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The Effect of Warning Symbols in Combination with Education on the Frequency of Erroneously Crushing Medication in Nursing Homes – an Uncontrolled Before and After Study

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ABSTRACT

Objectives: Residents of nursing homes often have difficulty swallowing (dysphagia) which complicates the administration of solid oral dosage formulations. Erroneously crushing medication is common, but few interventions have been tested to improve medication safety. Therefore we evaluated the effect of warning symbols in combination with education on the frequency of erroneously crushing medication in nursing homes.

Setting: This was a prospective uncontrolled intervention study with a pre- and post-intervention measurement. The study was conducted on 18 wards (total of 200 beds) in three nursing homes in the North of the Netherlands.

Participants: We observed 36 nurses/nursing assistants (92% female; 92% nursing assistants) administering medication to 197 patients (62.9% female; mean age 81.6).

Intervention: The intervention consisted of a set of warning symbols printed on each patient's unit dose packaging indicating whether or not a medication could be crushed as well as education of ward staff (lectures, newsletter and poster).

Primary outcome measure: The relative risk (RR) of crushing errors in the post-intervention compared to the pre-intervention period. A crushing error was defined as the crushing of a medication considered unsuitable to be crushed based on standard reference sources. Data were collected using direct (disguised) observation of nurses during drug administration.

Results: The crushing error rate decreased from 3.1% (21 wrongly crushed medicines out of 681 administrations) to 0.5% (3/636), RR=0.15 (95% CI 0.05-0.51). Likewise, there was a significant reduction using data from patients with swallowing difficulties only, 87.5% (21 errors /24 medications) to 30.0% (3/10) (RR 0.34, 95% CI 0.13-0.89). Medications which were erroneously crushed included enteric-coated formulations (e.g. omeprazole), medication with regulated release systems (e.g. Persantin®; dipyridamol), and toxic substances (e.g. finasteride).

Conclusions: Warning symbols combined with education reduced erroneous crushing of medication, a well-known and common problem in nursing homes.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- An innovative and feasible intervention consisting of warning symbols in combination with education reduced erroneous crushing of medication in nursing homes.
- Information on whether medication may be crushed was available at the stage of medication administration.
- The study design (an uncontrolled before and after study) means that we could not control for other factors potentially influencing the error rate.

INTRODUCTION

Nursing home residents often receive a large number of medicines.[1, 2] A considerable proportion of residents has difficulty swallowing (dysphagia) which complicates the administration of solid oral dosage formulations.[3] Often, dose form modifications such as crushing tablets or opening capsules are done to administer medications. However, crushing formulations with special coatings or regulated release systems may result in sub-therapeutic (crushing coatings) or toxic (crushing regulated release systems) blood concentrations of the medicines causing adverse events. Furthermore, medications containing substances such as cytotoxic agents should not be crushed as small particles may harm the person handling the administration.[4, 5] Recent studies in nursing homes suggest that between 0.5% and 10% of medications are erroneously crushed,[4, 6-9] although this type of error seemed to be uncommon/absent in two other studies.[10, 11]

Few studies have investigated interventions to reduce medication administration errors and most of these studies have been carried out in the hospital setting.[12-14] Little is known about interventions to reduce the rate of erroneously crushing formulations in nursing homes. In a study in Dutch nursing homes, Stuijt et al.[9] showed that a multi-faceted intervention including education and a computerised system alerting staff to patients with swallowing difficulties was effective in reducing the frequency of wrongly crushed medication, but an error rate of about 3% was still observed. In a study in Belgian nursing homes, an educational intervention including information on crushing of medication eliminated erroneous crushing.[6] More research is needed to develop interventions to improve medication safety in the nursing home setting. Warning symbols in combination with education are widely used in health care to promote safety-appropriate behaviour.[15] To our knowledge it has not been tested whether warning symbols can be used to reduce crushing errors. Therefore, we

evaluated the effect of warning symbols in combination with education on the frequency of erroneously crushing medication in nursing homes.

METHODS

Design and setting

This was a prospective uncontrolled intervention study with a pre- and post-intervention measurement. The study was conducted on 18 wards (8-10 beds/ward, total of 200 beds) in three nursing homes in the North of the Netherlands. Patients were cared for by elderly care physicians, nurses, nursing assistants and volunteers. Electronic medical records and electronic prescribing systems were used in all institutions. Medication was supplied weekly by one hospital pharmacy as unit dose packages. Pharmaceutical services provided by pharmacists included daily computerised monitoring of all new prescriptions (e.g. to detect drug-drug interactions) as well as regular multidisciplinary medication reviews of all patients. Nurses and nursing assistants were responsible to administer medication to residents. Administrations were recorded on the medication charts.

The study was not reviewed by a medical ethics committee, as according to Dutch regulation, approval of the medical ethics committee was not required as there was no direct interaction with patients and patient data were anonymized (Dutch Medical Research Involving Human Subjects Act).[16] Moreover, the intervention was part of an ongoing initiative for quality improvement and not put in place for the purpose of the study. Ward supervisors and management approved the study.

Intervention

The intervention consisted of the following four elements:

- Warning symbols printed on the unit dose sachets produced by the automatic tablet dispensing and packaging system. Two symbols were chosen, a positive symbol indicating that a tablet or capsule could be crushed and a negative symbol indicating that this could not be done. The symbols were added to the description line of each medication on the sachets (Figure 1). These were introduced on 1 February 2014. The information whether medication could be crushed or not was gathered by SvW, LW and TB based on standard reference sources [17, 18].
- A 20 min lecture, given by a pharmacist (LW or TB) for nurses and nursing assistants on each study ward in January and February 2014. It covered information on drug formulations which should not be crushed and informed staff on alternatives as well as explaining the introduction of the new symbols. Overall, 77 nurses and nursing assistants out of 160 (48%) attended the lectures, about four per ward.
- A newsletter, send digitally to all nursing home staff in February 2014, summarising the content of the lecture on one page. This was a special edition of the quarterly newsletter of the hospital pharmacy. The newsletter was written by SvW, LW and TB.
- A poster, explaining the meaning of the two symbols and emphasising that nursing staff should contact the physician or pharmacy department for patients with dysphagia who were prescribed medication which could not be crushed. The poster was introduced during the lectures. Nursing staff were advised to place the poster on the wards as a reminder. The poster was written by SvW, LW and TB.

