Original Article

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Evaluation of appropriateness of alerts overrides and physicians' responses of the medication-related clinical decision support system in China, a hospital-based study

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SUMMARY This study was designed to investigate the *state quo* of the appropriateness of alerts overrides of the medication-related clinical decision support system (MRCDSS) in China. The medication-related alerts in one hospital from Jan 2022 to Dec 2022 were acquired and sampled. Rates of alert overrides, appropriateness of alert generation and physicians' responses were observed. Total 14,612 medication-related alerts (≤ level 3) were recorded, of those, 12,659 (86.6%) alerts were overridden. The top 3 alert types were: drug and diagnosis contraindications (23.8%), drug and test value contraindications (23.3%), and compatibility issues (17.7%). Of all sampled 1,501 alerts, 80.2% of them were appropriately overridden by the physicians. The appropriate rate of alert generation was 57.9% and the inappropriate rate was 42.1%. The inappropriate rate of physicians' responses was 17.8%, and 2.0% physicians' responses were undetermined. A few medications accounted for over 10% of overrides, 88.3% of "overridden reasons" inputted by the physicians were meaningless characters or values, indicating an obvious "alert fatigue" in these physicians. Our results indicated that the overridden rate of MRCDSS in China was still high, and appropriateness of generation of alert was quite low. These data indicated that the MRCDSS currently using in China still needs constantly optimization and timely maintenance. Proper sensitivity to reduce triggering of useless alerts and generation of alert fatigue might play a vital role. We believed that these findings are helpful for better understanding the *state quo* of MRCDSS in China and providing useful insights for future developing and improving MRCDSS.

Keywords medication-related clinical decision support system (MRCDSS), alerts, alert fatigue, hospital information system (HIS)

1. Introduction

Medication-related clinical decision support system (MRCDSS) has become an indispensable component of hospital information system (HIS) (*1*). It's algorithms commonly include data of clinical characteristics of patients (demographic data, results of laboratory examinations, severity, *etc.*), drug instructions based on pharmacopoeia, and clinical guidelines (*2*). Once the medical orders are determined as "risky", it may generate "alerts", which are reportedly more specific than alerts from basic medication surveillance (*2*). Most of MRCDSS alerts are interruptive, and require users to choose "accept" or "override" the alerts before continuing. Alerts from MRCDSS cannot be ignored during the processes of making a medical order, which are greatly helpful for the physicians to prevent potential errors during the prescription. However, due to the limitations of software and algorithms (*2*), alerts generated by the MRCDSS might be "appropriate" or "inappropriate", of those, many alerts might be overridden by the physicians in light of the clinal pathophysiological state of a certain patients. Meanwhile, the responses of physicians are also not always appropriate. Thus, evaluation of the override rate is useful for better understanding the *state quo* of the performance of the MRCDSS in use

and the knowledge, attitude and practice (KAP) of the physicians concerning the MRCDSS which is important to improve the performance of MRCDSS, fix the bugs of software, and carry out education/training to improve the operation skill of the physicians. Poly *et al.* reviewed that approximately 46.2%-96.2% of alerts were overridden, of those, 29.4%-100% of the overrides alerts were identified as "appropriate" (*3*). Another study in Australia reported that approximately 90% physicians complained that too many alerts were triggered in the electronic medical records (EMRs). They therefore suggested that most of alerts should be removed and the alerts should be triggered with a more specific and less sensitive manner (*4*). A study in Korea found that the override rate of alerts of MRCDSS was 92.9%. Conversely, only 7.3% of the alerts were clinically appropriate. Too many unnecessary alerts were generated (*1*). These published findings indicate that the MRCDSS so far is far from satisfactory. Main problem lies in oversensitivity of the MRCDSS induces too many unnecessary alerts are generalized, which may make the medical staff fatigue and begin to ignore the alert information. Such negative attitude to the alerts of MRCDSS might lead an inappropriate override, which are reportedly associated with enhanced risk of generation of adverse events during the clinical practice (*5,6*). Hence, development of more optimized algorithms for MRCDSS has been an ultimately task for global researchers, which first step is grasping the *state quo* of alert generation and override rate of the MRCDSS in use in a certain country. However, these data are unreported and unavailable in China, which has limited development of better algorithms for MRCDSS in China.

