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Examining causes and prevention strategies of adverse events in deceased hospital patients: a retrospective patient record review study in the Netherlands

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Objective:To improve patient safety and possibly prevent mortality from adverse events (AEs) in hospitals, it is important to gain insight in their underlying causes. We aimed to examine root causes and potential prevention strategies of AEs in deceased hospital patients.
Methods: Data on 571 AEs were used from two retrospective patient record review studies of patients who died during hospitalization in the Netherlands. Trained reviewers assessed contributing factors and potential prevention strategies. The results were analyzed together with data on preventability of the AE and the relationship of the AE with the death of the patient.
Results: In 47% of the AEs, patient-related causes were identified, in 35% human causes, in 9% organizational causes, and in 3% technical causes. Preventable AEs were caused by technical, organizational, and human causes (78%, 74%, and 74%, respectively) more often than by patient-related causes (33%). In addition, technical factors caused AEs leading to preventable death (78%) relatively often. Recommended strategies to prevent AEs were quality assurance/peer review, evaluation of safety behavior, improving procedures, and improving information and communication structures.
Conclusions: Human failures played an important role in the causation of AEs in Dutch hospitals, because they occurred frequently and they were frequently the cause of preventable AEs. To a lesser extent, latent organizational and technical factors were identified. Patient-related factors were often identified, but the preventability of the AEs

with these causes was low. For future research into causes of AEs, we recommend combining record review with interviewing.

Hospital care is continuously developing. The number and complexity of diagnostic procedures and therapeutic interventions are growing rapidly. At the same time, with an increase in older patients and related comorbidity, patient care is becoming more complex. The increasingly complicated techniques and large numbers of healthcare providers involved in the care process increase the potential for failures. Despite these innovations, and maybe even as a result of these changes, a substantial number of adverse events (AEs) occur during hospitalization.Adverse events are defined as “unintended injuries among hospitalized patients that result in disability, death or prolonged hospital stay, and are caused by healthcare management.”[1]

Since the beginning of this century, many Western countries have examined the incidence of AEs in their hospitals.[2–7] The mean incidence of in-hospital AEs has been estimated at 9% of which 44% were judged preventable.[2] It has been shown that when a patient dies during the admission, the likelihood of an AE is even larger.[8] Studies on the incidence of AEs have increased the sense of urgency to improve patient safety in hospitals. However, to design effective interventions, it is important to know which causal factors underlie the AEs.

Previous studies have examined the causes of specific groups of AEs in hospitals, such asmedication events or events at specific hospital departments. Only a few studies have examined the causes of AEs in general. The methods used were patient record review [9,10] or event reporting.[10,11] To our knowledge, the most recent study used data from 2006 to 2008.[11] Because there have been many efforts to improve patient safety in hospital care during the past decade, an up-to-date study into the causes of AEs is highly relevant.

The aim of this studywas to examine the causes of AEs and potential prevention strategies of AEs in patients who died during hospitalization. Studying inpatient deaths will not only provide information on the most serious outcomes of AEs but also provide where improvements are possible, because there is a higher risk of preventable AEs among deceased patients.[8]

Methods

Study Design and Setting

Data were collected in two retrospective patient record review studies examining AEs in Dutch hospitals. Patient records were included during April 2011 to March 2012 and during April 2015 to March 2016. In both studies, a random sample of approximately 20% of all Dutch acute care hospitals was drawn. The hospital samples were stratified for hospital type and geographical area, taking into account the density of population per region.[1] In the first study, 20 hospitals participated, and in the second study, 19 hospitals participated, with seven hospitals participating in both samples. To be eligible for participation, hospitals had to have at least 200 beds and an intensive care unit. All hospitals that were invited participated.

In each hospital, a random sample of patient records of patients who deceased in hospital were selected for review: 100 patient records per hospital in the first study and 150 in the second study. In both studies, university hospitals were oversampled to enable subgroup analyses for hospital type in other publications. Admissions of psychiatric patients, obstetric patients, and children younger than 1 year were excluded because the screening criteria used were not developed for these patient populations (Appendix 1, http:// links.lww.com/JPS/A228).1 The methods of the study were based on previous AE studies in the Netherlands and in other countries and have been described in detail elsewhere.[1,7,8] The study protocols of both studies were approved by the ethical review board of the VU University Medical Center in Amsterdam.

