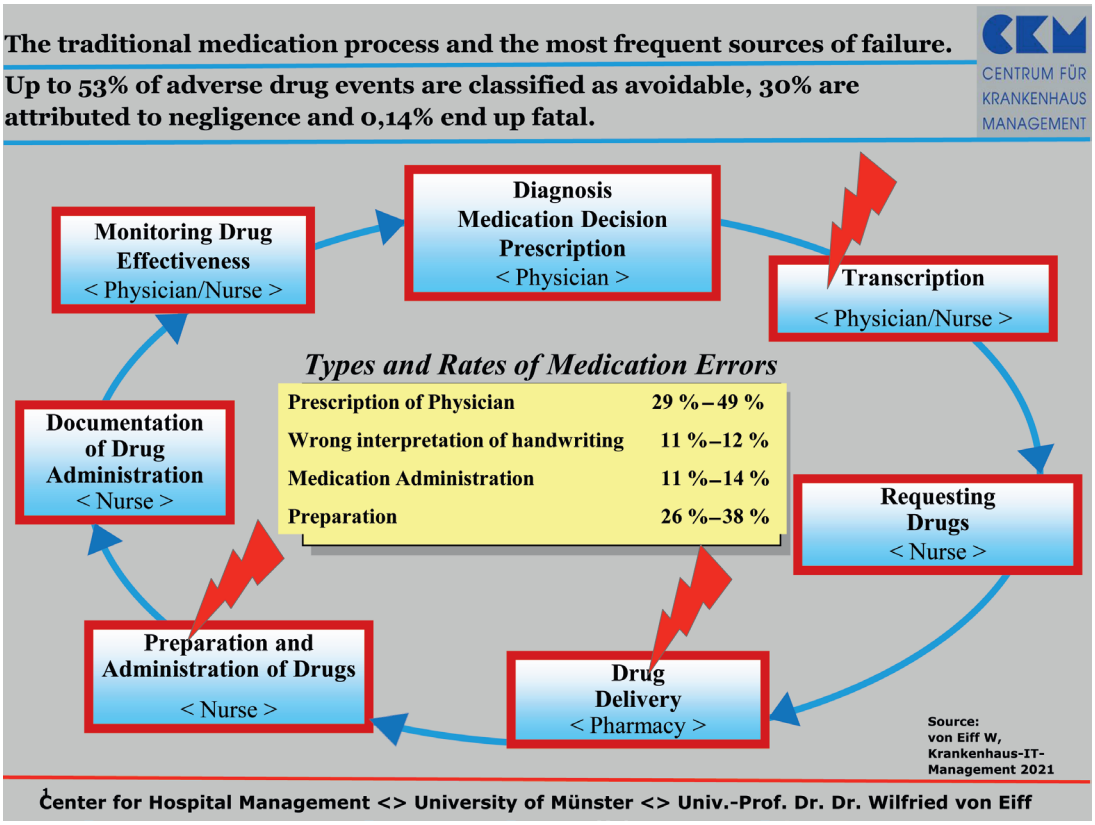


*Figure 1 Types and rates of medication errors in a non-digitalised working environment*
*Source:* Authors.

- The matching between patient and medication in 57 per cent of the hospitals is done via visual check by the nurse.

Based on experience, both work sequences are extremely prone to error.

In order to overcome these typical failure modes, the German government decided, in 2020, to oblige hospitals by legal regulation[16,17] to implement a closed-loop administration system for the complete medication management process, including a unit dose approach (see Figure 2).

A closed-loop system is a feedback controlled, robust and fail-safe, self-steering system. Barcodes or radio-frequency identification (RFID) transponders are used for patient-medication identification (match between right patient and right medication).

To put the closed-loop process in order, an electronic verification should be used to ascertain 'the six rights' (Figure 3). This is how many things should go right in order to ensure proper and safe medication treatment. Closed-loop medication means that the entire medication administration chain should be electronic, and at no point of the chain is data transferred via printed matter. All medication data is available to the people involved in the patient's treatment process, real-time at every stage of care, immediately available and electronically accessible. By doing so, information breaks are eliminated and errors minimised.