On the basis of the aforementioned backgrounds, we designed this single-center, observational, retrospective study to investigate the *state quo* of MRCDSS performance in China. We attempt to provide useful information regarding the type of overridden alert, appropriate rate of alert display, and physicians' responses. We believe that the findings of the present study are helpful for development of optimized algorithms for MRCDSS in China.

2. Materials and Methods

2.1. The rational medication smart prescription review system currently used in China

All data of the present study were acquired from the medical records of the HIS (HIS, Winning Health Technology Group Co., Ltd., China) in a 1200-bed comprehensive hospital. All medication orders were inputted to the system, then the medication-related clinical decisions were firstly made by a commercial Rational Medication Smart Prescription Review software (Visense Technology Co., Ltd., China, *http://www.ivisense.com/*), which is a representative and widely used MRCDSS software in hospitals in China (*7-9*). The knowledge base of this software includes enormous quantity of drug instructions, the Chinese Pharmacopoeia and Chinese Pharmacopoeia Clinical Medication Instruction (*10*). This system can conduct risk review of all inputted medication orders based on the 6-category build-in drug use risk review rules including dose range, drug interactions, drug duplicate, compatibility issues, administration route, contraindications. Once the system detected a medical order was "risky", it would general the alerts. All alerts are displayed in one window. A single drug may generate multiple alerts, which are individually counted in the data table. This system can provide four levels of alerts. Level 1 to level 4 are presented from strength to weak. Level 1 alerts are mandatory. Accordingly, involved medical orders were directly intercepted and physicians must the modify prescriptions. Level 2 alerts are determinable, physicians are allowed to choose accept or override the alerts. If they choose "accept", they need to modify the prescribed medications; if they choose "override", they need to state the reasons for the override. Level 3 alerts are reminder only, the physicians need not revise the prescriptions or enter the reasons for override. Level 4 alerts is not prompted which are only recorded in the back end.

2.2. Experimental design

This is a single-center, observational, retrospective study based on the medication-related alerts with levels 2 and 3 generated by the HIS from January 2022 to December 2022. All the alerts were processed with stratified sampling in random using the combination of "department + drug name + alert type" with the 1% sampling rate and at least one case per combination. The appropriateness of each alert override was independently analyzed by 2 clinical pharmacists and their consistency was tested as well. In case of any disagreement, discussion would be held by 1 clinical physician to reach mutual agreement.

This study used the evaluation framework described in a previous study (*11*). Alerts are classified by the results of appropriateness evaluation. Due to the fact that Level 3 alerts do not have reasons of override, there are situations that their appropriateness could not be determined, which were defined as "non-decidable" here. In brief, the appropriateness of alert overrides includes both appropriateness of alert generation and appropriateness of physicians' responses. The appropriateness of alert generation refers to the situation whether the alert is appropriately generated when the conditions reach the criteria of the rule of "risky" including the administrative, laboratory, and treatment-related data and trigger the alerts. Alerts might be incorrectly triggered due to the system deficiencies (such as lack of data and maintenance errors, or bugs of software) are considered "inappropriate". Appropriate physicians' responses refer to the situations that the

physicians have to override the alerts based on the patients' conditions, or evaluation of the benefits/risks of the medications in light of guidelines, expert consensus, and literature data, although the alerts are relevantly and accurately generated. We provided the evaluation criteria of overridden criteria in Table S1 in various situations (Table S1, *http://www.ddtjournal.com/action/getSupplementalData.php?ID=198*), which were developed by senior pharmacists. In addition, the demographic data in the patients of the involved recorders, including gender, age, severity evaluated by Charlson comorbidity index, and the number of alert overrides were acquired from the EMRs.

This study was designed and conducted as per the guidelines of the Declaration of Helsinki of the World Medical Association (2000), and was approved by the Ethics Committee of Longhua Hospital of Shanghai University of Traditional Chinese Medicine (approval number: 2024LCSY013). Informed consent was signed by the tested clinical pharmacists.

