Research Article

System weaknesses as contributing causes of accidents in health care

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Abstract

Objectives. Accidents in health care, resulting in injury or death to the patient, are a matter of considerable concern. The aim of this study is to examine whether system weaknesses can contribute to these accidents, and if so, how.

Design. Eight consecutive accidents reported to the Health Authority in Sweden were analysed using MTO (Man–Technique–Organization) analysis.


Results. All cases that involved the system supported the assumption that system weaknesses are a contributing factor to accidents. In this study two types of latent failure could be identified: process control latent failures and interactional latent failures. The time span from activation of process control latent failures to operator error was very short, and the study demonstrates the simple relationship between situational factors and operator errors. Interactional latent failures exert system influence in a more indistinct manner. Latent failures, as seen in this study, act not only by creating opportunities for operator errors but also by hindering error detection in the time window available. Safety barriers, which might have prevented the accidents, could be proposed in seven out of eight cases.

Conclusion. System weaknesses seem to play an important role in accident evolution. Consequently, certain measures can be suggested in order to improve patient safety: (i) sufficient resources should be allocated for research and development at both medical schools and hospitals in order to establish competence and procedures for systematic analyses of processes; and (ii) authorities handling accident cases should have adequate competence in system analysis.

Keywords: accident, barrier, health care, ISO 9000, latent failure, MTO analysis, situational factor, system weakness
effect of such an action, thus making the system ‘error tolerant’ or forgiving [2,13,14].

The barrier concept has, for many years, played a key role in the nuclear power industry’s accident prevention efforts [15,16]. The importance and function of barriers in health care have been exemplified by Feldman and Roblin [9].

An example of an administrative barrier is a written procedure stating that a junior doctor may not discharge a patient with abdominal pain from the emergency department before first undergoing examination from a senior doctor.

An example of a technical barrier is the design of the plugs of the ECG apparatus, thus preventing them from being plugged into the main power supply.

According to Rasmussen [17], external influences, situational factors, can often be identified as ‘triggers’ for accidents. This term is also used by the nuclear power industry [15]. A situational factor in this study is specified as an unplanned ‘unlucky’ circumstance, local in space and time, which increases risk (probability and/or consequence). In this study we identify situational factors that contributed significantly to the fact that the studied accident occurred when and where it did.

This study aims to answer the following questions: Can latent failures contribute to accidents in health care, and if this is so, how do latent failures contribute to system breakdown? Can missing or inadequate barriers contribute to accidents in health care, and if so, how? Given this, how do situational factors and latent failures interact?

Materials and method

Material

The material consists of accidents reported to the regional Health Authority in southern Sweden. This region has 2 million inhabitants, served by 12 emergency care hospitals, including two university hospitals (Lund and Malmö). According to a government act, all health care units must report cases to the regional health authority in the event of the patient dying or suffering severe injuries whilst receiving care. Cases where death or injury is due to ‘calculated medical risks’ need not be reported.

Inclusion criteria for this study were reports concerning death, severe or near-accident from the county hospitals (emergency care units). The cases consisted of consecutive reports to the authority during the period October 1996–January 1997.

In two instances the incoming cases fulfilling the inclusion criteria exceeded that which it was possible for the investigator to handle in due time, taking into account the authority’s procedures for swift handling. This meant that on two occasions it was necessary to omit a case in the consecutive series. A decision was made to include the case involving the more serious outcome, and omit the less serious one.

Reports from psychiatric ward units, from the municipalities (care for the elderly), and from private practitioners were excluded. The material consists of eight cases; see Table 1.

Method

The cases were analysed with a method used by the Swedish nuclear power industry under the name of MTO (Man–Technology–Organization) analysis [18]. It is derived from the American nuclear power industry’s Human Performance Enhancement System (HPES) [15,16].

The method is based on a process model where the accident is seen as a flow of events along a time axis [19]. It incorporates an industrial engineering systems view, highlighting management responsibility [20]. It is described in more detail in Ternov [13].

In short, the method is a structured way of gathering and analysing information. Information is transferred to a flow chart (MTO block diagram, Table 2). The analysis includes the following elements: (i) detailed mapping of the event, plotted against a time axis; (ii) causal analysis for inappropriate or faulty actions in the sequence; (iii) identification of situational factors; (iv) barrier analysis: analysis of the role of barriers in the actual context for not being able to stop the chain of events leading up to the accident.

