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ORIGINAL RESEARCH

Analysis of Factors Related to Domestic Patient Safety Incidents Using Decision Tree Technique

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Purpose: To address the increasing number of patient safety incidents, their scope and extent should be assessed and the situations in which they occur determined. This study employed a decision tree analysis based on patient safety incident cases to identify groups at high risk for adverse patient safety incidents and provide data to develop prevention strategies for minimizing their occurrence or recurrence.

Methods: In total, 8934 patient safety incidents were analyzed using the "2021 Patient Safety Report Data", which were systematically collected by the Korea Institute for Healthcare Accreditation. A decision tree analysis (Chi-square Automatic Interaction Detection) was employed to identify the characteristics associated with the degree of risk for patient safety incidents.

Results: The groups most vulnerable to adverse events were those who experienced healthcare-associated infections (HAI) in long-term care facilities, followed by those experiencing HAI in tertiary hospitals, general hospitals, or clinics, and those experiencing fall-related events in neuropsychiatry departments of tertiary hospitals, general hospitals, or clinics.

Conclusion: The most important factor in the degree of harm in patient safety accidents was the type of accident, followed by the type of medical institution, and then the treatment department. Particularly, HAI and falls are the most important factors determining the degree of harm in patient safety accidents.

Keywords: decision tree, infection, incident, patient safety, prevention

Introduction

A patient safety incident is defined as an event that has caused or is likely to create damage or ill effects to a patient's body, mind, or life when providing healthcare services to them, rather than their underlying ailment.[1] It may also unnecessarily harm a patient. Patient safety is crucial to prevent medical errors and adverse effects on patients in the process of providing healthcare services.[2] Patient safety incidents increase costs and affect various clinical outcomes.[3] There are three main types of patient safety incidents: near misses, adverse events, and sentinel events.[4,5] A near miss refers to an error that occurs but does not reach the patient, while an adverse event is an injury resulting from a healthcare intervention that is not associated with the patient's underlying condition. Lastly, a sentinel event is any event that causes unexpected death or loss of significant function that is not linked to the natural course of the patient's disease or underlying condition.

In South Korea, interest in patient safety has increased after a death incident caused by a medication error in a pediatric patient receiving chemotherapy for leukemia. Since then, the country has applied a healthcare accreditation system to all healthcare institutions to induce voluntary and continuous efforts to improve patient safety and medical quality. In addition, a patient safety report learning system has been introduced to systematically collect data on patient safety incidents, prevent their recurrence, and provide warnings and information to ensure patient safety.[6] Despite these efforts, the reported number of patient safety incidents has steadily increased over the past five years, with a 142% increase to 13,919 cases reported in 2021 compared to 2018, indicating an upward trend.[7] However, as only serious patient safety incidents are subject to mandatory reporting in South Korea, the real number of incidents is projected to be greater.

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To improve patient safety, it is crucial to measure and quantify the scope and scale of patient safety incidents and conduct a comprehensive evaluation of patient safety issues based on real-world cases of patient safety incidents.[8,9] Studies analyzing factors and trends related to patient safety incidents[1,10,11] have identified age, location of occurrence, and type of incident as common factors influencing adverse events. The time of occurrence, hospital size, and healthcare institution grade were also suggested as influencing factors. However, no study has been conducted to distinguish the situations in which patient safety accidents occur based on actual patient safety incident data in Korea.

Decision tree analysis is a method of analysis that divides the study group into meaningful subgroups and predicts them.[12,13] The visualization of characteristics closely related to target variables makes it easy to identify the variables that have a relative influence on the classification of a particular state.[14] Consequently, decision tree analysis has been proposed as a useful method for exploring the risk and vulnerability factors of subjects,[15] and has also been used to provide stronger support for the results of regression analysis.[16] Thus, this study aimed to use the decision tree structure based on patient safety incident cases in Korea to identify groups that are vulnerable to adverse patient safety incidents with ease. Additionally, it aimed to present the essential data required to develop strategies for protecting vulnerable groups from patient safety incidents and their recurrence.