2.3. Analysis

A SPSS software (V 25.0, IBM, USA) was used for statistical analysis. The alert override rate and appropriateness of alert overrides of different alert types were presented in percentage. The consistency of evaluation in two clinical pharmacists was verified using a Cohen's Kappa approach (*12*), where a score above 0.8 was considered as good consistency. $P < 0.05$ was considered as the significant difference.

3. Results

A total of 303,600 medication orders of 31,625 admitted patients involving 1,513 types of drugs were involved in this study. Of those, 60,497 alerts were generated, with 14,612 alerts ≤ level 3, of which 12,659 (86.6%) alerts were overridden. Finally, a total of 1,501 alerts involved 1,387 patients were randomly sampled according to combination of "department + drug name + alert type" (Figure 1).

The baseline data were presented in Table 1. Of all involved patients, 52.42% were male and 47.58% were female, 72.23% patients were aged over 60 years. The severity of comorbidities assessed by Charlson Comorbidity Index shows that 40.88% of patients had a score of 6 or above. In terms of the department-wise, general surgery, oncology-hematology, critical care medicine, and nephrology were the main departments covered by the alerts, contributing 51.3% alert. Most of the patients had a single overridden alert (Table 1).

Table 2 shows the appropriateness of alert generation and physicians' responses. The total appropriate rate of

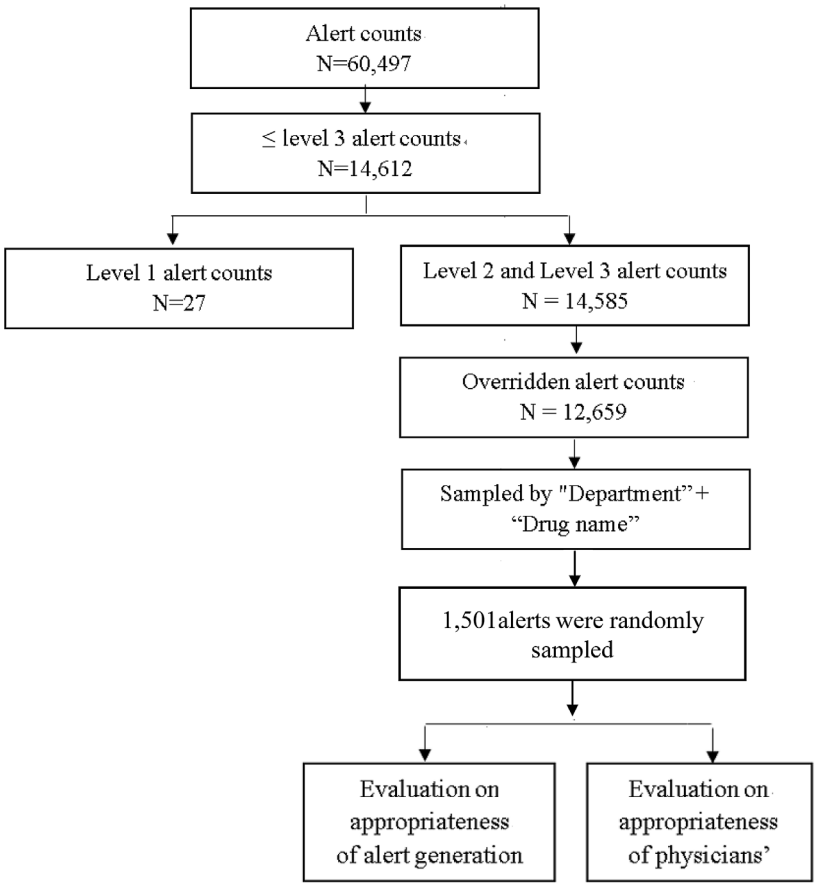

Figure 1. The flow chart of the present study.

physician's responses regarding alert display was 80.2% whereas the inappropriate rate was 17.8%. Meanwhile, the total appropriate rate of alert display was 57.9% whereas the inappropriate rate was 42.1%. In the appropriate generated alert display, 38.1% of physician's responses were correct, whereas 17.8% were incorrect. In addition, 2.0% of the physician's responses could not be determined. With respects to the inappropriate alert display, the appropriate rate of physician's response was 42.1%. No incorrect/undetermined responses were found for the inappropriate alert display (Table 2). Data of Cohen's Kappa coefficients measuring the consistency between two clinical pharmacists show that the Kappa for alert display was 0.884 (95% CI: 0.86-0.91, $P < 0.0001$), and for physician's responses was 0.923 (95% CI: 0.89-0.94, $P < 0.0001$), indicating a satisfactory consistency between the evaluators (Table 3).