The cause analysis is the difficult part of the MTO analysis. Basically it consists of asking ‘why’ a sufficient number of times and tracing a causal chain backwards (upwards) within the organization. The question is: when should one stop asking the question ‘why’, i.e. how should the stop rule be defined [14]? In this study the stop rule is applied when identified causes fulfil one or more of these criteria: it is beyond the operator’s influence in the organization to eliminate the cause; the potential of the cause to give rise to error is global, i.e. it might happen to any operator who happens to be ‘in the wrong place at the wrong time’; the cause is linked to the management system; the cause is not unique for the accident being studied. If it remains in the system it could result in other types of accidents, and, finally, the cause may involve poor design of the human–machine interface.

A preliminary analysis is made from a written accident report. Hypotheses are formed concerning causes and barriers. In the next stage of the analysis the personnel and managers involved are interviewed, and the results from the cause and barrier analysis are modified according to this new information.

Possible barriers will be proposed during these discussions. Whether these are realistic and acceptable to the personnel involved will then be evaluated. Only if these requirements are met will the barriers be included in the final results.

Results

Identified latent failures, barriers, and situational factors

Latent failures could be identified in all cases but one. For these seven cases, barriers might have prevented system breakdown if they had been adopted and had been adequate.

Situational factors, triggering events towards system breakdown, could be identified in all cases. Table 3 shows for each case active (operator) failures, latent failures, and suggestions for measures against inadequate or missing barriers.
Table 1  Case histories for the eight cases included in the study, and the outcome for the patients

<table>
<thead>
<tr>
<th>Case number</th>
<th>Case history</th>
<th>Outcome for the patient due to the error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A radiologist misinterprets a pelvic X-ray on a pregnant woman.</td>
<td>Cesarean section performed unnecessarily. Long-term outcome not known.</td>
</tr>
<tr>
<td>2</td>
<td>A patient attends the emergency department due to acute pain in the abdomen. It is diagnosed and treated as a stone in the ureter and the patient is discharged. Next morning he is found dead in his home. Autopsy revealed a perforated ulcer in the stomach.</td>
<td>The patient develops an abscess around his aortic valve prosthesis and has to undergo open heart surgery twice. Long-term outcome not known. A blood glucose test discloses the error and glucose is administered with good result. Any long-term effects are not known.</td>
</tr>
<tr>
<td>3</td>
<td>A patient is admitted for investigation of gastrointestinal bleeding. During the stay at the hospital he contracts sepsis and is treated with antibiotics. At discharge the doctor forgets to prescribe antibiotics for further treatment.</td>
<td>The patient develops an abscess around his aortic valve prosthesis and has to undergo open heart surgery twice. Long-term outcome not known. A blood glucose test discloses the error and glucose is administered with good result. Any long-term effects are not known.</td>
</tr>
<tr>
<td>4</td>
<td>An elderly patient in long-term care dislocates his hip prosthesis. After an unsuccessful attempt to relocate the hip he is scheduled for reoperation the next morning. Due to a diabetic condition an insulin infusion is prescribed. The night nurse miscalculates the dosage and administers 10 times too much insulin.</td>
<td>The patient develops paraplegia. It is not possible to determine to what extent the waiting time contributed to the paraplegic condition.</td>
</tr>
<tr>
<td>5</td>
<td>A young man, intoxicated by alcohol, jumps from a bridge, head first. The water is shallow resulting in a fracture to the neck. At the emergency department the ambulance driver reports to a nurse assistant who misinterprets the seriousness of the condition. The patient is made to wait in a room for 45 minutes before being seen by a doctor.</td>
<td>The patient develops paraplegia. It is not possible to determine to what extent the waiting time contributed to the paraplegic condition.</td>
</tr>
<tr>
<td>6</td>
<td>A man with a known asthmatic condition attends the emergency department because of the effect of breathing difficulties. He also suffers from diabetes. For three hours his diabetic ketoacidosis remains undiagnosed. After diagnosis proper treatment is delayed for several hours.</td>
<td>The patient is carefully monitored for transfusion reaction. None such is discovered. Death.</td>
</tr>
<tr>
<td>7</td>
<td>During a minor gynaecological operation the patient starts to bleed massively. Blood for transfusion is given. After two hours it is discovered that the patient received blood intended for another patient.</td>
<td>The patient is carefully monitored for transfusion reaction. None such is discovered. Death.</td>
</tr>
<tr>
<td>8</td>
<td>A patient is admitted for suspected microemboli of the foot. Dextrane is prescribed. The nurse is not aware that Dextrane 1 must be administered prior to Dextrane to prevent anaphylactic shock. After infusion for 30 seconds the patient went into anaphylactic shock.</td>
<td>The patient is carefully monitored for transfusion reaction. None such is discovered. Death.</td>
</tr>
</tbody>
</table>

