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ORIGINAL ARTICLE

Efficiency of computerized clinical decision support systems involving anticoagulants: A flashmob study in Dutch hospital pharmacies

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Aims: Computerized decision support systems (CDSSs) aim to prevent adverse drug events. However, these systems generate an overload of alerts that are not always clinically relevant. Anticoagulants are frequently involved in these alerts. The aim of this study was to investigate the efficiency of CDSS alerts on anticoagulants in Dutch hospital pharmacies.

Methods: A multicentre, single-day, cross-sectional study was conducted using a flashmob design in Dutch hospital pharmacies, which have CDSSs that operate on both a national medication surveillance database and on self-developed clinical rules. Hospital pharmacists and pharmacy technicians collected data on the number and type of alerts and time needed for assessing these alerts. The primary outcome was the CDSS efficiency on anticoagulants, defined as the percentage of alerts on anticoagulants that led to an intervention. Secondary outcomes where among other CDSSs efficiency related to any medications and the time expenditure. Descriptive data-analysis was used.

Results: Of the 69 hospital pharmacies invited, 42 (61%) participated. The efficiency of CDSS alerts on anticoagulants was 4.0% (interquartile range [IQR] 14.0%) for the national medication surveillance database alerts and 14.3% (IQR 40.0%) for alerts from clinical rules. For any medication, the efficiency was lower: 1.8% (IQR 7.5%) and 13.4% (IQR 21.5%) respectively. The median time for assessing the relevance of all alerts was 2 (IQR 1:21) h/day for pharmacists and 6 (IQR 5:01) h/day for pharmacy technicians.

Conclusion: CDSS efficiency is generally low, both for anticoagulants and any medication, while the time investment is high. Optimization of CDSSs is needed.

KEYWORDS
anticoagulants, clinical decision support systems, direct oral anticoagulants, electronic health record, flashmob study, heparin, low molecular weight heparin

1 | INTRODUCTION

Medication safety is a crucial aspect of healthcare as adverse drug events (ADEs) are frequent, can be serious and even lead to death.[1,2] Computerized decision support systems (CDSSs) contribute to the prevention of ADEs.[3] These systems automatically generate medication safety alerts. A medication safety alert is generated when medication is prescribed in the electronic health record (EHR) that matches a rule in the knowledge database, alerting for a potential medication safety risk. The knowledge database contains information on drug–drug interactions, contraindications (including pregnancy and breastfeeding), duplicate medication, under- and overdosages, and drug allergies and intolerances. These alerts can be presented real-time to the prescriber, the pharmacist and/or the pharmacy technician at the time of prescribing medication. If the alerts are perceived relevant and no intervention was performed by the prescriber, the pharmacy staff intervenes by contacting the prescriber. This process is also known as *medication surveillance*.

Unfortunately, current CDSSs generate an overload of medication safety alerts because the rule-based algorithms are insufficiently personalized, not-well tailored to the clinical context, or have low evidence base.[4] This leads to limited clinical relevance of the alerts and alert fatigue in prescribers and pharmacists, with many alerts being overridden or ignored (49–96%).[4,5] This could reduce trust in CDSSs and compromise patient safety as relevant alerts could be missed.[3] Furthermore, evaluating the alerts is a time-consuming process.[4] The time needed for assessing irrelevant alerts could be better spent on other ways of preventing ADEs, such as medication reviews and education.[5,6]