Procedure

The patients' nursing and medical records were reviewed by trained nurses and medical specialists. Nurses screened all records using screening criteria (triggers) indicating potential AEs, for example, an unplanned readmission, unplanned return to the operating room, or unexpected death (Appendix 1, http://links.lww.com/ JPS/A228).1 When one or more criteria were met, the record was subsequently reviewed by a medical specialist. The medical specialists determined, among other things, the presence of one or more AEs, the type of AE, and the degree of preventability, based on a standardized and elaborate procedure and review form. A six-point Likert scale was used to score the likelihood of the AE being caused by healthcare management as well as the preventability of the AE (Appendix 2, http://links.lww.com/JPS/A229). An AE was marked as caused by healthcare or as potentially preventable when medical specialists gave a score of 4 or higher on the six-point Likert scale, indicating a more than 50% of chance of being caused by healthcare or being preventable. In case of an AE, the medical specialist also determined whether the AE had contributed to the death of the patient or not, using several decision-aiding questions in the review form.[1,7] This was an expert opinion of the reviewer based on all the information in nursing and medical records. To examine the interrater reliability of the assessment of the presence of triggers and AEs and of the degree of preventability, 10% of the records were reviewed by two reviewers. The percentages of positive and negative agreement were calculated.[12] The percentages of positive and negative agreement between nurses for their assessment of the presence of any triggers were 89% and 66%, respectively. The percentages of positive and negative agreement between medical specialists for the presence of an AE were 56% and 82%, respectively. For the assessment of whether the AE was preventable or not, the percentages of positive and negative agreement between medical specialists were 74% and 82%, respectively (Appendix 3, http://links.lww.com/JPS/A230).

The medical specialists indicated in which part of the healthcare process the AE occurred, by selecting one of the following types of AEs: surgical procedure, medication, diagnostics, nonsurgical intervention, other clinical activities (e.g., nursing), or nonclassifiable. In addition, they assessed the underlying causes of each AE. They scored all causes that could be identified from the information present in the medical record; they were not asked to indicate a "main" cause. The review form presented six causal factor categories to choose from: technical, human, organizational, patient-related, violation, and others.[9,13,14] For each AE, reviewers selected one or more of these causal factors based on the information in the medical record and their perception of the situation. Having indicated technical, organizational, and/or human causes, reviewers were asked to select one or more subcategories of causal factors. The causal factor categories were derived from a recognized taxonomy of root causes: the Eindhoven Classification Model of PRISMA medical, a root cause analysis tool.[13,14] We added the category "Violation" to the taxonomy to cover all concepts of the Model of Unsafe Acts of Reason.[9,15] In Table 1, the causal factor categories and subcategories are listed and described.

The assessment of preventability was related to the AE, not to the preventability of each cause underlying the AE. For each preventable AE, based on their own judgment, the reviewers selected one or more strategies that they considered relevant to prevent the AE from happening again (Table 2). The categories were based on PRISMA medical14 and the Canadian patient record review study.[16]

Statistical Analysis

Causes of AEs and prevention strategies were analyzed using descriptive statistics. Percentages were calculated using weights, which corrected for overrepresentation of patients admitted to a university hospital in our sample. The sampling weight was the inverse of the probability of being included in the sample because of the sampling design.[1] Correlations between causal factors were not weighted. Because of the small absolute number of AEs of both individual studies, we only present combined results. A comparison of causes at the highest category level showed a similar

distribution at both measurements. The statistical analyses were performed using Stata Statistical Software 14 (StataCorp LP, College Station, TX).[17] The unregularized partial correlation network (Fig. 1) was produced using Team RC, a language and environment for statistical computing (R Foundation for Statistical Computing, Vienna).[18]

Results

Patient Characteristics

In total, 4871 patient records were reviewed. The reviewers identified 571 AEs in 531 of these records. Of the patients with AEs, 53% were male. The mean age was 74 years (range, 2–100; median, 76 y); 38% were older than 80 years. The admission department was surgical in 44% of the patients (e.g., surgery, orthopedics, urology) and was nonsurgical in 56% (e.g., internal medicine, cardiology, lung diseases). The mean length of hospital stay was 16 days (range, 0–153; median, 13 days).