Table 2  MTO block diagram, simplified example

<table>
<thead>
<tr>
<th>Date, time</th>
<th>Monday 8.15</th>
<th>Monday 8.20</th>
<th>Tuesday 10.15</th>
<th>Tuesday 13.45</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operator action</td>
<td>Action A</td>
<td>Action B (erroneous)</td>
<td>Action C</td>
<td>Action D, etc.</td>
</tr>
<tr>
<td>Questions/causes (used in the preliminary MTO analysis, i.e. before interviews are carried out)</td>
<td>Missing piece of information</td>
<td>Why did the operator act wrongly?</td>
<td>Missing piece of information</td>
<td></td>
</tr>
<tr>
<td>Situational factors</td>
<td>Can any unlucky circumstances be identified, explaining why the erroneous act took place this time?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latent system failures</td>
<td>Latent system failure L1</td>
<td>If barrier B1 had been in place it might have prevented the erroneous act</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3  Examples of operator failures, latent failures, and suggestions for improvement of barriers

<table>
<thead>
<tr>
<th>Case number</th>
<th>Operator (active) failure(s)</th>
<th>Latent failure(s)</th>
<th>Suggested barrier(s)</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The doctor misinterprets a pelvic X-ray.</td>
<td>The procedure for film–object adjustment is aberrant compared with procedures in other hospitals.</td>
<td>Distinct indication on the frontal X-ray if the film–object distance differs from a fixed and known ratio.</td>
<td>At rounds it was customary to let the nurse present the case. The doctors would then decide what to do based on this information. Consequently the senior doctor responsible did not read the patient’s record on the day of the discharge. Therefore, he missed the vital information that the patient had an aortic valve prosthesis. The junior doctor might have detected it during the discharge procedure, but this defence did not work due to the fuss created by the patient’s non-compliant behaviour.</td>
</tr>
<tr>
<td>2</td>
<td>The doctor makes a wrong diagnosis.</td>
<td>None identified.</td>
<td>None identified.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>The doctor discharges a patient with sepsis without prescribing the necessary antibiotics.</td>
<td>Allocation of responsibility between doctors is indistinct. The routines for decision-making at rounds are inadequate.</td>
<td>There should be adequate routines for the responsible doctor’s signature on the letter of discharge.</td>
<td>At rounds it was customary to let the nurse present the case. The doctors would then decide what to do based on this information. Consequently the senior doctor responsible did not read the patient’s record on the day of the discharge. Therefore, he missed the vital information that the patient had an aortic valve prosthesis. The junior doctor might have detected it during the discharge procedure, but this defence did not work due to the fuss created by the patient’s non-compliant behaviour.</td>
</tr>
<tr>
<td>4</td>
<td>A nurse miscalculates the dose of insulin and gives the patient 10 times the required amount.</td>
<td>Interdepartmental activities are poorly controlled. The documents describing the actual procedure are obsolete.</td>
<td>Double-check of the calculation of dosage by another nurse might have caught the error. An electronic aid for calculation of dosage may reduce the risk of miscalculation.</td>
<td>It was not appropriate to let the patient stay in the long-term care unit. The staff there have little experience of preparing the patient for operations. The nurse at this unit got little or no support from the doctors. The procedures of the long-term care unit for document control were poor. In this case it concerned an old, expired document describing how to prepare insulin infusion. This confused the nurse immensely. Due to inappropriate procedures vital information was conveyed to the wrong person.</td>
</tr>
<tr>
<td>5</td>
<td>A nurse assistant misunderstands information from the ambulance personnel, thereby making a wrong decision concerning the urgency of the case.</td>
<td>The procedures for communication between ambulance personnel and emergency department staff are unsafe.</td>
<td>A procedure should allow only the nurse (not the nurse assistant) to receive a report from the ambulance personnel.</td>
<td>The junior emergency department doctor got into a state of mental overload (caused by lack of experience). This contributed to ‘tunnel vision’, i.e. an inability to see ‘the grand picture’ of the patient, i.e. both asthma and diabetes.</td>
</tr>
<tr>
<td>6</td>
<td>The doctor misses an important laboratory result (a high value for base excess, implicating that the patient’s acid–base balance was severely impaired).</td>
<td>The procedures for defining necessary levels of training for work tasks at the emergency department are inadequate. Emergency department work procedures, amongst others, concerning exchange of information, are inappropriate.</td>