An example of a high-risk medication class with many alerts, is the group of anticoagulants. In hospitalized patients, anticoagulants are 1 of the medication classes most frequently involved in ADEs and fatal ADEs, mainly bleeding and thrombotic events, such as stroke or pulmonary embolism.[1] Especially, during the initiation of anticoagulation therapy and throughout the perioperative process, the risk of medication errors with anticoagulation therapy is high as a result of many medication changes. Drug–drug interactions and duplicate medication alerts are frequent in anticoagulants, but often not tailored to the specific patient. For example, the alerts are irrelevant, when a patient is adequately monitored on a drug–drug interaction and timely adaptations are implemented, or in case the patient uses 2 anticoagulants but this duplicate medication is indicated for a certain period of time.[7–10] Attempts to improve the clinical relevance of CDDS alerts by creating more sophisticated clinical rules (CRs), that take into account medication, various patient characteristics, laboratory values, medical procedures, diagnoses and time windows, have shown some progress.[11] Such CRs can be created either by knowledge base providers or developed in-house by a hospital pharmacy. However, a Dutch study of De Wit *et al.* showed that the average efficiency, defined as the percentage of alerts leading to an intervention, remains low and only a few CRs have an efficiency > 10%.[12] Hospital pharmacy staff is continuously dedicated to improving medication surveillance to make the process more efficient and achieve a higher patient safety. Examples of such attempts include refining CRs developed in-house to be more specific or developing in-house electronic reports that focus on a specific group of patients at risk of an ADE, such as users of anticoagulants. Whether these improvements have led to a higher efficiency of the CDSS is currently unknown.

What is already known about this subject

- Several studies show a low efficiency of clinical decision support systems resulting in too many nonspecific alerts and alert fatigue.
- These studies recommend more advanced clinical decision support using clinical rules.

What this study adds

- A flashmob study design was used to collect data in 42 hospitals in 1 day.
- Clinical decision support based on clinical rules is more efficient than the national medication surveillance, but both have a low efficiency and require much time.
- Further optimization of clinical decision support systems remains necessary.

Therefore, the primary aim of this study was to determine the current efficiency of CDSSs on anticoagulants in Dutch hospital pharmacies. Secondary aims were to study efficiency of CDSS on any medication, the efficiency per type of CDSS alert and the time spent on medication surveillance per type of pharmacy staff member.

2 | METHODS

2.1 | Study design and setting

A multicentre, single-day, cross-sectional study was conducted in Dutch hospital pharmacies using a flashmob design. This design was based on the concept of flashmobs, where groups of people suddenly meet in a public place, briefly perform a specific act and then quickly disappear.[13,14] This design enables the collection of large amounts of data in a short period, to answer a relatively straightforward question. In this study, the period consisted of 1 dayshift.

No patient data were collected, so informed consent from patients was not applicable. The responding members of hospital pharmacy staffs provided informed consent by participating in the study. Furthermore, the study did not fall under the scope of the Medical Research Involving Human Subjects Act. A waiver was obtained from the Medical Ethics Review Board of the University Medical Center Groningen (METC nr. 2023/477). This review board also concluded that the proposed research does not fall within the scope of the Medical Device Regulation (MDR, EU 2017/745) or Clinical Trial Regulation (CTR, EU 536/2014).

2.2 | Medication surveillance

In all Dutch hospital pharmacies, CDSSs are used in which medication safety alerts are triggered based on rules of a knowledge database. The knowledge database that is used in the Netherlands is called the *G-Standard*, which is a national medication surveillance database maintained by the Royal Dutch Association for the Advancement of Pharmacy (KNMP in Dutch). The G-Standard contains rule-based alerts consisting of multiple steps of *if then else* logic to generate medication safety alerts based on data in the EHR. The G-Standard rules are basic, looking mostly at medication only, and generating alerts for drug–drug interactions, duplicate medication, contraindications, drug allergies and intolerances (provided the medication [group] for which the patient is allergic or intolerant is entered into a structured field of the EHR) and over- and underdosing. Contraindications are based on the actual disease provided if it is entered into a structured field in the EHR, or based on medication use, e.g. a patient using insulin is labelled as having diabetes mellitus. Increasingly, other parameters are included in the G-Standard rules, but this is still at an early stage and the complexity of the rules remains low.