Materials and Methods

Research Design

This study involved a secondary data analysis using the "2021 Patient Safety Report Data" collected by Korea Institute for Healthcare Accreditation (KOIHA), to identify factors related to the degree of harm in patient safety incidents.

Participants and Data Collection

The "2021 Patient Safety Report Data" comprise patient safety incident reports from healthcare institutions; these data were systematically collected by the KOIHA in accordance with the Patient Safety Act enforced in 2016. In South Korea, patient safety reports are entered by medical institutions' patient safety personnel or health care workers, patients, and guardians according to the patient safety report form (www.kops.or.kr). The entered data are released so that the person in charge of the Central Patient Safety Center can check and verify the contents, delete the personal identification information, and use the report data. The patient safety reporting system collects data for the past year in May every year and publishes it on the website, and notifies anyone to use the data. This study used data downloaded from the website of the patient safety report learning system in March 2023. The selection criteria for the data were patient safety incidents that occurred in 2021, and the exclusion criteria were data that had information omitted from the patient safety incident report form. A total of 13,146 patient safety incidents were reported in 2021, and 1453 cases with an incident date prior to 2021 were excluded, resulting in 8940 cases. In addition, pharmacies and healthcare institutions with 'none' hospital beds were excluded because of the low number of cases. The final analysis was performed on 8934 cases (Figure 1).

Research Design

This study involved a secondary data analysis using the "2021 Patient Safety Report Data" collected by KOIHA to identify factors related to the degree of harm in patient safety incidents.

Analytical Framework of Research

This study collected data on sex, age, healthcare institution classification, hospital size, place of occurrence, incident time, type of incident, and degree of harm. Patient safety incident refers to an event or situation that may unnecessarily damage a patient. In the original data, the degree of harm caused by patient safety incidents was classified into six levels: no harm, near miss, mild harm, moderate harm, severe harm, and death. In this study, it was divided into three levels that are used by domestic healthcare institutions in real-world clinical settings. In terms of the degree of harm in patient safety incidents, no-harm and near-miss events were classified as near misses, mild and moderate events as adverse events, and severe and fatal events as sentinel events. As there were only 152 sentinel events, they were included under adverse events for the analysis of their characteristics.