We chose the three different educational approaches (lecture, newsletter and poster) to maximise the number of staff we could reach. Furthermore, these approaches were commonly used in our study setting (but also in other nursing homes) which increased the feasibility of the study and the applicability in other settings.

>>>place Figure 1 somewhere here

Data collection

Data were collected using the disguised observation method, recognised as a valid and reliable method (gold standard) to detect medication administration errors and suitable to be used to evaluate interventions.[12, 19-21] Ward staff were told that the observer was attending the medication rounds to get a general idea of the medication administration process as part of his hospital placement. Data were collected by one pharmacy student (author SKAvW), trained in observation technique including a 3-day test period on different wards. The observer asked each participating nurse/nursing assistant for permission to observe prior to the medication round. Sex and level of education (i.e. qualified nurse or nursing assistant) was noted. He then accompanied staff during the medication rounds, observing all medication administrations to the patients. It was agreed that the observer should intervene in case he became aware of a potentially serious medication administration error, but this was not the case. The observer made a mental note of all medication which was crushed by nursing staff and recorded this information on paper immediately after leaving the ward.

After the drug round was completed, the observer retrieved data on observed patients and all medication administrations of oral solid dosage forms (i.e. tablets and capsules) from the computerised pharmacy information system and entered this in Excel MS (Microsoft Corp., Redmond, Washington). Data comprised: name of the nursing home, type of ward, date and time of drug round, sex and age of the patient and medication details (number of medications administered during observed drug round). For all medication which was crushed full

medication details (name and dose) were retrieved. SKAvW de-identified all patient information retrieved from the pharmacy information system.

Data were collected in November-December 2013 (pre-intervention period) and March 2014 (post-intervention period). One medication round was observed on each ward in each period. The morning drug administration round (07:00-10:00am) was selected as the majority of medication was administered during this round. Data collection was carried out on 18 consecutive weekdays each period, excluding weekends.

We defined a crushing error as the crushing of oral solid dosage forms considered unsuitable to be crushed according to Dutch standard references. We used two sources, a handbook by hospital pharmacists and the electronic database of the Royal Dutch Pharmaceutical Society.[17, 18] Both sources are based on consensus of professionals. We chose the sources to ensure we include cases which have been judged to be clinically relevant, i.e. crushing potentially leading to changes in pharmacological response due to destroyed coating or regulated release systems or crushing of formulations containing toxic substances potentially harming staff handling the administration. The observer analysed the data and this was independently checked by two qualified pharmacists (TB and LW).

Main outcome measure

The main outcome was the relative risk (RR) of crushing errors in the post-intervention compared to the pre-intervention period.

Sample size

Based on an expected rate of 3% wrongly crushed medication and a 66% reduction by the intervention, 500 medication administrations needed to be observed to be able to indicate a significant reduction (α=0.05; power of 0.08). It was estimated that 15 wards of about 8 patients needed to be included.

Analysis

Categorical data were compared by performing a χ^2 test, means were compared by performing a students t-test. Data were analysed using SPSS version 20.0.0.2 (SPSS inc., Chicago, Illinois). We calculated the percentage of erroneously crushing medication by dividing the number of crushing errors by the number of observed solid oral doses as has been done in previous studies.[6, 9, 14] We also calculated the error rate by dividing the number of crushing errors by the number of medications which should not have been crushed in patients with swallowing difficulties. We determined the relative risk (RR) and 95% confidence interval of erroneous crushing occurring after the intervention.

RESULTS

We observed 36 nurses/nursing assistants (92% female; 92% nursing assistants) administering medication to 197 patients (62.9% female; mean age 81.6). The groups of the pre- and post-intervention measurement were partly the same. There was no statistical difference between general characteristics of patients and the nursing staff of the pre- and post-intervention measurement (Table 1).

Table 1: Characteristics of participating nursing staff and patients.

	Pre-intervention	Post-intervention	P value
Total number of nursing staff	20	20	
Number of female nursing staff (% of all nursing staff)	18 (90%)	19 (95%)	0.548[a]
Number of nursing assistants (% of all nursing staff)	19 (95%)	18 (90%)	0.548[a]
Total number of patients	164	150	
Number of female patients (% of all patients)	106 (64.6%)	99 (66.0%)	0.800[a]
Mean age of patients	81.7	81.5	0.893[b]
Nursing home A – number of patients (% of all patients)	40 (24.4%)	37 (24.7%)	0.667[a]
Nursing home B - number of patients (% of all patients)	63 (38.4%)	64 (42.7%)	
Nursing home C - number of patients (% of all patients)	61 (37.2%)	49 (32.7%)	
Mean number of observed oral solid medications per patient/observed drug round	4.15	4.24	0.761[b]

[a] *χ^2 test,* [b] *student t-test*

We observed 681 medication administrations to 164 patients pre-intervention and 636 medication administrations to 150 patients post-intervention. The number of patients who had their medication crushed decreased from 19 (11.6%) to 11 (7.3%) (p=0.20). These patients received 24 (pre-intervention period) and 10 (post-intervention period) medications which should not be crushed.

We observed 21 crushing errors before and 3 crushing errors after the intervention. There was a significant decrease of erroneously crushing medication from 3.1% to 0.5% (RR 0.15 (95% CI 0.05-0.51) using the denominator of all observed doses. Likewise, there was a significant reduction using data from patients with swallowing difficulties only, 87.5% (21 errors /24 medications) to 30.0% (3/10) (RR 0.34, 95% CI 0.13-0.89). Medications which were erroneously crushed included enteric-coated formulations (e.g. omeprazole), medication with

regulated release systems (i.e. Persantin®; dipyridamol), and toxic substances (e.g. finasteride). Erroneous crushing was observed on 11 out 18 wards (61%) pre-intervention and 3 out of 18 wards (17%) post-intervention. Error rates per ward can be found in appendix 1.

DISCUSSION

We observed a significant reduction in the rate of erroneously crushing medication after introducing warning symbols combined with education. The strength of our intervention was that information on crushing was available at the stage of administration at the point when nursing staff have to make a decision how to give the medication to the patient. Technical limitations of the software of the unit dose dispensing system restricted the choice of warning symbols which could be printed on the sachets. Therefore we had to choose relatively simple symbols and could not add any colour. Our symbols could be improved by adapting one of the existing pharmaceutical pictograms which should be further tested to ensure comprehension.[15] We gave lectures, distributed posters and send a newsletter to combine the warning symbol with education to remind staff about inappropriate crushing and ensure comprehension of the symbols.