Unit dose attribution to the patient is basically for orally administered drugs. Therefore, the challenge for every medication administration logistic organised

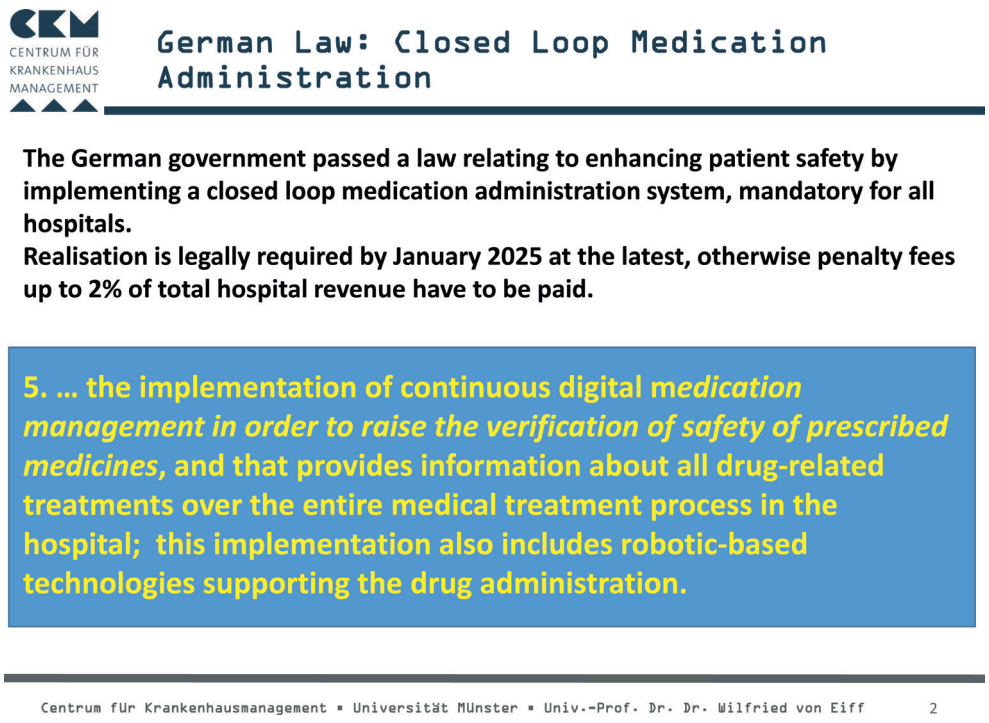


*Figure 2* *By legal order, German hospitals are obliged to implement a closed-loop medication system in combination with unit dose drug logistics*

*Source:* Authors.

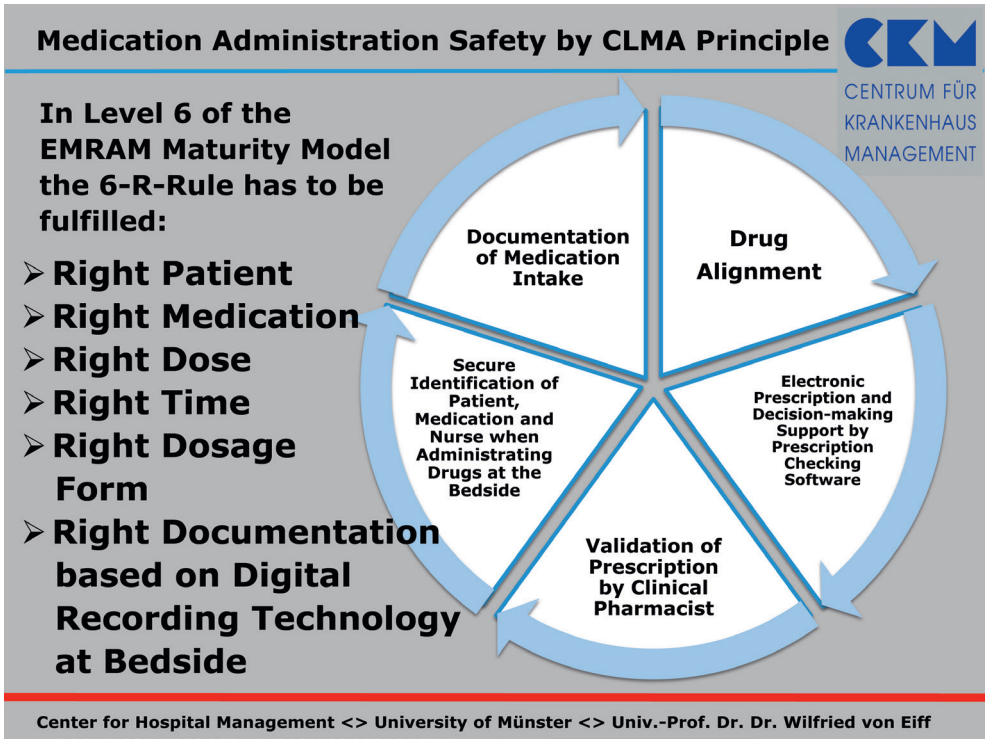


*Figure 3* *The 'Six Rights' ensure a safe and controlled medication administration process*