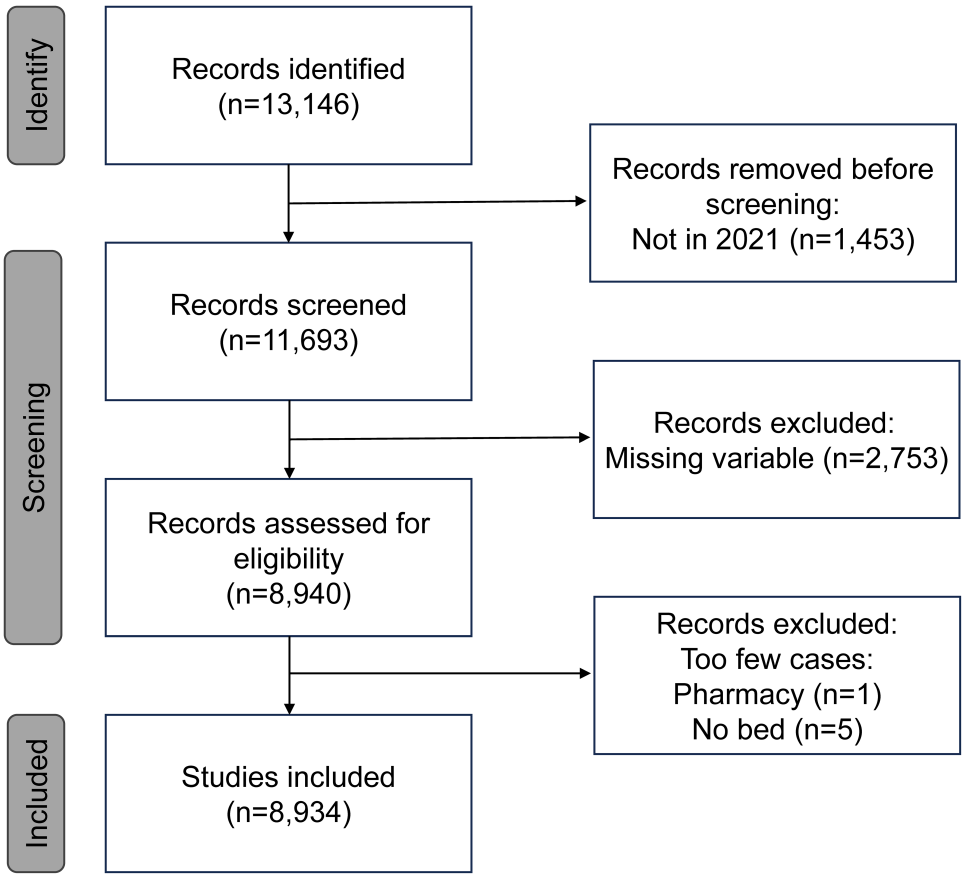

Figure 1 Database identification process for the study.

Data Analysis

The data were analyzed using IBM Statistics SPSS 25.0. In this analysis of secondary data, missing fields were treated as just missing (without any substitutions). The alpha level was set at 0.05. First, frequency analyses (frequencies and percentages) were performed on patient safety incident information and the basic characteristics of patient information. Second, a chi-square test was conducted to determine the difference in the degree of harm according to the characteristics of patient safety incident information and patient information. Third, a decision tree analysis was performed to identify the characteristics associated with the degree of harm in patient safety accidents. This study used the Chi-square Automatic Interaction Detection method for decision tree analysis. To avoid data overfitting of the analysis results, the stopping rule was limited to a maximum tree depth of 3.

Ethical Considerations

This study used the "2021 Patient Safety Report Data" disclosed in the patient safety report learning system and submitted a research plan to the Konyang University Institutional Review Board (IRB). This study was approved for IRB exemption because it was a secondary data analysis using previously published data (IRB No. KYU 2023-02-003).

Results

Differences in Risk Level According to Patient Safety Incidents, Patient Information, and Incident Information

There was a statistically significant difference in the rate and number of patient safety incidents depending on patient information such as age (χ^2=163.53, p<0.001), sex (χ^2=8.21, p=0.004), and the medical specialty (χ^2=232.43, p<0.001) to

which the patient was admitted. The rate of adverse events was high primarily in the older age group, and the rate of adverse events did not exceed 50% in those aged 59 or less. However, it exceeded 50% in those aged 60 or more. In terms of sex, 52.5% of men and 55.5% of women experienced an adverse event. This may have been due to the higher proportion of women aged 80 or more: 68% were women. In terms of medical departments, the rates of adverse events in patients admitted to the departments of neuropsychiatry and family medicine were 74.1% and 72.9%, respectively; these rates were 20% higher than those in patients admitted to other departments (Table 1).

Table 1 Differences in the Degree of Harm According to Patient Information of Patient Safety Incidents (n=8934)

		Near Miss n (%)	Adverse Event n (%)	Total n (%)	χ^2	*p*
Age (yr)	0–9	107 (56)	84 (44)	191 (100)	163.53	<0.001
	10–19	44 (58.7)	31 (41.3)	75 (100)		
	20–29	118 (54.9)	97 (45.1)	215 (100)		
	30–39	168 (58.3)	120 (41.7)	288 (100)		
	40–49	335 (56.4)	259 (43.6)	594 (100)		
	50–59	600 (51.5)	565 (48.5)	1165 (100)		
	60–69	807 (47)	911 (53)	1718 (100)		
	70–79	1004 (45.8)	1187 (54.2)	2191 (100)		
	≥ 80	918 (36.8)	1579 (63.2)	2497 (100)		
Sex	Male	1993 (47.5)	2202 (52.5)	4195 (100)	8.211	0.004
	Female	2108 (44.5)	2631 (55.5)	4739 (100)		
Specialty	Internal Medicine	1461 (47.4)	1619 (52.6)	3080 (100)	232.434	<0.001
	Orthopedics	571 (55.2)	464 (44.8)	1035 (100)		
	Rehabilitation Medicine	379 (44.7)	468 (55.3)	847 (100)		
	Neurosurgery	350 (54.3)	295 (45.7)	645 (100)		
	General Surgery	274 (47.9)	298 (52.1)	572 (100)		
	Neuropsychiatry	157 (25.9)	449 (74.1)	606 (100)		
	Family Medicine	127 (27.1)	342 (72.9)	469 (100)		
	Neurology	202 (41.0)	291 (59.0)	493 (100)		
	Emergency Room	131 (48.0)	142 (52.0)	273 (100)		
	Obstetrics and Gynecology	100 (47.4)	111 (52.6)	211 (100)		
	Pediatrics and Adolescents	87 (49.4)	89 (50.6)	176 (100)		
	Urology	53 (47.7)	58 (52.3)	111 (100)		
	Thoracic and Cardiovascular Surgery	49 (51.0)	47 (49.0)	96 (100)		
	Others	160 (50.0)	160 (50.0)	320 (100)		
Month	January-April	1549 (45.4)	1862 (54.6)	3411	0.906	0.636
	May-August	1511 (45.9)	1783 (54.1)	3294		
	September-December	1041 (46.7)	1188 (53.3)	2229		

