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Preventable in-hospital deaths and years of life lost were uncommon among patients in a Finnish secondary teaching hospital

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Abstract

Background Despite quality standards and trained personnel, deaths caused by adverse events occur in healthcare. Estimates of in-hospital deaths caused by avoidable harm are contradictory. Old age and comorbidities increase the risk of death from adverse events. The aim of this retrospective study was to analyze the rate of preventable deaths associated with adverse events and their relationship with life expectancy among hospitalized patients with somatic disease.

Methods The study examined all deaths in a Finnish secondary teaching hospital over one year, in 2017. The medical records of adult patients in somatic wards whose in-hospital deaths were unanticipated upon admission were analyzed. Two separate, independent reviewers evaluated the association of death with existing adverse events and estimated the preventability of death on a 5-point scale. The years of life lost were estimated among patients whose death was considered potentially or likely preventable.

Results The total number of unanticipated deaths among adult in-hospital somatic patients during the study year was 253. Altogether 236 patients died in the hospital, and 17 end-of-life patients at discharge died within 30 days. The median age at death was 79.9 years, and the median number of chronic conditions was three. Among the deaths evaluated as the means of two reviewers, 95.3% were estimated to be not preventable, and 4.7% were estimated to be potentially or likely preventable. The latter patients were younger and had fewer comorbidities. Half of them were considered to have a competing cause that would have led to death in the coming months. Among those whose deaths were considered likely preventable, only one patient would have likely lived for more than three months.

Conclusion The assessment of avoidable inpatient mortality is challenging but important for improving the safety of healthcare. According to this study, preventable deaths caused by adverse events and years of life lost were uncommon. Large-scale studies with adequate analysis of clinical data are needed to update the estimates and causes of deaths related to adverse events.

Keywords Patient safety, Inpatient death, Preventable death, Adverse events, Medical error, Preventable years of life lost

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Text box 1. Contributions to the literature

- Our study from a Finnish teaching hospital included all hospitalized patients from a catchment area of 170 000 inhabitants over one year.
- In a population with high life expectancy, mainly elderly and fragile patients are prone to avoidable deaths, and the years of life lost are few.
- Even though adverse events occurred, preventable deaths caused by avoidable harm were uncommon among hospital patients.
- Based on the results, the statement that patient safety incidents are a major cause of mortality requires reconsideration.

Background

Since the expert estimate by Kohn et al. that even 98,000 patients die annually due to medical errors in US hospitals, several studies concerning avoidable deaths caused by adverse events in health care have been published [1–5]. In contrast to the highest estimates of in-hospital deaths, recent nationwide cause-of-death data from the U.S. revealed medical adverse events as the underlying cause of death in 43,899 cases (0.24%) from 1999 to 2019 [6].

Although most adverse events in health care cause harm, which is defined as temporary discomfort, sentinel and more serious events, by definition, may result in death, permanent harm, or severe temporary harm. These include wrong site surgery, foreign body retention, falls, suicide, delay in treatment, and medication errors, among others [3–5]. As a negative outcome of medical treatment, the most common adverse events leading to death are healthcare-associated infections, heart failure, pulmonary embolism, bleeding, ileus, perforation, stroke, or intracerebral bleeding. In addition, there may also be delays in diagnostics, i.e., obtaining or responding to tests or diagnostic procedures causing unintended harm [2, 7, 8].

There is some variation in the reported rates of avoidable serious harm or death [9]. Landrigan et al. analyzed 588 harms reported from ten hospitals for over 10,000 patient days. There were 57 harms per 1000 patient days and 25 harms per 100 admissions. Among the identified avoidable harms ($n = 364$), 9.6% were life-threatening, 3.6% caused permanent harm, and 2.5% caused or contributed to death [5]. Zegers et al. reported that 12.8% of all adverse events result in permanent disability or contribute to death [10]. Bates et al. reported adverse events in nearly one in four admissions, and approximately one-fourth of the events were preventable. Hospital mortality was less than 0.3%, and only one of seven deaths was deemed preventable [2].

Accurate and routinely performed assessment of factors contributing to inpatient mortality remains challenging [8]. The number of avoidable inpatient deaths was recently estimated to be lower than previously thought [11]. The incidence of avoidable deaths among patients with at least 3 months of life expectancy was only 0.5–1%. This also highlights the need to analyze whether adverse events contributing to death caused years of life lost among those affected.

On the basis of our literature search, there is a need to fill a knowledge gap concerning mortality caused by avoidable harm among populations with high life expectancies. Many elderly health care patients have progressive comorbidities. As one of the Nordic countries, Finland has publicly funded health care that is considered safe and of relatively high quality. Secondary teaching hospitals cover the majority of specialized health care in their catchment areas, thus forming a representative study population for studies about avoidable harm and deaths.

