Appendix A: Example of search strategy used (Pubmed). Similar strategy was used for the other databases.

Search	Query
#31	Search (#30 AND #12 AND #22) Filters: published in the last 10 years
#30	Search (#25 OR #26 OR #27 OR #28 OR #29)
#29	Search Robotics[MeSH Terms]
#28	Search Medication Systems[MeSH Terms]
#27	Search electronic*[Title/Abstract]
#26	Search robot*[Title/Abstract]
#25	Search automat*[Title/Abstract]
#23	Search (#12 AND #22)
#22	Search (#13 OR #14 OR #15 OR #16 OR #17 OR #18 OR #19 OR #20 OR #21)
#21	Search "Technology, Pharmaceutical"[MeSH Terms]
#20	Search "Pharmacy Service, Hospital"[MeSH Terms]
#19	Search distribut*[Title/Abstract]
#18	Search prescrib*[Title/Abstract]
#17	Search label*[Title/Abstract]
#16	Search (stock[Title/Abstract] OR stocks[Title/Abstract])
#15	Search dispens*[Title/Abstract]
#14	Search pack*[Title/Abstract]
#13	Search pick*[Title/Abstract]
#12	Search (#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #10 OR #11)
#11	Search pharmacy[MeSH]
#10	Search pharmaceutical*[Title/Abstract]
#9	Search pharmacist*[Title/Abstract]
#8	Search (inventory[Title/Abstract] OR inventories[Title/Abstract])
#7	Search prescription*[Title/Abstract]
#6	Search pharmacy[Title/Abstract]
#5	Search drug*[Title/Abstract]
#4	Search dosage*[Title/Abstract]
#3	Search dose*[Title/Abstract]
#2	Search medicament*[Title/Abstract]
#1	Search medication*[Title/Abstract]

Appendix B: Summary of included articles

#	Journal Citation / Country, Study year	Objective	Study Design & Study population	Context	Intervention (Type of machine)	Outcome Measure & Results	NOS Scale / Quality
Case Studies (n=7)							
1.	Beard RJ, Smith P. Integrated electronic prescribing and robotic dispensing: a case study. SpringerPlus. 2013;2:295. doi:10.1186/2193-1801-2-295. UK, 2013	To quantify the efficiencies that can be gained from the use of an integrated electronic prescribing-robot system	Descriptive Pharmacy staff, n = Unspecified Comparator = Manual dispensing Study duration = 3.5 years	Hospital Pharmacy – Both	Packs/ blisters dispensing systems	**Medication Error** Medication errors was reduced to zero per month. **Manpower/ Workload** **Cost Saving** Manpower was reduced by 1.4 FTEs and cost savings was found to be around £35000 per year; savings of £500000 above business case requirement was achieved (Min £250000 reduction).	7 Excellent
2.	James KL, Barlow D, Bithell A et al. The impact of automation on workload and dispensing errors in a hospital pharmacy. International Journal of Pharmacy Practice. 2012;21(2):92-104. doi:10.1111/j.2042-7174.2012.00238.x. UK, 2013	To determine the effect of installing an original-pack automated dispensing system (ADS) on dispensary workload and prevented dispensing incidents in a hospital pharmacy	Descriptive Pharmacy staff, n = 45 Comparator = Pre-Automation Study duration = 12 weeks	Hospital Pharmacy – Both	ROWA dispensing machine	**Manpower/ Workload** Post-automation the median dispensary workload was significantly greater (13.17 items/person/h, IQR = 9.74–17.58) than pre-automation (9.20 items/person/h, IQR = 6.15–11.90; U = 29302, $P < 0.001$). **Medication Error** The rate of prevented dispensing incidents was significantly lower post-automation (0.28%) than pre-automation (0.64%; $c2 = 66.67$, $P < 0.0001$). No statistically significant difference in the categories of error types reported pre- and post-automation by the participating hospital ($P = 0.277$).	5 Good