As mentioned earlier, in addition to the national medication surveillance database, hospitals can develop CRs in-house (i.e., self-built clinical rules) to trigger medication safety alerts or electronic reports for patients at risk of ADEs. These CRs can also be developed in the form of best practice advisories (BPAs) that serve as reminders or warnings to clinicians during their workflows. The logic used for the CRs or BPAs can vary from basic (combining 1 or 2 parameters to provide alerts, e.g. IF drug A AND laboratory value > threshold THEN alert), to more advanced (combining multiple patient characteristics when producing alerts, e.g. IF patient has characteristic X AND Y AND Z AND uses drug A AND has a laboratory value > specified threshold THEN alert).[4] Most of the CRs are developed and used to replace nonspecific G-Standard alerts; e.g. a CR on medication potentially needing a dose adjustment based on the kidney function of a patient, taking into account the dose of the concerning medication and the most recent estimated glomerular filtration rate of the patient. However, a CR can also be used in addition to the G-Standard alerts if the G-Standard does not offer a suitable solution, e.g. to identify patients having 3 or more anticoagulants. The G-Standard alerts only consider double medication, but no triple medication. Finally, hospitals can develop electronic reports. Electronic reports enable checking a list of patients with specific characteristics. For example, a list can be generated for patients using 2 or more anticoagulants. Pharmacy staff can then review the EHR to verify if the anticoagulants are prescribed by the same physician and assess the indication and duration of therapy to determine suitability for the individual patient.

For the purpose of this study, CRs were defined to include both the BPAs and the electronic reports. The operational processes used in Dutch hospitals with regard to medication surveillance for the alerts based on the G-Standard and the alerts based on the CRs vary extensively. In all hospitals, alerts are presented to physicians, but it varies between hospitals which G-Standard and/or CR alerts are exactly presented. Physicians can either act upon the alert or ignore it. The ignored alerts subsequently enter the hospital pharmacy medication surveillance process, in which pharmacists and pharmacy technicians are involved. Besides ignored alerts, pharmacy staff also screens alerts from pharmacy-specific CRs. Usually, the pharmacy technicians conduct a triage of the alerts for the pharmacist and are allowed to intervene on the relatively straightforward alerts without consulting the pharmacists. An example of an alert that is completely handled by pharmacy technicians is the so-called *time drug–drug interaction*, applying to 2 medicines that need to be taken with a time interval in order to prevent diminished absorption. Furthermore, the use of *forwarded alerts* can be part of the process, where the technician forward alerts to the pharmacist when uncertain about how to handle them and/or when an intervention is needed. In some hospitals pharmacy technicians do not engage in medication surveillance at all, while in other hospitals pharmacy technicians assess all alerts and pharmacists focus solely on assessing how the technicians handle the alerts or focus only on a small set of high-risk alerts.

2.3 | Study population

All hospital pharmacies in the Netherlands ($n = 69$) were approached to participate in this flashmob study by sending an invitation to the head of the hospital pharmacy and/or medication surveillance expert of the hospital pharmacy. The Dutch Association of Hospital Pharmacists (In Dutch: Nederlandse Vereniging voor Ziekenhuis Apothekers, NVZA) was asked to provide a list of all Dutch hospital pharmacies. Study participants included all staff members from the hospital pharmacy involved in medication surveillance on the study date, such as pharmacy technicians and hospital pharmacists. Some of the hospital pharmacies were providing care at multiple locations of a hospital. All hospital locations were invited to participate.

An invitation for participation and registration was sent on 7 September 2023 and on 4 October 2023. Hospital pharmacies were able to register for participation in the study. The goal was to include as many Dutch hospital pharmacies as possible to conduct a comprehensive assessment of the efficiency of CDSS systems. The participants were asked to collect data during a single dayshift, which is typically between 08:30 and 17:00 h. The study date was planned for Thursday, 2 November 2023. Hospital pharmacies that were unable to participate on that date were given the opportunity to participate on another Thursday between 26 October and 21 December.

2.4 | Study procedures

All required data were collected by sending out a survey to the participating hospital pharmacies. The survey was constructed online using Research Electronic Data Capture (REDCap), version 12.4.6 (Vanderbilt University, Nashville, United States) as a data collection tool. All hospital pharmacies received a unique link to the questionnaire, to prevent unauthorized access. Multiple participation via the unique link was prevented by asking to fill out the affiliation. Eight

online information sessions were organized prior to the study date to provide practical guidance on the research. Hospitals were invited to participate in these sessions on a voluntary basis.

