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Healthy Life-Years Lost and Excess Bed-Days Due to 6 Patient Safety Incidents

Empirical Evidence From English Hospitals

Katharina D. Hauck, PhD, Shaolin Wang, PhD, Charles Vincent, PhD,† and Peter C. Smith, PhD‡*

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Background: There is little satisfactory evidence on the harm of safety incidents to patients, in terms of lost potential health and life-years.

Objective: To estimate the healthy life-years (HLYs) lost due to 6 incidents in English hospitals between the years 2005/2006 and 2009/2010, to compare burden across incidents, and estimate excess bed-days.

Research Design: The study used cross-sectional analysis of the medical records of all inpatients treated in 273 English hospitals. Patients with 6 types of preventable incidents were identified. Total attributable loss of HLYs was estimated through propensity score matching by considering the hypothetical remaining length and quality of life had the incident not occurred.

Results: The 6 incidents resulted in an annual loss of 68 HLYs and 934 excess bed-days per 100,000 population. Preventable pressure ulcers caused the loss of 26 HLYs and 555 excess bed-days annually. Deaths in low-mortality procedures resulted in 25 lost life-years and 42 bed-days. Deep-vein thrombosis/pulmonary embolisms cost 12 HLYs, and 240 bed-days. Postoperative sepsis, hip fractures, and central-line infections cost <6 HLYs and 100 bed-days each.

Discussion: The burden caused by the 6 incidents is roughly comparable with the UK burden of Multiple Sclerosis (80 DALYs per 100,000), HIV/AIDS and Tuberculosis (63 DALYs), and Cervical Cancer (58 DALYs). There were marked differences in the harm caused by the incidents, despite the public attention all of them receive. Decision makers can use the results to prioritize resources into further research and effective interventions.

Key Words: patient safety, medical errors, hospital quality, hospital performance, administrative hospital data

(*Med Care* 2017;55: 125–130)

Patient safety incidents cause significant harm to patients, and their treatment leads to excess costs for health care providers. Most countries spend significant resources on the prevention of safety incidents.[1–5] However, hospitals have limited budgets, and many competing demands for improvement initiatives. It is therefore important to understand the harm and costs associated with patient safety incidents to provide guidance on where to prioritize preventive efforts. Incidents may increase hospital expenditure, in the form of longer lengths of stay and additional treatment. From its own narrow perspective, a hospital should clearly implement any preventive intervention that reduces its net treatment costs, by averting incidents. However, even costly prevention may be worthwhile implementing if the associated gains to patient health are sufficient.[6] The health gains are the harm caused by safety incidents that can be averted by the preventive measure.

Harm of incidents has been estimated by a number of studies,[3,7–15] but usually simply as the number of deaths attributable to the incidents, calculated from incidence and excess mortality risk. Attributable deaths are misleading estimates of health loss because they do not consider how long and in what health a patient would have lived if care had been optimal.[16,17] In reaction to the seminal Institute of Medicine[18] report, McDonald et al[17] stated early on that "Unlike most people who step into motor vehicles, most patients admitted to hospitals have high disease burdens and high death risks even before they enter the hospital." Previous attempts to adjust for baseline health status mostly relied on retrospective record reviews,[19] but they were limited in scope and could not predict future health

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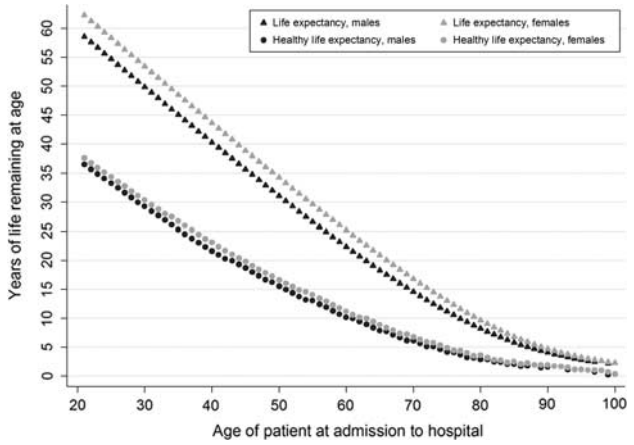

FIGURE 1. Life expectancy and healthy life expectancy, control patients for pressure ulcers. This figure shows expected remaining life expectancy and healthy life expectancy for males and females. Healthy life expectancy is adjusted for observed comorbidities that were associated with significant reductions in quality of life in matched control patients, and were estimated as part of this study. The values in this figure are for pressure ulcers control patients, and averaged across all English hospitals and the years 2005/2006–2009/2010. Values for other incidents are very similar (see Table SDC9, Supplemental Digital Content 1, http://links.lww.com/MLR/B270). For example, a male of age 50 years in the general population has a remaining life expectancy of around 34 years, and a (population level) healthy life expectancy of 24 years. However, an average 50-year-old male admitted to a hospital in England is in less good health, and has a remaining healthy life expectancy of only around 16 years on average because of comorbidities that are expected to result in reduced quality-of-life over the remaining life-years. If a 50-year-old male hospital patient would contract a pressure ulcer in hospital and die from it, a calculation of lost life-years that did not adjust for quality-of-life would overestimate lost healthy life-years by 18 years.

