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Error recovery in a hospital pharmacy

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A field study was performed in a hospital pharmacy aimed at identifying positive and negative influences on the process of detection of and further recovery from initial errors or other failures, thus avoiding negative consequences. Confidential reports and follow-up interviews provided data on 31 near-miss incidents involving such recovery processes. Analysis revealed that organizational culture with regard to following procedures needed reinforcement, that some procedures could be improved, that building in extra checks was worthwhile and that supporting unplanned recovery was essential for problems not covered by procedures. Guidance is given on how performance in recovery could be measured. A case is made for supporting recovery as an addition to prevention-based safety methods.

Keywords: Error recovery; Near misses; Incident analysis; Medication error; Patient safety; Hospital pharmacy

1. Introduction

Research into incident causation (e.g. Wagenaar and Groeneweg 1987, Reason 1990, Van der Schaaf 1996b, Svenson 2001) has demonstrated that there are usually multiple failure factors underlying both accidents and near misses. Accidents are defined here as incidents where failure factors have caused human errors and/or other types of failures, which in turn have led to at least some undesired safety-related negative consequences. Even though near misses share the same underlying failure factors as accidents, negative consequences have been avoided, which makes them a less serious form of incident (Van der Schaaf *et al.* 1991). This happens sometimes by coincidence, but more often through a timely detection that something is wrong, as a first step towards recovery, followed by timely and effective further recovery actions. Recovery factors explain what made such recovery possible.

In its recent report on safety data standards for the healthcare domain (Aspden *et al.* 2004), the US National Academy's Institute of Medicine proposed that recovery factors are an important complement to failure factors. Next to the traditional safety

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management approach of preventing failures by understanding the main failure factors, understanding recovery factors offers another way of improving safety. By introducing conditions and system characteristics, which build in or strengthen opportunities for successful recovery, an organization may protect itself against initial errors or other failures turning into actual damage, injury or other negative consequences. Given that this is a fairly novel approach, the literature does not contain much guidance on how this may be achieved. This contribution starts filling this gap, by using near-miss data collected in a field study performed in the pharmacy of a large hospital in the Netherlands.

Since they are responsible for preparing and dispensing the medication needed in the hospital of which they form part, hospital pharmacies play a vital role in preventing or recovering medication errors – or rather adverse drug events, as these adverse events are not always caused by human error alone. Adverse drug events are one of the most common types of medical adverse events (Leape *et al.* 1991). An extensive review by Kohn *et al.* (2000) of studies into medical mishaps shows that medication errors or adverse drug events occur quite frequently in hospital settings, ranging from anywhere between approximately 3 to 53 per 1000 medication orders, or between approximately 65 to 200 per 1000 admissions, or between approximately 19 to 24 per 1000 patient days. These numbers are most likely an underestimation of the actual amount as many errors go unreported (e.g. Kohn *et al.* 2000, Lawton and Parker 2002, Armitage and Knapman 2003, Crawford *et al.* 2003). Even though not all medication errors result in actual harm to (or even death of) the patient, when they do, considerable costs are involved (Kohn *et al.* 2000). The need to tackle medication errors to increase patient safety has been recognized for many years, dating as far back as at least the 1950s. One of the more thorough studies performed in that era was done by Safren and Chapanis (1960). Since then, numerous studies have documented and analysed errors in prescribing (e.g. Dean *et al.* 2002, Van den Bemt *et al.* 2002), preparing and dispensing (e.g. Rolland 2004, Ashcroft *et al.* 2005) or administering (for a review, see O'Shea 1999, Armitage and Knapman 2003) medication. With the amount of available medications steadily increasing, the potential for medication errors increases accordingly, thus making the medication process to date an even more important target for safety measures. The importance of measures aimed at error prevention notwithstanding, so far it has proven to be impossible to rule out all errors, which makes it useful to also include safety measures supporting error recovery.

The near-miss data collected in the present study makes it possible to take a closer look at the processes that were followed in recovery, thus avoiding negative consequences. The main research question was: Which factors have a positive influence on recovery processes in the pharmacy and which factors have a negative influence? By promoting the positive influences on recovery and removing the negative influences identified by answering this question, the pharmacy can create an environment where the chances of successful recovery are increased.

The next section starts with a brief overview of recovery processes and the factors that influence these processes. After that, a description follows of the processes for preparing medication that were included in the study, the risks of getting things wrong and the procedures that are in place to ensure that this does not happen. Consequently, this study addresses the process of data collection and the description and coding of the near misses for further analysis. Then, the results are used to present an answer to the research question and to provide guidelines for the pharmacy on how to improve their recovery processes, their safety performance and thus patient safety. This paper concludes with an

attempt to generalize these guidelines to health care activities other than medication preparation.