In cases where the research team identified any uncertainty or missing data, they reached out to the respective hospital pharmacy to seek clarification. When no data were filled out on the online form within 2 weeks after the study date, a reminder was sent to the participant which was repeated every 2 weeks until the data were filled out or the end date of the study occurred (31 December 2023).

A pilot study was conducted on Thursday, 21 September 2023 in 6 different hospitals before the main study. This pilot aimed to evaluate the data collection procedure and address any unforeseen problems during data entry or collection. The data collected during the pilot were not included in the final results of the study. All 6 pilot hospitals also participated on the study date of 2 November 2023.

2.5 | Data collection and definitions

Supporting information 1 presents the questions asked to the pharmacists and pharmacy technicians of the participating hospitals. The participants were asked to fill out the number of medication safety alerts that were assessed that dayshift for the G-Standard alerts and the CRs. Furthermore, they were asked to fill out how many of the alerts involved anticoagulants, and the number of alerts that required an intervention overall and specifically for anticoagulants. The participants were asked to write these numbers down per type of medication safety alert; *G-Standard* or CRs (including BPAs and electronic reports) and for *G-Standard* alerts also per subtype; drug–drug interactions, contraindications (including pregnancy and breastfeeding), duplicate medication, under- and overdosages, and drug allergies and intolerances.

Furthermore, the time spent on conducting medication surveillance by the pharmacy technician(s) and the pharmacist(s) was recorded. The participants were asked to record the overall time spent on the study date. It was not explicitly specified how to keep track of the time. No distinction was made between the time spent on G-Standard alerts and CRs. Performing medication surveillance was defined as evaluating the (relevance of) alerts, and deciding whether or not an intervention was necessary. The time spent on execution of the interventions (documenting advice, calling a physician, adapting medication) was not included in the time measurement, since that time cannot be saved by a more efficient system.

Finally, general information on the participating hospitals (hospital type, number of hospital beds and the EHR system used) was collected.

2.6 | Inclusion and exclusion criteria

All medication safety alerts generated by the CDSS system and interventions concerning hospitalized patients on the study date that were handled by pharmacy staff were included. An intervention was defined as an action taken in response to a medication safety alert, such as adjusting a medication order or providing written or oral advice to a prescriber. Consultations, defined as instances when a prescriber contacts a pharmacist or pharmacy technician with a question, were not considered interventions in this study. If follow-up to an alert was required by another pharmacist or pharmacy technician at a later time, this was also not considered as an intervention.

A medication alert or intervention on anticoagulants referred to the following medication used in the Netherlands: vitamin K antagonists (acenocoumarol, phenprocoumon), low molecular weight heparins and other heparins (heparin, dalteparin, enoxaparin, nadroparin, tinzaparin, fondaparinux, danaparoid), platelet aggregation inhibitors (acetylsalicylic acid, carbasalate calcium, clopidogrel, prasugrel, ticagrelor, dipyridamole, acetylsalicylic acid in combination with clopidogrel or dipyridamole) and direct oral anticoagulants (rivaroxaban, apixaban, edoxaban, dabigatran).

2.7 | Primary and secondary outcomes

The primary outcome was the efficiency of the CDSSs on anticoagulants, defined as the percentage of CDSS alerts on anticoagulants resulting in an intervention by hospital pharmacy staff. Median efficiency percentages were calculated for G-Standard alerts and CRs, and per pharmacy staff member. Secondary outcomes were the efficiency of CDSSs related to any medication, the proportion of interventions for G-Standard alerts and CRs, and the time spent on assessing CDSS alerts' relevance per type of hospital pharmacy member (pharmacy technician, pharmacist).