*Source:* Authors.

according to the principle 'closed-loop medication administration' is to cope with the following issues:

1. How to administer and organise the flow of >Prepared/Ready-to-Use Syringes, >Injectables, >Ampules and >Therapeutic Ointments.
2. How to integrate drugs that need to be stored in a fridge.
3. How to administer and organise the flow of medications the patient has brought along him/herself.
4. How is the therapeutic unit dose assembled and allocated to the patient, and is the 'last mile' (= preparation of the patient-individual therapeutic unit dose by the nurse until observed drug intake by the patient) organised in a 'poka-yoke' (= fail-safe) way?

In order to ensure proper medication treatment also under these conditions, ADCs are used as a backbone in a digitalised medication chain. The 'final product' of a closed-loop system is the 'therapeutic unit dose', an RFID-tagged tray containing the complete medication arrangement (oral drugs, injectables, ointments, etc) administered to a defined patient at a specific date. The different types of medication are assembled out of the smart cabinet by a nurse. This process of selection and withdrawal of the medication is controlled by so-called 'guided lights', which means, in effect, that only shelves containing medication dedicated to the specific patient can be opened. In combination with a medication test software, allergic reactions and wrong medication intake can be avoided.

From the logistical point of view, every withdrawal of medication from the smart cabinet initiates an end-to-end routine for checking the minimum stock, triggering stock replenishment and billing automatically without any intervention by a human being.

## THE GENERIC PROCESS MAP AND THE ROLE OF SMART CABINETS

In order to establish an integrated medication administration process meeting all requirements for a safe, efficient and effective drug delivery to the patient, including all different types of drugs and application forms, a 'generic process map' was developed by the authors (see Figure 4).

The generic process map explains the interdependencies between the medication logistics process and the medication administration process. This process map also demonstrates the pivotal role of a smart cabinet as an integrative element that controls the complete medication management oriented to patient safety, economic efficiency and medical effectiveness.

The realisation of a closed-loop system, in practice, requires the fulfilment of well-defined criteria and proven characteristics (see Figure 5). From the German point of view, the most important precondition for establishing safe and effective medication management is the role of the 'clinical pharmacist on the ward' as a consulting institution for the physician. But this basic requirement cannot be fulfilled because of a significant lack of pharmacists. While in US hospitals six pharmacists care for 100 beds and a 4:100 relation is realised in National Health Services (NHS) hospitals (UK), in German hospitals[18] this ratio is 0.3:100. There is evidence that the number of clinical pharmacists working cooperatively with the clinicians directly affects the incidence of ADEs.[19] Currently, in less than 50 per cent of German hospitals, clinical pharmacists on the ward are employed in order to contribute to a safer patient-centred medication administration process.[20]

## RESULTS

By analysing reports in the literature, the effects of electronic cabinets used as a