Causes of AEs

Of all AEs, 206 (34%) were considered preventable, and in 143 AEs (25%), the death of the patient was preventable. The 571 AEs were categorized into the following types: 35% surgical procedure, 30% medication, 11% diagnostics, 11% nonsurgical intervention, 11% other clinical activities (e.g., nursing), and 3% nonclassifiable.

For 142 of the 571 AEs, the reviewers were unable to assess the causes. The remaining 429 AEs were associated with 588 causal factors, because reviewers could select more than one category per AE (technical, human, organizational, patient related, violation, and others). Table 3 presents the weighted percentages of the identified causal factor categories. Patient-related factors (e.g., comorbidity and age) were predominantly involved in AE causation (in 47% of the AEs). In 35% of the AEs, human causes were involved. In 9% of the AEs, there was a deliberate deviation from rules or procedures (violation). In 9% of the AEs, organizational factors contributed to the AE, in 3% technical factors, and in 1% other factors.

Patient-related factors relatively infrequently caused preventable AEs. Of all AEs with a patient-related cause, 33% were considered preventable, compared with 72% to 78% for the other causal categories. Technical factors relatively often caused AEs with preventable death (78%), compared with 22% to 55% for the other causal categories.

For some causal categories, the reviewers could select one or more specific subcategories of causes. Scores on subcategories of the organizational and human causes are also presented in Table 3. Human causes were predominantly related to knowledge (33% of all AEs with human causes), skills (18%), and monitoring (15%). These causal factors were also associated with large proportions of preventable AEs (78%–87%), as well as inadequate verification (90%). In addition, skill-based failures relatively often caused AEs leading to preventable death (72%).

[Table 1], [Table 2]

Transfer of knowledge and organizational culture were the most frequently cited organizational factors contributing to AEs (respectively, 83% and 49% of all AEs with organizational causes). Failures relating to organizational culture caused a relatively high proportion of preventable AEs (86%) and AEs with preventable death (66%) (see Table 4 for examples of AEs).

Combinations of Causes

Substantial correlations exist between different subtypes of organizational factors, meaning that these causes relatively often occurred simultaneously. Organizational culture (OC) and transfer of

knowledge (OK) showed the highest correlation (r = 0.43). Moderate correlations were found between culture (OC) and management priorities (OM) (r = 0.34) and between transfer of knowledge (OK) and protocols (OP) (r = 0.30). Several human failure subcategories also showed moderate correlations: human knowledge–based failures (HKK) correlated with qualifications (HRQ) (r = 0.34) and monitoring failures (HRM) (r = 0.32) and intervention failures (HRI) correlated with monitoring failures (HRM) (r = 0.26). Correlations between subcategories from different higher level categories were less strong, with the highest positive correlation between organizational management (OM) and human coordination (HRC) (r = 0.25). Figure 1 shows a correlation network of the causal factors.

[Table 3]

Potential Prevention Strategies

For all preventable AEs (n = 206), reviewers were asked to select one or more prevention strategies. For six AEs, they did not select any of the prevention strategies. For the remaining 200 AEs, they selected 647 prevention strategies (range, 1–6; mean, 3.2; median, 2 strategies). Quality assurance/peer review was the most frequently selected strategy (75%), followed by evaluation of safety behavior (67%) and improving procedures (56%). Increasing the number of personnel, financial investments, upscaling of the problem to a higher organizational level, and technological improvements were least often considered as relevant methods to prevent AEs (0%–4%) (Table 5). For the AEs with human causes, reviewers predominantly recommended quality assurance/peer review (79%). Adverse events caused by organizational factors were considered most preventable by improving information and communication (83%) and AEs with patient-related factors by evaluation of safety behavior (79%) (not in table).