2. Recovery

During the last decades, a few researchers have started to focus on recovery. Most recovery research has been performed in domains other than health care, including aviation (e.g. Wioland and Amalberti 1998, Helmreich *et al*. 1999, Sarter and Alexander 2000), air traffic control (e.g. Bove and Andersen 2001), process industry (e.g. Duncan 1987, Kanse and Van der Schaaf 2001b, Kanse 2004) and human–computer interaction (e.g. Bagnara *et al*. 1988, Frese 1991, Rizzo *et al*. 1995). Edmondson (1996), Van der Schaaf (1996a) and Van Vuuren and Kanse (2003) are among the few exceptions who have studied recovery from errors and in the last case also other types of failures in medical settings.

Researchers who have studied recovery processes seem to agree that there are three main types of steps or phases involved in recovery (e.g. Bagnara *et al*. 1988, Van der Schaaf 1988, Frese 1991, Zapf and Reason 1994, Rizzo *et al*. 1995, Kontogiannis 1999, Kanse and Van der Schaaf 2001b, Kanse 2004). First, there is the detection of the (combination of) failures or at least the immediate resulting deviation or problem. This is followed by any combination of explanation of the problem and its causes and countermeasures aimed at returning to the normal situation or at least limiting the consequences, including recurrences, or even entirely skipping one or both of these last two phases. Figure 1 contains a model of the recovery process that was developed and validated by one of the authors based on studies in the chemical industry (Kanse 2004). This model presents the three phases and possible transitions between them, as indicated by arrows. Links are also made to the chain of events preceding (and necessitating) a recovery process and the outcomes or end result of the process.

Only a few researchers (e.g. Kanse and Van der Schaaf 2001a, Bove 2002) have specifically studied recovery factors; that is, the factors that influence recovery steps, transitions between steps and their overall success. Person-related factors such as experience and knowledge can play a role in recovery. Technical factors can also play a role, such as the design of the workplace, equipment and interfaces, as well as

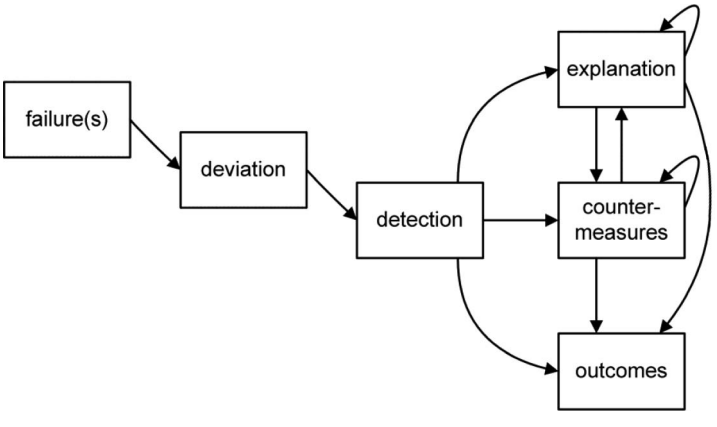

Figure 1. Recovery process model.

organizational factors, such as culture, work design and procedures and management priorities. Organizational factors may be the most important, as they determine the context in which people work and thus affect many of the other factors influencing recovery.

Taking an organizational perspective on people's behaviour during recovery processes, Kanse and Van der Schaaf (see Kanse and Van der Schaaf 2001b, Kanse 2004) have distinguished between planned and unplanned recovery steps. Planned recovery steps involve the activation of defences or barriers that are built into the organization to avoid negative consequences (Hollnagel 1999, Svenson 2001). Examples of barriers or defences are automatic safety controls or procedures to follow under certain conditions. Such procedures can either be formally documented rules or work instructions, or unwritten but approved and generally followed work practices that people learn on the job or via specific training. Unplanned recovery steps are usually more ad hoc and depend on the creative problem-solving abilities of the people involved. Even though a person who performs such unplanned recovery steps may have performed the steps before and may have devised a plan as to what to do, as long as these steps are not a standard practice and are not known to everyone in the same job, the steps qualify as unplanned behaviour. Given this difference between planned vs. unplanned recovery steps, factors that influence the former may be quite different from factors influencing the latter.

3. The medication preparation processes

The main responsibilities of the pharmacy involved in the present study were to prepare and provide on-demand medication to the various hospital wards, including chemotherapy medication, and to maintain local general medication stock levels in hospital wards. The procedures in place to fulfil these responsibilities were quite elaborate. They required the involvement of several pharmacy employees at various stages, ranging from senior pharmacists to junior pharmacists and pharmacy assistants. Some of these stages were supported by computer systems. Several stages involved checking for potential errors that could lead to harm to a patient. Furthermore, especially the procedures for chemotherapy medication preparation also included steps aimed at avoiding exposure of employees to hazardous ingredients.

Chemotherapy medication orders are made by doctors using special request forms that are sent via a pneumatic tube system to the pharmacy. The steps that follow after such a request is received at the pharmacy are shown in figure 2.