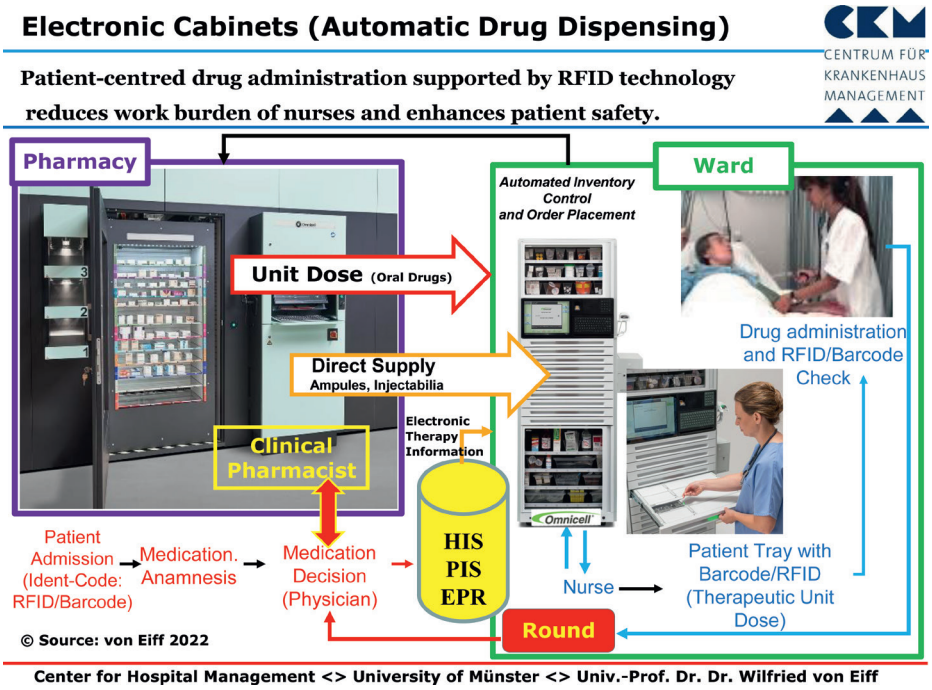


*Figure 4 Generic process map for a closed-loop medication administration in combination with unit dose delivery and a smart cabinet as digital backbone*

*Source:* Authors.

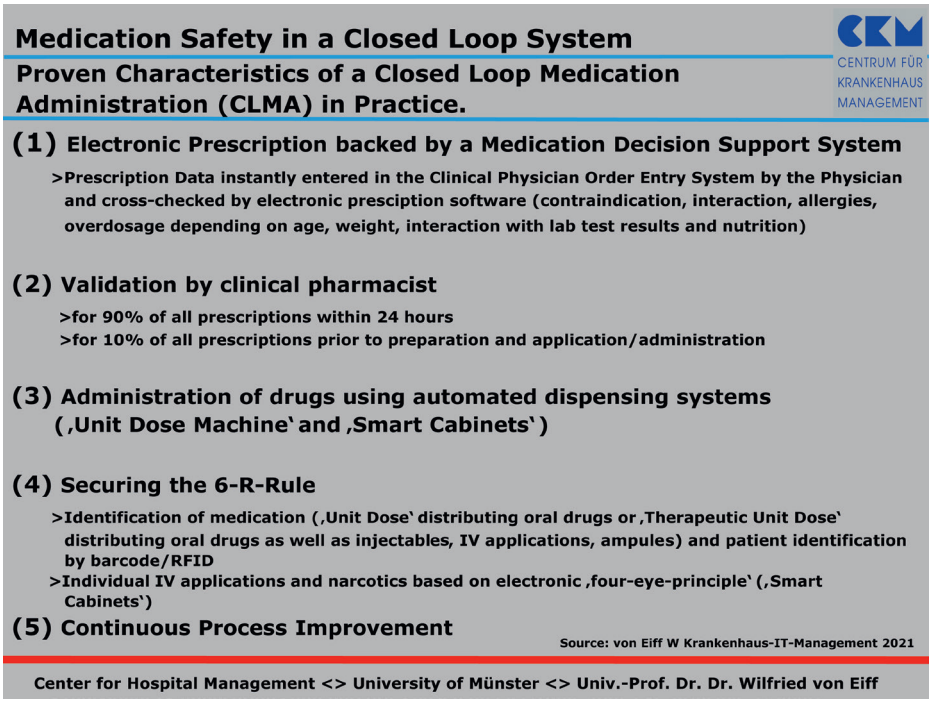


*Figure 5 Necessary preconditions that a closed-loop system has to fulfil in practice*

*Source:* Authors.

backbone of the medication administration process have been identified. In several case studies, electronic cabinets are evaluated to contribute successfully to significantly higher safety for patients in the context of drug therapy and to avoid drug failure-related opportunity costs caused by an extended length of stay, worsened patient outcome and additional therapy, all simultaneously.

The results are segmented into four areas of appraisal criteria.

1. **Employee acceptance and satisfaction with ADCs**

   Automated dispensing cabinets (ADCs) contribute to significant relief of nursing staff from all logistical tasks, and this effect is an important reason for the acceptance of a new and innovative technology that has the power to reorganise workflows and to change the way of cooperation between occupational groups. Furthermore, from the engineering sciences, we know that employee acceptance is a major precondition for an efficient and effective technology use in day-by-day work processes.[21]

   Most nurses favour the implementation of an automated dispensing system because of reduced overall medication errors related to picking, preparation and administration of drugs, especially in intensive care units.[22,23] Also, nurses report spending less time on medication-related activities, saving an average of 14.7 hours per day in a 33-bed ward.[24]

   About 80 per cent of nurses in an intensive care unit (ICU) and 42 per cent in the OR found that ADCs make their work easier, because the time spent on dispensing and preparing medications decreased on average by 32 minutes per 8-hour shift, making more time available for direct patient care activities.[25]