(*Continued*)

Table 1 (Continued).

		Near Miss n (%)	Adverse Event n (%)	Total n (%)	χ^2	*p*
Hour	0:00–5:59	654 (42.7)	879 (57.3)	1533	22.457	<0.001
	6:00–11:59	1283 (45.7)	1525 (54.3)	2808		
	12:00–17:59	738 (43.6)	954 (56.4)	1692		
	18:00–23:59	1426 (49.2)	1475 (50.8)	2901		
Healthcare Institution	Tertiary Hospital	840 (50.0)	841 (50.0)	1681	441.921	<0.001
	General Hospital	2314 (54.3)	1948 (45.7)	4262		
	Primary Hospital	346 (43.7)	446 (56.3)	792		
	Mental Hospital	103 (28.2)	262 (71.8)	365		
	Other Hospital	15 (40.5)	22 (59.5)	37		
	Long-Term Care Facility	483 (26.9)	1314 (73.1)	1797		
Hospital Size	Less than 200 beds	358 (44.6)	445 (55.4)	803	35.133	<0.001
	200–500 beds	1856 (43.0)	2462 (57.0)	4318		
	More than 500 beds	1887 (49.5)	1926 (50.5)	3813		
Place of Occurrence	Inpatient room	2395 (46.0)	2812 (54.0)	5207	207.439	<0.001
	Outpatient clinic	82 (70.7)	34 (29.3)	116		
	Corridor	247 (37.8)	406 (62.2)	653		
	Examination room	228 (46.2)	265 (53.8)	493		
	Bathroom	170 (34.9)	317 (65.1)	487		
	Pharmacy	112 (99.1)	1 (0.9)	113		
	Treatment/procedure room	33 (38.4)	53 (61.6)	86		
	Operating room	114 (55.1)	93 (44.9)	207		
	Others	720 (45.8)	852 (54.2)	1572		
Type of incident	Fall	2135 (39.8)	3236 (60.2)	5371	826.668	<0.001
	Drug/transfusion error	1151 (70.9)	472 (29.1)	1623		
	Examination error	268 (75.7)	86 (24.3)	354		
	Injury	47 (12.9)	317 (87.1)	364		
	Treatment/procedure	55 (35.9)	98 (64.1)	153		
	Medical materials contamination	42 (75.0)	14 (25.0)	56		
	Infection	11 (20.0)	44 (80.0)	55		
	Others	392 (40.9)	566 (59.1)	958		

Abbreviations: KOIHA, Korea Institute for Healthcare Accreditation; CDC, Centers for Disease Control and Prevention; HAI, healthcare-associated infection.

There was a statistically significant difference in the number of patient safety incidents depending on incident information that did not include the month of occurrence, time of occurrence, healthcare institution, size of hospital, place of occurrence, and type of incident.