<td>Blood glucose should as a routine be checked on all diabetics in the emergency department, and, if high, the urine should be checked for acetone.</td>
<td>The junior emergency department doctor got into a state of mental overload (caused by lack of experience). This contributed to ‘tunnel vision’, i.e. an inability to see ‘the grand picture’ of the patient, i.e. both asthma and diabetes.</td>
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<tr>
<td>Case number</td>
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</tr>
<tr>
<td>-------------</td>
<td>-----------------------------</td>
<td>-------------------</td>
<td>----------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>7</td>
<td>#1: A nurse assistant selects the wrong blood bags from the blood bank unit’s refrigerator.</td>
<td>The procedures for delivery of blood products are inappropriate.</td>
<td>The patient personal identification number (PIN) must be given to the person who collects the blood. The personnel involved must check both the name and PIN before taking the blood from the blood unit’s delivery refrigerator</td>
<td>No procedures were in place for separating acute from non-acute deliveries. In addition, the procedures for sorting out leftover blood products are inappropriate.</td>
</tr>
<tr>
<td>#2: The anaesthetist nurse fails to check the personal identification number of the patient before giving her the blood</td>
<td>The working tasks for the anaesthetist nurse are inappropriately designed.</td>
<td></td>
<td>Among other things the anaesthetist nurse had to answer multiple calls on a cellular phone at the same time as carrying out her patient monitoring duties.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>The doctor does not prescribe Dextrane 1 when prescribing Dextrane.</td>
<td>The organization of the work is a latent failure which is reinforced by another latent failure, the lack of procedures for continually reviewing departmental processes for safety.</td>
<td>All prescriptions must be written and signed by the physician</td>
<td>Dextrane 1 is a haptendextrane with the purpose of neutralizing Dextrane active antibodies. In order to prevent anaphylactic reactions to Dextrane, the haptene should be administered in injection form a few minutes prior to the commencement of a Dextrane infusion. A complicated combination of latent failures contributed to system breakdown: the organization of the work at the department implies that the doctor on duty works together with a nurse who is not really known to him/her (latent failure 1). This in combination with the absence of procedures for continually reviewing procedures for safety (latent failure 2), and lack of procedures for internal auditing (latent failure 3), created the setting for this accident. The doctor working at the emergency department and at the intensive care department, where Dextrane was frequently used, was accustomed to the practice that the nurses automatically gave an injection of Dextrane 1 before starting the infusion with Dextrane. However, the doctor was also a vascular surgeon and was called, in a consultant capacity, to another department to see a newly admitted patient with micro-emboli of the foot. Dextrane was seldom used in this department.</td>
</tr>
</tbody>
</table>
Table 4 Unlucky circumstances, ‘situational factors’, which explain why the accident took place at that particular moment

<table>
<thead>
<tr>
<th>Case number</th>
<th>Situational factor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The doctor works as a locum and comes from a hospital where other routines are practised.</td>
</tr>
<tr>
<td>2</td>
<td>The patient is mentally retarded. The mother is very talkative in a way which is misleading.</td>
</tr>
<tr>
<td>3</td>
<td>The whole team of doctors is changed during the vacation period. The patient is discontented about his stay in hospital and would like to go home immediately. The doctor with the necessary vital information happens to be off duty when the information is needed.</td>
</tr>
<tr>
<td>4</td>
<td>The combination of an elderly patient in a long-term care ward, with a diabetic condition and an attempt to reposition a luxated hip prosthesis under anaesthesia during the preceding evening.</td>
</tr>
<tr>
<td>5</td>
<td>Midsummer’s Eve (heavy workload). A new administrative computerized system has been recently introduced.</td>
</tr>
<tr>
<td>6</td>
<td>The patient is suffering from two conditions. The patient deteriorates between shifts of doctors. The patient temporarily improves at the ‘wrong’ time. The patient expresses a severe dislike for being transferred to the intensive care unit, as per the advice of the doctor. There are initially no beds available at the intensive care unit.</td>
</tr>
<tr>
<td>7</td>
<td>Two patients with similar names and blood groups are admitted to the hospital at the same time. The patient starts to bleed at the same time as having an asthma attack.</td>
</tr>
<tr>
<td>8</td>
<td>An ‘older’ nurse is on duty (nurses with a more recent qualification should know that Dextrane 1 must be administered together with Dextran).</td>
</tr>
</tbody>
</table>