Subgroup analyses for the two most frequent types of AEs showed that for surgical AEs, reviewers predominantly recommended evaluation of safety behavior (92%) and improving procedures (82%) and that for medication AEs, reviewers recommended quality assurance/peer review (70%) and evaluation (62%). In case of surgical events, motivating staff to follow generally accepted rules was frequently selected compared with the total group of AEs (66% versus 38%) as well as information and communication (73% versus 47%) (Table 5).

Discussion

Main Findings

Patient-related causes, e.g., comorbidity and age, were most commonly identified as causes of AEs in deceased patients. Human causes were also relatively frequently identified, and as expected, these contributed to preventable AEs more often than patient-related causes. Human failures most often involved knowledge-based behavior of healthcare professionals who were unable to apply existing knowledge in different situations.

Latent technical and organizational causes were not identified frequently. However, these causes contributed relatively often to preventable AEs. Organizational factors most often involved the organizational culture and caused a relatively high proportion of preventable AEs and AEs leading to preventable death.

[Table 4]

Adverse events were often caused by a combination of different types of causes within the same higher level category. The most frequent combination of causes was organizational culture and transfer of knowledge, meaning that relatively often AEs are caused by a culture in which it is difficult to take adequate measures to ensure that knowledge or information is transferred to others.

[Table 5]

The most frequently recommended strategy to prevent AEs was quality assurance/peer review, a broad strategy to reduce AEs in general. Other frequently recommended strategies were evaluation of safety behavior, improving procedures, and improving available sources of information and communication structures. For surgical AEs, motivating staff to follow generally accepted rules as well as improving information and communication were relatively frequently recommended, compared with other types of events.

Comparison With Previous Studies

In previous studies, causes of AEs have been examined with patient record review, incident reporting, interviewing, or claims notes review.10 Because of the heterogeneity of study methods, it is difficult to make a good comparison of results. In a systematic review of Sari et al. (2010),[10] the authors used a structured narrative method to summarize the results and found that the majority are linked to individual human failure and a smaller proportion with system failure. This corresponds with our results.

In two Dutch studies, one patient record review study[9] and one incident reporting study,[11] the same root cause taxonomy to classify the causes was used, which facilitates a comparison with our study. The methods of the record review study were identical to the current study, except for the patient population of which half were patients discharged alive. Patient records were from 2004. Like in the current study, using records from 2011 to 2012 and from 2015 to 2016, human causes played a large role in the causation of AEs in 2004. However, the proportion of human causes was higher (61%) than in the current study (35%) and the percentage of human causes related to preventable AEs was lower (61% in 2004 compared with 74% in 2011–2016). On the other hand, the percentage of patient-related causes increased between the two measurement periods (39%–47%). This may be related to the increased complexity of the patients. The 2004 study had a lower percentage of AE patients older than 80 years (28% versus 38%).[1] It is likely that the patients in our study were more complex, because comorbidity increases with age. Complex patients are more at risk ofAEs, and these patients are less likely to recover from an AE because of their vulnerability. The percentage of latent organizational and technical factors decreased a little between the two measurements (18%–12%). The recommended strategies to prevent AEs were comparable, but in the other study, the reviewers less often considered training as a relevant strategy to prevent AEs and more often recommended improvements in information and communication than in the current study. The differences in causes and prevention strategies between the two measurements could be related to the launch of a national patient safety program for hospitals “Prevent harm, work safely” in 2008.19 By implementing and complying with guidelines and interventions for 10 clinical topics and implementing a safety management system, Dutch hospitals aimed to work toward reducing potentially preventable AEs in hospitalized patients for a period of 5 years. Hospitals were supported with practical guidelines and interventions for the 10 clinical topics. The safety program included interventions to reduce the influence of latent organizational and technical factors such as training on specific themes and using barcodes on wristbands and medicine jars and scan both before administering the medication to the patient.[20] In addition, hospitals implemented several other patient safety improvement interventions, such as team training[21,22] and evaluations of the Individual Functioning of Medical Specialists, which includes peer review.[23]