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3.	James KL, Barlow D, Bithell A, et al. Role conflict: occupational stressors versus patient safety. The effect of workload and pharmacy staff stressors on prevented dispensing incidents in hospitals with manual and automated dispensing systems. International Journal of Pharmacy Practice. 2009:B2-B3. UK, 2009	To compare dispensary workload, staff stressors and prevented dispensing incidents in hospitals with ADS against manual dispensing systems	Comparative Pharmacy staff, n = 35 (Site A) = 22 (Site B) Comparator = Manual Dispensing Study duration = Approx. 6 weeks	Hospital Pharmacy – Both	Not specified	**Manpower/ Workload** **Medication Error** Manual dispensing (site A) was associated with the lowest workload (direct time: 7.5 items/person/h, SD ± 7.5; benchmarking: 9.5 items/person/h, SD ± 10.6) yet highest rate of prevented dispensing incidents (0.6%). In contrast, ADS (site B) gave the highest workload (direct time: 11.7 items/person/h, SD ± 8.3; benchmarking: 12.6 items/person/h, SD ± 8.8) but lowest prevented dispensing incident rate (0.3%). There was a significant difference between workload (direct time: $P < 0.01$; benchmarking: $P < 0.01$) and prevented dispensing incident rate ($P = 0.003$) reported for both hospitals. A strong positive relationship was reported between workload and incidence of prevented dispensing incidents (site A: $r = 0.483$, $P < 0.01$; site B: $r = 0.142$, $P = 0.01$). **Satisfaction/ Perception** Manual dispensing systems were associated with greatest staff stress, overwork and autonomy	3 Fair

4.	Lin AC, Huang YC, Punches G, Chen Y. Effect of a robotic prescription-filling system on pharmacy staff activities and prescription-filling time. American Journal of Health-System Pharmacy. 2007;64(17):1832-1839. doi:10.2146/ajhp060561. US, 2007	To explore the time spent by pharmacy staff on various activiy before and after the installation of the ScriptPro SP-200 and to determine the direct and indirect prescription filling time required	Descriptive Pharmacy staff, n = Unspecified Comparator = Pre-Automation Study duration = 1 week	Community Pharmacy	ScriptPro Sp-200	**Time Saving** The time spent on filling was significantly reduced by nearly 0.56 minute per prescription. With the exclusion of nonproductive time, the average prescription filling time was reduced by nearly 0.22 minute although there was no statistical difference.	7 Excellent
5.	Mobach MP. The merits of a robot: a Dutch experience. Journal of Pharmacy and Pharmaceutical Sciences. 2006;9(3): 376-87. Netherlands, 2006	To determine the merits of a robot at the community pharmacy in a quasiexperiment based on 8 topics that were investigated: basic costs of the robot, workload, waiting times, congestion and slack, general work, counter work, consultation-room work, and overall economics of the robot	Descriptive Unspecified study population Comparator = Pre-Automation Study duration = 6 weeks pre- and post-Automation	Community Pharmacy	Packs/ blisters dispensing systems	**Manpower/ Workload** Workload was higher in the pretest without robot than in the post test with robot. In the robot situation each staff member handled 15 prescriptions less a day. This may have affected at least parts of the results of the study. However, if all other things are kept equal, the total pharmacy working systems needs 6.8 FTE instead of 7.1 FTE to dispense the observed 14,410 prescriptions of the pretest. The robot working system needs 0.3 FTE less for staffing in a situation with a robot; estimated on EUR 11,000. **Time saving** Total patient waiting time decreased with one minute and 18 seconds per dispensing process. Patients had well-over a minute shorter waiting time until counter contact. The waiting time after counter contact remained relatively stable. All standard	6 Good

						deviations were lower in the situation with the robot. Less waiting times differed from the mean, indicating that the different waits were more comparable in duration	
6.	Ong YS, Chen LL, Wong JA et al. Evaluating the Impact of Drug Dispensing Systems on the Safety and Efficacy in a Singapore Outpatient Pharmacy. Value in Health. 2014;17(7):A791-A792. doi:10.1016/j.jval.2014.08.440. Singapore, 2014	To evaluate the impact of the DDS on safety and efficacy in the pharmacy	Retrospective Unspecified study population Comparator = Manual Dispensing Study duration = 1 year	Hospital Pharmacy – Both	Packs/ blisters dispensing systems	**Medication Error** An average of 141 (79 - 162) prevented dispensing incidents per month were committed by manual picking while 0 (0 - 6) were committed by the DDS. The median rate of prevented dispensing incidents per month committed by manual picking [2.73 (1.88 - 3.57)] was significantly higher (p < 0.05) than the DDS [0 (0.00 - 0.46)]. For each type of prevented dispensing incident, manual picking also contributed a significantly higher (p < 0.05) median percentage per month as compared to the DDS. **Manpower/Workload** DDS had greater picking efficiency with each FTE in the DDS having an average of 6175 picks per month which was significantly higher (p < 0.05) than each FTE in the manual picking stations which had an average of 4867 picks per month.	5 Good

