APPENDIX2: Description of the dispensing systems

Type of dispensing system **Specified system**, 1st writer and year	**Description of the dispensing system / Information about (automation in) drug-dispensing process:**	**Other technologies used in process:**
Decentralized drug dispensing systems (n=19)		
- **ADCs** (n=10) Rodriguez-Gonzalez CG et al., 2012[36] and Rodriguez-Gonzalez CG et al, 2015[8]	Dispensing is facilitated by profiled ADCs, from which nurses can withdraw medication once it has been prescribed and validated by the clinical pharmacist. High-volume drugs, such as fluids and topical formulations, are stored in the nursing floor stock. The hospital's CPOE system has to be checked regularly for new or modified medication orders. Any changes required a new MAR to be printed, as this document is used to retrieve medication from the ADC (2012). The pharmacy service consists of continuous online centralized order validation, except for the night shift (2015).	CPOE and semi-electronic MAR
Cottney A, 2014[2]	ADCs are locking cabinets that control access to medication. Nurses can gain access to the cabinet by using a password, or by scanning their fingerprint. A touchscreen is then used to select the required patient from a list, and then to select the medication needed for administration. When the medication is selected, the cabinet unlocks to allow access only to the location in which that particular medication is stored, and guides the nurse to that location so that they can remove the required dose.	No EP or BC technology
Fanning L et al., 2016[29]	ADCs are medication storage and dispensing units that are computer controlled. Access to ADCs is controlled by biometric technology. Medications are obtained via operation of the touch screen at each ADC. Patient details are available on the touch screen as a result of interfacing with the hospital's patient admission system. The nurse first selects the patient and then searches for the appropriate medication on the screen. Once the medication is selected, the cabinet releases a drawer that contains the selected medication. Sound-alike and look-alike medications are deliberately stored in different areas of the cabinets to avoid accidental and incorrect selection. Moreover, for medications stored in high-security bins, access is restricted to only the medication selected. For medications contained in low-security bins, there is access to all medications contained within the same drawer; however, a guiding light provides direction to the exact location for the selected medication. The physical separation of similar medications, the restricted access to some medications and the guiding light technology may provide enhanced safety and may help to guard against selecting the incorrect medication when compared with openshelf storage and configuration of pharmaceuticals.	No EP
Skibinski KA et al., 2007[39]	The cart-fill process was modified from dispensing medications to an individual patient medication drawer (preimplementation) to dispensing inventory to the ADC (postimplementation).	Point-of-care and BC technology
Zaidan M et al., 2016[16]	ADCs provide computer-controlled storage, dispensing, and tracking of drugs at the point of care in patient care units. Pharmacists are responsible for delivering medication to patients.	No information
Rochais É et al., 2014[1]	Controlled drugs and about 20 high-risk medications are identified by BC reading before they are added to the stock in the ADC. With the exception of the emergency department, every prescription has to be transmitted to the pharmacy and is entered in the patient's pharmacological file (ie, health record). The orders are displayed on the unit care's ADC, and the drug can be selected by the nurse. Users may access ADCs with biometry technology or with a username and password combination. Medication may also be accessed prior to a pharmacist validation, if the order is made when the pharmacy is closed or in case of an emergency.	BC reading
Hull T et al., 2010[32]	Patients' routine medications and the supplies necessary for administration of medications (e.g. medication cups, syringes, needles, alcohol pads, stickers for labeling) were stocked in the cabinets. Both pre- and post-installation controlled substances, stat medications, and as needed medications were stored in cabinets.	BC technology
Roman C et al., 2016[37]	Almost all medications were stored within the cabunets. A small number of high turnover medications with low risk of misuse remained accessible from an open shelf in the medication room.	No EP

Romero AV et al., 2005[38]	A nurse logs in, selects the patient and the medication and number of units to be removed from the ADM. It is possible to program the ADM to display a screen that requires nurses to answer a multiple-choice question when a particular medication, such as a tracer drug, has been selected for removal.	No information
- **ADSs** (n=3) Balka E et al., 2007,[23] Chapuis C et al., 2010[13] and Chapuis C et al., 2015[25]	Computer-controlled ADS stores most of the medications in the nursing unit and records each drug delivery. The automated cabinet is locked, made up of a touch screen monitor and keyboard, with various other secure storage spaces connected to it (i.e. refrigerator). To access the ADS a password or fingerprint is required. The nurse selects a patient profile from a list of options and selects the medication that has to be administered for that patient. The cabinet then unlocks a drawer or carousel containing the medication, allowing the user access to that drawer for a specified amount of time. The ADS computer records the time, the nurse identity, the patient name and the medications removed. For narcotic medications, they also had to enter the physician's name.	COPE (Chapuis C et al., 2015)