The aim of this retrospective study was to analyze the preventability of hospital deaths associated with adverse events in a Finnish secondary teaching hospital by examining all deaths among patients treated in somatic wards for one year. By using a semistructured questionnaire, two blinded reviewers evaluated independently the association of death with adverse events and evaluated the preventability of death on a 5-point scale.

The research objectives were as follows:

- To identify all inpatient deaths not anticipated upon admission to the hospital among adult patients on somatic wards for one year;
- To evaluate whether an existing adverse event contributed to or caused death during the hospital stay or predicted impeding death within 30 days after discharge;
- To evaluate the preventability of deaths by using a 5-point rating and to calculate the percentage of potentially or likely preventable deaths, and.
- To estimate the preventable years of life lost (PrYLL) among patients under 75 or 80 years of age whose death was considered potentially or likely preventable.

Methods

Study design and setting

The research was a register-based retrospective observational study in the setting of Vaasa Central Hospital, a secondary care teaching hospital in western Finland, with a catchment population of 170,000 inhabitants. The study period was one year.

Study sample

Our study included all adult inpatients, aged 18 and over, in somatic wards who died in the hospital or within 30 days after discharge at end-of-life stage and whose death was not considered unavoidable at the time of admission. Patients who were only in the emergency department

and were waiting for examination or intervention and were registered as somatic inpatients were not included. Patients treated in psychiatric wards, patients in palliative or hospice care and newborns were excluded.

In Vaasa Central Hospital's catchment area, the total number of deaths was 1786 according to the death registry in Finland during the year 2017. In total, 322 deaths occurred in hospital or within 30 days after discharge.

For 60 patients, in-hospital death was considered unavoidable because of terminal illness, such as advanced cancer or dementia, or end-stage cardiac, pulmonary, or renal disease. There were additional nine patients who were excluded from the analysis because of a lack of full medical data.

Thus, after applying the inclusion and exclusion criteria, the whole study sample consisted of 253 patients, of whom 236 inpatients registered in somatic wards died in the hospital, and another 17 patients discharged at end-of life stage died in another institution or at home within 30 days.

Electronic mortality review form and data

The study data consisted of background variables and variables related to potentially avoidable causes of death. The following background variables were collected: social security code, age, sex, date of admission and discharge, chronic diseases according to the list of 21 diseases [12] place of death and the first diagnosis during the period of hospitalization that ended in death, length of stay in days, and end-of-life related information (e.g., limitations of treatment).

A review form was presented by Provenzano et al. [8] was used to gather information on the prevention of in-hospital mortality. After receiving permission to use the method, only minor changes were made to the original English version for an electronic questionnaire [see Additional file 1].

With respect to the possible contribution to death, the following four categories of adverse events were assessed: (1) healthcare-associated infections (e.g., ventilator-associated pneumonia), (2) common hospital-associated complications (e.g., venous thromboembolism, adverse drug events or surgical complications), (3) delays in obtaining or responding to tests or procedures (e.g., blood tests or radiology exams), and (4) barriers to communication between clinical teams (e.g., floor team to intensive care unit team, outside hospital transfers arriving without prior notice). The occurrence of adverse events was evaluated dichotomously as acquired before admission (e.g., during a previous hospital stay) or during the hospital stay.

After reading the medical records, the following summary assessments were collected:

a brief clinical summary and a rating of the preventability of death. The rating included five classes: (1) The death was not preventable because the patient was already in the terminal stage of illness at admission; (2) The death was not preventable even though preventive measures had been taken. (3) The death was not preventable, but a medical deviation or system error was detectable. (4) A death caused by a medical error or system error could have been preventable; (5) A death resulting from a medical error or system error would likely have been preventable.

Data collection

The data were collected by six reviewers who were experienced senior clinicians in different specialties at the hospital. The first reviewer searched all the information related to the background questions and the questions concerning death from the electronic medical records and entered the information and their own assessments into the electronic questionnaire. Thereafter, a second assessment of the questions was made by one of five other reviewers, who were blinded to the data entered by the first reviewer, except for the background variables. Among those hospital deaths that at least one of the two researchers considered potentially (>0%, but <50% likelihood) or likely (≥50% likelihood) preventable, the Preventable Years of Life Lost (PrYLL) were later separately evaluated by two researchers in two ways. The time was dichotomized into short (less than three months) and long (three months or more), and the preventable years of life lost before the ages of 75 and 80 years were also separately calculated.

