37. Jahrgang · Heft 1 · Januar 2016

Krankenhauspharmazie

Zeitschrift des Bundesverbandes Deutscher Krankenhausapotheker (ADKA) e.V.

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Krankenhauspharmazie

Zeitschrift des Bundesverbandes Deutscher Krankenhausapotheker (ADKA) e.V.

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Printed by: TYPOfactory Stuttgart GmbH

Translated reprint from Krankenhauspharmazie 2016;37:1–8

Automation and optimisation of pharmaceutical logistics with the Rowa Vmax logistics system in the pharmacy department of the University Medical Center Mainz

Mareike Kunkel and Irene Krämer, Mainz

After almost 20 years of storing and dispensing by utilization of a stock channel system, the hospital pharmacy at the University Medical Center Mainz has implemented a new, fully automatic logistics system. The new system consists of 5 components: the Rowa Vmax storage and dispensing system, the Rowa conveyor system for packages and the conveyor system for ward boxes (SSI Schäfer), the automatic sorting system Rowa ProLog, the Rowa destacking system for ward boxes and the sorting system Chicago::LVS with a workstation for dispensing. Handheld scanners were introduced for the manual picking of products that are not stored in the automatic system, which can be used to identify products and their expiry dates when dispensing. The fully automatic storage, simplified inventory and automatic expiry date check are of great benefit. By using the handheld scanners the risk of error in manual dispensing has been reduced to a minimum. The entire fully automatic logistics system allows an increase in reliability and efficiency in the pharmaceutical logistics at the University Medical Center Mainz.

Key words: **Pharmaceutical logistics, automated retrieval system, automatic stock entry and dispensing, warehouse management system**

Krankenhauspharmazie 2016;37:1–8.

The University Medical Center Mainz (UM) is a tertiary care university hospital with more than 1600 beds and over 60 specialised clinics, institutes and departments. The provision of medical supplies for the inpatient and outpatient facilities as well as for the diagnostic and research laboratories is carried out by the Pharmacy of the UM. Furthermore, the pharmacy handles supply orders from external (rehabilitation) clinics and emergency medical services. The comprehensive supply area requires sophisticated pharmaceutical logistics. Since 1996, a semi-automated retrieval system from P@P Picking Systems GmbH had been used for picking medicinal products and common pharmacy supplies. In the meantime, more advanced automated picking systems are available that are also implemented in German hospital pharmacies [1–3]. The establishment of the Rowa Vmax logistics system, which was established in this configuration for the first time in Germany at the pharmacy of the UM, is described below.

The ROWA Vmax® logistics system

The newly-established logistics system in the medicinal product dispensary of the UM consists of five components (**Fig. 1**):

- Rowa Vmax® Automated Storage and Retrieval System
- Conveyor technology: Rowa conveyor system for packages and conveyor system for ward boxes (SSI Schäfer)
- Automatic Storage System Rowa ProLog®
- Rowa® Box System: a destacker system for ward boxes
- Warehouse Management System Chicago::LVS with workplaces for the subsequent picking ("I-points")

Rowa -Vmax® Automated Retrieval System

The Rowa Vmax used in the department of pharmacy of the UM consists of two identical machines (**Fig. 2**) with two grippers and two storage conveyers each (**Fig. 3**). If one machine fails because of a technical defect, the other one takes over the complete picking and retrieval to ensure the proper supply of medicinal products. Two grippers per machine increase the speed of stock entry and dispensing. In order to enable continuous manual stock entry, two stock entry conveyor systems for each machine were installed. While the second conveyor is being filled, the packages on the first conveyor can be stored in the shelves by the gripper. Each Rowa Vmax dual system has

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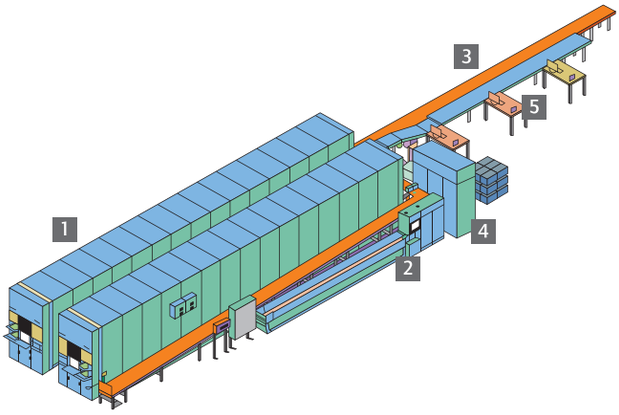