- **Decentralized automated cabinets and electronic trolleys** (n=2) Franklin BD et al., 2007[30] and Franklin BD et al., 2008[31]	A closed-loop system comprising e.g. ward-based automated dispensing. The majority of medications was stored in automated cabinets. The doses required were transferred by nursing staff to an electronic drug trolley at each drug round. The automated cabinets, contained computer-controlled drawers and a touchsensitive computer screen. Products that were ward stock were in product-specific drawers containing only that drug, dose and formulation, in original packs. Non-stock medication dispensed for individual patients was stored in patient-specific drawers, which could contain several products dispensed for that patient. The patient's name was indicated on the drawer using a liquid crystal display. The computer screen indicated the patients for whom doses were due in the next 2 h. To prepare for a drug round, the nurse selected each patient using the touch-sensitive screen and was then presented with a list of the doses due. On selecting each dose, the relevant drawer in the cabinet opened so that the nurse could take the number of dosage forms required and place these in the electronic drug trolley. Each trolley contained 20 drawers and could be docked with the automated cabinet. When medication was being prepared for a drug round, only one drawer in the drug trolley opened at a time, and the patient's name was indicated on the drawer's liquid crystal display. Once all the medication had been prepared for a given drug round, the trolley could be disconnected and taken around the ward. The BC on each patient's wristband was scanned, which triggered the system to open that patient's drawer in the trolley so that the medication could be administered. The nurse confirmed administration using a touch-sensitive screen on the trolley, and entered the reasons for any doses not given. On completion of the drug round, details of all doses administered and reasons for any omission were uploaded to the main server once the trolley was docked. Medication prescribed ''to be given when required'' was generally given separately outside the main drug rounds.	EP, BCMA and eMARs.
- **ADCs combined with drug trolleys** (n=1) Barber N et al., 2007[24]	For each drug prescribed, a unique drawer in a wall cabinet opened as did one drawer with the patient's name on it in a computerised drug trolley. Once the dose was transferred from the storage cabinet drawer to the trolley drawer, the cabinet drawer closed and the process was repeated for other required drugs. The patient's drawer would then be closed and automatically locked. Then the nurse selected another patient and the process was repeated. During the drug round the wristband with BC was scanned by a reader. The patient's drawer in the trolley then opened and the drugs were administered with details of administration noted on the trolley's computer.	EP, eMAR and BC technology

- **ADDS** (n=1) Dib JG et al., 2006[27]	The computerized ADDS provides secure storage of UD and bulk medications, as well as narcotics. It is based on a customized list that aims to fulfill 90% to 95% of the needs of a particular clinical area for immediate and routine use. Each of the automated storage and dispensing cabinets is interfaced to the pharmacy management system, whereby each station has unit-specific admission, discharge, and transfer information and patient-specific medication profiles that are updated to the minute. As a pharmacist enters and verifies a new medication order in the pharmacy computer, it is instantly added to the patient's medication profile. Ths enables nurses to log in to the ADDS and obtain the newly ordered medication for administration to the patient immediately. The ADDS automatically bills the dose to the hospital's accounting system and updates the medication administration records to document the medication acquisition time from the ADDS.	BC technology
- **Automated dispensing devices** (n=1), Tsao NW et al., 2014[14]	Articles reporting on the use of ward-based (i.e., decentralized) automated dispensing devices.	No information
- **MVS** (n=1) Ardern-Jones J et al., 2009[22]	A ward-based MVSs consists of a number of drawers and storage cupboards that are computer-controlled, and accessed via a pin number and fingerprint scan. Product selection is supported by a fixed location within the system, restrictions on drawer opening and a visual display on the system monitor screen.	BC technology
Centralized drug dispensing systems (n=6)		
- **Individualized automated dose dispensing system** (n=2) Lahtela A et al., 2010[21] and Dussart C et al., 2009[28]	Pharmacy-coordinated system provides doses of patient individual medications ready for delivery to hospital wards and for medication administration. Medications are contained in single unit packages dispensed in a ready-to-administer form.	No information
- **Unit-dose DDS / Wardstock DDS** (n=1), Al Adham M et al., 2011[41]	Wardstock DDS: drugs are dispensed from the pharmacy to the hospital departments and stored in the departments' stocks and then used by nurses according to physicians' orders. Unit-dose DDS: drugs are dispensed in amounts that fulfil the needs of each individual patient for only 24 hours.	No information
- **Carousel dispensing system (+ ADC)** (n=1) Temple J et al., 2010[40]	CDT is designed as a medication storage and retrieval system used to automate medication dispensing. CDT integrates into the dispensing phase of the medication-use process and links to ADCs to increase the efficiency of cabinet restocking. Patient-specific medication drawers are filled overnight by a centralized robotic system supplemented by a technician who manually retrieves medications to complete the cart fill. Other medications filled centrally are delivered to patient care units on hourly rounds. Doses due before the next scheduled delivery are sent to the unit via the pneumatic tube system. ADCs are located on patient care units and in clinics to facilitate access to as-needed medications, controlled substances, and some routine first doses.	BC technology, The dispensing software helps to prioritize workflow and purchase medicines.