Within medication error research an important choice is the way of calculating the medication error rate.[22, 23] We calculated the crushing error rate by dividing the number of crushing errors by the total number of observed solid oral dosage forms. This is in line with previous studies on crushing errors [6, 9, 14] and studies on medication administration errors in general.[22, 24] We therefore chose this method to allow for comparison with the literature. In fact, our error rate was within the range of previous studies. An alternative way to calculate

the error rate was to divide the number of crushing errors by the number of medications which should not have been crushed in patients with swallowing difficulties. This also showed a significant decrease of the error rate supporting our conclusions. The second way of determining the error rate is less likely to be influenced by changes in medication use patterns.

We recommend wider implementation of the warning symbols in nursing homes. But this depends on the use of unit dose dispensing systems and technical possibilities to add warning symbols on the sachets. Furthermore, it is important to have a service in place providing information on alternative medications for patients. An advantage is a good relationship between the pharmacy department and the nursing home staff like we have in our setting. [25] Nurses were advised to contact the prescriber or the pharmacist to discuss alternatives (e.g. liquid formulations) for patients with swallowing difficulties. Our computer system used for electronic prescribing also provided the possibility for physicians and nursing staff to document swallowing difficulties in the medication records. The pharmacist could then select alternative formulations before dispensing medication to the ward. Full implementation of documentation of dysphagia in the electronic records may be the next step in reducing crushing errors further. Stuijt et al.[9] have already shown that this is a successful strategy in reducing crushing errors.

Our study has several limitations. First, we used a before and after study design without including a control group. It was impossible to include a control group in our own setting as there was only one machine available to supply the unit doses. Technically, all wards had to receive the same unit doses (all with or without symbols). However, we are not aware of any changes taking place in the nursing homes during the intervention period which may have

influenced the crushing error rate. Second, some limitations need to be discussed concerning the disguised observation technique. The presence of an observer may have an effect on behaviour of nursing staff, but this effect has been shown to be relatively limited.[19] The observer was carefully trained in the observation technique. As a research group we have ample experience with observation based research.[20, 21, 26] The observer took "mental notes" of medication which had been crushed and recorded these instances straight after completing observation of each drug round. We chose this method, as taking notes during observation may be regarded as obtrusive and raise suspicion about the true nature of the study. There were only few doses which were crushed in each drug round so it was easy to remember these instances correctly. All details of the administered medication were retrieved from the electronic dispensing records available in the pharmacy department. Furthermore, it is important to note that the observer was not involved in any of the educational activities, so nursing staff were not aware of a link between the observer and the intervention. Unfortunately, we could not keep the observer blind. Being aware of the nature of the intervention theoretically could have introduced some bias in the data collection and analysis. However, the definition of a crushing error was based on clear guidelines and assessment was independently checked and confirmed by two pharmacists so we think that this effect is negligible. Third, we did not assess the clinical significance of the observed errors.[27] Anecdotal evidence would suggest that serious adverse events occur rarely,[4, 28] so more research is needed to study the cost effectiveness of our intervention. A final limitation is that we neither investigated the contribution of each "ingredient" of our intervention separately nor the long-term effect of our intervention. Based on theoretical grounds we believe that a warning symbol should be accompanied by education to ensure comprehension.[15] It remains to be studied how often educational sessions need to be repeated to ensure effectiveness of the intervention. Although, we reached a reasonable number of staff (about 4

members of staff of each study ward attended the lectures, in total 77 out of 160 eligible members of staff, 48%), it remains a challenge to distribute information effectively to all members including part time and temporary staff. Continuous education, improved symbols and the documentation of dysphagia problems in medical records may be a way to reduce the crushing error rate further. Finally, we hope to inspire others to use warning symbols or pictograms to improve patient safety following promising examples from patient education.[29, 30]

CONCLUSION

Warning symbols combined with education reduced erroneous crushing of medication, a well-known and common problem in nursing homes. Wider implementation of this intervention could improve patient safety.

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Contributors

All authors were involved in study design, analysis and interpretation of the data, SvW collected the data, SvW en KT wrote the initial draft of the paper, all authors revised the content and approved the final version of the manuscript.

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Competing interest

The authors have no competing interest.

Data Sharing

No additional data available

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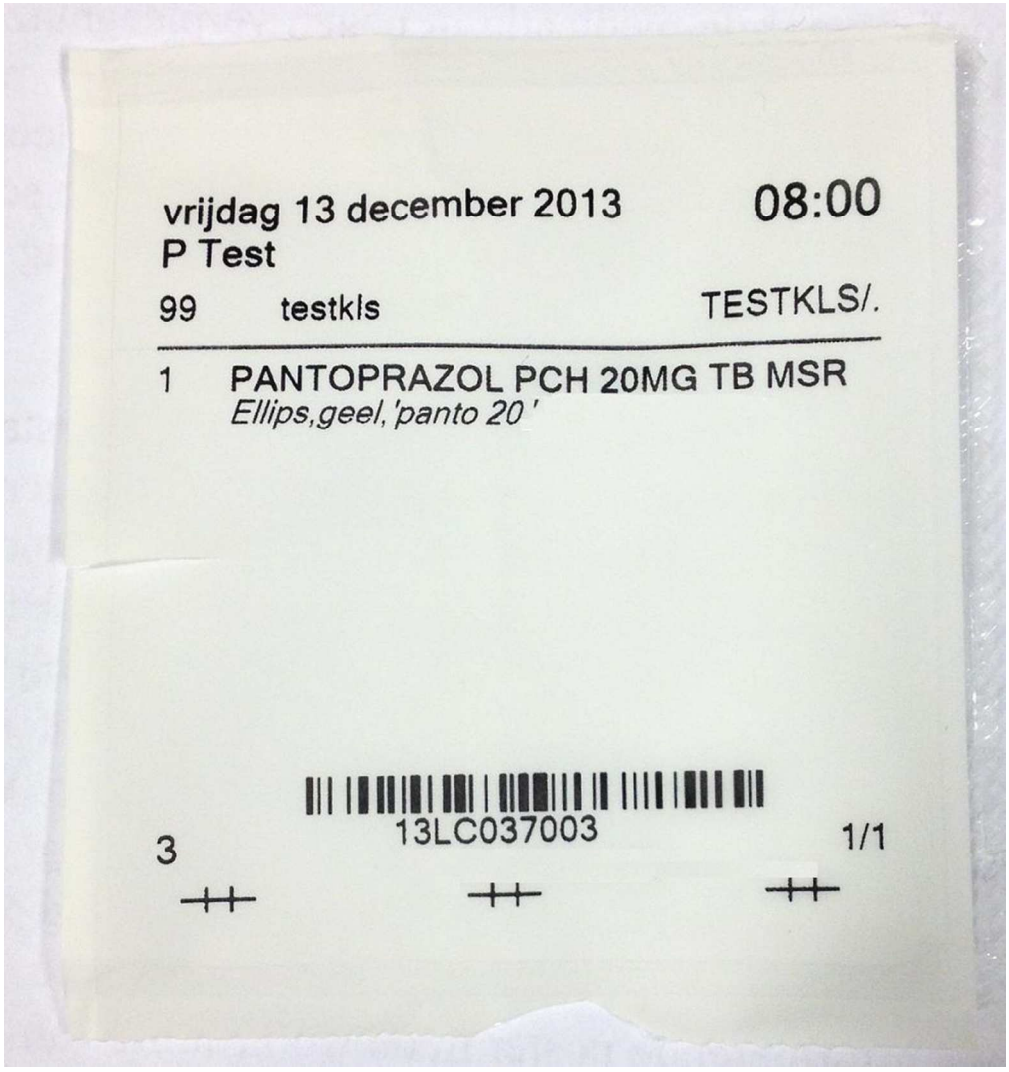
Caption: Figure 1:

1a: An example of the unit dose sachet before introduction of the warning symbol.

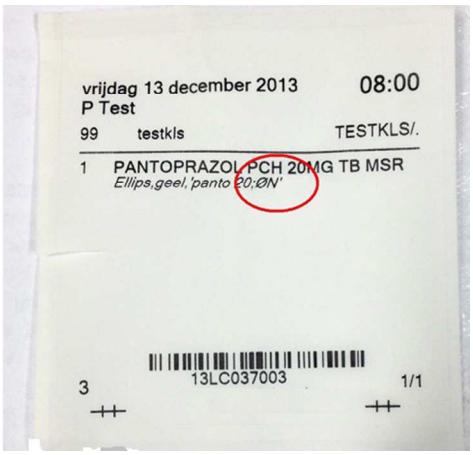
1b: Explanation of the two warning symbols. Positive symbol: formulation may be crushed (J as short for ja=yes); negative symbol: formulation may not be crushed (N as short for nee= no); Right: Example of the unit dose sachet including the warning symbol.



1a: An example of the unit dose sachet before introduction of the warning symbol. The symbols were added to the
259x275mm (96 x 96 DPI)

ØJ positive symbol

ØN negative symbol



1b: Explanation of the two warning symbols. Positive symbol: formulation may be crushed (J as short for ja=yes); negative symbol: formulation may not be crushed (N as short for nee= no); Right: Example of the unit dose sachet including the warning symbol.
The symbols were added to the
171x76mm (144 x 144 DPI)

Appendix 1: Details of the number and percentage of patients, medications and crushing errors which were observed on each ward for the pre-intervention and post-intervention period.

Pre-intervention period

Ward	# Patients	# Medications	# Patients who have medication crushed	% Patients who have medication crushed	# Medications of patients who have medication crushed	# Medications which should not be crushed	# Medications which were erroneously crushed	% erroneous crushing $
1	22	46	2	9%	10	4	4	8.7%
2	8	30	1	13%	2	0	0	0.0%
3	7	29	2	29%	9	2	2	6.9%
4	8	26	1	13%	3	1	1	3.8%
5	16	51	2	13%	9	1	1	2.0%
6	8	42	0	0%	0	0	0	0.0%
7	8	41	1	13%	7	1	1	2.4%
8	8	40	1	13%	9	1	0	0.0%
9	8	45	2	25%	10	4	3	6.7%
10	8	41	1	13%	6	3	2	4.9%
11	8	41	1	13%	4	2	2	4.9%
12	8	43	1	13%	8	2	2	4.7%
13	8	39	2	25%	9	1	1	2.6%
14	8	41	2	25%	8	2	2	4.9%
15	8	31	0	0%	0	0	0	0.0%
16	8	28	0	0%	0	0	0	0.0%
17	8	36	0	0%	0	0	0	0.0%
18	7	31	0	0%	0	0	0	0.0%
TOTAL:	**164**	**681**	**19**		**94**	**24**	**21**	**3.1%**

Post-intervention period								
Ward	**# Patients**	**# Medications**	**# Patients who have medication crushed**	**% Patients who have medication crushed**	**# Medications of patients who have medication crushed**	**# Medications which should not be crushed**	**# Medications which were erroneously crushed**	**% erroneous crushing $**
1	10	16	1	10%	3	2	1	6.3%
2	13	43	3	23%	8	1	0	0.0%
3	10	55	0	0%	0	0	0	0.0%
4	9	33	1	11%	3	1	0	0.0%
5	7	19	0	0%	0	0	0	0.0%
6	7	33	0	0%	0	0	0	0.0%
7	8	47	1	13%	6	1	1	2.1%
8	7	32	0	0%	0	0	0	0.0%
9	8	42	0	0%	0	0	0	0.0%
10	7	31	0	0%	0	0	0	0.0%
11	8	33	1	13%	5	2	0	0.0%
12	8	38	0	0%	0	0	0	0.0%
13	8	34	1	13%	3	1	0	0.0%
14	8	42	1	13%	5	1	0	0.0%
15	8	36	2	25%	11	1	1	2.8%
16	8	31	0	0%	0	0	0	0.0%
17	8	37	0	0%	0	0	0	0.0%
18	8	34	0	0%	0	0	0	0.0%
TOTAL:	**150**	**636**	**11**		**44**	**10**	**3**	**0.5%**

$ Percentage erroneous crushing calculated as: number of crushing errors divided by the total number of medications administered on this ward

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The Effect of Warning Symbols in Combination with Education on the Frequency of Erroneously Crushing Medication in Nursing Homes – an Uncontrolled Before and After Study

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The Effect of Warning Symbols in Combination with Education on the Frequency of Erroneously Crushing Medication in Nursing Homes – an Uncontrolled Before and After Study

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ABSTRACT

Objectives: Residents of nursing homes often have difficulty swallowing (dysphagia) which complicates the administration of solid oral dosage formulations. Erroneously crushing medication is common, but few interventions have been tested to improve medication safety. Therefore we evaluated the effect of warning symbols in combination with education on the frequency of erroneously crushing medication in nursing homes.