2.8 | Data analysis

Data from the survey collected with REDCap were transferred to and analysed in Excel version 2307 (Microsoft, Redmond, Washington, USA). Descriptive statistics were used to analyse the data. Categorical variables were expressed as numbers and proportions. Continuous variables were expressed as mean with standard deviation if normally distributed or as median with interquartile (IQR) range for non-normally distributed variables. Normality was checked using the Shapiro–Wilk test in IBM SPSS statistics version 22 (IBM, Armonk, NY, USA).

In case both the pharmacy technician and the pharmacist were involved in the same alert (pharmacy technician forwards the alert; pharmacist assesses the alert), it counted double. The efficiency percentages were calculated per hospital (number of interventions divided by the number of alerts) and thereafter the median efficiencies were calculated. The total time spent on medication surveillance for both the pharmacist and the pharmacy technician was divided by the total number of alerts, in order to calculate the time per alert.

3 | RESULTS

3.1 | Respondent characteristics

Of the 69 hospital pharmacies that were invited, 44 participated in this study on various study dates, resulting in a response rate of 64% (Figure 1). The primary reasons for nonparticipation were mainly related to the hospital pharmacist's anticipation that participation was unfeasible due to inadequate time and personnel allocation. After exclusion of 2 hospital pharmacies due to missing data to calculate the main outcome, 42 were included.

Most of the participating hospitals (67%) used Chipsoft Hix as EHR system (Table 1). For the hospitals having multiple locations serviced by the pharmacy department, some hospital pharmacies

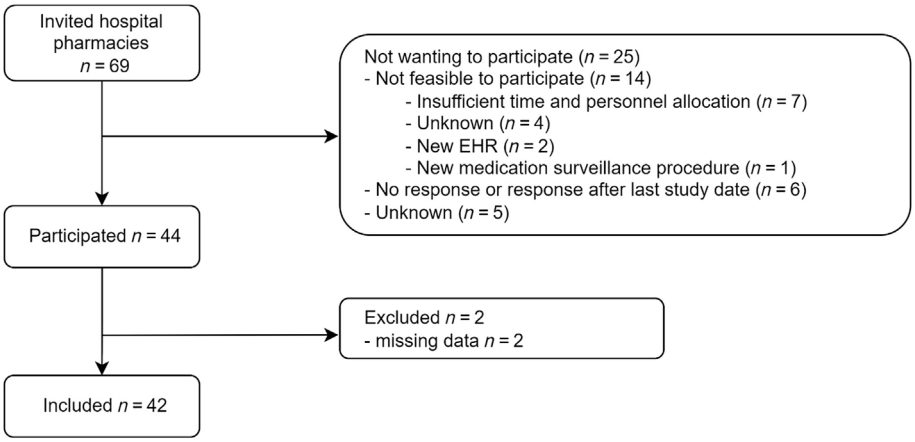

FIGURE 1 Flow diagram participation flashmob study.

TABLE 1 Participant characteristics and flashmob participation date ($n = 42$).

Characteristic		n (%)		
Hospital type[a]	General	22 (51)		
	Teaching	16 (38)		
	Academic	4 (10)		
Electronic health record system used	Chipsoft Hix	28 (67)		
	Epic	8 (19)		
	Nexus	5 (12)		
	Other	1 (2)		
No. of hospital locations per participant	1 location	28 (67)		
	2 locations	9 (21)	1 location participated	2 (22)
			All locations participated	7 (78)
	3 locations	4 (10)	1 location participated	3 (75)
			All locations participated	1 (25)
	4 locations	1 (2)	2 locations participated	1 (100)
Study date	26-10-2023	1 (2)		
	02-11-2023	28 (67)		
	09-11-2023	3 (7)		
	23-11-2023	2 (5)		
	07-12-2023	1 (2)		
	14-12-2023	3 (7)		
	21-12-2023	4 (9)		
		Mean (standard deviation)		
Number of beds	General	301 ± 95		
	Teaching	648 ± 215		
	University	999 ± 255		

[a]In the Netherlands, the hospital pharmacies are located in 36 (52%) general, 26 (38%) teaching and 7 (10%) university hospitals.

sent in data of all locations and others only sent data from selected locations.

