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Original Article

Dispensing and Administration Errors after Conversion from Unit Dose Drug Distribution to Daily Dose Drug Distribution Systems

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Abstract The study compared frequency of dispensing errors (DE) and administration errors (AE) occurring in unit dose drug distribution (UDDD) and daily dose drug distribution (DDDD) systems in a 25-bed ward of Surat Thani Regional Hospital. Pre-post evaluation design was used. Sample size was 2,000 drug doses. Main outcome measures were rates, types, causes, and severity of DE and AE at the time during which the UDDD system operated and 4 weeks after introducing the DDDD system. Double checking and disguised-observation technique were employed to identify the errors. DE rate of the UDDD was significantly lower than that of the DDDD systems (5.2% vs. 7.0%, $p = 0.012$) while the AE rate in the UDDD system was significantly higher (17.9% vs. 11.3%, $p < 0.0001$). Of all, the highest frequency of DE was extra medication (55.9%) and was omitted medication (50.0%) for the UDDD and the DDDD systems, respectively. The corresponding figures for AE were wrong time errors (78.6% and 77.2%). The most frequent causes of the errors in both systems were in the transcription process (78.4% and 84.3%) for the DE, and at the stage of nurses preparing medication for administering (85.6% vs. 83.5%) for the AE. All errors in both systems resulted in no harm to patients. In conclusion, DE were more common with the DDDD than with the UDDD systems, and vice versa for AE. Changing from the UDDD to DDDD systems did not significantly increase serious DE and AE.

Keywords: administration errors, daily dose drug distribution, dispensing errors, unit dose drug distribution

INTRODUCTION

Most hospitals in Thailand have employed traditional drug distribution systems, namely, floor (ward) stock, individual prescription orders, or a combination of both. The UDDD is a system in which a medication is prepared in a ready-to-administer single dose unit. The pharmacy supplies each medication for total number of doses to be used within 24 hours. It is the drug distribution system recommended by the American Society of Hospital Pharmacist.[1] A previous study confirmed that medication errors increased with the traditional drug distribution systems compared to the UDDD system.[2] Studies published from 1960 to 1990[3] showed that the UDDD system had overall medication errors rates between 1.7% to 42.0%, with 8.9% to 19.6% AE rates lower than the traditional drug distribution systems. The DE rate varied from 0.87% to 2.9% in the UDDD system. The figure was nearly three-fold lowered when the system was decentralised.[3]

In Thailand, the UDDD system has been the standard drug distribution system endorsed by the Hospital Accreditation (HA) program under the Ministry of Public Health and the Association of Hospital Pharmacy as well as

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the Pharmacy Council since 1999.[4] A recent study of medication errors in the UDDD system among hospitals in Thailand found DE rate to be 22.65 events per 100,000 drug doses.[5] Studies which compared the UDDD to the traditional drug distribution systems showed an increased DE rate from 0.52% to 2.95%.[6,7] However, with the UDDD system, AE rates were 4 to 14 fold lower.[7-11] A study in Thailand estimated that the UDDD system demanded more time of the pharmacist (5.35 working hours per day) and of pharmacy technician (8.94 working hours per day).[12]

In 2002, the UDDD system was implemented in 3 general-surgical wards, 3 orthopaedic-surgical wards and 2 special wards at Surat Thani Hospital, an 800-bed regional medical centre in southern Thailand. Due to pharmacy heavy workload, only 8 out of 24 wards in the hospital could be started with the UDDD system. The hospital's pharmacy department thus modified the UDDD system into a DDDD system so that it could reduce pharmacy times in preparing the medications. However, the best indicator for a drug distribution system of choice is medication error rate. There is hence a need to evaluate the modified drug distribution system concerning patient safety against the UDDD system in a pilot ward before introducing the modified system to all wards. In Thailand, there was one study examining medication errors associated with the DDDD system.[13] There have been no studies elsewhere to compare the UDDD against the DDDD system for the medication errors. The present study was to measure and compare occurrences of DE and AE encountered in the UDDD system and after substituting it with the DDDD system in a study ward. In addition, causes of AE and DE, as well as acceptance of nurses and pharmacy technicians of the system were also determined.

MATERIALS AND METHODS

Definitions

– DE categories[14]

Omitted medication: A medication ordered in the administration list is not present in the patient medication cassette in the cart.