2. **ADCs' contributions to patient safety**

   Based on a before-and-after comparison between two intensive care units in a 2,000-bed university hospital, it was observed that after having implemented an automatic dispensing system on one ICU ward the percentage of total opportunities for error was reduced significantly from 20.4 per cent to 13.5 per cent.[26] A deeper analysis of specific opportunities for error showed a significant impact of ADCs in reducing preparation errors. Medication errors related to picking and drug administration were also reduced. Essentially, a decline in medical errors from 3.5 to 0.5 per 1,000 patients can be expected.[27]

3. **Efficiency, cost containment effects and return on investment**

   ADCs contribute significantly to reducing ADEs, thereby helping to avoid opportunity costs caused by an extended length of stay of 2.9 days on average.[28] The additional costs of a patient suffering from an ADE are tremendous and not reimbursed by the sickness funds (medical aid funds). The direct costs of treating the patient add up to between €1,500 and €2,700 per case. In addition, opportunity costs have to be reckoned with: a stay extension of 2.9 days means that 2 to 3 ADE patients cause a loss of revenue for at least one operating procedure with an average length of stay between 6 to 9 days. Focusing on interventions like total hip replacement, total knee arthroscopy or transapical valve intervention, a loss of contribution margins between €7,500 and €20,000 could be calculated.[29]

   Furthermore, ADCs reduce the cost of drug storage, mainly by avoiding expiration.[30] A comparison of drug stock and drug consumption on different internal medicine wards during one year yielded a reduction of 61 per cent when having an ADC in operation.[31,32] The same source reported that the costs of implementing one ADC (€61,000 in five years) could be paid off in 4.4 years. Bonnabry/Francois[33] report yearly cost savings of 0.2 full-time equivalents

(€21,000) per smart cabinet located in a 33-bed ward. Moreover, reduced drug use of 5 per cent of the medication budget was stated, and 1 per cent of the budget could be saved by avoiding shortfalls. Compared with the traditional forms of warehousing management based on the KANBAN principle ('split supply')[34] or supply-chain assistants, ADC technology leads to 30 per cent lower storage and inventory costs.

Finally, electronic cabinets used in the process of providing the wards with controlled substances contributed to time savings, referring to ordering and inventory activities between 80 and 120 minutes per day on a ward serving 24 patients on average.[35]

4. **Evaluation of ADCs from the viewpoint of hospital managers and pharmaceutical decision makers**

Despite these convincing results reported by different hospitals from various countries, German hospital managers (CEOs, procurement officers, pharmacists) have not so far been willing to implement smart cabinets in their hospitals. Therefore, no smart cabinet-based medication process can be encountered in German hospitals to date.

In order to determine the reasons for steadfastly refusing the implementation of electronic cabinets that have successfully been used in hospitals outside Germany, 59 decision makers of German hospitals were surveyed.[36]

Some surprising results were obtained (see Figure 6):