3.2 | Efficiency of CDSS on anticoagulants

The median efficiency concerning G-Standard alerts on anticoagulants was 4.0% (IQR 14.0%) (Table 2). The efficiency for pharmacy technicians was a little higher than for pharmacists. For CRs on anticoagulants, a higher median efficiency of 14.3% (IQR 40.0%) was found for pharmacists and pharmacy technicians combined.

3.3 | Efficiency of CDSSs on all medication

The overall median CDSS efficiency concerning any G-Standard alert, was 1.8% (IQR 7.5%). Again, this was a little higher for pharmacy technicians (Table 2). For CRs a higher overall median efficiency of 13.4% (IQR 21.5%) was found for pharmacists and pharmacy technicians combined. Here, the efficiency of pharmacists was slightly higher.

3.4 | Efficiency per type of CDSS alert

Of the 42 included hospital pharmacies, 30 provided information per subtype of CDSS alert. See supporting information 2 for detailed data on the subtype of CDSS alerts. The most common CDSS alert subtypes on anticoagulants were alerts on duplicate medication, with a median of 8 alerts (IQR 11.3), followed by alerts on dosages (4 alerts, IQR 7.5) and on drug–drug interactions (2 alerts, IQR 7.0).

For any medication, alerts on duplicate medication were most frequent with a median of 67.5 alerts (IQR 97.3), followed by alerts on dosages (57.0 alerts, IQR 78.5) and alerts on drug–drug interactions (52.5 alerts, IQR 72.0). Alerts on drug–drug interactions led to most interventions with an efficiency of 2.7% (IQR 10.7%), followed by alerts on duplicate medication (1.4%, IQR 6.2%) and on dosages (0.3%, 3.4%).

3.5 | Time spent on assessing the relevance of alerts

Pharmacists spent a median of 2:00 (IQR 1:21) h/day on assessing the clinical relevance of all medication surveillance alerts (based on measurements of 41 pharmacists). The median time investment of pharmacy technicians was 5:55 (IQR 5:01) h/day (based on measurements of 35 technicians). The median time spent per alert was 28 (IQR 36) s for pharmacists and 1:14 (IQR 1:50) min for pharmacy technicians.

4 | DISCUSSION

To the best of our knowledge, this is the first study using a flashmob research design to determine the efficiency of CDSS alerts on anticoagulants. The CDSS efficiency of alerts on anticoagulants was low, with 4.0% for G-Standard alerts and 14.3% for CRs. The CDSS efficiency of alerts for any type of medication is even lower, with 1.8% for G-Standard alerts and 13.4% for CRs. For any medication alerts drug–drug interaction alerts were most frequently intervened upon.

TABLE 2 Efficiency of computerized clinical decision support systems on anticoagulants.

		Number of alerts		Number of interventions		
		Median (IQR)	Total	Median (IQR)	Total	Efficiency in % Median (IQR) *
Anticoagulant alerts						
G-Standard	Pharmacist ($n = 42$)	18.5 (19.3)	1094	1.0 (2.0)	63	3.0 (11.6)
	Pharmacy technician ($n = 33$)	19.0 (24.0)	912	1.0 (3.0)	84	5.8 (21.3)
	Overall	19.0 (21.5)	2006	1.0 (2.0)	147	4.0 (14.0)
Clinical rules	Pharmacist ($n = 37$)	5.0 (9.0)	297	1.0 (2.0)	55	14.3 (40.8)
	Pharmacy technician ($n = 14$)	3.0 (4.0)	39	0.0 (0.5)	8	12.5 (35.0)
	Overall	3.5 (7.3)	336	0.0 (1.3)	63	14.3 (40.0)
All medication alerts						
G-Standard	Pharmacist ($n = 42$)	242.0 (190.0)	12 189	4.0 (8.0)	261	1.4 (3.9)
	Pharmacy technician ($n = 33$)	211.0 (316.0)	10 916	8.0 (10.0)	506	5.8 (8.7)
	Overall	221.0 (244.5)	23 105	5.0 (9.5)	767	1.8 (7.5)
Clinical rules	Pharmacist ($n = 36$)	24.0 (18.0)	1203	4.0 (5.0)	187	14.3 (20.3)
	Pharmacy technician ($n = 14$)	9.0 (30.0.0)	179	1.0 (2.0)	35	11.8 (23.6)
	Overall	21.0 (23.0)	1382	3.0 (4.3)	222	13.4 (21.5)