Incorrect medication: A medication in the patient medication cassette in the cart is not the same one as ordered in the administration list.

Extra medication: A medication in the patient medication cassette is not specified in the administration list.

Incorrect dosage: A medication in the patient medication cassette is correct according to the administration list, but its strength is not as ordered.

Incorrect dosage form: A medication in the patient medication cassette is correct according to the administration list, but its dosage form is not as ordered.

Incorrect administration time: A medication in the patient medication cassette is correct according to the administration list, but the labelled administration time is not as ordered.

– AE categories[15]

Omission error: Failure to administer an ordered dose of medication. This excludes patient refusal to take the ordered medication, and when the dose is not administered because of recognized contraindication.

Unauthorized drug error: Administration to the patient of a medication dose which is not authorized for patient. This includes a dose given to the wrong patient, a duplicated dose, and administration of an unordered drug.

Wrong dose error: Any dose that is administered in an incorrect unit, e.g. tablet/ capsule or any dose administered above or below the ordered dose. For liquid medications, plus or minus 20% from the amount ordered is counted as a wrong dose error.

Wrong dosage form error: Administration of medication in a dosage form different to that specified by the doctor. Purposeful alteration, e.g. crushing of conventional tablet; substitution such as replacing a liquid dosage form for a tablet to facilitate administration, was not considered a wrong dosage form error.

Wrong time error: Administration of a drug dose at a time which deviates beyond plus or minus one hour from its scheduled time.

– Degree of severity of the errors[4]

Level 0: An error was detected before it reached the patient.

Level I: An error already reached the patient but resulted in no harm.

Level 2: An error already reached the patient and resulted in a need for increased patient monitoring, but there was no change in vital signs as well as no harm to the patient.
Level 3: An error reached the patient and resulted in a need for increased patient monitoring. There was a change in vital signs but ultimately no harm to the patient.
Level 4: An error reached the patient and resulted in an adverse event requiring treatment or increased length of stay.
Level 5: An error reached the patient and resulted in permanent harm to the patient.
Level 6: An error reached the patient and resulted in the patient's death.

Study Design, Setting and Outcome Measures

Design. The study was a pre and post evaluation design, i.e. the period during which the previous system (UDDD system) was still functioning and 4 weeks following the implementation of the DDDD system.

Setting. A 25-bed orthopaedics surgical ward in the 800-bed regional hospital, Surat Thani, was selected for a pilot ward.

Outcome measures. Primary outcomes were rates of DE and AE. Secondary outcomes were types, causes of the errors, their degree of severity, and acceptance of nurses and pharmacy technicians to the DDDD system.

Drug Distribution Systems in the Hospital

UDDD system. Medication was dispensed for a 24-hour supply and was prepared in a single unit of use in a plastic envelope labelled with the patient's name, medication name and its strength, as well as the scheduled administration time specific for each dose. Each medication cassette in a medication cart was assigned to an individual patient. The cassette was divided into eight boxes covering each possible scheduled administration time, i.e. before three main meals, after three main meals, at bedtime and as needed regimen. Injection medications were not prepared in a unit of use but the total amount of use within 24 hours. They were also packed in an envelope with similar labelling. By this system, each unit of use for oral medication was ready to dispense or administer to the patient.

DDDD system. Medications were also prepared for a 24-hour supply with the total quantity of each medication put together in its plastic envelope. Labelling was similar to that of the UDDD. Each medication cassette was divided into four boxes for each scheduled administration time, i.e. before meals, after meals, at bedtime and as needed regimen. By this system, nurses have to prepare each dose of medication then administer it to the patient.

Sample Size Calculation

– Sample size for determination of the DE rate

$$n = \frac{2(Z_\alpha + Z_\beta)^2 PQ}{(P_A - P_B)^2} = 1,521$$

Where, n = drug doses needed for each phase of the drug distribution systems

Z_α = confidence interval of Type I error = 1.96 ($\alpha = 0.05$)

Z_β = confidence interval of Type II error = 0.842 (power = 80%)

P_A = rate of DE expected to occur in the UDDD system

= 0.09

The P_A was obtained via a pilot study in the UDDD system where 200 drug doses were included and the DE rate was found to be 9%.