Examples of situational factors

Unique ‘unlucky circumstances’, i.e. situational factors contributing to system breakdown, are shown in Table 4.

Contribution of latent failures to system breakdown: interaction between situational factors and latent failures

The material suggests some differences in the mechanisms by which the latent failures make the system unstable and contribute to an evolution towards accidents. Also, the trigger mechanisms of situational factors seem to be more or less tightly coupled to the activation of the latent failures. The ‘triggering’ effect of situational factors appears rather ambiguous. In some cases a situational factor is a necessary precondition for ‘activation’ of a latent failure, in other cases a latent failure may have a harmful system effect without interacting with a situational factor.

Latent failures identified in this study can be classified in four groups according to how the latent failures contribute to system breakdown: (i) creating opportunities for active failures; (ii) as a hindrance for error detection; (iii) creating disruptive situations; (iv) inducing cognitive bias.

Latent failures creating opportunities for active failure. In cases 1, 5, 7, and 8 a latent failure constituted a distinct ‘error trap’ for the operator, i.e. if that particular latent failure had not existed in the system the operator failure would probably not have occurred.

For example, if the film–object adjustment had been made according to standard practice the doctor would probably not have misinterpreted the X-ray (case #1).

If the nurse, instead of the nurse assistant, had received the information from the ambulance personnel the prioritization would probably have been made correctly (case #5).

If the blood delivery routines had been appropriate, and if the organization of the work task for the nurse had been more suitable, the wrong units of blood would probably not have been given to the patient (case #7).

If doctors were not allowed to make prescriptions within other departments, and if the routines for reviewing the safety of processes were adequate, the patient would probably have been prescribed Dextrane 1 (case #8).

Furthermore, in these cases the situational factors were preconditions for the harmful effect of the latent failures, i.e. without the situational factors events would probably have continued in the usual way, and no one would have noticed the danger of the latent failures. In this study the situational factors served as preconditions in the following ways.

If the obstetrician in case #1 had been a permanent staff member, and not a locum tenens (situational factor), the X-ray department’s aberrant procedures for film adjustment (latent failure) would not have acted as an error trap.

If it had not been Midsummer’s Eve (situational factor in case #5) the inappropriate procedures for reporting (latent failure) would probably not have resulted in delayed treatment (active failure) because some of the nurses would have had the time to pay attention to the arrival of the ambulance.

If there had not been two patients with similar names admitted at the same time (situational factor in case #7) the poor procedures for delivery of blood products (latent failure) would not have resulted in selecting the wrong blood (first active failure), and there would have been no mismatch (second active failure) to detect.
If the nurse (case #8) had not happened to have undergone an older type of training programme (situational factor) she would have known the importance of administering Dextrane 1 before Dextrane.

The time from the onset of the harmful effect of a latent failure to system breakdown is very short, from seconds (#1) to minutes. The operator failures, however, differ in these cases. In case #1 a misinterpretation has been made, and only one operator is involved. For the other cases, elements of impaired error recovery are involved. An error is introduced into the system by some other person. A time window seems to exist where the opportunity for error detection is good, but due to system weaknesses in combination with situational factors, the errors are not detected before system breakdown. This is most clearly seen in case #7. The error introduced is the delivery of wrong blood units to the anaesthetist nurse, but the error is not recovered due to system weaknesses concerning the nurse’s working situation and the situational factors (the patient has an asthmatic attack).

The failure of the nurse assistant to report the arrival of the ambulance with a severely ill patient (case #5) might have been detected by the nurse had she not been so busy.

The error of not making the prescription for Dextrane 1 in writing (case #8) might have been detected by a nurse.