Abbreviation: IQR, interquartile range.
*The efficiency percentages are calculated per hospital (number of interventions divided by the number of alerts) and thereafter the median efficiencies are calculated and presented.

The time investment for assessing the relevance of the alerts was high compared to the number of interventions performed: median 2 h/day for pharmacists and median almost 6 h/day for pharmacy technicians for a median of 8 respectively 9 interventions.

A review by van der Sijs *et al*. in 2006 on overriding drug safety alerts revealed override rates ranging from 49 to 96%.[5] This flashmob study, conducted 17 years later, indicates that these override rates have not shown improvement despite considerable efforts. A potential explanation may include the difficulty of turning G-Standard alerts off on a hospital-wide scale due to the fear of missing relevant signals. A second study of van der Sijs *et al*. showed that this is problematic due to differences among physicians, which assesses alerts before the hospital pharmacy sees them, regarding medication-related knowledge and differences across the hospital in routine medication surveillance practices.[15] Furthermore, in a study of Strasberg *et al*. poor agreement was found among physicians on assessment of clinical relevance of drug–drug interactions.[16] Nevertheless, a substantial variation in the number of alerts was identified, as indicated by the IQR in table 2, indicating that some hospitals optimized their CDSS, e.g. by replacing a group of G-Standard alerts by building (a more efficient) CR. These hospitals may act as a best practice example for other hospitals. Additionally, building more efficient CRs can be a solution to be able to replace inefficient G-Standard alerts.

The results from this flashmob study reveal that the efficiency of CDSS alerts on anticoagulants is higher compared to all medication safety alerts. In addition, the efficiency of CRs is higher than of G-Standard alerts, with percentages of 14.3% for alerts on anticoagulants and 13.4% for alerts on any medication compared to 4.0 and 1.8%, respectively. The efficiency percentages found on CRs are relatively high compared to literature mentioning efficiency percentages varying from 3 to 10%.[4,12,17] This study shows that developing CRs can be a pivotal step towards enhancing the efficiency of CDSSs. However, this study also shows that the vast majority of the alerts does not lead to an intervention. Furthermore, literature shows that alerts from CRs do not always cause a change in medication policy or are clinically relevant,[18,19] which is not investigated in this study, indicating that the actual efficiency might be even lower. Priority needs to be given to building more efficient CRs on anticoagulants that account for (more) patient and medication characteristics, in order to optimize medication surveillance in this high-risk group of medication.[1,2,20]

Pharmacy technicians perform relatively more interventions on G-Standard alerts and pharmacists perform slightly more interventions on alerts from CRs.[4,21,22] The difference in handling of G-Standard alerts may be explained by the fact that a considerable proportion consists of so-called time drug–drug interactions, caused by 2 medications that interact when administered at the same time.[4] This can be solved by adapting the administration times, a task for pharmacy technicians in most hospitals. Specifically for anticoagulants, another explanation is more likely as these time interactions do not occur in anticoagulants. Pharmacy technicians may also be more likely to follow protocols and thus intervene purely when the protocol says to do so. Pharmacists are trained to take other patient specific parameters into account, which may lead to a lower intervention percentage on G-Standard alerts as they only check the high-risk alerts. Furthermore, in most hospitals the CRs are (mainly) handled by pharmacists, since several patient characteristics have to be taken into account to make a decision.