P_B = rate of DE expected to occur in the DDDD system

= 0.063

The figure was from an assumption which predicted that the DE rate in the DDDD system might reduce by 30% from that of the UDDD system.

$P = (P_A + P_B) / 2$, and $Q = 1 - P$

– Sample size for determination of the AE rate

$$n = \frac{2(Z_\alpha + Z_\beta)^2 PQ}{(P_A - P_B)^2} = 1,488$$

Where, n = drug doses needed for each phase of the drug distribution systems

Z_α = confidence interval of Type I error = 1.96 ($\alpha = 0.05$)

Z_β = confidence interval of Type II error = 0.842 (power = 80%)

P_A = rate of AE expected to occur in the UDDD system

= 0.22

The P_A was obtained via a pilot study in the UDDD system where 200 drug doses were included and the AE rate was found to be 22%.

P_B = rate of AE expected to occur in the DDDD system

= 0.264

The figure was from an assumption which predicted that the AE rate in the DDDD system might increase by 20% from that of the UDDD system.

$P = (P_A + P_B) / 2$, and $Q = 1 - P$

Therefore the study used 2,000 drug doses as a minimum sample size for each phase of the drug distribution systems.

Method of Data Collection

Data were collected on 2,000 drug doses for each drug distribution system. They were considered a total opportunity of error (TOE) which was a total sum of administered and omitted doses. Only oral and injection medications were included. Time interval for data collection was between 7.00 a.m. and 8.00 p.m. Pharmacist investigator's double-checking was used to identify DE independent of routine pharmacist in charge while disguise observation technique by the same investigator pharmacist was used for AE. Data collection was first done in the UDDD system till 2,000 drug doses were reached. After the DDDD system was implemented, 4-week lapse was allowed before the data was recollected for the new drug distribution system. This was to permit adequate time for the modified drug distribution system to be in place. The AE and DE rates were then determined in another 2,000 drug doses.

Short questions were used to gauge nurses' and pharmacy technicians' acceptance of the UDDD and the DDDD systems. Scores of 1 to 5 were applied to answer the question. They represented the scale of least agreed to strongly agreed.

Data Analysis and Statistics

DE and AE rates were calculated as a frequency of the detected errors divided by the TOE and by total errors. The frequency of each type of errors between the two drug distribution systems was compared using chi-square test at a 95% confidence interval. Causes of errors and degree of their severity were presented descriptively as frequency and percentage. Student *t*-test or Man-Whitney *U*-test was used to compare mean ± S.D. of general demographic data, i.e. number of patients per day, number of drug doses per day and number of drug doses per patient per day, between the two phases.

RESULTS

Characteristics of Staff and Patients

During both periods of data collection, ward staff (doctors and nurses) and pharmacy staff were the same. Number of patients per day and average number of medication doses per day for the UDDD and the DDDD systems were similar while number of medication doses per patient per day of the UDDD system (8.7 ± 1.5) were significantly higher than that of the DDDD system (7.4 ± 1.7) (Table 1).

Dispensing Errors

Rates and types of DE for each drug distribution system are shown in Table 2. Overall DE rates identified in the UDDD were significantly lower than those of the DDDD systems (102/2000, 5.2% vs. 140/2000, 7.0%, $p = 0.012$). Omitted medication and

Table 1. Characteristics of patients in each drug distribution system

Characteristics	Unit dose drug distribution (mean ± S.D.)	Daily dose drug distribution (mean ± S.D.)	*p*-Value
No. of patients	97	78	-
No. of patients per day	13.2 ± 4.7	15.4 ± 5.9	0.203[a]
No. of drug doses per day (dose)	111.1 ± 29.9	111.1 ± 40.3	1.000[b]
No. of drug doses per patient per day (dose)	8.7 ± 1.5	7.4 ± 1.7	0.018[b]

[a] Mann-Whitney *U*-test, [b] Student *t*-test.