The causes identified in the incident reporting study were based on voluntary reports and interviews in 2006–2008. Of all root causes, 70%were human, 17%were organizational, 7% were technical, and 6% were categorized as patient related or others.[11] Fewer patient-related causes and more latent factors were identified compared with the results from our current study. This could be explained by the difference in methods: in voluntary incident reports, patient information is rarely

noted, whereas patient records include all available patient information because the records are used for patient care. Another possible explanation may lie in the difference in the severity of the events; incidents include events without patient harm, whereas AEs always result in disability, death, or prolonged hospital stay. If a healthcare professional notices a suboptimal organizational or technical condition, this can be reported as an incident, regardless if it affected the patient. In incident reporting, the focus is more on processes than on outcomes.

Strengths and Limitations

By joining two patient record review studies on AEs, we had a large number of AEs to analyze. The inclusion of deceased patients enabled us to examine the subgroup of AEs with preventable death.

Causes and prevention strategies were examined together with the assessment of the presence of AEs. Therefore, the reviews were based on original records and not on summaries of information compiled for review afterward. Moreover, we used the same methods as were used in a previous study into the causes and prevention strategies of AEs in 2004, enabling us to discuss changes in the prevalence of causes after one decade of improvements, including national patient safety interventions.[19,20]

Using patient records to examine causes of AEs also has some limitations. For one quarter of the AEs, the reviewers were not able to assess the causes. For the other AEs, it is possible that not all causal factors that contributed to the AE were identified. This could have resulted in the fact that for some AEs only patient-related factors were identified and no causal factors related to healthcare management. Because of privacy restrictions, there was no contact between the reviewers and the involved healthcare professionals to gather more information about the event and contributing factors. Human actions are regularly reported on inpatient records and therefore human causes are most visible for reviewers. One can imagine that healthcare providers are less inclined to note technical or organizational factors in the record of an individual patient, whereas these factors influence the acting and nonacting of healthcare professionals. This can be an explanation for the relatively small numbers of technical and organizational factors identified in our study.

Implications for Practice and Future Research

Patient-related factors were predominantly and increasingly involved in AE causation, likely indicating an increased complexity in the conditions of patients. Therefore, it is recommended to direct special attention to patients with multimorbidity. Because multimorbidity increases with age and given the demographic developments, patient safety for vulnerable elderly patients was one of the topics of the Dutch national patient safety program for hospitals “Prevent harm, work safely.” In addition, a promising improvement strategy to monitor patients, especially postoperatively, is the Modified Early Warning System. It is being used worldwide to monitor patients’ vital signs and react accordingly.[24,25]

Furthermore, we recommend continuing the execution of peer review among healthcare professionals. Examples of peer review are complication meetings, visitations, and, if applicable, multidisciplinary consultations. Moreover, safety behavior should be evaluated continuously, in an open culture in which people feel free to speak up if patient safety is threatened. Moreover, procedures and other sources of information should be complete and easily available for all healthcare professionals. We also recommend optimizing information and communication structures. This is especially important because of the increased multidisciplinary collaboration in healthcare and the consequential higher number of handovers.

For future research into the causes of AEs, we recommend a more prospective design in which a combination is made of record review and interviewing. The period between the occurrence of the AE and the assessment of its causes should be only a few weeks. In that case, involved healthcare

providers can be interviewed to provide more information about latent organizational and technical factors that contributed to the AE, enabling a comprehensive root cause analysis.

Finally, recommend supplementing retrospective safety assessments with other measurement and monitoring activities, including sensitivity measures (e.g., safety walk-rounds, patient safety officers), anticipation approaches (e.g., safety culture analyses, prospective risk assessments), and the creation of a continuous learning system, as proposed by the Measurement and Monitoring of Safety Framework of Vincent et al.26 Moreover, it is increasingly believed that the focus should be on what goes right as well as on learning from what goes wrong. This new way of thinking about patient safety is incorporated in the Framework for Safe, Reliable, and Effective Care of the Institute for Healthcare Improvement.[27]

Conclusions

The study provides an overview of causes of AEs and recommended remedial actions. It showed that active human failures play an important role in AE causation because of their high prevalence and relation with preventable AEs. To tackle these causes, quality assurance/peer review was recommended. To a lesser extent, reviewers also identified latent organizational and technical factors that were present in the system, although these factors frequently caused preventable AEs. To deal with latent factors, improving information and communication was recommended.