Fig. 1. (1) Rowa Vmax, (2) Rowa ProLog, (3) Conveyor system SSI Schäfer, (4) Rowa Box System, (5) Chicago::LVS with I-Points

the dimensions 15×1.63×2.90 m (L×W×H). The height was limited by the ceiling height of the room and can be individually adapted from 2.0 to 3.5 m in 5 cm steps. The storage spaces consist of glass shelves that can be installed at different height intervals depending on the assortment. The storage location depth is 340 mm. Depending on the package size, up to eight packages of the same or different articles can be consecutively stored (**Fig. 3**). For stock dispensing, a gripper can grasp up to eight packages at a time. For the average sizes of the outer package of medicinal products, this on average corresponds to three finished medicinal products.

About 70,000 packages can be stored in the dual system. Approximately 1000 different articles are currently stored in the facility. An external cold air supply can keep the prescribed storage temperature below 25 °C even at higher outside temperatures in the summer without air conditioning. A module for storing medicinal products at 2 to 8 °C was not installed because of the existing cold storage room. The stocked block-shaped packages must conform to the following minimum and maximum packaging dimensions:

- Minimum packaging size (Width×Height×Depth): 15×15×35 mm
- Maximum packaging size (Width×Height×Depth): 140×145×230 mm
- Maximum package weight: 1000 g
- Round packages must conform to the following minimum and maximum package dimensions:
- Minimum size: diameter = 45 mm, height = 15 mm
- Maximum size: diameter = 140 mm, height = 145 mm
- Maximum weight: 800 g

There must be no protruding lids on bottles and round packages (guidelines from the Rowa Vmax Operating Manual). Multi-packs can only be stored with firmly attached shrink wrap. Packages where a strip can easily be detached, or with outer packaging in which the gripper can get caught, for example loose foils, are not suitable for automatic picking.

The stocking system operates by space-saving "chaotic order". To dispense the rear-most package, all packages are drawn onto the gripper; the rear-most package, which now lies at the front of the gripper, is removed and the other packages returned to storage.

The dispensing process always has highest priority, which is why stock entry is significantly slower during the day than at pick-free times. Provided that there is a better storage location, packages in the Rowa Vmax are relocated particularly at night in order to make optimal use of the capacity of the automatic storage system.

Conveyor technology

The conveyor technology for transporting packages inside and outside of the Rowa Vmax is part of the Rowa system and is controlled by this system. The conveyor technology for ward boxes was installed by SSI Schäfer and is in part operated with compressed air (8 bar) for automatic transport. The conveyor technology begins after the Rowa box system, which provides the empty ward boxes. The bar code located on the containers is scanned at the filling

Fig. 2. Rowa Vmax – Exterior view of two identical machines

Fig. 3. Rowa Vmax – Interior view of shelf system with chaotic warehousing, two grippers and two stock entry conveyor belts

point to identify the container and assign it to an order. After automatic picking, the medicinal products are conveyed into the container and the container is further transported to a conveyor belt, where manual picking and completion of the order can take place. The conveyor belt for removing the containers is located parallel to the conveyor of the subsequent picking process. A photoelectric barrier is installed between the conveyers. An interruption of the photoelectric barrier, for example by shifting a container from the front to the rear conveyor, triggers a signal for transporting the ward boxes onwards.

Rowa proLog® automatic sorting system

The sorting system consists of a buffer conveyor, a separator, a measuring table with cameras, a gripper and a collecting container (**Fig. 4**). The sorting system for stock entry can handle both goods receipt and return. The packages to be stored are tipped onto the buffer conveyor and transported by the conveyor to the separator, which in turn transports the packages onto the measuring table. The packages must show a bar code which serves to identify each respective article. The ProLog cameras photometrically enter the package dimensions and position. The gripper draws in the packages and transfers them onto the transfer conveyor belt, which provides both machines equally with packages. If the gripper cannot pick a package, the package is disposed into a box in the ProLog. If the cameras cannot identify the package, the package is transported by the transfer conveyor belt through the Vmax machine and to the side of the manual storage through the output magazine into a collecting container. The ProLog can store cube-shaped as well as round packages.
Problems for automatic storage can arise during the gripping process due to braille writing on the package, package identification on shiny packages, a bar code that is too small, or also if several bar codes are too close to each other on one side of the packaging.