For most medication other than chemotherapy, doctors write requests during their daily rounds for each of their patients. Nursing staff then put all the medication requests for a ward in a single folder. Junior pharmacists visit the wards twice per week. They

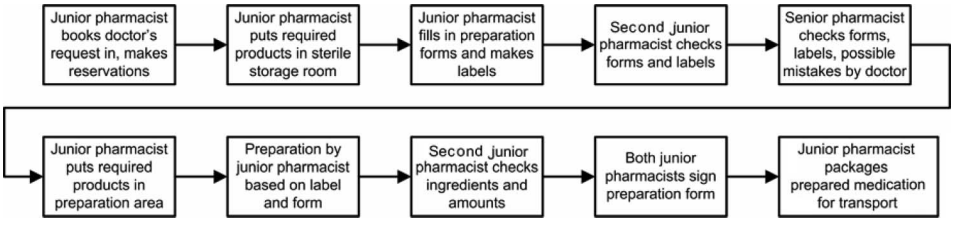

Figure 2. Preparation process for chemotherapy medication.

update the pharmacy's list of medication currently needed in each ward, take the self-carbonated copies of all new medication requests and leave the originals in the ward's medication requests folder. Via this folder, they also notify the nursing staff which medication is available locally in the ward's own stock and which medication will be delivered as on-demand medication for individual patients. The preparation process for on-demand medication is summarized in figure 3. The process of maintaining ward medication stock levels is summarized in figure 4.

Despite all the precautions that are built into these medication preparation processes, occasionally things still go wrong. The dosages and mixtures of chemotherapy medication vary greatly between individual patients and most steps in the preparation process involve human activity with plenty of opportunities for error. Things regularly go wrong in the process of preparing on-demand medication, entering requests into the computer system and delivering to the ward. Furthermore, there are often shortages in medication kept in stock locally at the hospital wards. To avoid further development of these problems into negative consequences for patients in the hospital wards, who depend on the right medication being available for them in the right dose via the right route at the right time, pharmacy employees regularly engage in recovery actions. Sometimes people from outside the pharmacy are involved in the recovery process. For example, the nursing staff at a hospital ward may detect problems with the medication supply and inform the pharmacy about this.

4. Data collection and description and coding of near misses

A few years before the start of this study, with the approval and support of management and employees, the pharmacy had set up a voluntary, confidential and blame-free near-miss reporting system, following the principles outlined in Van der Schaaf and Wright (2005). Near misses were reported via paper-based reporting forms and were de-identified and entered into a database by a trusted person to whom the role of near-miss reporting coordinator was assigned. Even though the number of near misses reported had decreased after the end of an initial study based on data obtained via the reporting system, the basics were available. After gaining the cooperation and trust of the pharmacy's management and employees, one of the authors revived the reporting system (Vrijland 2004). From the new reports that came in, he followed up all of the 36 near misses from the medication preparation areas described above that were reported within a 6-week period, by conducting confidential interviews with the people involved. These interviews provided additional data about both the failure processes and the recovery processes involved. A semi-structured interview approach was used, based on the critical

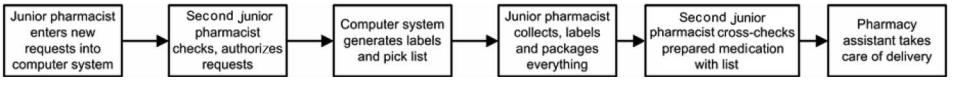

Figure 3. Preparation process for on-demand medication.

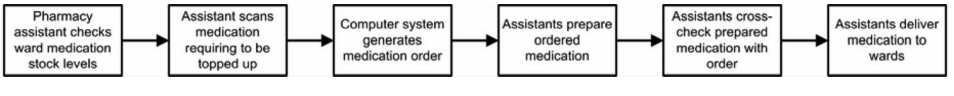

Figure 4. Process of maintaining ward medication stock levels.

incident technique originally developed by Flanagan (1954) and resembling a more recent extension of this technique called critical decision method (e.g. Hoffman *et al*. 1998, Wong 2004, Klein *et al*. 2005). First, a person involved in a reported near miss was asked for a step-by-step account of the event, to develop a timeline of what happened, for both the 'what went wrong?' part of the near miss as well as the 'how was it recovered?' part. After that, for every element of this story the probe question was asked: 'why could this happen?' or 'how was this possible?' or 'what contributed to this?'. This probing was repeated to derive not only the direct or immediate causes but also the underlying indirect causes. Furthermore, for the recovery side of the near miss, the interviewer asked if the actions involved were standard, prescribed by the organization, something everyone else would do too or rather something this person spontaneously thought of at the time. The interviewees' accounts were also verified by cross-checking with procedure manuals, by comparing their claims with information obtained for similar near misses, and by asking co-workers, trainers or supervisors, while maintaining the confidential nature of the interviews.

Only those near misses about which enough information could be obtained were used to find an answer to the research question. This led to a total of 31 events, 15 involving the preparation of chemotherapy medication and 16 involving on-demand and hospital ward local stock medication. These events included reports made by junior pharmacists, senior pharmacists, pharmacy assistants and pharmacy administrative staff members. Had there been no recovery, the reported events would have resulted in at least one of the commonly (e.g. Benjamin 2003) referred to five wrongs in medication:

1. Wrong patient (e.g. a case involving two patients with same name but different birthdates, where the wrong patient was selected to be printed on the labels).
2. Wrong drug (e.g. confusing drugs with similar names or reading wrong line on standard drug order list).
3. Wrong route (e.g. intravenously instead of subcutane).
4. Wrong dose (e.g. using standard dose instead of requested dose or making a mistake in writing down quantities or wrong position of decimal point).
5. Wrong time (e.g. rush order after the detection by nursing staff who requested medication had not been delivered).