The rate of adverse events was the highest at 57.3% between 12 AM and 6 AM. The rate of adverse events in mental hospitals was 71.8% and that in long-term care facilities was the highest at 73.1%. The corresponding rate was the highest at 57% when the hospital had 200–500 beds and was the highest at 65.1% in bathrooms, followed by 62.2% in corridors, 61.6% in treatment/procedure rooms, 54.2% in other rooms, 54% in inpatient rooms, 53.8% in examination rooms, 44.9% in operating rooms, 29.3% in outpatient clinics, and 0.9% in pharmacies. The rate of adverse events was the highest at 87.1% when the type of incident was injury; the corresponding values were 80%, 60.2%, 59.1%, 29.1%, 25%, and 24.3% when the types of incidents were infections, falls, others, drug/transfusion errors, medical materials contaminations, and examination errors (Table 1).

Factors Related to Patient Safety Incident Risk

Patient safety incidents were divided into 16 subgroups. In node 0, in terms of the degree of harm, near misses accounted for 45.9% of the incidents, and adverse events (including sentinel events) for 54.1%. The type of incident appeared to be the most important factor, followed by the type of healthcare institution, the location of the incident, and the medical department and hospital size. Factors related to the degree of harm in patient safety incidents were primarily related to incident information (Figure 2).

If the type of incident is "falls or others" and the healthcare institution is "long-term care facility, mental hospital, or others", the incident is classified according to the place of incident. The rate of adverse events that occurred in "inpatient rooms, outpatient clinics, corridors, and bathrooms" was 73.9% (node 19) and the rate in "examination rooms and treatment/procedure rooms" was 50.8% (node 20). If the type of incident was "falls or other" and the healthcare institution was "a tertiary hospital, general hospital, hospital, or clinic", the incident was classified according to the medical department. The rate of adverse events in the "department of neuropsychiatry" was the highest at 83.1% (node 18), followed by the "departments of neurology, thoracic and cardiovascular surgery, internal medicine, family medicine, urology, emergency medicine, and obstetrics and gynecology", where the rate was 57% (node 16), and the "departments of rehabilitation medicine, surgery, orthopedics, neurosurgery, and pediatrics and adolescents", where the rate was 47.1% (node 17).

"Infection" as a type of incident accounted for 6.2% (554 cases) of the total rate of incidents, which indicated a low rate of incidence; however, it was most likely to be a harmful event. When "infection" was the cause of the incident, the degree of harm varied based on the type of healthcare institution. In node 9, where the type of healthcare institution was "general hospital", the rate of adverse events was 77%; in node 10, where the type of healthcare institution was "clinic, mental hospital, or tertiary hospital", the rate of adverse events was 88.9%. In node 10, where the type of medical healthcare was "long-term care facility or others", the rate of adverse events was 95.8%.

Among the incident types, "drug/transfusion or examination errors" was classified according to the place of incident. First, when the place of the incident was "pharmacy", the rate of adverse events was 1.5% (node 13). Next, if the incident

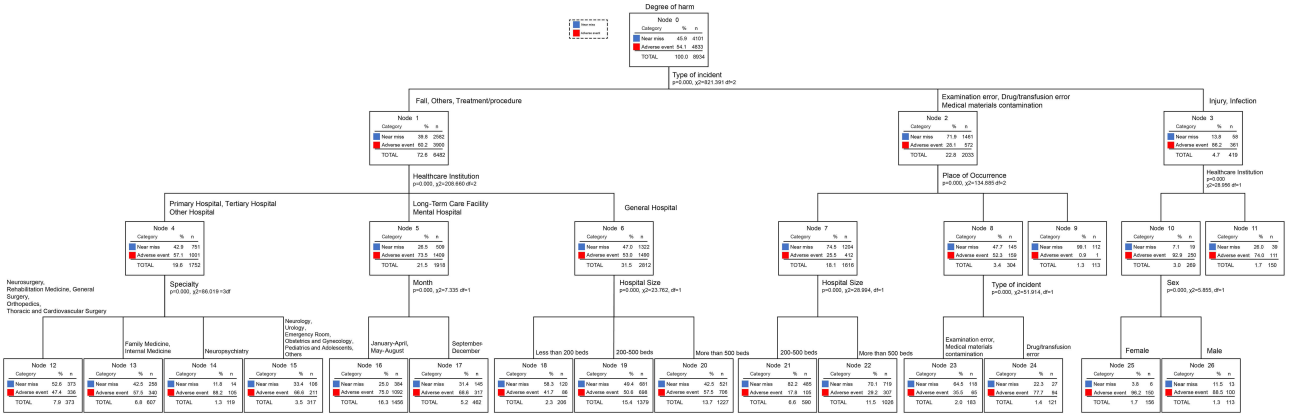

Figure 2 Decision tree of patient safety incident adverse events.