All the data were entered into a database, which was stored in the information systems of Awanic Ltd., a limited company that maintains several patient safety information systems in Finland. During the analysis phase, the data were stored in the information systems of Vaasa Central Hospital and kept secure according to the data protection policy.

Statistical analysis

Statistical analyses were conducted with IBM SPSS 28 and the R program [13] package DescTools. Categorical variables are reported as frequencies and percentages, and quantitative variables are reported as the means, medians, standard deviations, minimums and maximums. The small amount of missing data was not considered. The interrater agreement was analyzed with the kappa coefficient on dichotomous scales and with weighted kappa, with quadratic weights, on ordinal scales.

The preventability of death was analyzed via the dichotomized "no preventability vs. potential/likely preventability" version of the variable, which was analyzed

Table 1 Characteristics of the background variables of 253 patients included in the study of in-hospital deaths (in the year 2017) in Vaasa Central Hospital, Finland. Presented as descriptive data and percentage

Variable		
Sex	n	%
Female	111	43.9%
Male	142	56.1%
Age		
Mean (SD)	77.5 (12.1)	
Median	79.9	
Range	26.8–100.4	
Length of hospital stay (days)		
Mean, (SD)	7.7 (10.1)	
Median	4	
Q1, Q3	2, 10	
Range	0–87	
Number of chronic conditions		
Mean (SD)	2.7 (1.8)	
Median	3	
Range	0–9	
Most common classes of first diagnoses	n	%
Diseases of the circulatory system	70	27.7%
Neoplasms	38	15.0%
Diseases of the respiratory system	36	14.2%
Infectious diseases	29	11.5%
Injury, poisoning and certain other consequences of external causes	29	11.5%
Limitations of treatment introduced	n	%
Never	42	16.6%
Before the current treatment period	52	20.6%
During the current treatment period	157	62.1%
Symptomatic treatment only	145	57.3%

in subgroups of the following variables: age (≥ 80 years vs. <80 years), sex, number of comorbidities (≥ 3 vs. <3) and occurrence of events belonging to one of the four categories. The dichotomies of age and number of comorbidities were based on the median. Fisher's exact test was used for comparisons between categorical variables. Correlations were analyzed with Spearman rank correlation. P values ≤ 0.05 were considered statistically significant. All significance tests were performed as two-sided tests. All reported confidence intervals (CIs) are 95% CIs.

Ethical considerations

The present study was conducted in accordance with the principles of the national advisory board on research ethics. As a registry study, an ethics committee's statement was not needed. The permission to conduct the study was granted by the Medical Director of Vaasa Central Hospital. All personal data were processed in compliance with data protection legislation without the risk of any personal data to be compromised.

Table 2 Occurrence of chronic conditions among 253 patients included in the study of in-hospital deaths (in the year 2017) in Vaasa Central Hospital, Finland. Presented as frequency and percentage

Chronic condition	*n*	%
Alzheimer's disease and dementia	45	17.8%
Myocardial infarction	47	18.6%
Atrial fibrillation	92	36.4%
Colon and rectal cancer	12	4.7%
Prostate cancer	15	5.9%
Uterine cancer	2	0.8%
Breast cancer	7	2.8%
Lung cancer	8	3.2%
Cataract	51	20.2%
Chronic kidney disease	38	15.0%
Chronic obstructive pulmonary disease	42	16.6%
Depression	6	2.4%
Diabetes	65	25.7%
Glaucoma	8	3.2%
Heart failure	83	32.8%
Fracture of the hip or pelvis	14	5.5%
Coronary artery disease	72	28.5%
Osteoporosis	18	7.1%
Rheumatoid arthritis and osteoarthritis	24	9.5%
Stroke	31	12.3%
Transient ischemic attack	9	3.6%

Results

The total number of included deaths was 253 among somatic adult in-hospital patients during the study year. Among these patients, 236 died in the hospital, and 17 died within 30 days after discharge.

Characteristics of the background variables

The majority of the patients were male, and the median age was 79.9 years. The median length of hospital stay was four days. The three most common classes of first diagnoses during the period of hospitalization that ended in death covered 57.0% (144/253) of all patients and were diseases of the circulatory system, neoplasms and diseases of the respiratory system. For only one-sixth of the patients, limitations of treatment were not introduced at any stage, while more than half of the patients were switched to only symptomatic treatment. Among all patients, more than 90% had chronic conditions, with a median of three (Table 1). The following chronic conditions occurred in more than a quarter of the patients: atrial fibrillation, heart failure, coronary artery disease and diabetes (Table 2).