Fig. 4. Rowa Prolog with buffer conveyor for automatic storage

Fig. 5. Rowa Box System (left) with subsequent conveyor belt for transporting word boxes; the Mosaic computer is on the right of the picture

Rowa® Box System

The Rowa box destacker system can store a maximum of 90 containers (**Fig. 5**). These are arranged in three stacks. The system ensures that sufficient containers are always available on the conveyor technology for automatic picking.
At the UM, the box system is manually filled with the containers. In the latest version, small transport box trolleys can drive the transport containers directly into the destacker.

Warehouse Management System Chicago::LVS with I-Points

There are three workplaces, so-called I-Points, at the conveyor belt for subsequent picking with a PC, monitor, label printer, delivery note printer and hand scanner installed at each place (**Fig. 6**). The storage management system Chicago::LVS is installed on the PCs. Incoming electronic orders are released online to the wards by the pharmacy with the SAP ERP 6.0 MM, and sent to the warehouse management system. The warehouse management system and the Vmax machines are connected via the Mosaic computer. Orders that do not contain any articles stored in the Rowa Vmax machine are directly shown in the picking list at the I-Point. Orders with articles capable of being processed automatically are only shown at the I-Point after the completion of automatic picking. After the order is entirely completed, the picked articles are reported back to the SAP ERP 6.0 MM with the relevant quantities, where the booking takes place. The warehouse management system is also depicted on the handheld units, although not all functions are available here because of limited screen size. Patient data are not forwarded to Chicago::LVS.

Fig. 6. Three subsequent picking places with set up I-Points at the conveyor belt for subsequent manual picking [pictures: private]

Storage entry process

Stock entry can take place manually at the head end of the machines in each case or fully automatically with the Rowa ProLog system. In both cases, the packages are identified by a bar code, which primarily consists of the German nationwide medicinal product identifier code (PZN Code 39). If the PZN is missing but another bar code (e.g. EAN) is available on the package, it can be read and also serve to identify the article in the case of corresponding updating in the article master record of the material management software (in the UM SAP ERP 6.0 MM). If no bar code is present, the SAP article number of the UM hospital pharmacy is converted into a bar code and used to identify the article.

A readable bar code must be present on the package surface for automatic storage, and the goods to be stored with the conveyor belt of the ProLog must come from the same batch with a uniform expiry date, since currently the scope of storage possibilities demands article identification exclusively by bar code. For full-coverage deployment of 2D bar codes, the assignment of an expiry date and the batch designation can also take place automatically. Articles with various expiry dates are stored manually, since a query of the date and an appropriate confirmation or new entry must explicitly take place.

Picking process

Both automatic as well as manual picking were restructured.

For faster processing, an order is split into orders for both machines. Within these split orders, package stock with the shortest expiry date is dispensed in each case. For automatic picking, the Rowa Vmax calculates the necessary number of transport containers on the basis of a maximum automatic filling degree of 40 %. This percentage rate is due to the fact that the articles fall unsorted into the container and thereby require a larger volume. For subsequent manual picking, the containers, which have already been automatically filled, are scanned on the conveyor belt by an employee with a handheld unit or a hand scanner at the I-Point. The order of the scanned box is thereby automatically retrieved, and the boxes belonging to the total order and which articles are located in which box, are displayed along with which articles are still missing and have to be manually picked. The employee can either assign the missing articles to an already existing box into which he places the articles, or alternatively add a new box by scanning or typing in the container number. Subsequent article picking is done with the hand scanner at the I-Point or scanned with a handheld while picking, thus identifying the articles. Available stock quantities with their expiry dates and possibly batch designations are shown on the monitor or display. The employee selects the relevant stocked article and enters the quantity which was picked. Alternatively, every package can also be scanned in order to verify the quantities. Since selection must take place before every scanning, the reliable method has not proved itself in practice due to lack of time. Errors in the dispensed quantity can therefore not be precluded. If a transport container is full, it is electronically closed by the employee, and a label with the delivery address and the identification number of the container is automatically generated. When an order is completely picked, it is displayed on the handheld; articles are no longer shown on the picklist and at the I-Point, a green beam on the monitor shows that the order has been 100 % picked.

The order is concluded and a delivery note is automatically created. A final inspection of the of the items being picked is not carried out before the completion of the order, since the error rate of automatic picking is very low. After completion, the picked articles are transferred by the Chicago::LVS to the SAP ERP 6.0 MM, and the SAP automatically closes the order and books the quantities.