Table 2. Types and rates of dispensing errors between the unit dose and daily dose drug distribution systems

Types of dispensing errors	Unit dose drug distribution		Daily dose drug distribution		*p*-Value[a]
	No. of errors in 2,000 drug doses (%)	% Of each error (in 102 errors)	No. of errors in 2,000 drug doses (%)	% Of each error (in 140 errors)	
Omitted medication	31 (1.6)	30.4	70 (3.5)	50.0	< 0.0001
Incorrect medication	1 (0.05)	1.0	0 (0.0)	0.0	0.32
Extra medication	57 (2.9)	55.9	55 (2.8)	39.3	0.85
Incorrect dosage	1 (0.05)	1.0	10 (0.5)	7.1	0.007
Incorrect dosage form	0 (0.0)	0.0	0 (0.0)	0.0	N/A
Incorrect administration time	12 (0.6)	11.7	5 (0.3)	3.6	0.089
Total	102 (5.2)	100	140 (7.0)	100	0.012

[a] Chi-square test, N/A = not applicable.

Table 3. Causes of dispensing errors in each drug distribution system

Causes of dispensing errors	Unit dose drug distribution		Daily dose drug distribution	
	No. of errors in 2,000 drug doses (%)	% Of each error (in 102 errors)	No. of errors in 2,000 drug doses (%)	% Of each error (in 140 errors)
Transcription process				
Nurse not sending a copy of doctor's order sheet	54 (2.7)	52.9	47 (2.4)	33.6
Incorrect transcribing order by pharmacist	26 (1.3)	25.5	71 (3.6)	50.7
Subtotal	80 (4.0)	78.4	118 (6.0)	84.3
Preparing medications at pharmacy				
Pharmacist incorrect checking prepared medications	17 (0.9)	16.7	17 (0.9)	12.1
Pharmacy technician placing incorrect medications in patient's cassette	5 (0.3)	4.9	5 (0.3)	3.6
Subtotal	22 (1.2)	21.6	22 (1.2)	15.7
Total	102 (5.2)	100	140 (7.2)	100

incorrect dosage were significantly less prevalent in the former when compared to the later. Among all DE, extra medication and omitted medication occurred most frequently for the UDDD (55.9%) and the DDDD (50.0%) systems.

Causes of the DE in each drug distribution system are presented in Table 3. The most common causes of all DE found in both systems were involved with the transcription process. Nurse not sending a copy of doctor's order sheet (54/102, 52.9%) and pharmacists' wrong transcribing (71/140, 50.7%) accounted for the highest frequencies of causes in the UDDD and the DDDD systems, respectively.

Among all DE in both drug distribution systems, most were of severity level 0 which did not reach the patient (63/102, 61.8% for

the UDDD system and 120/140, 85.7% for the DDDD system). No errors of higher severity levels (3 to 6) were encountered in both systems.

Administration Errors

Rates and types of AE in each drug distribution systems were compared in Table 4. Overall AE rates within the UDDD system were significantly higher than those of the DDDD system (355/2000, 17.8% vs. 224/2000, 11.2%; $p < 0.0001$). Wrong time error constituted the majority of all errors in both systems.

Table 5 described various causes of the AE. Of all errors, the most common causes found in both systems were at the stage of nurses administering medication (304/355, 85.6% for the UDDD system and 187/224, 83.5% for the DDDD system). Based on the TOE, the same trend remained.

Almost all AE in the UDDD (349/355, 98.3%) and the DDDD (222/224, 99.1%) systems were of severity level 1 which caused no harm to patients. Higher severity levels of 3 to 6 were not found in either system.

Acceptance of the DDDD System

Ward nurses (n = 13) rated for perception of workload (3.54 ± 0.66 vs. 3.31 ± 0.63, p = 0.27), time spent for preparing medicines for administration to a patient (3.69 ± 0.63 vs. 3.46 ± 0.78, p = 0.33) and overall satisfaction (3.69 ± 0.95 vs. 3.62 ± 0.77, p = 0.81) were similar for the DDDD and the UDDD systems, respectively.

Pharmacy technicians (n = 5) perceived that the DDDD system significantly reduced workload in preparing medicines (2.20 ± 0.45) compared to the UDDD system (3.60 ± 0.89, p = 0.005). They also felt flexibility with the DDDD when compared to the UDDD systems (4.00 ± 1.00 vs. 2.40 ± 0.89, p = 0.016).

Both groups did not favour either system over the other when asked about extending either one to the other wards (pharmacy technicians: 3.80 ± 0.84 vs. 2.20 ± 0.84, for the DDDD and the UDDD systems, respectively, p = 0.078; ward nurses: 3.62 ± 1.12 vs. 3.54 ± 1.27, p = 0.75).