Next to these five categories of medication 'wrongs', sometimes two additional categories are also distinguished (e.g. Safren and Chapanis 1960): medication omission and extra medication. Among the near misses that were collected, there were also events that without recovery would have produced outcomes in these categories (e.g. medication omission after a misplaced medication repetition request; extra medication after preparing a chemotherapy that was already cancelled).

Each near miss was analysed according to the Prevention and Recovery Information System for Monitoring and Analysis (PRISMA) method (e.g. Van der Schaaf 1992, 1996b). PRISMA is a risk management method in which incidents and process deviations are continuously and systematically monitored, analysed and interpreted. Following this method, based on the notes taken by the interviewer, first the near misses were described using the 'causal tree' approach, which is derived from fault tree analysis (e.g. Kirwan 1994). A causal tree starts with the reported symptom as the top event and traces this to direct causes of the event, then to the indirect causes, until finally the causes at the most fundamental level (which should still be within the organization's control) are identified. In the case of near-miss incidents the causal tree has both a failure side, identifying

factors causing things to go wrong, and a recovery side, explaining how this problem was detected and further recovered. As soon as they were constructed, each causal tree was verified by everyone involved in the depicted near miss, i.e. the reporting person as well as any others, plus one or more other local subject matter experts, always resulting in a total of at least three reviewers. This process also made it possible to collect further information where needed. The failure factors at the bottom or root of the failure side of the causal trees were coded using the PRISMA failure factor classification model (also called Eindhoven Classification Method). This classification model is built on the notions of latent failures (Reason 1990), most often taking the form of either technical factors or organizational and management characteristics, and the skill-, rule- and knowledge-based behaviour model (Rasmussen 1986) for the human contribution to the incident. For the purpose of this study, the medical version of the model was used (Battles *et al*. 1998, Kaplan *et al*. 1998), which acknowledges the influence of patient-related factors. Recovery factors were coded using the PRISMA recovery taxonomy (Nyst and Van der Schaaf 2001, Van der Schaaf 2002) by distinguishing between planned and unplanned steps as outlined in section 2, as well as by differentiating between technical provisions such as computer systems, organizational provisions, such as prescribed checks and other procedures, and human actions.

To assess reliability of the coding, three of the authors, all trained in the coding system, independently coded all the failure and recovery factors identified at the roots of the causal trees. An inter-rater agreement check, using the method proposed by Siegel and Castellan (1988) for measuring agreement between multiple coders, corrected for chance agreement, revealed $\kappa = 0.80$ ($p < 0.001$). Following guidelines provided by Landis and Koch (1977), this result indicated substantial agreement. Where differences in coding were identified, consensus was reached between the coders regarding the final coding assigned to the factors involved before proceeding to further analysis.

5. Findings regarding negative and positive influences on recovery processes

To identify which factors had a negative influence on recovery, this study looked at the failed or missed recovery opportunities before the eventual successful recovery in the near misses in the dataset and identified the factors that contributed to this happening. With regard to missed recovery opportunities, one can differentiate between planned and unplanned recovery opportunities from the organization's point of view, as explained in section 2. The planned recovery opportunities available to pharmacy employees concerned mainly built-in, prescribed checks, as described in section 3. The unplanned recovery opportunities available mainly concerned using one's knowledge and experience to detect or further recover from things that were not as they should be, without being told to do this by specific procedures or instructions. The factors that contributed to missing or failing of these planned and unplanned recovery opportunities, i.e. negative recovery influencing factors, could be coded as failure factors. Only in three near misses, no recovery opportunities were missed at all. In total in the 31 near misses, 25 unplanned recovery opportunities were missed, as a result of 33 failure factors, and 30 planned recovery opportunities were missed, as a result of 37 failure factors – note that in one missed opportunity multiple failure factors could have played a role.

Table 1 shows that in terms of the medical version of the PRISMA failure factor classification model, the dominant failure factor contributing to missing planned recovery opportunities was organizational culture. A certain slackness had crept into performing all of the prescribed checks. This appeared to be shared among all pharmacy personnel.

Over time, people had started to perceive the abundance of checks aimed at catching errors before patients could be harmed as too much and had become less aware of their importance. Other failure factors that played a role in missing planned recovery opportunities were organizational factors other than culture, such as management priorities, shortcomings in or lack of procedures, insufficient transfer of knowledge and information to personnel, technical factors related to the design and programming of the computer system used for medication preparation, a skill-based human error and several rule-based human errors.

Table 2 shows that the dominant failure factor in missing unplanned recovery opportunities was shortcomings in, or lack of, procedures or protocols, making it very difficult for people to detect and further recover from errors and other failures. Other factors that played a role were technical design of the computer system used in the pharmacy for medication preparation, organizational culture, errors made by people

Table 1. Failure factors involved in missing planned recovery opportunities.