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7.	Walser L, Skinner J, Chisholm A. Early Impact of a Decentralized Automated Early Impact of a Decentralized Automated dispensing System in a Small Regional Hospital. Canadian Journal of Hospital Pharmacy. 2011;44(1). Canada, 2011	To find out if automated drug distribution can enhance patient safety, provided cost savings and improve staff satisfaction	Descriptive Pharmacy/ Nursing staff, n = Unspecified Comparator = Manual Dispensing Study duration = Unspecified	Hospital Pharmacy – Both	Unit dose dispenser	**Medication Error** Medication related reportable occurrences decreased by 37%. **Cost saving** Medication departmental costs decreased by 24% compared to the same period one year earlier.	3 Fair
Cross-sectional studies (n=5)							
8.	Blaker K, White L, Poyser W. Dispensary assistants' attitudes and perceptions regarding automated dispensing machines in community pharmacies. International Journal of Healthcare Technology and Management. 2013;14(1/2):90-109. doi:10.1504/ijhtm.2013.055088. Australia, 2013	To determine the attitudes and perceptions of dispensary assistants regarding ADMs within a community pharmacy setting	Retrospective Dispensary manager and assistants, n = 50 Comparator = Manual Dispensing Study duration = Unspecified	Community Pharmacy	Not specified	**Satisfaction/ Perception** The attitudes and perceptions of dispensary assistants towards ADMs are mixed, but primarily those who have experienced the use of the ADM tended toward more positive.	6 Good

| 9. | Cheung KC, van den Bemt PM, Bouvy ML, Wensing M, De Smet PA. Medication Incidents Related to Automated Dose Dispensing in Community Pharmacies and Hospitals - A Reporting System Study. PLoS ONE. 2014;9(7):e101686. doi:10.1371/journal.pone.0101686.

Netherlands, 2014 | To provide insight into the nature and consequences of medication incidents related to ADD across the full range of phases of the medication process (from prescribing to dispensing, storage and administration), as reported by healthcare professionals in community pharmacies and hospitals | Descriptive

Medication Error Reports from a database (CMR, Netherlands), n = 15113

No comparator

Study duration = 1 year 1 month | Hospital Pharmacy – Unspecified

Community Pharmacy | Unit dose dispenser | **Medication Error**
Most incidents were concentrated in two typical pharmacy phases: entering the prescription into the pharmacy information system (Hospital 24.1%; Community 43.3%) and filling the ADD bag (Hospital 26.8%, Community 18.9%).

The most frequent immediate cause of medication errors in community settings is the alteration of the medication regimen (24.2%, n=55) while that on a hospital setting is during admission to hospital, discharge from hospital and transfer to another ward (36.6%, n=15). | 4

Good |
| 10. | Humphries TL, Delate T, Helling DK, Richardson B. Impact of an automated dispensing system in outpatient pharmacies. Journal of the American Pharmacists Association. 2008;48(6):774-779. doi:10.1331/japha.2008.07114.

US, 2008 | To evaluate the impact of an automated dispensing system (ADS) on pharmacy staff work activities and job satisfaction. | Survey

Pharmacist, n = 136 Pharmacist Technicians, n =160

Comparator = Manual Dispensing

Study duration = 14 – 25 months | Hospital Pharmacy – Outpatient | ScriptPro Sp-200 | **Time saving**
Patient counseling rates did not differ when automated pharmacies were compared with nonautomated pharmacies. Pharmacists in automated pharmacies did not report spending more time completing clinical reviews; neither did they report spending less time filling medication orders. Similarly, technicians in automated pharmacies did not report spending less time filling medication orders

Manpower/ Workload
Satisfaction/ Perception
A high percentage of responding pharmacists agreed that they were satisfied with their current job (81%). This response was reported equivalently between pharmacists in nonautomated pharmacies (88%) and automated pharmacies (76%; | 6
Good |