A strength of this study is that by employing the flashmob design, we were able to collect a large amount of data within a short period of time. Due to the fact that the study period per hospital pharmacy was only 1 day and the data collection was feasible, the willingness to participate in the study was high, with 44 out of 69 hospital pharmacies willing to participate, which contributes to generalizability of study results. However, the flashmob design also comes with some limitations. Extensive preparation is necessary beforehand to ensure that the collected data are accurate and comprehensive. In this study, extensive preparation could not prevent that data from 2 hospitals had to be excluded due to missing data regarding the main outcome. In addition, not all hospitals provided all the requested data; some participants did not take track of the time spent on assessing the alerts and some participants did not specify the subtype of alert (interaction, double medication etc.). Another limitation is that no insight is available into the clinical relevance of the interventions and whether the interventions lead to a change in the medication policy. Therefore, the efficiency found in this study may be an overestimation of the number of interventions that eventually lead to a clinically relevant outcome. Furthermore, selection bias may have occurred, since the hospitals that did not participate in the study mentioned most frequently that it was not feasible to participate due to limitations of the hospital system, indicating that the CDSS efficiency is possibly even lower in those hospitals. Finally, the flashmob design requires the collection of a limited dataset and therefore data on the number of patients and the number of prescriptions on the flashmob day were not collected. Such data could have helped to explain the differences between hospitals.

Future research should explore the reasons for the large variation in CDSS efficiency between the hospital pharmacies, for example by collecting potential determinants that could be included in a regression analysis. Studies could explore whether time investment can actually be reduced by increasing the efficiency of medication surveillance, or explore the most safe and efficient alert handling by pharmacy technicians in relation to hospital pharmacists. Best practices from hospital pharmacies with a high efficiency can be exchanged between hospitals. Furthermore, other options to optimize the process of medication surveillance have to be explored. Research on optimization of data extraction of the EHR systems might reveal better options to bring together the relevant data from the patient files for the assessment of the medication alerts. Another potential solution to increase clinical relevance of medication alerts and thereby increasing the efficiency, is to better design medication alerts by increasing clinical relevance, e.g. by personalizing the alerts using for example artificial intelligence technology.[23–25] Artificial intelligence technology can account for complex patterns of patient conditions, medication characteristics and healthcare provider actions. Given the time spent on medication surveillance, investing in such studies will be worthwhile.

5 | CONCLUSION

The CDSS efficiency of alerts on anticoagulants is low, with alerts of clinical rules achieving a higher efficiency than the national medication surveillance database alerts. The efficiency of alerts for all medications is even lower for both types of alerts. For any medication, drug–drug interaction alerts were most frequently intervened upon. Medication surveillance requires a high time investment of hospital pharmacy staff with low efficiency. The process of medication surveillance is in high need of optimization, which may save time of scarce hospital pharmacy personnel and reduce healthcare costs.

AUTHOR CONTRIBUTIONS

Conceptualization: Jetske Graafsma, Joanna E. Klopotowska, Hieronymus J. Derijks, Ewoudt M. W. van de Garde, Rien H. L. Hoge, Fatma Karapinar-Carkit and Patricia M. L. A. van den Bemt. *Funding acquisition*: Patricia M. L. A. van den Bemt. *Investigation*: Jetske Graafsma. *Methodology*: Jetske Graafsma, Joanna E. Klopotowska, Hieronymus J. Derijks, Ewoudt M. W. van de Garde, Rien H. L. Hoge, Fatma Karapinar-Carkit and Patricia M. L. A. van den Bemt. *Writing—original draft*: Jetske Graafsma. *Writing—review and editing*: Jetske Graafsma, Joanna E. Klopotowska, Hieronymus J. Derijks, Ewoudt M. W. van de Garde, Rien H. L. Hoge, Fatma Karapinar-Carkit and Patricia M. L. A. van den Bemt.

CONFLICT OF INTEREST STATEMENT

R.H. is a CMO at GastonMedical which is a software company that develops medical decision support systems. The other authors report no competing interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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