Failure factor	Number of times factor played a role	Example
Organizational – culture	25	Negligence in performing planned checks; negligent authorization of medication requests; rushing to be back in time for break
Organizational – management priorities	3	Low priority given to checking for expired medication
Organizational – procedures	2	No standard check of previous steps during preparation
Organizational – transfer of knowledge and information	1	Employee lacks knowledge of correct dosages
Technical	2	No overdose settings for own product in computer system
Human – skill-based	1	Remark that request was provisional not noted
Human – rule-based	3	Poor communication about task distribution
Total	37	

Table 2. Failure factors involved in missing unplanned recovery opportunities.

Failure factor	Number of times factor played a role	Example
Organizational – culture	4	Insufficient attention paid to dosage during authorization
Organizational – procedures	15	No procedure for checking requests submitted via telephone; no procedure for reporting delays to wards
Technical	2	During input in computer system no feedback re. errors
Human – rule-based	6	Wrong form in tray not noticed; no attention paid to requested dosage, which differed from standard
Human – knowledge-based	4	Incomplete correction only on form not in computer system
Human – external	2	Nursing staff did not report missing medication
Total	33	

outside the pharmacy or human error inside the pharmacy (both rule-based and knowledge-based mistakes).

To find out which factors had a positive influence on recovery, this study looked at the recovery processes that were eventually followed in the near misses to successfully return the situation to normal (see table 3).

Most recovery processes took the form of detection followed by countermeasures, and only two processes included an explicit step aimed at finding an explanation for the detected problem and its causes. In terms of the PRISMA recovery taxonomy, detection was most often the result of a planned organizational provision. In the remaining cases, the detection involved unplanned, more ad hoc human activity. In 18 cases, the detection was done by people from outside the pharmacy, in these cases hospital ward nursing staff. In all but one of these 18 cases, the nursing staff followed a standard procedure or protocol that led to the detection. Both the explanation steps observed were planned, using organizational provisions such as available documents and systems, and were performed by pharmacy employees. All of the countermeasures, or corrections, were performed by pharmacy employees. Nearly all countermeasures were based on planned, organizational provisions; only two involved ad hoc, unplanned human action.

The above results indicate that even though some (early) planned checks may fail, the eventual recovery is mostly still the result of (later) steps pre-planned by the organization, especially with regard to countermeasures. Without such provisions, it could have been much harder to recover. Therefore, organizational provisions such as procedures and training also served as positive recovery influencing factors. The importance of people's own reasoning abilities, however, most obvious in the unplanned detections, should not be underestimated. The knowledge and experience of the people involved, applied in a way not prescribed by the organization, were a positive influence on the recovery process. In addition, in half (i.e. four) of the near misses involving unplanned detection, no earlier planned recovery opportunities were missed, indicating that these situations depended completely on ad hoc unplanned detection to be recovered.

Table 3. Successful recoveries.

Process phase	No. planned	Example	No. unplanned	Example
Detection	23	During planned check senior pharmacist detects wrong administration form indicated in protocol	8	Based on ward knowledge junior pharmacist detects medication has incorrectly been indicated the day before as available in local stock
Explanation	2	Junior pharmacists traces back all steps performed so far during preparation to find a suspected error	0	Not applicable
Countermeasures	29	Pharmacy employees following standard procedures to prepare required medication to replace missing or wrong medication	2	Junior pharmacist retrieving required medication during weekend from other ward where he knows it is available

6. Guidelines for improving recovery processes in the pharmacy

For the pharmacy to improve their performance with regard to recovery and thus increase patient safety in the hospital, they should aim to reduce the identified negative influences on recovery and reinforce the positive influences.

This analysis suggests several ways in which the pharmacy can reduce negative recovery influences. First, given that organizational culture was a major factor in missing recovery opportunities, such as planned checks, pharmacy management needs to change this culture by increasing awareness among all employees that these checks are vital to prevent patients from being harmed either by receiving the wrong medication or by delays in receiving the required medication. One of the ways such awareness may be fostered is the continuation and strengthening of the current near-miss reporting scheme: each decision by an employee to report a deviation is another step towards a better culture (Aspden *et al*. 2004). Demonstrating this by sharing information on real, de-identified examples of failed recovery from the near-miss database should also help to drive this message home. In addition, recovery was regularly made very difficult because of shortcomings in, or lack of, procedures. The pharmacy needs to address these problems, too. If procedures do not work, people are less likely to follow them. Finally, the computer system used in the pharmacy was another negative influence on recovery. Computer systems can facilitate recovery processes by helping to detect conflicts in data, but they need to be programmed to do this. This often involves feeding data such as standards into the system and keeping it up to date. Currently, the system is not reaching its full potential with regard to supporting recovery. This is another area that the pharmacy should address.