Main reasons for overriding alert might lie in evidence-based support, need for evaluation of the therapeutic benefits and potential risks, and need for ongoing monitoring of indicators. Figure 2 shows the counts of overridden alerts classified with the reasons. The top 3 overriding reasons were drug and disease contraindications (23.8%), drug and test value contraindications (23.3%) and compatibility issues (17.7%) (Figure 2). Table 4 shows some examples of

Table 1. The demographic data in patients of the involved recorders

Items	Patients, *n* (%)
Gender	
Female	727 (52.42%)
Male	660 (47.58%)
Age (years)	
≤ 49	195 (14.06%)
50-59	190 (13.70%)
60-69	383 (27.61%)
70-79	350 (25.23%)
≥80	269 (19.39%)
Severity (by Charlson comorbidity index)	
0	66 (4.76%)
1	51 (3.68%)
2	142 (10.24%)
3	152 (10.96%)
4	201 (14.49%)
5	208 (15.00%)
≥ 6	567 (40.88%)
Number of alert overrides, *n* (%)	
1	1282 (92.43%)
2	97 (6.99%)
≥ 3	8 (0.58%)

Table 2. Evaluations on appropriateness of alert generation and physicians' responses

Alert display	Physicians' responses, *n* (%)			
	Appropriate	Inappropriate	Non-decidable	Total
Appropriate	572 (38.1%)	267 (17.8%)	30 (2.0%)	869 (57.9%)
Inappropriate	632 (42.1%)	0 (0.0%)	0 (0.0%)	632 (42.1%)
Total	1204 (80.2%)	267 (17.8%)	30 (2.0%)	1501 (100%)

Table 3. Assessments of consistency of the two clinical pharmacists

	Alert display			Physicians' responses		
	Value	S. E	Sig	Value	S. E	Sig
Kappa	0.884	0.012	< 0.0001**	0.923	0.013	< 0.0001**