Initially, only the picking of entire packages by the Chicago::LVS was intended, so that a delivery of individual ampoules for emergency kits or a delivery of expensive medicinal products, which were credited as an opened package in the case of goods returned by the ward, was very laborious. In the meantime, opened packages can also be handled using the warehouse management system.

Booking receipt of goods

The receipt of goods continues to be recorded in SAP ERP 6.0 MM and is automatically transferred as a receipt of goods to the Chicago::LVS. In the Chicago::LVS, the batch

designation and the expiry date can be recorded and a split of incoming goods with several expiry dates can be performed. After confirmation, the received goods are taken over to the virtual storage location "Incoming goods". When stock is entered in the Rowa Vmax, the storage location in the Chicago::LVS is automatically changed to "ROWA" and when goods are stored outside of the Rowa Vmax a redistribution to the relevant storage location, for example the cold-storage room, is carried out in the Chicago::LVS in each case. Several storage locations are also possible.
The objective is to optimise the order and the inventory volume in such a way that articles located in the Rowa Vmax for automatic picking are only stored there. At goods receipt, all the goods are stored (as a rule on the same day or the following day). There is no "extra stock". Articles which must be picked manually, for example the fast moving products in large packaging units or refrigerated goods, are likewise stored only at one stock location.

Processing returns

Returns are still processed by SAP. However, since in SAP ERP 6.0 MM the entry of an expiry date is not provided, an acceptance of returned goods was programmed in the Chicago::LVS. The credit notes are transferred and the expiry date subsequently entered in the Chicago::LVS. With the physical storage of the goods, the "interim storage" is relocated to the storage location.

Monitoring expiry dates

Warehouse statistics are integrated in the Rowa Vmax programme as a standard. For example, it specifies how many articles of which package size are to be stored, how many storage locations are vacant, when the articles were stored, and how many articles expire at which date.
For the articles not stored in the Rowa Vmax, expiry dates can be monitored by the reporting function of the warehouse management system. The packages that will expire in the near future can be analysed in a targeted manner and a decision can be made on their future use.

Order follow-up

The reporting function of Chicago::LVS also permits order follow-up. Before the installation of the Chicago::LVS, the identification numbers of the transport containers used were displayed on the delivery notes, but not saved in SAP ERP 6.0 MM. The mode of transportation selected by the wards when odering (there are three different transport types at the UM Mainz) and the time of the order, but not the time of order processing, were electronically documented.
Now the order number, container number, type and number of articles in each container, the date and time of the completed order and the selected mode of transportation can all be tracked in the reporting function. This makes it possible to provide specific information in the event of inquiries.

Inventory

In the future, the inventory will also be carried out in SAP ERP 6.0 MM, but the Chicago::LVS can also contribute valuable support. In the Chicago::LVS, a list of all articles still to be counted can be generated and the articles with the lowest stock displayed. The employee loads a selection of the articles to be counted onto the handheld. The storage locations and the current available expiry dates, but not the current available quantity are displayed. At the storage location, the employee types in the counted quantity for the predetermined expiry date (if nothing is there, then zero) or possibly adds stock with an expiry date other than that specified. On transfer, both the Chicago::LVS is corrected in the case of deviations and the total sum quantity from all expiry dates is generated in a file which is taken over in the SAP material management module. Then the actual inventory is booked with the transmitted quantities. For articles which are located in the Rowa Vmax, the stock is automatically added to the counted quantities (e.g. if goods are still located in goods receipt status or the quantity zero was counted) in the background. By this only packages which are located in the goods receipt area or in the intermediate depots from returns, as well as pallet goods, refrigerated medicinal products and narcotic agents have to be physically recorded in the customary way.

Servicing and training

Preventive servicing is carried out semi-annually according to the servicing contract. The required spare and replacement parts are contained in the servicing flat fee. Furthermore, Care Fusion integrates the technical improvements which are delivered as a standard for new systems.
When the equipment was first commissioned, all employees of the medicinal product dispensary were trained in the general operation of the ROWA Vmax, the user interface, safety aspects and error correction. A three-hour user training (max. five participants) with extended contents was conducted about two months after commissioning. Warehouse maintenance, warehouse optimisation and "Help for Self-Help" using the most frequent operator questions were also discussed. At the end of training, performance inspections were carried out. The participants

received a certificate for the successful participation in the two training sessions.