Occurrence of various categories of adverse events and their possible role in in-hospital death

Overall, 23.9% (60.5/253) of patients were evaluated to have at least one adverse event contributing to the cause of death. Healthcare-associated infections that

contributed to or caused death and were acquired during this hospitalization were identified by the two reviewers on average in 7.1% of patients, and the most common causes were sepsis and Clostridioides. The next most common category included various complications, e.g., adverse drug effects and technical surgical complications, with an average of 6.9%. Problems with the timing of an intervention that contributed to or caused death and occurred during this hospitalization were identified in 3.2% of patients, e.g., the timing of an imaging study and a surgical procedure in the operating room. Problems in cooperation and communication were the rarest cause of the four categories. In addition, the number of adverse events was evaluated as having already been acquired before admission. In particular, those in categories of health care-associated infections and various complications were evaluated to have contributed to or caused death, the latter of which even outnumbered the complications that occurred during the hospital stay (Tables 3 and 4).

Preventability of death and interrater agreement

The distributions and differences of the two ratings of preventability of death are presented in Table 5. As a means of the two reviewers' ratings, the percentages of classes ranging from classes 1–5 were 29.6%, 56.5%, 9.1%, 3.8% and 1.0%, respectively. Both reviewers selected the same category in 56.9% of the ratings. The difference was more than one class in only 13 patients (5.1%). When the classes with no preventability (1–3) and classes with at least potential preventability (4–5) are combined, 95.3% (95% CI 93.0–96.8%) of the ratings belong to classes 1–3, and 4.7% (95% CI 3.2–7.0%) belong to classes 4–5.

The interrater agreement in preventability of death was in the original five-level scale with a weighted kappa of 0.488 (95% CI 0.356–0.620). For the dichotomous scale, the kappa coefficient was 0.523 (0.264–0.782). Both p values were < 0.001.

Preventability of death in subgroups according to background variables

The preventability of death was analyzed via the dichotomized version of the variable in the dichotomized subgroups of the following variables: age, sex and number of comorbidities. The difference between the sexes was NS. Potential or likely preventability was more common in the younger age group (7.8%) than in the older age group (1.9%) ($p = 0.001$). The result was almost identical to the number of comorbidities: potential or likely preventability was more common (7.9%) in those with fewer comorbidities than in those with more comorbidities (1.9%) ($p = 0.001$). Age and the number of comorbidities were also significantly correlated with each other, with a Spearman correlation coefficient of 0.429 ($p < 0.001$).

Table 3 Occurrence of adverse events and their possible contribution to in-hospital death among 253 patients (in the year 2017) in Vaasa Central Hospital, Finland. The amounts reported as mean of two independent evaluations and percentage

Categories of adverse events		1. Infections		2. Selected complications		3. Timeliness of intervention		4. Teamwork and communication		All categories, Total		
		Previous	Recent	Previous	Recent	Previous	Recent	Previous	Recent	Previous	Recent	All
Timing of the event												
Adverse events	Number of events	26.5	36.5	38.5	40	9.5	29.5	1	16	75.5	122	197.5
	Patients, n	**22**	**32**	**34**	**35.5**	**9.5**	**21.5**	**1**	**15.5**	**55.5**	**76**	**111.5**
	Patients, %	**8.7%**	**12.6%**	**13.4%**	**14.0%**	**3.8%**	**8.5%**	**0.4%**	**6.1%**	**21.9%**	**30.0%**	**44.1%**
Contributed to or caused death	Number of events	16	21.5	23	18.5	2	11	0	2	41	53	94
	Patients, n	**13.5**	**18**	**21**	**17.5**	**2**	**8**	**0**	**2**	**33.5**	**37.5**	**60.5**
	Patients, %	**5.3%**	**7.1%**	**8.3%**	**6.9%**	**0.8%**	**3.2%**	**0.0%**	**0.8%**	**13.2%**	**14.8%**	**23.9%**

Table 4 Frequencies of most common adverse events in four main categories, their acquirement before or during hospital stay and reviewers' evaluation whether the event contributed to or caused in-hospital death in 253 patients (in the year 2017) in Vaasa Central Hospital, Finland. Numbers are mean of two independent evaluations and percentage. Rare adverse events with frequency less than 1.5 were omitted