Patient-related factors were less often related to preventable AEs but are important because of their high and increasing prevalence. This might be related to the increasing complexity of hospital patients. Therefore, it is recommended to focus interventions on care for patients with complex multimorbidity. For future research into the causes of AEs, we recommend a research design with the possibility to interview persons involved. Finally, a combination of retrospective assessment with prospective measurement and monitoring, including attention for things that go right, might be helpful to get a comprehensive picture of a hospital's safety.

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Tables and figures

Table 1 Description of Causal Factor Categories[13,14]

Category		Subcategory	Code	Description
Latent conditions				
Technical		Design	TD	Failures due to poor design of equipment, software, labels, or forms.
		Construction	TC	Correct design, which was not constructed properly or was set up incorrectly.
		Materials	TM	Material defects.
		External	T-ex	Technical failures beyond the control and responsibility of the investigating organization.
Organizational		Transfer of knowledge	OK	Failures resulting from inadequate measures taken to ensure that situational or domain-specific knowledge or information is transferred to all new or inexperienced staff.
		Protocols	OP	Failures relating to the quality and availability of the protocols within the department (too complicated, inaccurate, unrealistic, absent, or poorly presented).
		Management priorities	OM	Internal management decisions in which safety is relegated to an inferior position when faced with conflicting demands or objectives. This is a conflict between production needs and safety. Example: decisions that are made about staffing levels.
		Culture	OC	Failures resulting from a collective approach and its attendant modes of behavior to risks in the investigating organization.
		External	O-ex	Failures at an organizational level beyond the control and responsibility of the investigating organization.
Active errors				
Human	*Knowledge-based behavior*	Knowledge-based behavior	HKK	The inability of an individual to apply his/her existing knowledge to a novel situation.
	Rule-based behavior	Qualifications	HRQ	An incorrect fit between an individual's training or education and a particular task.
		Coordination	HRC	A lack of task coordination within a healthcare team in an organization. Example: an essential task not being performed because everyone thought that someone else had completed the task.
		Verification	HRV	The correct and complete assessment of a situation including related conditions of the patient and materials to be used *before* starting the intervention.
		Intervention	HRI	Failures that result from faulty task planning and execution. Example: washing red cells by the same protocol as platelets.
		Monitoring	HRM	Monitoring a process or patient status. Example: a trained technologist operating an automated instrument and not realizing that a pipette that dispenses reagents is clogged.
	Skill-based behavior	Skills	HSS	Failures in performance of highly developed skills or whole body movements. Examples: a computer entry error or a blood bag slipping out of one's hands.
		External	H-ex	Human failures originating beyond the control and responsibility of the investigating organization.
Violation		Violation	V	Failures by deliberate deviations from rules or procedures.
Other factors				
Patient related		Patient-related factor	PRF	Failures related to patient characteristics or conditions, which are beyond the control of staff and influence treatment. For example: comorbidity, age, communicative skills, treatment compliance.
Other		Unclassifiable	X	Failures that cannot be classified in any other category, e.g., complication, abstain policy, rare disease.

H-ex, human external; HKK, human knowledge–based behavior; HRC, human coordination; HRI, human intervention; HRM, human monitoring; HRQ, human qualifications; HRV, human verification; HSS, human skills; OC, organizational culture; O-ex, organizational-external; OK, organizational transfer of knowledge; OM, organizational management priorities; OP, organizational protocols; PRF, patient-related factor; TC; technical construction; TD, technical design; T-ex, technical external; TM, technical materials; V, violation; X, other.