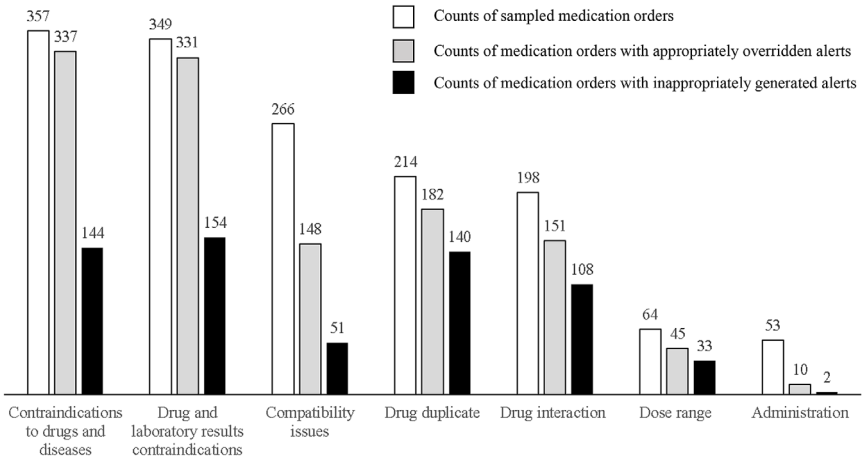

Figure 2. Distribution map of overridden alert types

Table 4. Examples of generating alert and the responses of physicians

Type of alerts	Patients (Gender/Birth)	Diagnosis	Alerted order	Appropriateness of generation of alert	Appropriateness of physician's response	Comments
Drug and disease contraindications	M/2014	Chronic kidney disease, hypokalemia	Potassium chloride injection: "Contraindicated for patients with renal insufficiency." Source: Drug package insert	Appropriate	Appropriate	Recommend by the Expert Consensus on the Management of Serum Potassium in Chronic Kidney Disease Patients in China (2020)
	F/1972	Chronic kidney disease, hemodialysis	Ferrous succinate sustained-release tablets: "Contraindicated for patients with chronic kidney failure." Source: Drug package insert	Appropriate	Appropriate	Recommended by the Clinical Practice Guidelines for the Diagnosis and Treatment of Renal Anemia in China (2021)
	F/1939	Anaphylactic shock, diabetes	Patients with diabetes are prohibited from using epinephrine injection solution. Source: Drug package insert	Appropriate	Appropriate	Currently under continuous monitoring
Drug and laboratory results contraindications	F/1931	Community-acquired pneumonia	Torsemide injection: "Contraindicated for patients with hyponatremia. Attention required if the patient's serum sodium is below the normal value" Source: Drug Package Insert.	Appropriate	Appropriate	The patient had a blood sodium level of 135 mmol/L, indicating mild hyponatremia. Continuous monitoring of electrolytes was in progress
Compatibility issues	F/1955	Breast cancer	Pirarubicin injection is incompatible with 0.9% Sodium chloride injection and should be avoided! Dissolve pirarubicin hydrochloride only with 5% dextrose injection or sterile water for injection to prevent the impact on potency or turbidity due to pH. Source: Drug package insert.	Appropriate	Not Appropriate	
Drug duplicate	M/1971	Gastric cancer	Oxycodone hydrochloride prolonged-release tablets and morphine hydrochloride tablets both belong to the opioid alkaloid	Appropriate	Appropriate	Morphine used for the relief of breakthrough pain
Drug interactions	F/1970	Thyroid nodule	Zhi Gancao (Processed Licorice) interacts with Seaweed, known as "Eighteen Incompatibilities"; Gancao antagonizes seaweed. Source: Chinese pharmacopoeia.	Appropriate	Appropriate	In the "Haizao Yuhu Decoction" (found in the "Orthodox Surgery" by Chen Shigong of the Ming Dynasty), the combination of Seaweed with Raw Licorice or Processed Licorice has the function of resolving phlegm, softening hardness, and dispersing goiter and tumors.

Table 4. Examples of generating alert and the responses of physicians (continued)

Type of alerts	Patients (Gender/Birth)	Diagnosis	Alerted order	Appropriateness of generation of alert	Appropriateness of physician's response	Comments
Dose range	F/1932	Respiratory failure, somnolence	Nicardipine injection solution, when administered intravenously, has a maximum dose of 1.25 grams per administration (approximately 3.3 vials). The current dosage is 5 vials. Please be cautious! Source: Drug package insert.	Appropriate	Appropriate	For patients with somnolence, initially administer 0.375g intravenously at a slow rate. Subsequently, add 1.875-3.75g to 500 mL of fluid, and infuse intravenously at a rate of 25-30 drops per minute. Source: Internal medicine (5th edition) The family members refused to use the ventilator and signed the informed consent
Route of administration	F/1974	Ovarian cancer	Carboplatin injection is prohibited for intraperitoneal infusion. Source: Drug package insert.	Appropriate	Appropriate	Recommended by the Expert Consensus on the Clinical Application of Intraperitoneal Hypothermic Perfusion Chemotherapy for Gynecological Malignant Tumors (2019)

generation of alert and the responses of physicians. Total 417 drugs/administrations, including injection of potassium chloride, ferrous succinate sustained-release tablets, and injection of epinephrine, triggered alerts, which accounted for over 10% of alerts (Table 4). In light of the system-provided inputting alert override reasons, 88.3% of the alert overrides reasons were inputted as some meaningless characters or values, such as "123", "aaa", *etc*., which indicated that an obvious "alert fatigue" existed, which made the physicians become impatient to the alerts, as well as the following overrides.