The findings presented in section 5 also indicated ways to increase positive influences on recovery. For example, having procedures and protocols to support detection and further recovery turned out to have a positive effect. Since some checks might fail, it pays to have several checks (double or triple checks) built into procedures if the severity of the potential negative consequences warrants this. But since it may not be possible to foresee all potential problems, and not practical or cost-effective to put procedures in place for all eventualities even if they can be foreseen, pharmacy employees must have the knowledge to detect and further recover from problems without the support of procedures. It is the responsibility of the pharmacy's management to ensure that knowledge and skill levels are up to date. Special training could use problem scenarios inspired by reported near misses to maintain everyone's creative problem-solving skills. Furthermore, as many recovery processes depended on involvement from people outside the pharmacy in the detection that something was wrong, the pharmacy should encourage this role and keep communication between the hospital wards and the pharmacy as easy as possible.

If organizations implement improvement measures, obviously they want to know if the measures lead to the desired effect. Similarly, it would be useful for the pharmacy's management to be able to measure whether their performance with regard to recovery has improved, that is, if their recovery processes have become more successful, after making the changes recommended above. Several indicators can be used to measure the success of a recovery process (e.g. Kanse 2004). One indicator is what consequences remain after all the recovery steps have been taken – more successful outcomes involve as few negative remaining consequences as possible. The remaining consequences of the near misses in this dataset, for example, varied from no negative consequences at all to having to process rush orders, delays in getting correct medication to patients, temporary shortages in medication stocked locally at hospital wards or having to throw away

incorrectly prepared or unneeded expensive medication. One may also want to take into account what the potential consequences were that were avoided as a result of the recovery process, both with regard to type and severity level. Another aspect worth considering is the resources (e.g. working hours and money) spent on recovery. It may be acceptable to spend more resources on avoiding very severe potential consequences than on cases where only minor consequences can result from doing nothing. In addition, one may want to include how widespread the effects have been before the recovery was complete and how many recovery opportunities had been missed or failed before eventually a successful recovery attempt was made. To a certain extent, as can be seen from the remaining consequence examples given above, the resources spent, the affected area and the missed recovery opportunities could even be incorporated into the remaining consequences, as specific types of remaining consequences. For each specific type of remaining consequence, with the assistance of domain experts several categories can be distinguished, corresponding with amount, size or level of severity. Weights can be assigned to these categories from low to high. These weights can be summed across all applicable types of remaining consequences per near miss and the result subtracted from a potential consequence score obtained in a similar manner. Larger results thus obtained indicate more successful recovery processes. By averaging a recovery process success score over all the reported incidents an overall recovery performance measure can be obtained.

Taking the above into consideration, the pharmacy can develop their own, tailor-made recovery performance measure, to help them determine if they are improving their recovery processes. A recovery performance measure would also add a positive measure to the list of safety performance measures that generally only count negative events.

7. General conclusion

Even though the guidelines presented above are based on data collected at one specific hospital pharmacy, some conclusions can be drawn that are potentially equally applicable for other pharmacies or even other areas in (and outside) the medical domain. For example, comparable findings from other domains, such as the chemical process industry (e.g. Kanse 2004), indicate that what was pointed out above regarding the importance of focusing on and supporting recovery is applicable in a variety of settings. With the shared concern being patient (or general) safety, any health care (or other) organization or organizational unit will benefit from measures aimed at strengthening opportunities for successful recovery.

Whether the guidelines given above regarding which negative influences to remove and which positive influences to reinforce are the most appropriate depends on how similar the processes and problems are to those in the pharmacy involved in the present study. When investigating a new domain, it would be advisable to study local near misses and recovery processes first, to identify specific areas in need of improvement. The description of how this was done in the present study can serve as guidance. The authors tried to minimize the potential for bias to which retrospective accounts of events are prone, especially events involving one's own errors, by ensuring that there should be no worry of repercussions, focusing on what went right and not only what went wrong, minimizing the time between the event and the follow-up interview, consulting several people about an event instead of only one and studying any written documentation relevant for the event such as procedures, requests and preparation forms. In future research, where possible, the use of additional data collection methods such as observations can help to

further reduce the sources of bias. The guidelines given above regarding how recovery performance can be measured are quite general and could equally apply in other organizations and organizational units.

It is to be hoped that with this contribution available insights have been added into how near-miss data can be used to increase the chance of successful recovery. It is also hoped that others have been encouraged to start focusing on recovery as a more positive alternative to strictly prevention-based safety management methods.

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References

Armitage, G. and Knapman, H., 2003, Adverse events in drug administration: a literature review. *Journal of Nursing Management*, **11,** 130–140.

Ashcroft, D.M., Quinlan, P. and Blenkinsopp, A., 2005, Prospective study of the incidence, nature and causes of dispensing errors in community pharmacies. *Pharmacoepidemiology and Drug Safety*, **14,** 327–332.

Aspden, P., Corrigan, J.M., Wolcott, J. and Erickson, S.M. (Eds.), 2004, *Patient Safety: Achieving a New Standard for Care*, pp. 22–33, 226–245 (Washington, DC: National Academies Press).