DISCUSSION

DE rate of the UDDD system in the study (5.2%) was more prevalent than 0.02% and 1.54% reported in the other studies.[5,7] The method employed in detecting the errors may explain the underestimated figures in the two studies in which the incident self-report by ward nurses or pharmacists was used. The method was dependent on their voluntary co-operation and workloads that could keep them

Table 4. Types and rates of administration errors between the unit dose and daily dose drug distribution systems

Types of administration errors	Unit dose drug distribution		Daily dose drug distribution		p-Value[a]
	No. of errors in 2,000 drug doses (%)	% Of each error (in 355 errors)	No. of errors in 2,000 drug doses (%)	% Of each error (in 224 errors)	
Omission errors	28 (1.4)	7.9	34 (1.7)	15.2	0.44
Unauthorized drug errors	47 (2.4)	13.2	12 (0.6)	5.4	< 0.000
Improper-dose errors	1 (0.05)	0.3	5 (0.3)	2.2	0.1
Wrong dosage-form errors	0 (0.0)	0.0	0 (0.0)	0.0	N/A
Wrong time errors	279 (14.0)	78.6	173 (8.7)	77.2	< 0.000
Total	355 (17.8)	100	224 (11.2)	100	< 0.000

[a] Chi-square test, N/A = not applicable.

Table 5. Causes of administration errors in each drug distribution system

Causes of administration errors	Unit dose drug distribution		Daily dose drug distribution	
	No. of errors in 2,000 drug doses (%)	% Of each error (in 355 errors)	No. of errors in 2000 drug doses (%)	% Of each error (in 224 errors)
Transcribing process				
Nurse not sending a copy of doctor's order sheet	35 (1.8)	9.9	0 (0.0)	0
Pharmacist incorrect transcribing orders	3 (0.2)	0.8	24 (1.2)	10.7
Subtotal	38 (2.0)	10.7	24 (1.2)	10.7
Preparation step at pharmacy department				
Pharmacist incorrect checking	2 (0.1)	0.6	0 (0.0)	0
Pharmacy technician incorrect placing prepared drugs in patients' cassettes	2 (0.1)	0.6	0 (0.0)	0
Subtotal	4 (0.2)	1.2	0 (0.0)	0 (0.0)
Nurses preparing medication card				
Loss of medication card	5 (0.3)	1.4	4 (0.2)	1.8
Incorrect medication card	0 (0.0)	0	1 (0.1)	0.4
Not taking off medication card	3 (0.2)	0.8	2 (0.1)	0.9
Subtotal	8 (0.5)	2.2	7 (0.4)	3.1
Nurses preparing for administration				
Omitted medication	21 (1.1)	5.9	7 (0.4)	3.1
Unauthorized medication	4 (0.2)	1.1	1 (0.05)	0.4
Incorrect medication	2 (0.1)	0.6	1 (0.05)	0.4
Incorreet number of oral dosage form	0 (0.0)	0.0	5 (0.3)	2.2
Incorrect administration time (beyond ± 60 minutes)	277 (13.9)	78.0	173 (8.7)	77.2
Subtotal	304 (15.3)	85.6	187 (9.5)	83.3
Patient				
Not on bed/away for physieal therapy	1(0.05)	0.3	1 (0.05)	0.4
Non-compliance	0 (0.0)	0 (0.0)	3 (0.2)	1.3
Sleeping	0 (0.0)	0 (0.0)	2 (0.1)	0.9
Subtotal	1(0.05)	0.3	6 (0.4)	2.6
Total	355 (17.8)	100	224 (11.2)	100

from reporting the errors. The present study used pharmacist double checking medication cassette which was highly likely to reveal more DE as also shown in the other study.[16] Similarly, the corresponding figure for the DDDD system (7.0%) was much higher than 0.7% reported in the other study in Thailand.[13] Again, the incident report technique by nurses was used in the cited study. The DE rate associated with the DDDD was significantly more prevalent than that of the UDDD systems. In the DDDD system, all doses of each medication were to put together in one package, hence should DE occur, the error applies to all doses. This could contribute to higher DE rate detected in the DDDD system. The same explanation applies to detecting more omitted medieations in the DDDD than in the UDDD system. However, the other studies found that omitted or

missing doses was more evident in the UDDD system than other systems.[17,18]

Most common causes of DE in the UDDD and the DDDD systems were in the transcription process related to either nurses or pharmacists (78.4% and 84.2% of all causes, respectively). The results were consistent to the other studies.[7,19] In contrast, similar study by Mayo *et al.*[20] found 64.5% of all causes of DE were from pharmacist incorrect checking prepared doses.