						P > 0.05). Similarly, an equivalent percentage of pharmacists from automated compared with nonautomated pharmacies reported that they were expected to perform too many traditional dispensing duties (26% vs. 12%) and that they did not have enough time to counsel patients (18% vs. 9%) (both P > 0.05). No differences between the groups of pharmacists were identified in the other job satisfaction questions (all P > 0.05; data not shown). Mean productivity increased modestly in outpatient pharmacies from 48.2 prescriptions per FTE per day before automation to 50.0 prescriptions per FTE per day after ADS installation. However, this change was not statistically significant (P > 0.05)	
11.	James KL, Barlow D, Bithell A, et al. The impact of automation on pharmacy staff experience of workplace stressors. International Journal of Pharmacy Practice. 2012;21(2):105-116. doi:10.1111/j.2042-7174.2012.00231.x. UK, 2013	To determine the effect of installing an ADS on staff experiences of work, the psychological contract (i.e. contract of choice, content of contract, met expectations and reward equity), individual life outcomes (i.e. job satisfaction and work–life balance) and future plans (e.g. employability and organisational commitment)	Survey Pharmacy staff, n = 45 Comparator = Pre-Automation Study duration = Approx. 2.5 years	Hospital Pharmacy – Both	ROWA dispensing machine	**Satisfaction/Perception** There was a significant difference between the median responses given by survey respondents pre- and post-automation for staff experience of job stress. Fewer staff reportedly experience stress post-automation (12.5%, n = 2) compared to pre-automation (34.3%, n = 12). Automation had no significant effect on staff experiences of the psychological contract. Both pre- and post-automation, survey respondents reported that they were satisfied with their job. Post-automation, none of the survey respondents indicated that their job had a negative effect on work–life balance. In contrast, pre-automation 14% (n = 5) reported that their job affected	4 Good

						their home life. Automation had no significant impact on staff perceptions of their employability, with survey respondents agreeing that they could easily find another job. However, both pre- and post-automation survey respondents reported they were embedded and committed to the organization.	
12.	Ruhle F, Braun R, Ostermann H. Impact of Robotic Dispensing Machines in German Pharmacies on Business Performance Indicators. Libyan Journal of Medicine. 2009;4(4). doi:10.4176/090731. Germany, 2008	To assess the impact of robotic dispensing machines in community pharmacies on staff efficiency and sales of over-the-counter drugs.	Retrospective Survey Pharmacy Managers, n = 253 Comparator = Manual Dispensing Study duration = Unspecified	Community Pharmacy	ROWA dispensing machine	**Cost Saving** As a result of using a robotic dispensing machine, personnel costs were reduced by an average of 4.6% during the first 12 months after start-up. Over-the-counter sales increased in the same period by an average of 6.8%. Despite average initial costs of 118,000 euros, total costs within the first 12 months fell in 50% of cases and at least remained the same in 44%. **Time Saving** In the conventional store, the time needed for inventory amounted to 38.5 hours every year. After installation of the robotic dispensing machine, the time required on average was only 15.3 hours. This corresponds to a saving of 24.8 hours per year and this time saving is significant.	6 Good
Interventional studies (n=1)							
13	Franklin BD, O'Grady K, Voncina L, Popoola J, Jacklin A. An evaluation of two automated dispensing machines in UK hospital pharmacy. International Journal	To assess the impact of the two different dispensing robot on the following: 1. the frequency and types of dispensing errors identified at the 'final-check' stage (safety)	Comparative Pharmacy staff, n = Unspecified Comparator = Manual Dispensing &	Hospital Pharmacy – Unspecified	Swisslog & ROWA Dispensing Machine	**Medication Error** At site 1, the overall reduction in dispensing errors from 2.7% to 1.0% following robot installation was statistically significant (CI −1.3% to −2.1%); the small reduction from 1.4% to 1.2% at the control site (site 2) was not (CI −0.5% to 0.1%). At site 2, following introduction of the robot, there was a	7 Excellent

	of Pharmacy Practice. 2008;16(1):47-53. doi:10.1211/ijpp.16.1.0009. UK, 2008	2. time taken to dispense inpatient, outpatient and discharge prescriptions (efficacy) 3. turnaround times for inpatient, outpatient and discharge prescriptions (efficacy) 4. drug storage space (efficacy) 5. Dispensary staff opinions and satisfaction (satisfaction)	Against another machine Study duration = 5 years			significant reduction from 1.2% to 0.6% (CI −0.3% to −0.9%). **Time Saving** Significant reductions occurred in picking times on each site following the introduction of the robot; median picking times reduced from 49 s to 32 s on site 1 (P = 0.001; Mann–Whitney test), and from 19 s to 0 s on site 2 (P < 0.001). A median picking time of 0 s was recorded on site 2 since in many cases all items had arrived from the robot before all the labels had been printed. There were no changes in median picking time during the control period on site 2, or in labelling or assembly times at any time. There was no conclusive effect on turnaround times. Increases in storage capacity occurred on each site; staff on site 2 were more satisfied following introduction of the robot; there was no difference on site 1.	