Bagnara, S., Ferrante, D., Rizzo, A. and Stablum, F., 1988, Causal analysis in error detection and recovery: When does it occur? In *Proceedings of International Conference on Joint Design of Technology, Organisation and People Growth*, 12–14 October, Venice, Italy.

Battles, J.B., Kaplan, H.S., Van der Schaaf, T.W. and Shea, C.E., 1998, The attributes of medical event-reporting systems: experience with a prototype medical event-reporting system for transfusion medicine. *Archives of Pathology and Laboratory Medicine*, **122,** 231–238.

Benjamin, D.M., 2003, Reducing medication errors and increasing patient safety: case studies in clinical pharmacology. *Journal of Clinical Pharmacology*, **43,** 768–783.

Bove, T., 2002, Development and validation of a human error management taxonomy in air traffic control. PhD thesis, Risø National Laboratory and University of Roskilde.

Bove, T. and Andersen, H.B., 2001, Types of error recovery in air traffic management. In *Third International Conference on Engineering Psychology and Cognitive Ergonomics*, D. Harris (Ed.), pp. 171–180 (Aldershot: Ashgate).

Crawford, S.Y., Cohen, M.R. and Tafesse, E., 2003, Systems factors in the reporting of serious medication errors in hospitals. *Journal of Medical Systems*, **27,** 543–551.

Dean, B., Schachter, M., Vincent, C. and Barber, N., 2002, Prescribing errors in hospital inpatients: their incidence and clinical significance. *Quality and Safety in Health Care*, **11,** 340–344.

Duncan, K.D., 1987, Fault diagnosis training for advanced continuous process installations. In *New Technologies and Human Error*, J. Rasmussen, K.D. Duncan and J. Leplat (Eds.), pp. 209–221 (Chichester: John Wiley & Sons).

Edmondson, A.C., 1996, Learning from mistakes is easier said than done: Group and organizational influences on the detection and correction of human error. *Journal of Applied Behavioral Science*, **32,** 5–28.

Flanagan, J.C., 1954, The critical incident technique. *Psychological Bulletin*, **51,** 327–358.

Frese, M., 1991, Error management or error prevention: Two strategies to deal with errors in software design. In *Human Aspects in Computing: Design and Use of Interactive Systems and Work With Terminals*, H.J. Bullinger (Ed.), pp. 776–782 (Amsterdam: Elsevier Science Publishers).

Helmreich, R.L., Merritt, A.C. and Wilhelm, J.A., 1999, The evolution of crew resource management training in commercial aviation. *International Journal of Aviation Psychology*, **9,** 19–32.

Hoffman, R.R., Crandall, B. and Shadbolt, N., 1998, Use of the Critical Decision Method to elicit expert knowledge: A case study in the methodology of cognitive task analysis. *Human Factors*, **40,** 254–276.

Hollnagel, E., 1999, Accidents and barriers. In *Proceedings CSAPC '99, Seventh European Conference on Cognitive Science Approaches to Process Control*, J.M. Hoc, P. Millot, E. Hollnagel and P.C. Cacciabue (Eds.), pp. 175–180 (Villeneuve d'Asq, France: Presses Universitaires de Valenciennes).

KANSE, L., 2004, Recovery uncovered: How people in the chemical process industry recover from failures. PhD thesis, Eindhoven University of Technology.

KANSE, L. and VAN DER SCHAAF, T.W., 2001a, Factors influencing recovery from failures. In *CSAPC '01–8th Conference on Cognitive Science Approaches to Process Control*, R. Onken (Ed.), pp. 123–136 (Neubiberg: Universitat der Bunderwehr).

KANSE, L. and VAN DER SCHAAF, T.W., 2001b, Recovery from failures in the chemical process industry. *International Journal of Cognitive Ergonomics*, **5,** 199–211.

KAPLAN, H.S., BATTLES, J.B., VAN DER SCHAAF, T.W., SHEA, C.E. and MERCER, S.Q., 1998, Identification and classification of the causes of events in transfusion medicine. *Transfusion*, **38,** 1071–1081.

KIRWAN, B., 1994, *A Guide to Practical Human Reliability Assessment* (London: Taylor & Francis).

KLEIN, G., PLISKE, R., CRANDALL, B. and WOODS, D.D., 2005, Problem detection. *Cognition, Technology and Work*, **7,** 14–28.

KOHN, L.T., CORRIGAN, J.M. and DONALDSON, M.S. (Eds.), 2000, *To Err Is Human: Building a Safer Health System*. (Washington, DC: National Academies Press).

KONTOGIANNIS, T., 1999, User strategies in recovering from errors in man-machine systems. *Safety Science*, **32,** 49–68.

LANDIS, J.R. and KOCH, G.G., 1977, The measurement of observer agreement for categorical data. *Biometrics*, **33,** 159–174.

LAWTON, R. and PARKER, D., 2002, Barriers to incident reporting in a healthcare system. *Quality and Safety in Health Care*, **11,** 15–18.

LEAPE, L.L., BRENNAN, T.A., LAIRD, N., LAWTHERS, A.G., LOCALIO, A.R., BARNES, B.A., HEBERT, L., NEWHOUSE, J.P., WEILER, P.C. and HIATT, H., 1991, The nature of adverse events in hospitalized patients. Results of the Harvard Medical Practice Study II. *New England Journal of Medicine*, **324,** 377–384.