On the patient safety side, no errors led to life-threatening conditions or deaths. All DE in both drug distribution systems were of severity level 0 or 1. The results were similar to the study by Pattanajak[5] who also applied similar definition of degree of severity and found 95.8% of all errors were of severity level 0.

Concerning the AE rates, the figure for the UDDD system was 17.8% which agreed with 16.7% detected by Moolasarn.[6] Discrepancies existed when compared to 0.9-6.88% from studies which classified AE differently.[7-11] Among these, some either included wrong time error more than ± 30 minutes or totally excluded wrong time error. The AE rate was less prevalent (11.2%) for the DDDD system in the study but more frequent than 4.5% reported by Eumkep *et al.*[13] who identified AE by checking medicines returned to the pharmacy, thus it could result in detecting lower error rates. The present study used pharmacist disguised observation method. A study showed that observation method even not blind was reliable and did not affect AE rate itself.[21] In the present study AE were less prevalent in the DDDD system in comparison to the UDDD system. It may be that with the DDDD system nurses have to prepare each dose from the labeled package thus allowing an opportunity to read and check dosage regimens before preparation. While for the UDDD system, medicines were prepared at the pharmacy in a ready-to-use dose with no need to review the dosage regimen again.

Wrong time error beyond ± 60 minutes was common in both systems due to the fact that doses ordered to be administered at 17.00 h or 18.00 h were given at the same time either at 17.00 h or 18.00 h.

The most common cause of AE found in both drug distribution systems were nurse administering medicines at incorrect administration times (almost 80.0% of total causes). There were diversities among other studies which showed the most frequent error occurred in the process of preparing medicines at the pharmacy department (46.9% of total causes),[10] nurse incorrect preparing orders (52.0% of total causes),[22] or pharmacist incorrect transcribing orders (29.26% of total causes).[23] The present study and the cited studies used disguised-observation technique to identify the AE. Nursing or pharmacy practices may vary in different settings. This might contribute to the wide range of the figures.

Almost all AE (over 98%) in both drug distribution systems resulted in no harm to patients. This was consistent with the other study of the UDDD system.[24]

Although transcribing process errors did not play an important role in AE, it was interesting to find that those stemmed from pharmacist when compared to nurse were more frequent in the DDDD than in the UDDD systems. The similar trend also applied for DE for which transcribing process errors contributed significantly. It might be that in the UDDD, medications had to be prepared in a single unit of use thus more attention by pharmacist may occur incidentally while translating doctor order for pharmacy technicians to prepare medications accordingly. On the other hand, preparing medications for an amount of daily use might make pharmacist less concerned about detailed dosage regimen but the total amount needed on a daily basis only. Perhaps the errors encountered in the present study were of human rather than of system errors. It was difficult to blame the systems themselves, unless there was truly a big difference in the flow activities between the UDDD and the DDDD systems.

For acceptance of the DDDD system, it could be concluded that ward nurses did not object the DDDD system and they did not perceive that the system demanded them more time in preparing administered doses for patients. On the other hand, pharmacy technicians felt reduced work load and flexibility with the DDDD system.

The results of the present study, however, represented only one ward which was an orthopaedies surgical ward. Difference in the nature of other types of ward should be taken into account, such as number of beds, number of nursing staff/doctors, type and complexity of drug dosage regimen. Time interval for data collection did not cover round the clock therefore missing an opportunity to observe an AE at other times beyond 7.00 a.m. to 8.00 p.m. Hence, an underestimate of the AE rate could result. Inevitably, nursing and pharmacy practices may vary among wards and settings.

In conclusion, the study indicated preparing medicines for a daily amount of use as in the DDDD system contributed to lower rate of AE while resulted in more frequent DE. Converting drug distribution system from the UDDD to the DDDD systems did not compromise patient safety. Nurses and pharmacy technicians accepted the system without perception of increased workload or demanding more times.

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