Fault correction in the Rowa Vmax

For the most part, errors occurring in the fully-automatic logistics system and error reports can be resolved on location, for example by PKAs (pharmacy assistants), (**Table 1**). If an error occurs in the machine, a separate error window opens in which precise instructions for error correction are described. In the case of faulty storages in one row, it must always be taken into account whether neighbouring rows are not also affected, for example if packages have been displaced. In this case, it does not suffice to remove the displayed row of packages from the bay, but the entire bay must be emptied and the removal confirmed on the monitor. Upon confirmation of an error, the removed packages will be automatically relocated from the storage location in ROWA to an intermediate depot. From here, the packages can once again be stored in the ROWA.
The most frequent errors are false axial positioning and a package interrupting the photoelectric barrier of the gripper during travel, usually during storage entry or redistribution.
In order to ensure maximum personal protection on entering the machine to correct an error, an additional precaution was introduced, i.e. the employee has to take along a key when entering the machine, without which it cannot be started.
If an error cannot be resolved by pharmacy or clinic personnel or by remote maintenance, or if there has been a complete machine failure, then Care Fusion guarantees that a servicing technician will be on location within four hours during the business hours. For problems which only affect the storage by ProLog for example, an appointment with a technician can be made. The servicing hotline is available on a 24-hour basis.

Table 1. Error display, causes, and correction

Error display	Cause	Fault correction
False axial positioning	Mechanical or electrical problem with one of the axes of the gripper	Move the axes
Photoelectric barrier during travel	The most frequent cause for this error is that during travel the packages move on the gripper and thereby interrupt the photoelectric barrier	Remove package from the gripper
No package recognised	Removal of a package by the gripper from a bay is not possible	Find cause and empty the bay if necessary
Incorrect package length on gripper	Packet length does not match with stored data	Remove package on the gripper
Output of packages with gripper has failed	The direct output flap is not closed	Close direct output flap, if necessary previously remove packages which are preventing the flap from closing from the output point
Stock error	Gripper should be empty (caused by previous switch-off of the system)	Remove package from the gripper
Spacing of the gripper is too small		Manual pushing apart required

System implementation

The system modernisation contains various simultaneous or time-delayed measures:

- Construction measures (dismantling the old and constructing the new automated picking system as well as the conveyor technology, relocation of the smoke detectors, provision of electricity, compressed air, network connections and WLAN)
- Conversion of the semi-automatic picking to manual picking and subsequently to fully automatic picking in combination with Chicago::LVS
- Establishment of the interfaces between SAP – Chicago::LVS -ROWA Vmax

For the readjustment phase with manual picking, the stock reserve as well as the over-stocking of the automated picking system and pallet goods were reduced at an early stage, gaining free storage space on the shelves. Successively, the stock reserves from the automated picking system were rearranged into the shelves. The time schedule following the old picking and conveyer system could subsequently be reduced within a few days and the floor replaced. The construction time of the new picking and delivery system was only three weeks, followed by a two-week start-up period. Only the implementation of the new warehouse management system Chicago::LVS, which was specially programmed for this installation, revealed to be problematic. Within one week, at least the most important applications and views were reprogrammed so that the new logistics system could be launched. As a consequence, the software was continuously further developed. Monitor views were improved, interfaces optimised and systematic errors resolved. A few months after establishment of the new logistics system, the routine procedures were running smoothly and satisfactorily.
The advantages of the system, such as the automatic storage, expiry date monitoring, traceability of the orders and transport containers, now reveal their particular benefits. Such far-reaching reorganisation and automation poses high requirements on the adaptation and willingness to learn as well as the patience of the affected employees. The occurrence of technical problems in the interaction between hardware and software appear to increase with the size and complexity of the systems [4]. The employees'

acceptance of such a complex system and equipment in the team must be created by appropriate communications, and trust in the reliability of the system must be built up. At no time of the of the reconstruction period did occur serious delivery bottlenecks.

Current picking performance

The current picking performance of the medicinal product dispensary is analysed in **Table 2** during one week as an example (without a holiday) and calculated for an average workday.

16% of the packages in the medicinal product dispensary of the UM are located in refrigerated (deep-freeze) areas, in a dangerous substance cabinet, or are narcotic drugs, so that automatic picking is not possible.

The automatic storage system ProLog in the UM manages to input 160 to 180 packages per hour under optimal conditions (no simultaneous outplacement). ProLog stocked 1080 packages per day during the evaluation week. Since, for example, there are still finished medicinal products without a PZN or EAN bar code on the market, some packages still have to be manually stocked. Along with goods not delivered from a single batch and multi-packs, for example, this was on average about 1000 packages each day. The capacity calculations performed in advance proved to be correct and sufficient.