4. Discussion

MRCDSS is useful to improve the safety of medication (*13*). However, if the system has flaws, such as oversensitivity, it might bring fatigue to the physicians and have a negative impact to the working efficiency (*1,4*), and potentially increase the adverse events of drugs (*5,6*). Constantly improvement of the algorithms is therefore indispensable, of those, understanding the *state quo* of the MRCDSS in practice is the first step. To the best of our knowledge, the present study is the first one to investigate the appropriateness of alerts generated by MRCDSS and the physician's responses in China. Our results show that 86.6% of alerts ≤ level 3 were overridden. Of the 1501sampled alerts, 80.2% were appropriately overridden. Of the sampled 1,501 alerts, 57.9% were appropriately generated and 42.1% were inappropriately generated. The top 3 alert types were drug and diagnosis contraindications (23.8%), drug and test value contraindications (23.3%), and compatibility issues (17.7%). In terms of the physicians' responses, 80.2% were appropriate, 17.8% were inappropriate, and 2.0% were undetermined. Most of the overrides reasons (88.3%) were inputted as meaningless characters or values, rather than cautiously inputted information. This phenomenon indicated that the physicians were quite impatient to the meaningless alerts, and had "alert fatigue". Our data suggested that the MRCDSS now using in China is far from satisfactory. More efforts on optimization of the system and algorithms are anticipant. We believe the findings of the present study are useful for better understanding the *state quo* of the MRCDSS in China.

4.1. Appropriateness of alert generation in MRCDSS in China

Our results show that 86.6% of alerts ≤ level 3 were overridden, and 57.9% of alerts were appropriately generated of the sampled 1501 alerts (Table 2), whereas 42.1% were inappropriate. The top 3 alert types were drug and diagnosis contraindications, drug and test value contraindications, and compatibility issues (Figure 2). In comparison with an analogous in Korea (*1*), our overridden rate was lower (86.6% *vs.* 92.9%). Because of

the difference of clinical guidance, pharmacopeia, habits of drug usage, and MRCDSS *per se* are quite different among different countries, these data might could not be compared directly. But the data in this study and in Korea were in a review paper (*3*), namely the ranges of overridden rate (46.2%-96.2%), and the appropriate rate (29.4%-100%). The potential reasons caused high overridden rate in our system might be: *i*) errors of trigger data, *ii*) lack of system functionality, *iii*) failure of unstructured text to be involved, *iv*) alerts content did not match drug instructions. Our data along with the previous studies (*1,3,4*) also supported that the MRCDSSs in practice by far are far from satisfactory. The most predominant problem is the oversensitivity of the system, that generates many useless and unnecessary alerts, which therefore must be overridden. However, the alerts can be reduced and become more specific by optimizing the knowledge base and updating the drug instruction. Some researchers developed a Disease-Drug Interaction Scoring Tool (DIST) based on available newest evidence, patient relevance and evidence credibility (*14*). Once this DIST were added and applied to the Kaiser Permanente's drug-disease knowledge base, the monthly alerts reduced from 32,045 to 1,168 (*15*). Since the drug instruction might be outdated in comparison with the newest evidence, constantly updating the knowledge base is indispensable. Another important issue is the severity of illness. An example of chronic kidney disease (CKD) can support this issue. Alerts of "use of contraindicated drugs" are more commonly triggered in patients with CKD stage 4 (*vs.* the other stages) due to the complicated pathophysiological states (*16*). To quantify the contraindications in drug and diagnosis, we suggest that disease, particularly the chronic diseases like hypertension, diabetes, and CKD, should be stratified by severity as mild, moderate and severe to improve the appropriateness of alerts. In addition, we found that several drugs, such as potassium chloride injection, ferrous succinate sustained-release tablets and epinephrine injection, accounted for more than 10% of overrides (Table 4). To reduce the alert override rate, selection of targeted interventions might be a solution. In a word, the MRCDSS requires timely maintenance, data updating, optimization of the algorithms, and fix of the bugs. Importantly, the sensitivity of triggering the alerts should be adjust to a proper level to avoid generation of inappropriate alerts.