Acquirement of the adverse event	Before admission		During hospital stay		
	All	Contributed or caused	All	Contributed or caused	
Number of patients as mean of the evaluations of two reviewers	n	n	n	n	% of pts
Main category 1: Infections. Total	**26.5**	**16**	**36.5**	**21.5 in 18 pts**	**7.1%**
Surgical Site Infection	6	4	1.5	0.5	0.2%
Systemic Fungal Infection or Fungal Pneumonia	2.5	2.5	3.5	3	1.2%
Clostridioides difficile Infection	3	1.5	5.5	3	1.2%
Catheter Associated Urinary Tract Infection	1	0	3	0.5	0.2%
Sepsis	4	3	7	6.5	2.6%
Extended Spectrum Beta Lactamase Producing Bacterial Infection	1.5	0	0.5	0.5	0.2%
Other Healthcare Acquired Infection	7.5	4.5	14	6.5	2.6%
Main category 2: Selected Complications. Total	**38.5**	**23**	**40**	**18.5 in 17.5 pts**	**6.9%**
Adverse Drug Event (Name of Medication)	12	6.5	14.5	7	2.8%
Venous Thromboembolism	4.5	3	3.5	2	0.8%
Fall resulting in injury	10.5	8.5	0.5	0	0.0%
Technical surgical complication	1	0	2	0	0.0%
Technical surgical complication requiring reoperation and/or blood transfusion	1.5	1	3	3	1.2%
Anesthesia-related complication	0.5	0	3	1	0.4%
Interventional radiology procedure related complication	0.5	0	2.5	0	0.0%
Non-surgical procedure related complication	1	0	2.5	0.5	0.2%
Pressure ulcers	3.5	1	1	0	0.0%
Other complication	3	2.5	6.5	4.5	1.8%
Main category 3: Timeliness of interventions. Total	**9.5**	**2**	**29.5**	**11 in 8 pts**	**3.2%**
Surgical procedure/operating room	1.5	0	3.5	2.5	1.0%
All other procedures	1.5	0	2	0.5	0.2%
Medication administration	0.5	0	2	0.5	0.2%
Obtaining imaging	5.5	0	11	4	1.6%
Obtaining blood work and/or results	0	0	5.5	1	0.4%
Clinical response	0.5	2	4.5	2	0.8%
Main category 4: Teamwork and Communication. Total	**1**	**0**	**16**	**2 in 2 pts**	**0.8%**
Primary team and consult service	1	0	3	0	0.0%
Nursing and the covering team	0	0	4	1	0.4%
During transfer process to hospital	0	0	1.5	0	0.0%
Other communication issue	0	0	3.5	0	0.0%

The occurrence of various categories of events in the two classes of dichotomized preventability was also tested. Among all four categories, only problems reported with the timing of an intervention were associated with an increased prevalence of preventability, 19.4% vs. 2.7% in the groups with potential or likely preventability vs. no preventability ($p < 0.001$).

Preventable years of life lost

Among all 253 hospital deaths, there were 17 deaths that at least one of the two researchers considered potentially (>0%, but <50% likelihood) or likely (≥50% likelihood) preventable, of which only seven deaths were considered at least potentially preventable by both reviewers.

The preventable years of life lost were evaluated both dichotomously (less than 3 months vs. 3 months or more) and quantitatively (PrYLL). There were patients with competing causes of death, for example, three patients with newly diagnosed cancer with no treatment options, one patient with cancer who had already relapsed twice, three old frail patients with multiple advanced diseases, and one patient with pulmonary embolism who died of profuse bleeding caused by anticoagulant therapy. A quarter of those whose death was considered potentially

Table 5 Ratings of preventability of in-hospital deaths in 253 patients estimated by two independent reviewers (in the year 2017) in Vaasa Central Hospital, Finland. A the distribution of both ratings and B the difference between 1st and 2nd ratings. Cross table with amounts, percentage and 95% confidence intervals of mean of ratings

A

		2nd rating								Mean of ratings	
	Classes*	**1**	**2**	**3**	**4**	**5**	**Total**	**%**	**95% CI**	**%**	**95% CI**
1st rating	**1**	39	33	3	0	0	75	**29.6%**	24.4-35.5%	**29.6%**	25.8-33.8%
	2	33	94	9	4	1	141	**55.7%**	49.6-61.7%	**56.5%**	52.2-60.8%
	3	3	16	6	1	0	26	**10.3%**	7.1-14.6%	**9.1%**	6.9-11.9%
	4	0	2	2	4	2	10	**4.0%**	2.2-7.1%	**3.8%**	2.4-5.8%
	5	0	0	0	0	1	1	**0.4%**	0.1-2.2%	**1.0%**	0.4-2.3%
	Total	75	145	20	9	4	253				
	%	**29.6%**	**57.3%**	**7.9%**	**3.6%**	**1.6%**					
	95% CI	24.4-35.5%	51.2-63.3%	5.2-11.9%	1.9-6.6%	0.6-4.0%					

B

	no diff	**1 class**	**2 classes**	**3 classes**	**4 classes**	**Total**
n	144	96	12	1	0	253
%	56.9%	37.9%	4.7%	0.4%	0.0%	
95% CI	50.8-62.9%	32.2-44.1%	2.7-8.1%	0.1-2.2%	0-1.5%	