Setting: This was a prospective uncontrolled intervention study with a pre- and post-intervention measurement. The study was conducted on 18 wards (total of 200 beds) in three nursing homes in the North of the Netherlands.

Participants: We observed 36 nurses/nursing assistants (92% female; 92% nursing assistants) administering medication to 197 patients (62.9% female; mean age 81.6).

Intervention: The intervention consisted of a set of warning symbols printed on each patient's unit dose packaging indicating whether or not a medication could be crushed as well as education of ward staff (lectures, newsletter and poster).

Primary outcome measure: The relative risk (RR) of crushing errors in the post-intervention compared to the pre-intervention period. A crushing error was defined as the crushing of a medication considered unsuitable to be crushed based on standard reference sources. Data were collected using direct (disguised) observation of nurses during drug administration.

Results: The crushing error rate decreased from 3.1% (21 wrongly crushed medicines out of 681 administrations) to 0.5% (3/636), RR=0.15 (95% CI 0.05-0.51). Likewise, there was a significant reduction using data from patients with swallowing difficulties only, 87.5% (21 errors /24 medications) to 30.0% (3/10) (RR 0.34, 95% CI 0.13-0.89). Medications which were erroneously crushed included enteric-coated formulations (e.g. omeprazole), medication with regulated release systems (e.g. Persantin®; dipyridamol), and toxic substances (e.g. finasteride).

Conclusions: Warning symbols combined with education reduced erroneous crushing of medication, a well-known and common problem in nursing homes.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- An innovative and feasible intervention consisting of warning symbols in combination with education reduced erroneous crushing of medication in nursing homes.
- Information on whether medication may be crushed was available at the stage of medication administration.
- The study design (an uncontrolled before and after study) means that we could not control for other factors potentially influencing the error rate.

INTRODUCTION

Nursing home residents often receive a large number of medicines.[1, 2] A considerable proportion of residents has difficulty swallowing (dysphagia) which complicates the administration of solid oral dosage formulations.[3] Often, dose form modifications such as crushing tablets or opening capsules are done to administer medications. However, crushing formulations with special coatings or regulated release systems may result in sub-therapeutic (crushing coatings) or toxic (crushing regulated release systems) blood concentrations of the medicines causing adverse events. Furthermore, medications containing substances such as cytotoxic agents should not be crushed as small particles may harm the person handling the administration.[4, 5] Recent studies in nursing homes suggest that between 0.5% and 10% of medications are erroneously crushed,[4, 6-9] although this type of error seemed to be uncommon/absent in two other studies.[10, 11]

Few studies have investigated interventions to reduce medication administration errors and most of these studies have been carried out in the hospital setting.[12-14] Little is known about interventions to reduce the rate of erroneously crushing formulations in nursing homes. In a study in Dutch nursing homes, Stuijt et al.[9] showed that a multi-faceted intervention including education and a computerised system alerting staff to patients with swallowing difficulties was effective in reducing the frequency of wrongly crushed medication, but an error rate of about 3% was still observed. In a study in Belgian nursing homes, an educational intervention including information on crushing of medication eliminated erroneous crushing.[6] More research is needed to develop interventions to improve medication safety in the nursing home setting. Warning symbols in combination with education are widely used in health care to promote safety-appropriate behaviour.[15] To our knowledge it has not been tested whether warning symbols can be used to reduce crushing errors. Therefore, we

evaluated the effect of warning symbols in combination with education on the frequency of erroneously crushing medication in nursing homes.

METHODS

Design and setting

This was a prospective uncontrolled intervention study with a pre- and post-intervention measurement. The study was conducted on 18 wards (8-10 beds/ward, total of 200 beds) in three nursing homes in the North of the Netherlands. Patients were cared for by elderly care physicians, nurses, nursing assistants and volunteers. Electronic medical records and electronic prescribing systems were used in all institutions. Medication was supplied weekly by one hospital pharmacy as unit dose packages. Pharmaceutical services provided by pharmacists included daily computerised monitoring of all new prescriptions (e.g. to detect drug-drug interactions) as well as regular multidisciplinary medication reviews of all patients. Nurses and nursing assistants were responsible to administer medication to residents. Administrations were recorded on the medication charts. In case patients had dysphagia and were prescribed medication they could not swallow, nurses contacted the prescriber or pharmacist, to ask for a suitable alternative formulation (e.g. liquid formulation) or nurses crushed medication.

The study was not reviewed by a medical ethics committee, as according to Dutch regulation, approval of the medical ethics committee was not required as there was no direct interaction with patients and patient data were anonymized (Dutch Medical Research Involving Human Subjects Act).[16] Moreover, the intervention was part of an ongoing initiative for quality improvement and not put in place for the purpose of the study. Ward supervisors and management approved the study.

Intervention

The intervention consisted of the following four elements:

- Warning symbols printed on the unit dose sachets produced by the automatic tablet dispensing and packaging system. Two symbols were chosen, a positive symbol indicating that a tablet or capsule could be crushed and a negative symbol indicating that this could not be done. The symbols were added to the description line of each medication on the sachets (Figure 1 a and b). These were introduced on 1 February 2014. The information whether medication could be crushed or not was gathered by SvW, LW and TB based on standard reference sources [17, 18]. We chose a positive and a negative symbol to give nurses complete information including confirmation which medication they were allowed to crush. This way, we ensured that medication without a symbol (e.g., medication where suitability of crushing had not been assessed yet) looked differently. Technical limitations of the software of the unit dose dispensing system restricted the size and the choice of warning symbols which could be printed on the sachets. Pictograms in the form of pictures as developed by the Pharmacopeial Convention of the United States could not be used.[19] We had to choose relatively simple symbols and could not add any colour."
- A 20 min lecture, given by a pharmacist (LW or TB) for nurses and nursing assistants on each study ward in January and February 2014. It covered information on drug formulations which should not be crushed and informed staff on alternatives as well as explaining the introduction of the new symbols. Overall, 77 nurses and nursing assistants out of 160 (48%) attended the lectures, about four per ward.
- A newsletter, send digitally to all nursing home staff in February 2014, summarising the content of the lecture on one page. This was a special edition of the quarterly newsletter of the hospital pharmacy. The newsletter was written by SvW, LW and TB.

- A poster, explaining the meaning of the two symbols and emphasising that nursing staff should contact the physician or pharmacy department for patients with dysphagia who were prescribed medication which could not be crushed. The poster was introduced during the lectures. Nursing staff were advised to place the poster on the wards as a reminder. The poster was written by SvW, LW and TB.