occurred in "inpatient room, treatment/procedure room, outpatient clinic, and others", the decision tree was classified according to the hospital size. The rate of adverse events was 32.5% (node 22) in hospitals with "more than 500 beds" and 17.5% (node 21) in hospitals with "less than 500 beds."

In cases where the incident occurred in "examination room, operating room, or corridor", the decision tree was reclassified according to the type of incident. The rate of adverse events after "drug/transfusion errors" was the highest at 71.8% (node 23) and after "examination errors" was the lowest at 33.2% (node 24).

When the type of incident was "treatment/procedure errors", the adverse event rate was similar to node 0, but the degree of harm was different depending on the type of healthcare institution. The rate of Adverse events was 46.1% in "general hospital and others", which was lower than that in node 0 (54.1%). In "clinic, long-term care facility, and tertiary hospital", the rate of adverse events was 65.3%, which was higher than that in node 0 (54.1%). However, the rate of patient safety incidents overall was low at 3% (276 cases).

When the type of incident was "medical materials", the rate of adverse events was 37.9%.

Discussion

This study used the "2021 Patient Safety Report Data", provided by the KOIHA, to visually build a model for the complex relationship of predictive factors that affect patient safety incidents, through a decision tree analysis. The significance of this study was that it presented specific directions for developing strategies for preventing and reducing patient safety incidents in the future. Incident type was the most important factor, and the possibility of adverse events was highest when an HAI occurred. It is noteworthy that there were differences according to the type of healthcare institution.

The decision tree analysis method confirmed that the group experiencing HAI in a long-term care facility was the most susceptible to the occurrence of adverse events of patient safety incidents. According to the Centers for Disease Control and Prevention (CDC), 2 million HAIs occur in the United States each year, of which, 100,000 result in death and healthcare costs of $4.5–6.5 billion.[17] Particularly, in long-term care facilities, various patients reside collectively in a certain space, and older adults or patients with chronic diseases have lower immunity than healthy adults. Inpatients are not only susceptible to HAIs but are also more likely to spread them to other patients when they catch an infectious disease.[18,19] According to a survey on hospital infection control in long-term care facilities in South Korea, only 17.4% of institutions had infection control departments within the hospitals, and only 37.3% of institutions reported conducting infection epidemic investigations.[18] Additionally, infection-related protective gear, hand hygiene-related drying facilities, and infection-related vaccinations were often inadequate.[18,20] Therefore, the risk of transmission of infection is high and can progress to serious complications due to inadequate management.[18] Among infection control activities, infection monitoring is the most basic and important task that helps identify whether HAIs and infection outbreaks have occurred. Various forms of support are needed at healthcare institutions—especially at the national level—so that long-term care facilities can actively take infection control measures by equipping infection control nurses and securing supplies necessary for infection control.

The group that was the second most vulnerable to adverse patient safety incidents included those who experienced a healthcare-associated infection (HAI) in tertiary hospitals, mental hospitals, or clinics, suggesting the need to manage HAIs in these facilities. While HAIs in long-term care facilities are related to multidrug-resistant bacteria, urinary tract infections, pneumonia, and skin soft tissue infections,[21] those in tertiary hospitals are related to ventilator-related pneumonia in intensive care units and bloodstream infections related to the central venous line.[22,23] Most mental hospitals, unlike general hospitals, have closed environments, and high patient density and interactions can increase the risk of bacterial or virus transmission and outbreaks.[24,25] Psychiatric inpatients with cognitive impairment may have difficulty following the instructions of healthcare workers, even when they show symptoms of infection, which may result in the infection becoming severe.[25] South Korea has a healthcare accreditation system, and the KOIHA evaluates patient safety and healthcare service quality for all healthcare institutions. Since the factors related to HAIs differ for each healthcare institution, it is necessary to apply these specific characteristics to certification standards and infection control guidelines to ensure patient safety.