Pros and cons of the new logistic system

The implementation of the fully-automated picking system Rowa Vmax above all leads to a reduction of storage space for articles to be automatically picked, since oversupply shelves are no longer necessary, and the chaotic storage system has lower space requirements than the previous batch-flow system.

The automatic storage with the ProLog means the greatest improvement for the employees, since previously the channels of the semi-automatic system had to be elaborately refilled by hand every morning. Before the implementation of the new warehouse management system, every package had to be checked for its expiry date twice a year, and all packages with a expiry date of less than 6 months had to be entered into a list. Moreover, the manually-maintained lists were never up to date compared to the lists generated from the reporting system of the Chicago::LVS due to the output of goods.

An additional advantage is the exact traceability of orders, so that in the case of inquiries from wards the processing status, order completion date and time, and the mode of transportation can be given precisely. Furthermore, all container numbers with the picked articles and quantities are recorded, making it unnecessary to keep delivery notes or perform order searches by looking through them.

Table 2. Picking performance

	Total [n]	Automatic picking [n]	Automation rate [%]
Orders	213	128	60
Order rows	1400	980	70
Packages	4030	2410	60

By entering the batch numbers at goods receipt in the Chicago::LVS, transposed digits or typing errors are avoided when dispensing. Furthermore, compared to the manual entry, time is saved by the indication of currently available batch numbers.

It is a disadvantage that the new form of manual subsequent picking takes more time, since the articles must not only be picked, but also scanned and the appropriate expiry date, provided there is more than one, must be selected as well as the appropriate quantity entered. This increased time demand is tacitly accepted because of the greater dispensing reliablity and a reduction in the dispensing error rate.

Furthermore, expiry date-related stock entry and dispensing is connected with an increased time demand for the maintenance of the expiry dates. In the SAP system, only one expiry date can be maintained on receipt of goods so that the receipt of goods in the Chicago::LVS must be split to allow several quantities and expiry dates to be entered. Also for returns processing, entry of an expiry date is not required in the SAP system, so that now the expiry date must be supplemented in the Chicago::LVS. Working with two systems requires more time, which was, however, inevitable since SAP ERP 6.0 MM does not offer these functions in the standard version.

A technical problem in the medicinal product dispensary at the UM is the uninterrupted availability of WLAN. Even though several access points were installed, during the manual subsequent picking, delays on transition from one point to another occur time and again. The delay could be minimised to a few seconds, but not completely avoided.

Conclusions

The simultaneous conversion to a fully automated picking system and a new warehouse management system meant a great challenge that could only be mastered with the enormous commitment and time expenditure of everyone involved. The initial difficulties with the newly programmed warehouse management system Chicago::LVS were resolved by the further development and adaptations of the processes. The fully automatic storage, simplified inventory and automated monitoring of the expiry dates are of great advantage in the logistics process. Along with handheld-supported manual picking, the probability of error is reduced to a minimum. The fully automatic logistics system is well harmonised and provides a definite

gain in reliability and efficiency in the pharmacy department logistics of the University Medical Center Mainz.

Conflict of interest declaration

There are no conflicts of interest.

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Krankenhauspharmazie

Zeitschrift des Bundesverbandes Deutscher Krankenhausapotheker (ADKA) e. V.

Herausgeber
Dr. Matthias Fellhauer, Villingen-Schwenningen, im Auftrag des Bundesverbandes Deutscher Krankenhausapotheker (ADKA) e. V.

Redaktion
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Tel.: (07 11) 25 82-234, Fax: -283
E-Mail: kph@deutscher-apotheker-verlag.de

Verlag
Deutscher Apotheker Verlag
Dr. Roland Schmiedel GmbH & Co.
Birkenwaldstraße 44, 70191 Stuttgart
Postfach 10 10 61, 70009 Stuttgart
Tel.: (07 11) 25 82-0, Fax: -290
www.deutscher-apotheker-verlag.de

Geschäftsführung
Dr. Christian Rotta, André Caro

Anzeigen
Leitung Media: Kornelia Wind (verantwortlich)
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Anzeigentarif: Zurzeit gültig Nr. 37 vom 1.10.2015

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ISSN 0173-7597

Druck: TYPOfactory Stuttgart GmbH,
Dieselstraße 32, 70469 Stuttgart