4.2. Appropriateness of physicians' responses

Appropriate rate of the physicians' responses in this study were 80.2%, whereas 17.8% were inappropriate, and 2.0% were undetermined. The reliability of the physicians' responses was confirmed by assessments of the consistency of the two clinical pharmacists (Table 3). Our appropriate rate is lower than that of Korea study (92.4%) (*1*). The higher appropriate rate of physicians' response than alerts generation indicated that the MRCDSS so far is still in a developing state, which requires constantly optimization. The appropriateness of physicians' response is decided by two aspects. One aspect is the factor of physicians. Certainly, KAP of physicians can certainly affect the appropriateness, but both the present study and Korea study reported a relative higher rate of physicians' response, indicates that the professional ability of the physicians is reliable. Thus, the KAP factor might play a less role in the appropriateness of the physicians' responses. Another aspect is the factor of MRCDSS, we believe that the flaws of the MRCDSS may be a more remarkable factor to influence the appropriateness of physicians' responses. Based on the oversensitive nature of the MRCDSS so far, most of the alerts were meaningless and unnecessary. This will cause a "cry wolf" effect, and bring fatigue to the physicians, which make the physicians are prone to ignore the alerts, and impact the appropriateness of physicians' responses. The problem of "alert fatigue" has been a main limitation of MRCDSS which might lower the application effects of MRCDSS, and requires urgent resolution (*17*). Thus, appropriate sensitivity and accuracy of MRCDSS can reduce generation of useless alert and related alert fatigue, which is the improvement direction in developing and maintaining the MRCDSS. Additionally, Dekarske *et al.* found that physicians tend to choose predefined override reasons if the list of override reasons is available. Accordingly providing an appropriate list of override reasons might be helpful (*18*).

4.3. Recommendation and insights

On the basis of our results and our clinical experience, the following issues are recommended as for development and optimization of the MRCDSS system: *i*) High-level newest evidence, such as clinical guideline, must be imported to the system during each optimization, and be ensured if it can be implemented correctly. *ii*) Our data of appropriateness of both alert generation and physicians' responses supported that appropriate sensitivity and accuracy of generating alerts contribute to reduction of the useless alerts and avoiding the "alert fatigue" of physicians, which play a vital in the future development/ optimization of MRCDSS system. *iii*) Delays of data synchronization should be eliminated. Natural language processing is recommended being used to solve the problems such as lack of structured data partially. *iv*) The alert system should be periodically reviewed and maintained to reduce generation of useless alerts. *v*) Alert-review-rules should be constantly optimized. High-frequency alerts against certain drugs shall be noticed and evaluated. Accuracy of these alerts should be checked and useless alerts should be timely removed. All the flaws and bugs should be revised in time. *vi*) The human-computer interaction interface should be friendly. For example, the drop-down menu should be designed

to allow selection of the override reasons, which can be customized and revised as per the actual situation.

4.4. Strengths and limitations of the present study

This study has several strengths: *i*) This is the first study describing the *state quo* of MRCDSS actually in practice in China. *ii*) We sampled 1501 alert recorders from 12,659 overridden medical orders, which sample size is higher than the analogous published studies. *iii*) The consistency between two clinical pharmacists was evaluated using the Cohen's Kappa coefficients, the results indicate that the results of the appropriateness of the physicians' responses were reliable. *iv*) MRCDSS evaluated in this study is a commonly used system in hospitals in China (*19*). The results of the present study contribute to better understanding the *state quo* of MRCDSS in China and providing useful insights for developing and improving MRCDSS in the future.

Meanwhile, this study also has several limitations: *i*) This is a single-center study, the data of the present study were acquired in one hospital, which might have limited representativeness. *ii*) We conducted only an observational study, many important issues, like the relationship between adverse events and overridden alerts, illness severity and overridden alerts, were not investigated. All these limitations will be addressed in our following investigations.

5. Conclusion

This one-center, observational, one-center study evaluated the appropriateness of overridden alerts of MRCDSS in China. Our data indicated that the overridden rate was still high, and appropriateness of generation of alert was only 57.9%. These data indicated that the MRCDSS so far needs constantly optimization and timely maintenance. Of those, proper sensitivity to reduce triggering of useless alerts and generation of alert fatigue in physicians might play a vital role, which is highly anticipated.