- 56 per cent of the decision makers in German hospitals admit refusing

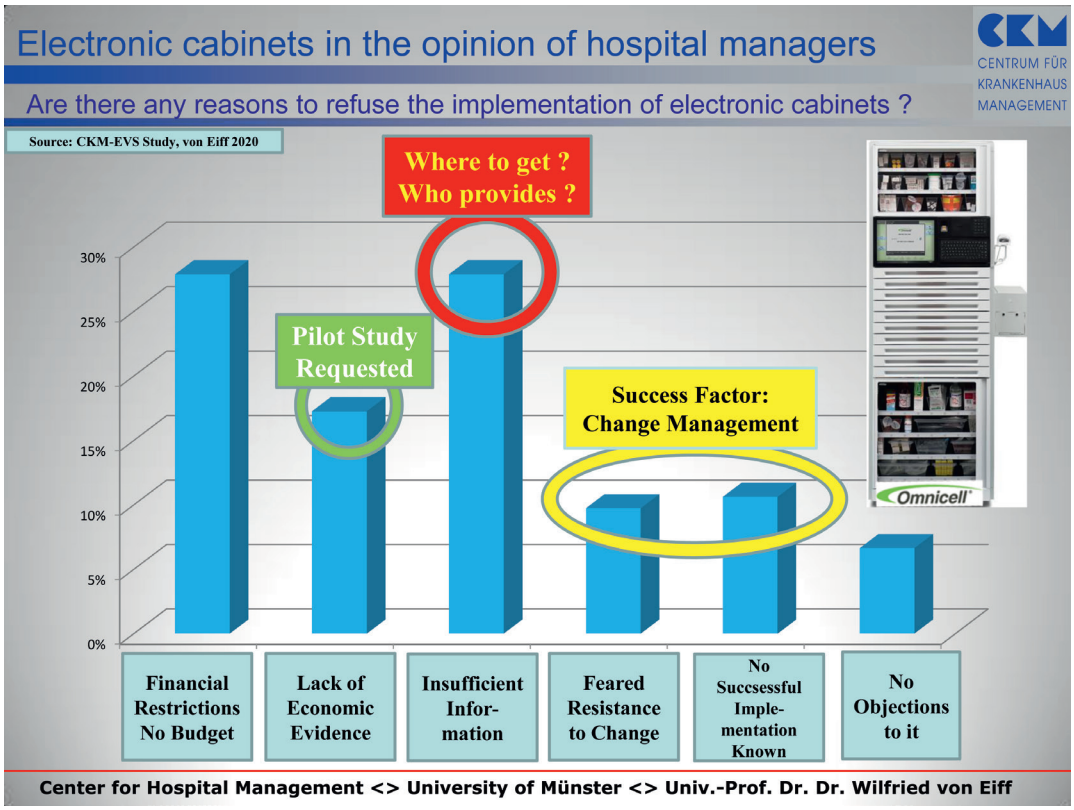


*Figure 6 Results of the survey of 59 German Hospital Managers*
*Source:* Authors.

to consider the potential of cabinet solutions owing to being satisfied with the current solution.
- This attitude conflicts with the fact that in 57 per cent of German hospitals, matching between patient and medication is operated via sight control by the nurse, without any digital support. Furthermore, only in 33 per cent of the hospitals is a medication testing software used in order to obtain a predictive early detection of drug interactions.
- 84 per cent of the decision makers criticise a lack of reliable cost-benefit analyses, despite the availability of studies demonstrating the success potential of smart cabinets in terms of enhancing patient safety and relieving staff work burden.
- Not a single respondent (0 per cent) specified 'being familiar with the functionality of ADCs and being well informed about the different smart cabinet opportunities in the market'.
- It is also noteworthy that there is a significant fear of not being able to manage the change from the traditional organisation of medication logistics to a digitally based organisation with smart cabinets.

## DISCUSSION

The generic process blueprint in combination with the best-in-class reports was expected to convince decision makers of the positive contribution that electronic cabinets can make to increased patient safety, reduction in nursing staff workload and higher cost-effectiveness.

Experience, however, shows that innovative technologies are associated with changes in workflow organisation and disruptions in interworking patterns. Accordingly, many employees fear being unable to fulfil the requirements of the new work environment and assume there is a risk of being overburdened by additional tasks and responsibilities.

Keeping this in mind, the successful implementation of electronic cabinets requires

- an effective change management organisation in order to support employees during the implementation process;
- a convincing and reliable cost-benefit study;
- a detailed description of the reorganised cabinet-based workflow; and
- a catalogue of advantages employees can expect for themselves from this new workflow.

Thus, an effective 'change management organisation' can be recognised as the dominant success factor when implementing an ADC-based closed-loop medication administration system.[37]

From the workplace engineering sciences, it is evident that work efficiency, measured by the criteria of efficiency and effectiveness of therapy, economy and patient safety, is determined mainly by staff acceptance of new technology and re-engineered workflows.[38]

Significant investments, especially those with substantial effects on working behaviour, cooperation between occupational groups, changes in workflows, responsibilities and tasks often create financial barriers in practice. The demonstration of a positive return on investment (ROI) can convince a hospital board to invest.

ADC technology seems to be most effective and efficient in intensive care units, emergency departments, internal medicine wards, operating theatres and oncological departments. These treatment areas are well known for a rapid change of medication schemes.

Furthermore, smart cabinets can be considered as an ideal technology that ensures the realisation of a closed-loop medication administration system encompassing all dosage forms. Therefore, ADCs close the gap a unit dose system typically opens owing to the focus of care on oral drugs.

Against this background, it is evident why ADC technology also plays a major role in the leadership concept of 'magnet nursing'.[39] The magnet nursing model implies a cause-and-effect correlation between working conditions and nurse staffing, on the one hand, and defined outcome indicators, on the other. In magnet hospitals, ADCs are used in order to avoid medication errors by reducing work pressure and stress levels of nursing staff. The integration of ADCs in comprehensive medication logistics is an important criterion in the accreditation process of American Nurses Credentialing Center (ANCC)[40] and Joint Commission.

Last but not least, it has to be considered that in practice digitalised work processes increasingly become a target for cyberattacks. On the other hand, hospitals have to reckon with IT-technical system failures. So when implementing an ADC technology, it is recommended to integrate ADCs in a cyber-secure and fail-proof IT environment.