We chose the three different educational approaches (lecture, newsletter and poster) to maximise the number of staff we could reach. Furthermore, these approaches were commonly used in our study setting (but also in other nursing homes) which increased the feasibility of the study and the applicability in other settings.

>>>place Figure 1 somewhere here

Data collection

Data were collected using the disguised observation method, recognised as a valid and reliable method (gold standard) to detect medication administration errors [20] and suitable to be used to evaluate interventions.[12, 21-23] In the current study, we have used the same approach as in our previous studies on medication administration errors (e.g., [24]) with essential elements comprising careful training of the observer and a consistent use of the definition of a crushing error. Ward staff were told that the observer was attending the medication rounds to get a general idea of the medication administration process as part of his hospital placement. Data were collected by one pharmacy student (author SKAvW), trained in observation technique including a 3-day test period on different wards. The observer asked each participating nurse/nursing assistant for permission to observe prior to the medication round. Sex and level of education (i.e. qualified nurse or nursing assistant) was noted. He then

accompanied staff during the medication rounds, observing all medication administrations to the patients. It was agreed that the observer should intervene in case he became aware of a potentially serious medication administration error, but this was not the case. The observer made a mental note of all medication which was crushed by nursing staff and recorded this information on paper immediately after leaving the ward.

After the drug round was completed, the observer retrieved data on observed patients and all medication administrations of oral solid dosage forms (i.e. tablets and capsules) from the computerised pharmacy information system and entered this in Excel MS (Microsoft Corp., Redmond, Washington). Data comprised: name of the nursing home, type of ward, date and time of drug round, sex and age of the patient and medication details (number of medications administered during observed drug round). For all medication which was crushed full medication details (name and dose) were retrieved. SKAvW de-identified all patient information retrieved from the pharmacy information system.

Data were collected in November-December 2013 (pre-intervention period) and March 2014 (post-intervention period). One medication round was observed on each ward in each period. The morning drug administration round (07:00-10:00am) was selected as the majority of medication was administered during this round. Data collection was carried out on 18 consecutive weekdays each period, excluding weekends.

We defined a crushing error as the crushing of oral solid dosage forms considered unsuitable to be crushed according to Dutch standard references. We used two sources, a handbook by hospital pharmacists and the electronic database of the Royal Dutch Pharmaceutical Society.[17, 18] Both sources are based on consensus of professionals. We chose the sources

to ensure we include cases which have been judged to be clinically relevant, i.e. crushing potentially leading to changes in pharmacological response due to destroyed coating or regulated release systems or crushing of formulations containing toxic substances potentially harming staff handling the administration. The observer analysed the data and this was independently checked by two qualified pharmacists (TB and LW).

Main outcome measure

The main outcome was the relative risk (RR) of crushing errors in the post-intervention compared to the pre-intervention period.

Sample size

Based on previous studies of crushing errors [4, 6-9], we assumed a rate of 3% wrongly crushed medication. Although using different interventions, previous studies showed considerable reductions in crushing error rates [6, 9], so we expected to see a 66% reduction by the intervention. Overall, 500 medication administrations needed to be observed to be able to indicate a significant reduction (α=0.05; power of 0.08). It was estimated that 15 wards of about 8 patients needed to be included.

Analysis

Categorical data were compared by performing a χ^2 test, means were compared by performing a students t-test. Data were analysed using SPSS version 20.0.0.2 (SPSS inc., Chicago, Illinois). We calculated the percentage of erroneously crushing medication by dividing the number of crushing errors by the number of observed solid oral doses as has been done in previous studies.[6, 9, 14] We also calculated the error rate by dividing the number of crushing errors by the number of medications which should not have been crushed in patients

with swallowing difficulties. We determined the relative risk (RR) and 95% confidence interval of erroneous crushing occurring after the intervention.

RESULTS

We observed 36 nurses/nursing assistants (92% female; 92% nursing assistants) administering medication to 197 patients (62.9% female; mean age 81.6). The groups of the pre- and post-intervention measurement were partly the same. There was no statistical difference between general characteristics of patients and the nursing staff of the pre- and post-intervention measurement (Table 1).

Table 1: Characteristics of participating nursing staff and patients.

	Pre-intervention	Post-intervention	P value
Total number of nursing staff	20	20	
Number of female nursing staff (% of all nursing staff)	18 (90%)	19 (95%)	0.548[a]
Number of nursing assistants (% of all nursing staff)	19 (95%)	18 (90%)	0.548[a]
Total number of patients	164	150	
Number of female patients (% of all patients)	106 (64.6%)	99 (66.0%)	0.800[a]
Mean age of patients	81.7	81.5	0.893[b]
Nursing home A – number of patients (% of all patients)	40 (24.4%)	37 (24.7%)	0.667[a]
Nursing home B - number of patients (% of all patients)	63 (38.4%)	64 (42.7%)	
Nursing home C - number of patients (% of all patients)	61 (37.2%)	49 (32.7%)	
Mean number of observed oral solid medications per patient/observed drug round	4.15	4.24	0.761[b]

[a] *χ^2 test,* [b] *student t-test*

We observed 681 medication administrations to 164 patients pre-intervention and 636 medication administrations to 150 patients post-intervention. The number of patients who had their medication crushed decreased from 19 (11.6%) to 11 (7.3%) (p=0.20). These patients received 24 (pre-intervention period) and 10 (post-intervention period) medications which should not be crushed.

We observed 21 crushing errors before and 3 crushing errors after the intervention. There was a significant decrease of erroneously crushing medication from 3.1% to 0.5% (RR 0.15 (95% CI 0.05-0.51) using the denominator of all observed doses. Likewise, there was a significant reduction using data from patients with swallowing difficulties only, 87.5% (21 errors /24 medications) to 30.0% (3/10) (RR 0.34, 95% CI 0.13-0.89). Medications which were erroneously crushed included enteric-coated formulations (e.g. omeprazole), medication with regulated release systems (i.e. Persantin®; dipyridamol), and toxic substances (e.g. finasteride). Erroneous crushing was observed on 11 out 18 wards (61%) pre-intervention and 3 out of 18 wards (17%) post-intervention. Error rates per ward can be found in appendix 1.