**Latent failures as a hindrance to error detection.** In case #3 the influence of situational factors is less clear and not so tightly coupled to the activation of latent failures.

The indistinct allocation of responsibility (latent failure 1) and the unsafe routines for decision-making during the rounds (latent failure 2) resulted in the omission of instructions to continue the prescription of vital antibiotics (active failure) on the patient’s chart. At this time the error was introduced in the system, but it might still have been detected.

The omission of the continuation of the prescription might have occurred even without the situational factor that the whole team of doctors had changed from Friday to Monday (though less likely), i.e. the latent failures mentioned might have been sufficient for this error to occur, obviously without any influence from the situational factors.

Other latent failures played their role later on in the chain of events, hindering error detection: the procedures for documenting round decisions were poor (latent failure 3), as were the routines for documenting prescriptions (latent failure 4). This, together with the lack of procedures for appointing a responsible doctor for the patient’s care (which might have acted as a barrier) substantially diminished the chances for detection and recovery of the error.

The situational factor consisting of the patient’s wish to leave the hospital immediately probably contributed significantly to a disruptive situation for the junior doctor but omission of prescribing antibiotics could have happened even without this situational factor taking place.

Thus it would seem in this case, as opposed to cases 1, 5, 7, and 8, that if the system is somewhat brittle, i.e. contains a ‘critical’ amount of latent failures, it is possible for these to interact and start an evolution towards an accident even without a clear triggering mechanism from the situational factors.

The case, however, resembles cases 5, 7, and 8 in that error recovery did not function. In case #3 the time window for error recovery was approximately 6 hours.

**Latent failures creating disruptive situations.** In case #4 the effect of the latent failures (poor procedures for interdepartmental activities and poor document control) commenced hours before the active failure, by creating such a disruptive situation that the nurse, according to the interview, was mentally quite exhausted when it came to the calculation of the volume of insulin. She described a feeling that ‘thoughts were grinding to a halt’ at that moment.

In this case the distribution of work between departments was badly planned. The orders to the nurse in the patient’s ward concerning preoperative procedures were insufficient, creating a lot of extra work for the nurse. The prescription of insulin infusion, for instance, was ordered by referring to an old document, which was difficult to find and not updated. Thus the nurse became very confused and had to spend a considerable amount of time and mental effort checking the information.

There is an important situational factor in this case but it is less transparent and not so easy to describe. It could be said that it consisted of the unfortunate combination of an elderly patient in long-term care, with diabetes, and with a hip fracture which has become dislocated, and which could not be repositioned by conservative treatment. That is, if the patient had been in the orthopaedic ward from the onset, or did not have diabetes, or had not been subjected to anaesthesia during the night, the latent failures would not have been triggered.

Therefore this case differs from the others in two aspects: the situational factor is somewhat opaque, and the latent failures start the evolution towards the accident at a very early stage, in fact hours before the active failure takes place, as opposed to cases 1, 5, 7, and 8 where the time span between the harmful system influence of the latent failure and the active failure was short and more obvious. This case does not show elements of a missed time window for error recovery.

**Latent failures inducing cognitive bias.** Case #6 seems to differ from the rest of the cases. The latent failures (level of training, inadequate work procedures) contributed to the transmission of cognitive bias to a senior doctor, i.e. focus on the asthmatic condition, not the diabetic one. But it is speculative as to what extent a more senior doctor in the ‘first line’ would have handled the situation better, i.e. there is a relatively weak coupling between latent failures and evolution towards accident. Instead, a most unfortunate combination of situational factors (see Table 3) strongly contributed to the continuation of the different nurses’ and doctors’ cognitive fixations.

A time window of several hours was available for error recovery. The diagnostic error was detected but unfortunately too late to save the patient’s life.

**Identification of danger signals**

As situational factors play an important role in endangering system stability it would be of interest if they could be anticipated, or formed as a question: Is it possible for operators to...
identify danger signals in the context, telling them that the stability of the system might be threatened?

The study hints at certain danger signals. (i) Unusual working situations and high workload seem to indicate danger. Examples of such situations are locum situations, holiday periods, and festivals (cases #1, #3, and #5). (ii) Execution of non-routine tasks (case #4), and novelties in the context (case #5). (iii) Attempts from a patient to bias the doctor towards a certain diagnosis or treatment (case #2), or the patient not complying with expected ‘patient behaviour’ (cases #3 and #6).