*1. The death was not preventable, because the patient was already in the terminal stage of his illness at the end of his illness at admission, 2. The death was not preventable even though preventive measures had been taken, 3. The death was not preventable, but a medical deviation or system error was detectable, 4. A death that was caused by a medical error or system error could potentially have been preventable, 5. A death resulting from a medical error or system error would likely have been preventable

Table 6 Estimated preventable years of life lost (PrYLL) in the 17 patients with possible or likely preventability of an in-patient death evaluated by two independent reviewers (in the year 2017) in Vaasa Central Hospital, Finland. Frequency of a dichotomous classification (less than 3 months / 3 months or more) and a calculation of estimated years of life lost

	Class of preventability			**Dichotomous classification**				**PrYLL**	
				< 3 months		**≥ 3 months**		**PrYLL [80]**	**PrYLL [75]**
Reviewer		***n***	**%**	***n***	**%**	***n***	**%**	**years**	**years**
Reviewer1	possible	10	4.0%	8	3.2%	2	0.8%	47.7	47.3
Reviewer2	possible	9	3.6%	6	2.4%	3	1.2%	50.9	47.0
Reviewer1	likely	1	0.4%	0	0.0%	1	0.4%	4.0	0.0
Reviewer2	likely	4	1.6%	3	1.2%	1	0.4%	4.5	0.3
mean of 'possible'		9.5	**3.8%**	7	**2.8%**	2.5	**1.0%**	**49.3**	**47.1**
mean of 'likely'		2.5	**1.0%**	1.5	**0.6%**	1	**0.4%**	**4.3**	**0.1**

preventable would have potentially lived more than three months.Among those patients whose death was considered likely preventable, only one patient would have likely lived for more than three months, which was a suicide of a youngish adult.

In the quantitative estimation, until the age of 80 years, the possibly preventable years of life lost (PrYLL) were, on average, 49.3 years, and the likely PrYLL was 4.3 years. Thus, the combined possibly and likely PrYLL was 53.6 years. Until the age of 75 years, the possibly and likely PrYLLs were 47.3 and 0.1 years, respectively, and were combined at 47.4 years. To test the sensitivity of the estimates, we calculated the combined PrYLLs for all 17 patients, with values ranging from 80 years to 55.6 years and 75 years to 47.5 years, and for only those 7 patients whose PrYLLs were equal to those of the other two reviewers, the respective PrYLLs until 80 years was 55.6 years and until 75 years was 47.0 years (Table 6).

Discussion

In this study from a Finnish secondary care teaching hospital, we were able to assess all deaths of somatic inpatients thoroughly during one calendar year. Two experienced reviewers evaluated the preventability of in-hospital deaths on a validated 5-point rating by using data from electronic health records. Our main findings were that in a population of elderly health care users, the proportion of possibly and likely preventable deaths was low, the median age of patients who died was high (79.9 years), and they had several chronic comorbidities. Even for those who experienced potentially or likely preventable deaths as a consequence of avoidable harm, the expected length of life was typically less than three months. Thus, the years of life lost were scarce, and the total years lost were caused mainly by one young adult patient with an unexpected self-intended death. Our results support previous studies that contradict the

assumption that patient safety incidents and adverse events are major causes of mortality in countries with advanced health care systems.

Hospitals are considered safe places and are responsible for providing effective medical services to patients. Nevertheless, medical errors still pose a substantial challenge to health care. In 1999, Kohn's report revealed that errors occur among highly educated health care professionals [4]. Later, in 2013, a literature review revealed an alarming incidence of deaths due to medical errors [14] and in 2016, an estimate of annual deaths suggested that inpatient deaths due to medical errors were the third leading cause of death next to heart disease and cancer [15]. These publications have raised considerable criticism for various methodological reasons. In 2021, the Centers for Disease Control and Prevention recognized medical errors as the fourth most common cause of death on the basis of reported mortality when system errors were included in the analysis [16]. Alarmingly, a recent register-based study from the U.S. demonstrated that after a relatively stable period from 1999–mid-2010s, the proportion of medical adverse event deaths relative to all deaths doubled between the mid-2010s and 2019 and that procedure-related deaths were found to have driven the trend [6].