DISCUSSION

We observed a significant reduction in the rate of erroneously crushing medication after introducing warning symbols combined with education. The strength of our intervention was that information on crushing was available at the stage of administration at the point when nursing staff have to make a decision how to give the medication to the patient. Technical limitations of the software of the unit dose dispensing system meant that we had to choose relatively simple symbols and could not add any colour. Our symbols could be improved by

adapting one of the existing pharmaceutical pictograms which should be further tested to ensure comprehension.[15] We gave lectures, distributed posters and send a newsletter to combine the warning symbol with education to remind staff about inappropriate crushing and ensure comprehension of the symbols.

Within medication error research an important choice is the way of calculating the medication error rate.[20, 25] We calculated the crushing error rate by dividing the number of crushing errors by the total number of observed solid oral dosage forms. This is in line with previous studies on crushing errors [6, 9, 14] and studies on medication administration errors in general.[20, 24] We therefore chose this method to allow for comparison with the literature. In fact, our error rate was within the range of previous studies. An alternative way to calculate the error rate was to divide the number of crushing errors by the number of medications which should not have been crushed in patients with swallowing difficulties. This also showed a significant decrease of the error rate supporting our conclusions. The second way of determining the error rate is less likely to be influenced by changes in medication use patterns.

We recommend wider implementation of the warning symbols in nursing homes. But this depends on the use of unit dose dispensing systems and technical possibilities to add warning symbols on the sachets. Furthermore, it is important to have a service in place providing information on alternative medications for patients. An advantage is a good relationship between the pharmacy department and the nursing home staff like we have in our setting. [26] Nurses were advised to contact the prescriber or the pharmacist to discuss alternatives (e.g. liquid formulations) for patients with swallowing difficulties. Our computer system used for electronic prescribing also provided the possibility for physicians and nursing staff to

document swallowing difficulties in the medication records. The pharmacist could then select alternative formulations before dispensing medication to the ward. Full implementation of documentation of dysphagia in the electronic records may be the next step in reducing crushing errors further. Stuijt et al.[9] have already shown that this is a successful strategy in reducing crushing errors.

Our study has several limitations. First, we used a before and after study design without including a control group. It was impossible to include a control group in our own setting as there was only one machine available to supply the unit doses. Technically, all wards had to receive the same unit doses (all with or without symbols). However, we are not aware of any changes taking place in the nursing homes during the intervention period which may have influenced the crushing error rate. Second, some limitations need to be discussed concerning the disguised observation technique. The presence of an observer may have an effect on behaviour of nursing staff, but this effect has been shown to be relatively limited.[21] The observer was carefully trained in the observation technique. As a research group we have ample experience with observation based research.[22, 23, 27] The observer took "mental notes" of medication which had been crushed and recorded these instances straight after completing observation of each drug round. We chose this method, as taking notes during observation may be regarded as obtrusive and raise suspicion about the true nature of the study. There were only few doses which were crushed in each drug round so it was easy to remember these instances correctly. All details of the administered medication were retrieved from the electronic dispensing records available in the pharmacy department. Furthermore, it is important to note that the observer was not involved in any of the educational activities, so nursing staff were not aware of a link between the observer and the intervention. Unfortunately, we could not keep the observer blind. Being aware of the nature of the

intervention theoretically could have introduced some bias in the data collection and analysis. However, the definition of a crushing error was based on clear guidelines and assessment was independently checked and confirmed by two pharmacists so we think that this effect is negligible. Third, we did not assess the clinical significance of the observed errors.[28] Anecdotal evidence would suggest that serious adverse events occur rarely,[4, 29] so more research is needed to study the cost effectiveness of our intervention. A final limitation is that we neither investigated the contribution of each "ingredient" of our intervention separately nor the long-term effect of our intervention. Based on theoretical grounds we believe that a warning symbol should be accompanied by education to ensure comprehension.[15] We did not assess the overall proportion of staff we reached with our educational activities. A reasonable number of staff attended the lectures (about 4 members of staff of each study ward, in total 77 out of 160 eligible members of staff, 48%). It remains a challenge to distribute information effectively to all members including part time and temporary staff.

In our study, we used relatively traditional ways of disseminating the information on our innovation. Future studies could explore alternative approaches such as social media. Although, we did not assess this as part of our trial, repeated educational efforts are probably necessary for a sustained effect. We also recommend to further develop easy to understand warning symbols/pictograms using colour, e.g., red for not crushing, green for crushing using established guidelines.[30] In summary, continuous education, improved symbols and the documentation of dysphagia problems in medical records may be a way to reduce the crushing error rate further. Finally, we hope to inspire others to use warning symbols or pictograms to improve patient safety following promising examples from patient education.[31, 32]

CONCLUSION

Warning symbols combined with education reduced erroneous crushing of medication, a well-known and common problem in nursing homes. Wider implementation of this intervention could improve patient safety.

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Contributors

All authors were involved in study design, analysis and interpretation of the data, SvW collected the data, SvW en KT wrote the initial draft of the paper, all authors revised the content and approved the final version of the manuscript.

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Competing interest

The authors have no competing interest.

Data sharing statement

No additional data available.