## References


1. Schwabe, U., Paffrath, D., Ludwig, W.-D., Klauber, J. (Hrsg.), eds., (2019), 'Arzneiverordnungs-Report 2019', Springer-Verlag, Berlin.
2. von Eiff, W. (Hrsg.), (2011), 'Patientenorientierte Arzneimittelversorgung', Sicherheit und Wirtschaftlichkeit des Arzneimittelmanagements, Stuttgart.
3. Schurig, A. M., Bohme, M., Just, K. S., et al., (2018), 'Adverse drug reactions (ADR) and emergencies', *Deutsches Arzteblatt International*, Vol. 115, pp. 251–258.
4. Stausberg, J., Hasford, J., (2011), 'Drug-related admissions and hospital-acquired adverse drug events in Germany: A longitudinal analysis from 2003 to 2007 of ICD-10-coded routine data', *BMC Health Services Research*, Vol. 11, p.134.
5. von Eiff, W., (June 2021), 'Closed loop medication administration: Mit "Unit Dose" und "Smart Cabinets" zum fehlersicheren Medikationsmanagement', *Das Krankenhaus*, Seite 498–503.
6. von Kluchtzner, W., Grandt, D., (2015), 'Influence of hospitalization on prescribing safety across the continuum of care: An exploratory study', *BMC Health Services Research*, Vol. 15, p. 197.
7. Schneeweiss, S., Hasford, J., Göttler, M., Hoffmann, A., Riethling, A.-K., Avorn, J., (2002), 'Admissions caused by adverse drug events to internal medicine and emergency departments in hospitals: A longitudinal population-based study', *European Journal of Clinical Pharmacology*, Vol. 58, pp. 285–291. doi:10.1007/s00228-002-0467-0.
8. Pirmohamed, M., James, S., Meakin, S., et al., (2004), 'Adverse drug reactions as cause of admission to hospital: Prospective analysis of 18 820 patients', *BMJ*, Vol. 329, pp. 15–19.
9. Just, K. S., Dormann, H., Bohme, M., et al., (2020), 'Personalising drug safety-results from the multi-centre prospective observational study on Adverse Drug Reactions in Emergency Departments (ADRED)', *European Journal of Clinical Pharmacology*, Vol. 76, pp. 439–448.
10. von Eiff, M. C., von Eiff, W., Roth, A., Ghanem, M., (2019), 'Employee acceptance of use: A precondition for enhancing therapy effectiveness, patient safety, and economic efficiency', *Frontiers in Public Health*, Vol. 7, p.353. doi:10.3389/fpubh.2019.00353.
11. Sommer, H., Dwenger, A., (2018), 'Action plan of the Federal Ministry of Health for improvement of medication safety in Germany: An inventory', *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz*, Vol. 61, pp. 1062–1065.
12. von Eiff, W., (January 2021), 'KHZG-Förderbereich "Medikationslogistik": Elektronische Versorgungsschränke im digitalen Closed-Loop-Konzept', *Krankenhaus-IT-Journal*, Seite 26–30.
13. Brinkrolf, P., Prien, Th., Van Aken, H., (2013), 'Medikationsfehler. Eine systematische Analyse der Berichte im CIRS-AINS', *Anästh Intensivmed*, Vol. 54, pp. 126–132.
14. von Eiff, M. C., von Eiff, W., Ghanem, M., (2021), 'Value-based leadership in turbulent times: Lessons from the Corona crisis and recommendations for post-pandemic management in the health sector', *Leadership, Education, Personality: An Interdisciplinary Journal*, Vol. 3, 157–169. https://doi.org/10.1365/s42681-022-00029-w.
15. von Eiff, W., (December 2020), 'Elektronische Versorgungsschränke (EVS) in der Arzneimittel-Logistik. Studie über die Einschätzung von Effizienz, Effektivität und Wirtschaftlichkeit von EVS-Systemen aus Nutzer- und Entscheidersicht', Centrum für Krankenhaus-Management, Universität Münster.
16. KHZG – Krankenhauszukunftsgesetz, (2020), 'Krankenhauszukunfts-gesetz für die Digitalisierung von Krankenhäusern', available at: https://www.bundesgesundheitsministerium.de/krankenhauszukunfts-gesetz (accessed 17th October, 2022).
17. 'Aktionsplan des Bundesministeriums für Gesundheit zur Verbesserung der Arzneimitteltherapiesicherheit in Deutschland 2021–2024', available at: https://www.akdae.de/AMTS/