Reviews of admissions, adverse events, resulting harm, and whether the events were preventable have been criticized for their indirectness when used to estimate the number of deaths due to medical errors. In contrast, studies of inpatient deaths offer a more direct way of estimating the rate of preventable deaths [17, 18]. There are several estimates derived from inpatient mortality. One study reported that 4.8% (50/1052) of deaths may have been preventable. Among those possibly preventable, 3.8% (40/1052) were preventable, and 0.95% (10/1052) were likely preventable [8]. These results are comparable to those of our study, where the proportion of potential or likely preventable deaths associated with adverse events was 4.7%. One explanation for the variation in the inpatient mortality rate is the need for health care at the end of life. Mortality in hospitals declines if patients are transferred to hospice care or home for death. Thus, the quality and availability of end-of-life care might have an impact on inpatient mortality.

Other studies have analyzed whether adverse events are associated with death or a shortened life expectancy in those affected. Baines et al. compared inpatient deaths to those discharged alive and reported twice as many adverse events and more preventable adverse events in patients who died in the hospital than in the control group. Half of the adverse events reported in the deceased patients were estimated to be preventable, and 5.8% of the deaths might have been preventable. In 4.5% of the patients, adverse events contributed to death. Patients who died during admission were older (> 80 years) and had a longer length of stay in the hospital [7]. Hogan et al. reported that 60% of preventable deaths occurred in elderly, frail patients with multiple comorbidities who were estimated to have had less than 1 year of life left to live [19]. These findings are similar to ours.

Healthcare is a complex industry with risks and invasive procedures. An improvement in overall health and life expectancy is shifting the need for medical care toward the elderly population, thus increasing the likelihood of death in the natural course. The shift in age pyramid results in elderly people having comorbidities needing and receiving medical treatment, innovative technologies, and new medications. Elderly patients are fragile, and even minor medical errors or complications may lead to a fatal clinical course. According to one study, each additional chronic condition decreases life expectancy by an average of 1.8 years per disease [12]. In our study, the main groups of diseases among patients who died unexpectedly were circulatory or respiratory conditions and neoplasms. There were 17 hospital deaths in which at least one of the two reviewers considered potentially or likely preventable. Of these, nine patients were frail with competing causes of death that would have led to death in the near future: newly diagnosed cancer with no treatment options, relapsed cancer, and, in one patient, an indicated anticoagulant therapy, which probably caused profuse bleeding and inevitable death.

One reason for the quite low estimated preventable years of life lost may be the presence of competitive causes of death [20]. Some preventable deaths were also identifiable among our study population; therefore, we calculated the preventable loss of life. It was relatively low, mainly resulting from a case of unforeseeable intentional death at a relatively young age. Previous reports have shown that the majority of hospital deaths occur in patients with less than 3 months of life expectancy. Most deaths are caused by underlying disease, not the quality of care [11]. This finding is similar to our findings. When analyzing likely preventable years of life lost, only one patient was estimated to have likely lived more than three months.

Accurately and routinely identifying factors contributing to inpatient mortality remains challenging [8]. Compared with our study, retrospective case record reviews of 1000 deceased patients in 10 acute hospitals in England were performed. Reviewers estimated their life expectancy on admission. After that, they analyzed the adverse events and their contributions to death and whether death could have been prevented. The reviewers judged 5.2% of deaths as having a 50% or greater chance of being preventable. In contrast to our results, in this study, the errors associated with preventable deaths were poor clinical monitoring, diagnostic errors, and inadequate drug

or fluid management [19]. One systematic review and meta-analysis on the rate of preventable inpatient mortality due to medical error estimated that the number of deaths was lower than previously thought. Their review revealed that 3.1% of the 12,503 deaths might have been preventable. They further reported preventable deaths for patients whose life expectancy was at least 3 months to be between 0.5% and 1.0% [11]. Our results are very similar to these findings in terms of preventability and life expectancy.

Preventable deaths in hospitalized patients still represent a significant cause of death and deserve the continued attention of clinicians, hospital administrators, and policy makers [11]. Others reported that preventable adverse events that contributed to death occurred in 3.8-8% of all hospital deaths [7–10, 19]. Avoidance of death is not always easy to define, and we also noticed some variation between reviewers. However, the interrater agreement in our study was rather high for this type of evaluation. All our reviewers were experienced clinicians, and some of them had former experience in rating the preventability of harm, e.g., by participating in global trigger tool assessments.

The most common type of medical error is medication error [1]. Medication errors in hospitalized adults may cause harm, additional costs, and even death. These events should be considered preventable when the medication is in the control of healthcare professionals [21]. In our study, the occurrence of adverse drug events was only 2.6%, which was the same as that reported for sepsis or other healthcare-acquired infections. Technical surgical complications were the third most common cause of preventable incidents in our sample. Efforts to improve medication safety and apply evidence-based indications and treatment protocols have been daily activities in our hospital since 2006. The surgical safety checklist was introduced in 2010. These safeguards are known to protect patients from unintended harm. The hospital has been SHQS (social and health quality service) certified since 2007.