Table 2 Description of Prevention Strategy Categories[14,16]

Prevention Strategies	Description
Technology/equipment	Redesigning of hardware, software, or interface parts of the man-machine system.
Procedures	Completing or improving formal and informal procedures.
Information and communication	Completing or improving available sources of information and communication structures.
Training	Improving (re)training programs for skills needed.
Motivation	Increasing the level of voluntary obedience to generally accepted rules by applying principles of positive behavior modification.
Up-scaling	Handling the problem at a higher organizational level, e.g., hospital department or hospital management level.
Evaluation	Evaluating the current way of behaving regarding safety.
Quality assurance/peer review	Continuously monitoring of data quality based on prespecified standards and assessment of a health professional's performance by one or more individuals in the same field.
Financial investment	Financial investments in required areas, e.g., increasing the availability of facilities and equipment.
Personnel	Increasing the number of personnel.

Figure 1 Unregularized partial correlation network of causal factors at the lowest category level of the Eindhoven Classification Model causal factor taxonomy. Solid lines indicate positive correlations, dashed lines indicate negative correlations. Abbreviations: H-ex, human external; HKK, human knowledge–based behavior; HO, human other HRC, human coordination; HRI, human intervention; HRM, human monitoring; HRQ, human qualifications; HRV, human verification; HSS, human skills; OC, organizational culture; OK, organizational transfer of knowledge; OM, organizational management priorities; OO, organizational other; OP, organizational protocols; PRF, patient-related factor; T, technical; V, violation; X, other. No subcategories are given for technical causes (T), because of the low number of this category.

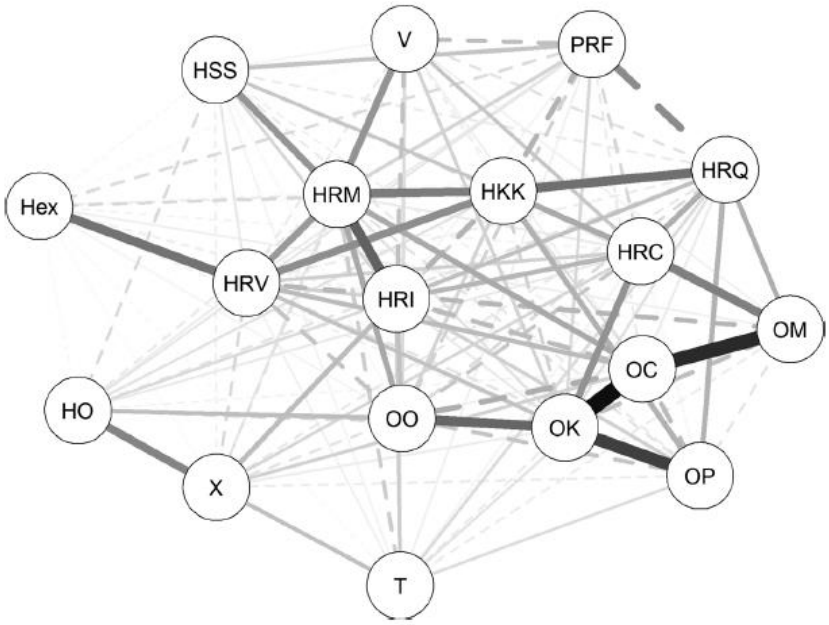

Table 3 Frequency and Proportion of Identified Causes of AEs, Proportion Related to Preventable AEs, and Proportion Related to Preventable Death on Category and Subcategory Level

Level	AEs n (Column %* Within Each Category)	Preventable AE n (Row %*)	Preventable Death n (Row %*)
Category			
Technical	14 (2.7)	11 (77.8)	11 (77.8)
Organizational	52 (8.9)	38 (73.6)	26 (50.2)
Human	197 (34.7)	141 (74.1)	107 (55.3)
Violation	49 (9.0)	35 (71.9)	23 (48.0)
Patient related	269 (47.4)	84 (32.7)	57 (21.8)
Other	7 (1.4)	3 (—)	1 (—)
Unable to assess	142 (24.9)	15 (12.0)	7 (5.3)
Subcategory (within organizational)			
Protocols	12 (38.4)	6 (—)	5 (—)
Transfer of knowledge	33 (82.6)	25 (75.0)	16 (49.3)
Management priorities	3 (8.8)	1 (—)	1 (—)
Culture	23 (48.9)	19 (85.5)	15 (65.7)
External	0 (0.0)	0 (—)	0 (—)
Other	7 (25.7)	6 (—)	5 (—)
Subcategory (within human)			
Knowledge	127 (33.2)	97 (77.9)	77 (60.7)
Qualifications	34 (9.4)	20 (60.6)	19 (58.2)
Coordination	21 (6.3)	13 (57.5)	9 (—)
Verification	29 (7.6)	26 (89.8)	17 (58.4)
Intervention	9 (1.7)	6 (—)	5 (—)
Monitoring	39 (14.8)	32 (84.6)	24 (61.3)
Skills	36 (18.3)	30 (86.7)	25 (71.8)
External	1 (0.5)	1 (—)	0 (—)
Other	16 (8.3)	9 (—)	7 (—)