**Discussion**

The study suggests that there might be at least two subgroups of latent failure. One subgroup is concerned with how an individual operator performs his/her working tasks. We will call these ‘process control latent failures’. It appears characteristic of the latent failures in this subgroup that they are activated by situational factors. The time span from activation of these latent failures to operator error is short. The interaction between situational factors and latent failures, and between latent failures and operator errors, is quite straightforward. This subgroup is represented by the cases mentioned in the first group of latent failures in the Results, possibly with the exception of case #8.

Another subgroup of latent failures is concerned with interactions between operators, or groups of operators, i.e. who is doing what, when and why? We will call these ‘interactional latent failures’. The interactions between latent failures and operator errors are less simple in this subgroup. Interactional latent failures act in a more insidious way, and do not necessarily need situational factors to be activated and contribute to system breakdown. They can collaborate to make the system unstable, as seen clearly in case #3. First, two latent failures create opportunities for introducing error into the system, then two other latent failures decrease the potential of the system for error recovery.

Latent failures not only exert negative system influence via operator errors (active failures), they can also act by hindering error recovery in the time window available (mainly interactional latent failures).

Reasonably strong barriers could have been designed in relatively simple ways, except for the case involving the incorrect diagnosis of the ulcer (#2). The proposed barriers were all concerned with process control, whether or not the latent failures in the case were of the interactional type or the process control type. This is logical since the purpose of barriers is to counteract operator failures or the consequences of operator failures, i.e. concerned with process control at carrying out specified tasks.

In the ulcer case, a barrier could be imagined, for instance, which involved all patients being examined by at least two doctors, or more if the first two should disagree. However, this would not fulfil the requirements for a barrier to be realistic and acceptable to the organization involved.

Situational factors are often said to ‘trigger’ latent failures, but linguistically this is an oversimplification of quite complex interaction mechanisms, as shown in this study.

Since system weaknesses in the cases studied play an important role in the accident evolution, and since the reports studied might be representative of reports to the Authority, it implies that investigators at the Health Authority ought to be properly trained in disclosing system weaknesses. This result of the study should also be considered when formulating any judgement policies at the Authority.

The material is very small to apply statistics in order to underline the representativeness of the reports studied for all reports reaching the Authority. Nevertheless, if we assume that system weaknesses contributing to the accidents will be present in only 50% of all reported cases, then the probability of finding seven out of eight cases by chance with these characteristics would be as low as 0.008 (0.57). This means we may be quite confident that system weaknesses contributing to accidents will be present in more, maybe much more, than 50% of the reported cases where the system is involved.

Can the findings be generalized to accidents in emergency care, not reported to the Health Authority? If not, one has to suppose the existence of selection mechanisms which favour accidents with system weaknesses to be reported. Such mechanisms are hard to imagine. Therefore it might be reasonable to assume that the findings can be generalized to all emergency care accidents (involving the system).

If this assumption is correct, an implication of the study is that, since system weaknesses seem to play an important role in accident evolution, sufficient resources should be allocated for research and development at both medical faculties and hospitals in order to establish competence and procedures for systematic analyses of processes, and for implementing suitable management systems.

**Inter-observer reliability in MTO analysis**

To what extent can the results from an MTO analysis be reproduced, i.e. would different investigators identify the same latent failures and flawed barriers? Other authors [12,17] discuss that the results depend very much on the experience and knowledge of the investigator.

The effect of inter-observer variability of experience and knowledge on the result of the analysis may vary from case to case. In the cases with process control latent failures a reasonably gifted MTO analyst might probably acquire the same results as in this study. One so to say ‘stumbles’ over the latent failures and situational factors.

Concerning proposed barriers for those cases, inter-observer reliability is probably smaller. Barrier analysis demands a certain amount of imagination and creativity for the analyst in cooperation with the department involved, and since creativity and communication skills are hard to standardize, alternative solutions might be the result for different analysts.

However, a group composed of persons familiar with different areas of the system, taking part in identifying barriers, should increase the inter-observer reliability and prove a good start for taking remedial action.

In order to identify interactional latent failures, the analyst should probably be trained in management system auditing,
as for instance described in the ISO 9000 series [11]. Consequently, an analyst of these types of accident cases ought to be trained in MTO analysis as well as in system auditing.

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References


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