NYST, C. and VAN DER SCHAAF, T.W., 2001, *The Near-miss Pilot Study in Anesthesia*.

O'SHEA, E., 1999, Factors contributing to medication errors: a literature review. *Journal of Clinical Nursing*, **8,** 496–504.

RASMUSSEN, J., 1986, *Information Processing and Human-Machine Interaction: An Approach to Cognitive Engineering* (New York: Elsevier Science Publishing Company).

REASON, J., 1990, *Human Error* (Cambridge: Cambridge University Press).

RIZZO, A., FERRANTE, D. and BAGNARA, S., 1995, Handling human error. In *Expertise and Technology: Cognition and Human-computer Cooperation. Expertise: Research and Applications*, J.M. Hoc and P.C. Cacciabue (Eds.), pp. 195–212 (Hillsdale, NJ: Lawrence Erlbaum Associates).

ROLLAND, P., 2004, Occurrence of dispensing errors and efforts to reduce medication errors at the Central Arkansas Veteran's Healthcare System. *Drug Safety*, **27,** 271–282.

SAFREN, M.A. and CHAPANIS, A., 1960, A critical incident study of hospital medication errors. *Hospitals*, **34,** 32–34, 57–66, 65–68.

SARTER, N.B. and ALEXANDER, H.M., 2000, Error types and related error detection mechanisms in the aviation domain: An analysis of Aviation Safety Reporting System incident reports. *International Journal of Aviation Psychology*, **10,** 189–206.

SIEGEL, S. and CASTELLAN, N.J. Jr., 1988, *Nonparametric Statistics for the Behavioral Sciences* (New York: McGraw-Hill).

SVENSON, O., 2001, Accident and incident analysis based on the accident evolution and barrier function (AEB) model. *Cognition, Technology and Work*, **3,** 42–52.

VAN DEN BEMT, P.M., POSTMA, M.J., VAN ROON, E.N., CHOW, M.C., FIJN, R. and BROUWERS, J.R., 2002, Cost-benefit analysis of the detection of prescribing errors by hospital pharmacy staff. *Drug Safety*, **25,** 135–143.

VAN DER SCHAAF, T.W., 1988, Critical incidents and human recovery: Some examples of research techniques. In *COST A1 Seminar on Risk Analysis and Human Error*, L.H.J. Goossens (Ed.) (Delft: Delft University of Technology).

VAN DER SCHAAF, T.W., 1992, Near miss reporting in the chemical process industry. PhD thesis, Eindhoven University of Technology.

VAN DER SCHAAF, T.W., 1996a, Human recovery of errors in man-machine systems. In *Proceedings of International Conference and Workshop on Process Safety Management and Inherently Safer Processes*, 8–11 October, Orlando, FL (New York: American Institute of Chemical Engineers).

VAN DER SCHAAF, T.W., 1996b, PRISMA: A risk management tool based on incident analysis. In *Proceedings of International Conference and Workshop on Process Safety Management and Inherently Safer Processes*, 8–11 October, Orlando, FL (Utrecht: Academy of the Dutch Health Inspectorate).

VAN DER SCHAAF, T.W., 2002, *IGZ Course on Patient Safety*.

Van der Schaaf, T.W., Lucas, D.A. and Hale, A.R. (Eds.), 1991, *Near Miss Reporting as a Safety Tool* (Oxford: Butterworth Heinemann).

Van der Schaaf, T.W. and Wright, L.B., 2005, Systems for near miss reporting and analysis. In *Evaluation of Human Work*, J.R. Wilson and N. Corlett (Eds.), pp. 877–900 (London: CRC Press).

Van Vuuren, W. and Kanse, L., 2003, Widening the scope of incident analysis in complex work environments. In *Komplexes Handeln in der Anaesthesie (Complex Activity in Anesthesiology)*, T. Manser (Ed.), pp. 186–207 (Berlin: Pabst Science Publishers).

Vrijland, N.D., 2004, PRISMA analyse van incidentmeldingen. PhD thesis, Eindhoven University of Technology.

Wagenaar, W.A. and Groeneweg, J., 1987, Accidents at sea: Multiple causes and impossible consequences. *International Journal of Man-Machine Studies*, **27,** 587–598.

Wioland, L. and Amalberti, R., 1998, Human error management: Towards an ecological safety model a case study in an air traffic control microworld. In *Proceedings of 9th European Conference on Cognitive Ergonomics*, 24–26 August, Limerick, Republic of Ireland.

Wong, B.L., 2004, Data analysis for the Critical Decision Method. In *Task Analysis for Human-Computer Interaction*, D. Diaper and N.A. Stanton (Eds.), pp. 327–346 (Mahwah, NJ: Lawrence Erlbaum Associates).

Zapf, D. and Reason, J.T., 1994, Introduction: Human errors and error handling. *Applied Psychology: An International Review*, **43,** 427–432.