Reviewers could select more than one causal factor per AE.
Preventability is related to the assessment of the preventability of the AE, not to the preventability of each cause underlying the AE.
Because of the low number of technical causes, the subcategories of this category are not shown.
*Percentages are weighted for oversampling of patients admitted to a university hospital.
— indicates no calculation of proportion related to preventable AEs and AEs leading to death if n < 10.

Table 4 Examples of Nonpreventable AEs, Potentially Preventable AEs and AEs With Potentially Preventable Death, With Patient Characteristics, AE Type, Identified Causes, and Prevention Strategies

Description of AE	Patient Characteristics	Type of AE	Identified Cause(s)	Prevention Strategies
Nonpreventable AE				
Fractures of femur and ulna (pathological) after fall on toilet of patient with nonsmall cell lung cancer, hypercalcemia and confusion	Male, 69 y	Other clinical activities	Patient related and organizational (protocols)	—
Death due to increasing dyspnea on the basis of pneumonitis and heart failure	Male, 78 y	Medication	Patient related	—
Potentially preventable AE				
Severe bleeding liver biopsy of metastatic tumor with insufficient interruption of oral anticoagulation	Male, 85 y	Medication	Organizational (transfer of knowledge), patient related, and violation	Information and communication, evaluation
Extensive injuries of bladder and urethra caused with a urinary catheter after removing of the catheter by the patient. The patient had five urinary catheters with insufficient fixation and preventive care	Male, 82 y	Other clinical activities	Patient related and organizational (culture)	Quality assurance, evaluation
Fall out of bed twice, no preventive measures after first fall	Male, 84 y	Other clinical activities	Human and patient related (knowledge-based behavior)	Training, motivation, quality assurance
Potentially preventable death				
Death due to cholangiosepsis in known biliary tract problems but interpreted as urosepsis	Female, 83 y	Diagnostics	Human (knowledge-based behavior)	Information and communication, quality assurance
Perforation of the bladder when inserting a suprapubic catheter followed by urosepsis, acute heart failure, reoperation, and death	Male, 81 y	Surgical procedure	Human (skills)	Evaluation
Death due to hypotension and arrhythmias occurring during placement of cemented head neck prosthesis	Male, 91 y	Surgical procedure	Technical (other) and patient related	Information and communication, motivation, evaluation

Table 5 Recommended Strategies for Preventing AEs for Total Group of Preventable AEs, Surgical AEs, and Medication AEs

Prevention Strategies	All AEs N = 206 n (%†)	Surgical Procedure* n = 66 (%*)	Medication* n = 47 (%*)
Quality assurance/peer review	147 (75.1)	76.9	69.6
Evaluation	146 (67.1)	91.8	61.7
Procedures	98 (56.0)	81.6	46.3
Information and communication	84 (47.4)	72.6	37.2
Training	107 (38.4)	50.3	28.7
Motivation	56 (37.5)	66.1	20.2
Technology/equipment	5 (4.3)	18.0	0.0
Up-scaling	4 (3.5)	14.8	2.3
Financial investment	0 (0.0)	0.0	0.0
Personnel	0 (0.0)	0.0	0.0

Reviewers could select more than one prevention strategy per preventable AE.

*Within subgroups of surgical and medication AEs, respectively.

†Percentages were weighted for oversampling of patients admitted to a university hospital.