In our study, the most typical process-related incidents were problems with the timing of an intervention, e.g., delays in diagnostics or treatment that contributed to or caused death. In a registry study such as this, only the greatest delays in, for example, diagnostic studies or treatment procedures are revealed. However, there may be frequent minor delays in treatment, for example, due to scarce doctor or nurse resources. Even these delays can cause problems for patients, especially when they accumulate. Another notable finding of our study was that many adverse events associated with death were acquired before admission to the hospital. The demand to shorten the length of hospital stay may be one explanation for why adverse events manifest only after discharge. This might increase the risk of delays in diagnosis and adequate treatment of hospital-acquired infections or complications of procedures, which might be disastrous to elderly and fragile patients.

In many countries, the healthcare community relies on voluntary reporting, which may create a bias of underestimating the number of adverse events. Several studies have shown that in hospital-based care, a high nursing workload and insufficient nurse staffing negatively affect outcomes such as mortality [22, 23]. Thus, registry studies based on voluntary incident reporting may underestimate preventable mortality, especially for process delays, because of high nursing workloads. Provenzano et al. noted the need not only to gather information about individual cases but also to identify systemwide issues. Monitoring avoidable deaths from a quality assurance perspective might provide useful information. Only with these methods can the processes and quality be improved throughout the hospital. They also encourage a culture of safety and reflection after every inpatient death [8].

Some limitations of our study need consideration. The study being a retrospective analysis, some risks of bias may arise. The deaths were collected from hospital discharge data, and clinical information was assessed from electronic medical records. These are reliable sources and cover all hospital patients. Only nine patients were not included because of a lack of full medical data, which is less than 3% of the records.

The data are from the year 2017, but we consider them not outdated because there have been no major changes in the population, clinical practice or quality and safety measures in hospitals since then, not considering the exceptional years of the COVID-19 pandemic. In terms of sample size, with a proportion of preventable mortality of 0.03 and 95% CI ± 0.02, the desired sample size would have been 280. The planned data for the year were slightly below the targeted sample size, so the confidence intervals of the results are quite wide. All the patients died after discharge without known adverse events and were likely not preventable. In our methods, we also excluded 60 deaths with terminal illness from the analysis, which might differ from the results of other studies [8].

The separate, independent rating of the preventability is an attempt to increase objectivity of the study. The reviewers were experienced clinicians who had not participated in the treatment of the deceased patients and who were blinded to each other's evaluation. In similar studies, interrater reliability for preventability of death is typically only moderate, for example, in a systematic review between 0.40 and 0.49 [11]. In our study, the kappa coefficient was 0.52 in the dichotomous comparisons, which can be considered a strength of our study. The rating system was applied from previously published research in order to increase the validity of the method.

However, among elderly and fragile patients with multiple morbidities it is not straightforward to draw conclusions about the associations to adverse events and preventability of death.

Generalizability of our results need confirmation from other studies. The generalizability depends on demographics, health care regulations, resources, and standards of the health system, as well as the education and competence of the staff.

Our study on preventable hospital deaths supports the observations of recent research data that deaths caused by safety incidents or adverse events are less frequent than estimated earlier by modeling from indirect data. Since the first reports of severe harm and death caused by medical errors, there have been systematic activities of patient safety and quality improvement in specialized health care, at least in developed countries, thus reducing the severe consequences of unintended harm.

Conclusions

According to this study, avoidable in-hospital deaths were uncommon. They mainly occurred in elderly and fragile patients with only a few months of life expectancy. This finding may warrant further studies about end-of-life care with respect to patient safety to avoid adverse events from procedures and medication. Large-scale studies with adequate analysis of clinical data are needed to update the estimates and causes of deaths related to adverse events.

Abbreviations

PrYLL	The Preventable Years of Life Lost
CI	Confidence Interval
NS	Not significant
SD	Standard Deviation

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions

AR, TI, and HY participated in the conception and design of the work. HY, PN, and AR were involved in the acquisition of data. SK executed the literature search and wrote the literature review with TI ja AR. HY, PN, AR, and SK analyzed the data. SK, AR, and TI were responsible for the extraction and interpretation of the data and findings. They also wrote and edited the manuscript. All the authors have read the work and revised it. All the authors have approved the submitted version of the manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The present study was conducted in accordance with the principles of the national advisory board on research ethics. As a registry study, an ethics committee's statement was not needed. The permission to conduct the study was granted by the Medical Director of Vaasa Central Hospital. All personal data were processed in compliance with data protection legislation.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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