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References

1. Park H, Chae MK, Jeong W, Yu J, Jung W, Chang H, Cha WC. Appropriateness of alerts and physicians' responses with a medication-related clinical decision support system: retrospective observational study. JMIR Med Inform. 2022; 10:e40511.
2. Becker ML, Baypinar F, Pereboom M, Lilih S, van der Hoeven RTM, Giezen TJ, Kingma HJ. The effect of medication related clinical decision support at the time of physician order entry. Int J Clin Pharm. 2021; 43:137-143.
3. Poly TN, Islam MM, Yang HC, Li YJ. Appropriateness of overridden alerts in computerized physician order entry: systematic review. JMIR Med Inform. 2020; 8:e15653.
4. Baysari MT, Zheng WY, Van Dort B, Reid-Anderson H, Gronski M, Kenny E. A late attempt to involve end users in the design of medication-related alerts: survey study. J Med Internet Res. 2020; 22:e14855.
5. Wong A, Amato MG, Seger DL, Slight SP, Beeler PE, Dykes PC, Fiskio JM, Silvers ER, Orav EJ, Eguale T, Bates DW. Evaluation of medication-related clinical decision support alert overrides in the intensive care unit. J Crit Care. 2017; 39:156-161.
6. Topaz M, Seger DL, Slight SP, Goss F, Lai K, Wickner PG, Blumenthal K, Dhopeshwarkar N, Chang F, Bates DW, Zhou L. Rising drug allergy alert overrides in electronic health records: an observational retrospective study of a decade of experience. J Am Med Inform Assoc. 2016; 23:601-608.
7. Xu KC, Fan QH, Feng LP, Cheng QT, Chen XD. Establishment and application effect analysis of the examination system of our hospital. Zhi Hui Jian Kang. 2020; 6:23-25. (in Chinese)
8. Wu GL, Lu XL, Wang H. Application and effectiveness of outpatient prescriptions pre-audit rules in children's specialist hospitals based on SWOT analysis method. Zhong Nan Yao Xue. 2023; 21:3345-3349. (in Chinese)
9. Tang X, Li X, Xu CX. Development and application of the management system of pre-trial prescription of rational drug use in hospital based on pharmaceutical knowledge base. Zhongguo Yi Xue Zhuang Bei. 2021; 18:129-132. (in Chinese)
10. Commission CP. Pharmacopoeia of the People's Republic of China 2020. China Medical Science Press, 2020.5.
11. McCoy AB, Waitman LR, Lewis JB, Wright JA, Choma DP, Miller RA, Peterson JF. A framework for evaluating the appropriateness of clinical decision support alerts and responses. J Am Med Inform Assoc. 2012; 19:346-352.
12. Tan X, Zhang J, Gu D, Ran S, Gu T, Lin X, Tao E, Asakawa T, Fang H. Evaluation of the reliability of the criteria for assessing prescription quality in Chinese hospitals among pharmacists in China. BMC Health Serv Res. 2022; 22:455.
13. Wright A, Ai A, Ash J, *et al*. Clinical decision support alert malfunctions: analysis and empirically derived taxonomy. J Am Med Inform Assoc. 2018; 25:496-506.
14. Bubp J, Kapusnik-Uner J, Hoberman B, Wright H, Kwahk E, Matuszewski KA. Description and Validation of the Disease Interaction Scoring Tool (DIST) for an Electronic Health Record (EHR) integrated drug knowledgebase. In: Pharmacotherapy (WILEY-BLACKWELL 111 RIVER ST, HOBOKEN 07030-5774, NJ USA, 2014; pp. E216-E216.
15. Bubp JL, Park MA, Kapusnik-Uner J, Dang T, Matuszewski K, Ly D, Chiang K, Shia S, Hoberman B. Successful deployment of drug-disease interaction clinical decision support across multiple Kaiser Permanente regions. J Am Med Inform Assoc. 2019; 26:905-910.
16. MacRae C, Mercer S, Guthrie B. Potentially inappropriate primary care prescribing in people with chronic kidney disease: a cross-sectional analysis of a large population

cohort. Br J Gen Pract. 2021; 71:e483-e490.
17. Curtain C, Peterson GM. Review of computerized clinical decision support in community pharmacy. J Clin Pharm Ther. 2014; 39:343-348.
18. Dekarske BM, Zimmerman CR, Chang R, Grant PJ, Chaffee BW. Increased appropriateness of customized alert acknowledgement reasons for overridden medication alerts in a computerized provider order entry system. Int J Med Inform. 2015; 84:1085-1093.
19. Wu MF, Shi WZ, Zhao ZG. Comparison of domestic prescription pre-audit systems in China. Zhong Nan Yao Xue. 2019; 9:1547-1552. (in Chinese)

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