- **UD system + ADC in pharmacy** (n=1), Oldland AR et al, 2015[34]	UD: a conventional UDD distribution system (handwritten provider orders), in which medications were stored in open bins arranged alphabetically on multi-tiered shelving. UD/ADC: an electronic storage and inventory system utilizing ADCs within the pharmacy. The central inpatient pharmacy was configured with segregated (non-alphanumerical) medication storage in electronically controlled ADCs. UD/ADC/BC1: ADCs combined with BC verification. Orders were completed within the central inpatient pharmacy using the UD/ADC system in conjunction with a BC scan-enabled product verification system. UD/ADC/BC2: ADCs and BC verification utilized with changes in product labeling and individualized personnel training in systems application. This evaluation period entailed use of the above BC scan-enabled system following product labeling changes and	CPOE verified by pharmacists and BC technology.

	re-training of all involved pharmacy personnel along with full implementation of BC scanenabled product verification within the clean-room sterile product preparation area.	
- **UD system + medication carts** (n=1), Rochais É et al., 2013[35]	Medication carts are equipped with 8 drawers. Each one is assigned to a patient and contains all the medication doses prepared by the pharmacy for administration over a 24-hour period. Cart access is restricted by a personal code. The carts contain a few high-use medications that are available nonnominally.	eMAR
Hybrid drug dispensing systems (n=5)		
- **Various systems** (n=1) Acheampong F et al., 2014[17]	The various options available in a hospital pharmacy setting including automated dispensing cabinets, automated mobile medication carts, automated pharmacy carousel systems and robotic picking systems.	CPOE and BCMA
- **UDDS and ADC** (n=1) Cousein E et al., 2014[26]	A daily UDDS, where pharmacy staff prepares for each patient the drugs required for a 24-hour period, sorted by administration time, according to physicians' orders. Doses are prepared by unit dose delivering robot, which prepares daily therapies in bags attached with a ring and sorted according to administration time. Each bag contains one dose (tablet, capsule, vial, half/quarter-tablet, sachet, unit dose collyrium) to be delivered to the patient, and indicates drug name and dosage, batch, and expiration date. UDDS period: Physicians' orders placed during morning and afternoon rounds were addressed by a UD delivering robot, which prepares daily therapies in bags attached with a ring and sorted according to administration time. Most drugs are packaged for single-dose dispensing. A label placed on each ring indicates the patient's name, ward, bed and all the drugs contained in the bag. Medications that cannot be handled by the robot (cold storage drugs, bulky bottles, intravenous delivery bags) are dispensed by racks or automated storage for each patient with a label printed via the pharmacy software, indicating the patient's name, unit, room, dosage and time of administration. Pharmacy technicians check the rings, label the medications not handled by the robot, and fill the appropriately assigned drawers on the nurses' medication carts. Each drawer contains the drugs required for a given patient's scheduled medication for the 24 hours to come. When an order is entered into the CPOE outside the operating hours of the robot, drugs are available for the nurses via an ADC, connected to the pharmacy software and to the admission/ discharge/transfer software. After signing on to the ADC, nurses can select the patient and the drugs to be administered to that patient, as physicians' orders are displayed for each patient on the ADC. Ward-stock period: Prescriptions on paper were placed in a medical record and then transcribed by nurses onto a drug administration sheet. Drugs were prepared every day by nurses using a large floor stock of formulary drugs, which were ordered from the pharmacy twice a week by nursing staff without regard to physicians' orders. Daily management of the floor stock is the responsibility of the nursing staff. For non-formulary drugs, and formulary drugs unavailable on the floor stock level, the pharmacy delivers the medications based on a prescription faxed to the pharmacy and checked by a pharmacist. Orders are only applicable to medications unavailable on the floor stock level. *UDDS1: CPOE without eMAR*. Orders are placed in a CPOE system based on the pharmacy software, and then printed simultaneously in the ward and in the pharmacy. Copies are used by both pharmacists and nurses to check th eorders and record medication administration. No decision support system exists at any stage in the drug delivering system. *UDDS2: CPOE including eMAR.* Orders are placed in an electronic patient record, including CPOE, pharmacy orders monitor and eMAR.	CPOE and eMAR