Aktionsplan/Aktionsplan-2021-2024/Aktionsplan-AMTS-2021-2024.pdf (accessed 11th June, 2022).
18. Seifert, J., (n.d.), 'ADKA – Apotheker auf Station', available at: www.gelbe-liste.de/apotheke/apotheker-auf-station (accessed 19th June, 2022).
19. Bond, C. A., Raehl, C. L., (2006), 'Clinical pharmacy services, pharmacy staffing, and adverse drug reactions in United States hospitals', *Pharmacotherapy: The Journal of Human Pharmacology and Drug Therapy*, Vol. 26, No. 6, pp. 735–747. https://doi.org/10.1592/phco.26.6.735.
20. von Eiff, ref. 15 above.
21. von Eiff, von Eiff, Roth, Ghanem, ref. 10 above.
22. Craswell, A., Bennett, K., Dalgliesh, B., et al., (November 2020), 'The impact of automated medicine dispensing units on nursing workflow: A cross-sectional study', *International Journal of Nursing Studies*, Vol. 111, p. 103773. doi:10.1016/j.ijnurstu.2020.103773.
23. Chapuis, C., Roustit, M., Bal, G., et al., (2010), 'Automated drug dispensing system reduces medication errors in an intensive care setting', *Critical Care Medicine*, Vol. 38, No. 12. doi:10.1097/CCM.0b013e3181f8569b.
24. Chapuis, C., Bedouch, P., Detavenier, M., et al., (2015), 'Automated drug dispensing systems in the intensive care unit: A financial analysis', *Critical Care*, Vol. 19, p. 318. doi:10.1186/s13054-015-1041-3.
25. Metsämuuronen, R., Kokki, H., Naaranlahti, T., Kurttila, M., Heikkilä, R., (19 April 2020), 'Nurses' perceptions of automated dispensing cabinets – An observational study and an online survey', *BMC Nursing*, Vol. 19, p. 27. doi:10.1186/s12912-020-00420-2.
26. Chapuis, Roustit, Bal, et al., ref. 23 above.
27. von Eiff, ref. 5 above.
28. Rottenkolber, D., Hasford, J., Stausberg, J., (September–October 2012), 'Costs of adverse drug events in German hospitals – A microcosting study', *Value Health*, Vol. 15, No. 6, pp. 868–875. doi:10.1016/j.jval.2012.05.007. Epub 2012 Aug 9.
29. von Eiff, von Eiff, Roth, Ghanem, ref. 10 above.
30. Chapuis, Bedouch, Detavenier, et al., ref. 24 above.
31. Bourcier, E., Maselaine, S., Archer, V., Kramp, F., Paul, M., Astier, A., (2016), 'Implementation of automated dispensing cabinets for management of medical devices in an intensive care unit: Organisational and financial impact', *European Journal of Hospital Pharmacy*, Vol. 23, pp. 86–90. doi:10.1136/ejhpharm-2014-000604.
32. Monzón Moreno, A., Merino Bohórquez, V., Villalba Moreno, A., (2016), 'Evaluation of the efficiency of an automated dispensing cabinet (ADC) in a ward of internal medicine', *Revista de la OFIL*, Vol. 26, No. 2, pp. 27–33.
33. Bonnabry, P., Francois, O., (2020), 'Return on investment: A practical calculation tool to convince your institution', *European Journal of Hospital Pharmacy*, Vol. 27, pp. 111–113. doi:10.1136/ejhpharm-2018-001733.
34. Kenney, C., (2011), 'Transforming Health Care. Virginia Mason Medical Center's Pursuit of the Perfect Patient Experience', CRC Press, Boca Raton.
35. von Eiff, ref. 12 above.
36. von Eiff, ref. 15 above.
37. Hänninen, K., Ahtiainen, H. K., Suvukas-Peltonen, E. M., (18 November 2021), 'Automated unit dose dispensing systems producing individually packaged and labelled drugs for inpatients: A systematic review', *European Journal of Hospital Pharmacy*. doi: 10.1136/ejhpharm-2021-003002.
38. von Eiff, von Eiff, Roth, Ghanem, ref. 10 above.
39. von Eiff, A. K. S., von Eiff, W., (2020), 'Das Magnet-Konzept. Merkmale und Realisierungsvoraussetzungen', *ZFPG*, Jg. 6, No. 2, Seite 24–28.DOI:10.17193/HNU.ZFPG.06.02.2020-05.
40. ANCC American Nurses Credentialing Center, (n.d.), 'Magnet Model – Creating a Magnet Culture', available at: www.nursingworld.org (accessed 13th April, 2022).