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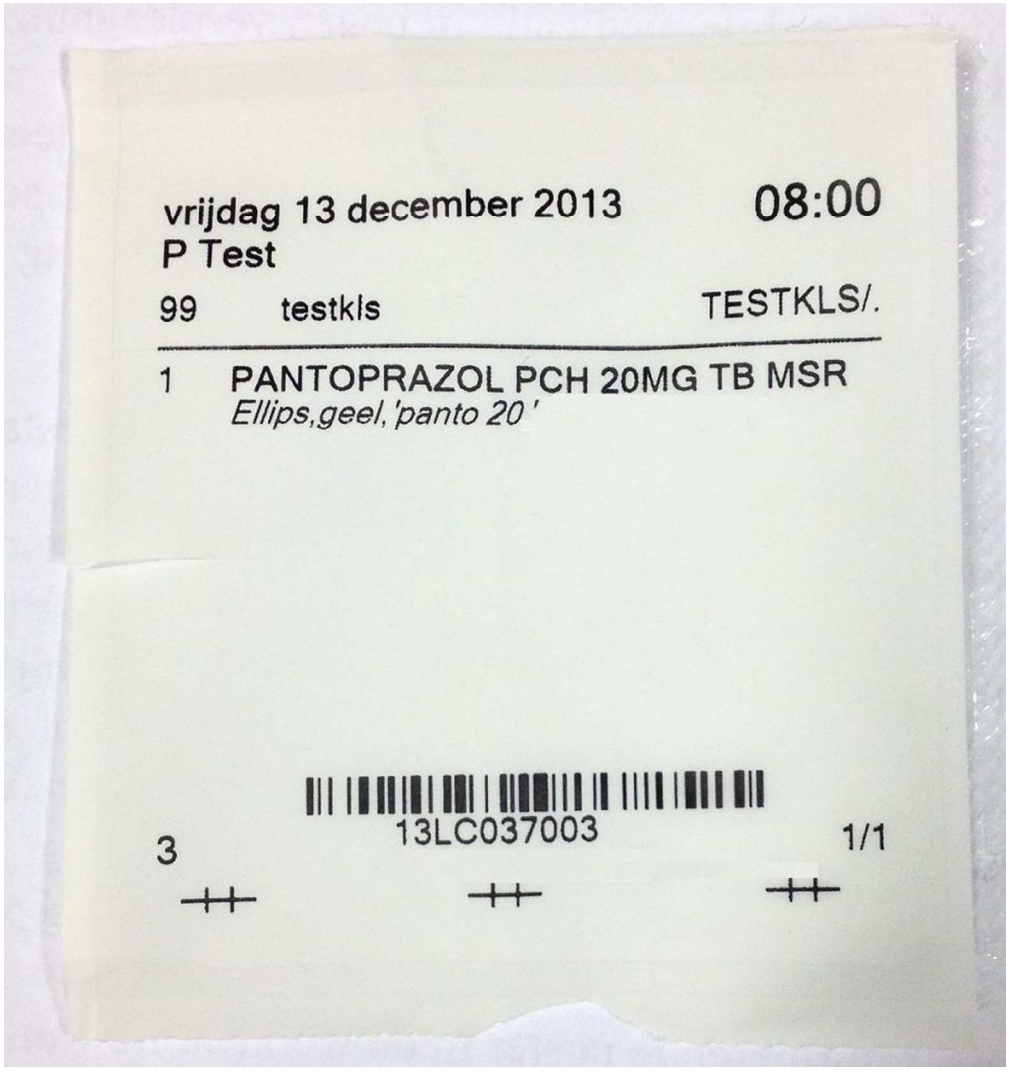
Caption: Figure 1:

1a: An example of the unit dose sachet before introduction of the warning symbol.

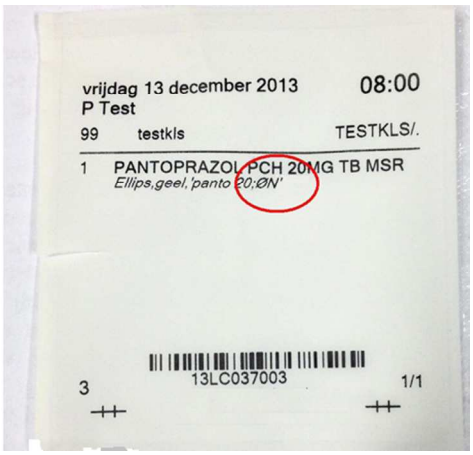
1b: Explanation of the two warning symbols. Positive symbol: formulation may be crushed (J as short for ja=yes); negative symbol: formulation may not be crushed (N as short for nee= no); Right: Example of the unit dose sachet including the warning symbol.



1a: An example of the unit dose sachet before introduction of the warning symbol. The symbols were added to the
259x275mm (300 x 300 DPI)

ØJ positive symbol

ØN negative symbol



1b: Explanation of the two warning symbols. Positive symbol: formulation may be crushed (J as short for ja=yes); negative symbol: formulation may not be crushed (N as short for nee= no); Right: Example of the unit dose sachet including the warning symbol.
The symbols were added to the
171x76mm (300 x 300 DPI)

Appendix 1: Details of the number and percentage of patients, medications and crushing errors which were observed on each ward for the pre-intervention and post-intervention period.

Pre-intervention period

Ward	# Patients	# Medications	# Patients who have medication crushed	% Patients who have medication crushed	# Medications of patients who have medication crushed	# Medications which should not be crushed	# Medications which were erroneously crushed	% erroneous crushing $
1	22	46	2	9%	10	4	4	8.7%
2	8	30	1	13%	2	0	0	0.0%
3	7	29	2	29%	9	2	2	6.9%
4	8	26	1	13%	3	1	1	3.8%
5	16	51	2	13%	9	1	1	2.0%
6	8	42	0	0%	0	0	0	0.0%
7	8	41	1	13%	7	1	1	2.4%
8	8	40	1	13%	9	1	0	0.0%
9	8	45	2	25%	10	4	3	6.7%
10	8	41	1	13%	6	3	2	4.9%
11	8	41	1	13%	4	2	2	4.9%
12	8	43	1	13%	8	2	2	4.7%
13	8	39	2	25%	9	1	1	2.6%
14	8	41	2	25%	8	2	2	4.9%
15	8	31	0	0%	0	0	0	0.0%
16	8	28	0	0%	0	0	0	0.0%
17	8	36	0	0%	0	0	0	0.0%
18	7	31	0	0%	0	0	0	0.0%
TOTAL:	**164**	**681**	**19**		**94**	**24**	**21**	**3.1%**

Post-intervention period								
Ward	**# Patients**	**# Medications**	**# Patients who have medication crushed**	**% Patients who have medication crushed**	**# Medications of patients who have medication crushed**	**# Medications which should not be crushed**	**# Medications which were erroneously crushed**	**% erroneous crushing $**
1	10	16	1	10%	3	2	1	6.3%
2	13	43	3	23%	8	1	0	0.0%
3	10	55	0	0%	0	0	0	0.0%
4	9	33	1	11%	3	1	0	0.0%
5	7	19	0	0%	0	0	0	0.0%
6	7	33	0	0%	0	0	0	0.0%
7	8	47	1	13%	6	1	1	2.1%
8	7	32	0	0%	0	0	0	0.0%
9	8	42	0	0%	0	0	0	0.0%
10	7	31	0	0%	0	0	0	0.0%
11	8	33	1	13%	5	2	0	0.0%
12	8	38	0	0%	0	0	0	0.0%
13	8	34	1	13%	3	1	0	0.0%
14	8	42	1	13%	5	1	0	0.0%
15	8	36	2	25%	11	1	1	2.8%
16	8	31	0	0%	0	0	0	0.0%
17	8	37	0	0%	0	0	0	0.0%
18	8	34	0	0%	0	0	0	0.0%
TOTAL:	**150**	**636**	**11**		**44**	**10**	**3**	**0.5%**

$ Percentage erroneous crushing calculated as: number of crushing errors divided by the total number of medications administered on this ward