The group that was the third most vulnerable to adverse patient safety incidents included those who experienced fall-related incidents in neuropsychiatry departments of tertiary hospitals, general hospitals, or clinics. Falls can cause serious adverse events that lead to an increased hospitalization period, unexpected surgery, or even death.[26] The risk of fall-related

accidents due to adverse effects, such as experiencing dizziness after being administered psychotropic drugs, is especially high in psychiatric patients.[27] Furthermore, in some cases, institutional control measures such as isolation in hospitals and compulsion may be implemented, which can delay the detection of falls and potentially lead to adverse events by suppressing physical reflexes.[28,29] Healthcare institutions use fall risk assessment tools, such as the Morse Fall Scale and the Johns Hopkins fall risk assessment tool, to identify high-risk groups for falls and implement preventive nursing interventions for patient safety. Additionally, the domestic patient safety report learning system provides education and guidelines for fall prevention.[30] However, there is currently no fall risk assessment tool or guideline for psychiatric patients. Considering the vulnerability of psychiatric patients and the severity of falls they might experience; it is necessary to develop assessment tools and guidelines to facilitate fall prevention activities.

Thus, HAI is a major factor in adverse events, and infection control guidelines that consider both environmental and patient characteristics are necessary for all healthcare institutions. In particular, infection control in nursing hospitals should be further strengthened, while also considering the designation of personnel exclusively responsible for infection. It is also crucial to recognize the importance and seriousness of HAIs and strive to prevent them. Falls are also a major factor in adverse events. A fall risk assessment tool and specific guidelines for preventive activities are required to select high-risk groups. It is necessary to develop and apply fall risk assessment tools and guidelines that target psychiatric patients. Falling is an incident that accounts for the largest proportion of patient safety incidents, and effective medical equipment should be developed to enable continuous evaluation rather than regular evaluation for high-risk groups.

Limitations and Suggestions

Although the analysis was conducted using domestic patient safety report data, it was not possible to examine the primary factors of patient safety in a balanced manner, as no organizational factors, such as working environment and human resources, are included in the patient safety report system. Sentinel events (severe illness or death) were included in the analysis as adverse events because there was a small amount of reported data. In South Korea, reporting is compulsory only when a sentinel event occurs; other patient safety incidents are reported voluntarily, so the research results may differ from reality. Therefore, the following suggestions are made. First, the medical institution's organizational environment (eg, the number of nurses per patient, number of nursing assistants, patient severity, compensation system, etc.) should be added to the report preparation form of the domestic patient safety reporting system. Second, a culture to revitalize autonomous reporting must be developed. Third, it is necessary to prepare an intervention strategy to prevent patient safety accidents or their recurrence through continuous research on patient safety accidents.

Conclusion

The groups most vulnerable to adverse events were those who experienced HAI in long-term care facilities; followed by those experiencing HAI in tertiary hospitals, general hospitals, or clinics; and those experiencing fall-related events in neuropsychiatry departments of tertiary hospitals, general hospitals, or clinics. The type of incident was identified as the most important factor, and the possibility of adverse events was the highest when an HAI occurred. Infection control guidelines and patient safety prevention activities tailored to the characteristics of healthcare institutions are needed. It is necessary to develop fall risk assessment tools and guidelines for psychiatric patients.

Abbreviations

KOIHA, Korea Institute for Healthcare Accreditation; CDC, Centers for Disease Control and Prevention; HAI, healthcare-associated infection.

Data Sharing Statement

Data cannot be shared publicly because of restrictions by the Konyang University Institutional Review Board. Data are available from the Konyang University Institutional Data Access/Ethics Committee for researchers who meet the criteria for access to confidential data. Data requests can be addressed to the Konyang University Institutional Review Board (82-42-600-8466, kirb@konyang.ac.kr).

Ethics Approval and Informed Consent

This study submitted a research plan to the Konyang University Institutional Review Board (IRB). The study was approved for review exemption (IRB No. KYU 2023-02-003). The need to obtain informed consent was waived due to the retrospective nature of the study.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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