- **Hybrid vs. decentralized system** (n=1), Gray JP et al., 2013[18]	Hybrid system: The pharmacy department uses a hybrid medication distribution system in which controlled substances and many 'as needed' medications are dispensed from ADCs on nursing units. The majority of scheduled maintenance doses are dispensed from the central pharmacy as part of a 24-hour cart fill using	Electronic health record

	automation (i.e., centralized robotic and medication carousel technologies). The daily cart fill is sent from the electronic health record to the pharmacy automation system, which is programmed to begin filling at midnight; cart-fill doses are filled for administration times starting at noon extending through on the following day. The filled patient cassette drawers are delivered to patient care units, at which time the contents of the newly filled cassette drawer are added to the drawer that is already on the unit. Discontinued and expired medications are removed from patients' medication drawers on a daily basis by pharmacy technicians. Decentralized system: The pharmacy department employs a decentralized medication distribution system, with approximately 89% of all doses dispensed from unit-based ADCs that contain a standardized unit-specific inventory; the remaining 11% of doses are stored in patient-specific bins within an ADC tower. Replenishment of nonstocked medications occurs via a "mini-cart fill," which is picked from a medication carousel during the night shift and delivered the following morning. At the study hospital, 25% of cabinets are restocked twice daily, and 75% are restocked once daily.	
- **Traditional vs. single-dose vs. EP and ADC** (n=1), Jiménez Muños AB et al., 2011[3]	Traditional system: The doctor writes the prescription on a treatment sheet, the nurse transcribes the prescription to a medication administration sheet, and the medication is administered from the stocks kept on the ward, which are replenished by the unit supervisor as agreed with the Pharmacy Department. Single-dose system: The prescription is written on a modified treatment sheet and validated by the pharmacist prior to dispensation; it is also transcribed by the nurse responsible for its administration. EP system: Computerised prescriptions are validated by the pharmacist and dispensed from automated cabinets, irrespective of whether they are transcribed by the ward nurses (although this depends on the individual department).	EP
- **Hybrid model** :70% central pharmacy, 15% ADC and 15% patient-specific extemporaneous i.v. or oral doses (n=1) Lathrop K et al, 2014[33]	Most scheduled maintenance doses were dispensed from the central pharmacy as a part of the 24-hour cartfill via a centrally located robot and medication carousels. Cartfill doses were dispensed 12–36 hours before their scheduled administration time and delivered in patient-specific cassette drawers that arrived at patient care units by 11 a.m. each day. The contents of newly delivered drawers were added to the drawer already present on the unit (i.e., a true exchange did not occur). Discontinued and expired medications were removed from patients' medication drawers by decentralized pharmacy technicians on a daily basis.	Bedside medication scanning, and CPOE

ADC= Automated dispensing cabinet, CPOE = Computerized psysician/provider order entry, (e)MAR = (electronical) medication administration record, EP = electronic prescriping, BC = bar code, AD(D)S = automated (drug) dispensing system, ADM = automated dispensing machine, BCMA = barcode medication administration, MVS = medicines vending system, DDS = drug-dispensing system, CDT = carusel dispensing technology, UD = unit dose, UDDS = Unit dose dispensing system