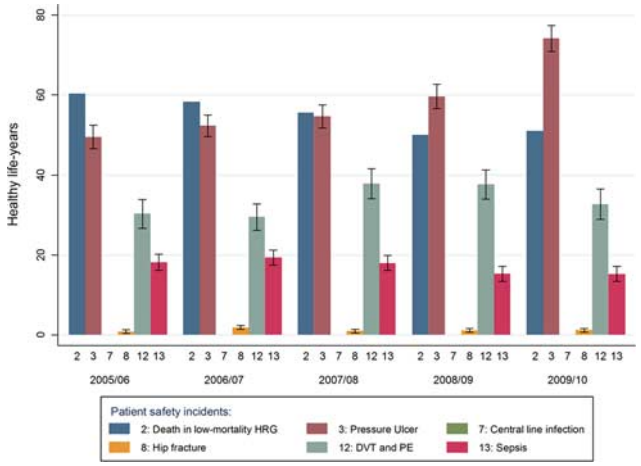

FIGURE 2. Healthy life-years lost due to 6 preventable patient safety incidents, annual totals for an average English hospital. Estimates of annual total healthy life-years lost to incidents for all hospitalized inpatients (≥1 night) at risk in an English hospital with the average number of incidents per year. 95% confidence intervals are indicated by the black bars. The estimate for deaths in low-mortality HRGs is deterministic by definition. The loss is zero for central line infections because mortality risk of patients with incidents was not statistically significantly different from mortality risk of matched control patients without incidents. DVT indicates deep-vein thrombosis; HRG, Healthcare Resource Groups; PE, pulmonary embolism.

and life-years. Some studies estimated the loss to patients based on compensatory damages paid,[20–22] but their value is affected by other factors apart from the adverse health impacts, most notably forfeited earnings.

The loss of health depends on baseline health of patients at the time of the incident, and on future health had these incidents not occurred. Fewer healthy years are lost to incidents that predominantly affect older and sicker patient groups, compared with incidents that affect generally younger and healthier patients. The objective of this study was to compare the loss of health caused by 6 commonly studied safety incidents. We used econometric methods to estimate the healthy life-years (HLYs) lost due to deaths attributable to the incidents. We further estimated excess bed-days as a proxy for additional treatment costs.

METHODS

Study Sample

The Hospital Episode Statistics for the financial years 2005/2006–2009/2010 were used for analysis. This is an administrative database containing medical records with detailed clinical data for all hospitalized patients in 273 English public hospitals.[23] We identified cases from up to 5.9 million inpatients at risk annually. There are considerable variations in the number of patients considered at risk across incidents and years (see "control patients" Table SDC4, Supplemental Digital Content 1, http://links.lww.com/MLR/B270). Data on staffing levels, bed numbers, teaching status, and bed occupancy were obtained from the Web site of the Health & Social Care Information Centre maintained by the UK Department of Health.[24] We identified 6 types of patient safety indicators via software modules developed by the Agency for Healthcare Research and Quality (AHRQ) that identify specific combinations of diagnoses and procedure codes in medical records[25] (see section 1 Supplementary Data: The Patient Safety Indicators in the SDC, Supplemental Digital Content 1, http://links.lww.com/MLR/B270). The 6 indicators were chosen because of the attention they receive by the public, policy makers, and academics, and because translations of the AHRQ algorithms into the English coding system had previously been developed.[13] Incidents were identified from all patients in whom the event is considered preventable according to AHRQ criteria. Incidence rates per 1000 hospitalizations in our data are comparable with similar results for the AHRQ indicators from previous studies on general hospitalizations of all ages from the United Kingdom,[11,13] the United States,[4,7,10,26] and OECD countries.[3] Estimates range from <1 case per 1000 patients at risk for comparably rare events such as central-line infections, postoperative hip fractures, and deaths in low-mortality Healthcare Resource Groups (HRGs) to 14 cases for

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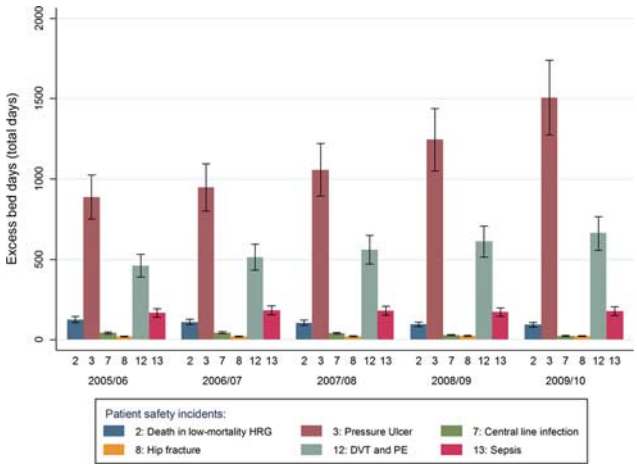

FIGURE 3. Excess bed-days due to 6 preventable patient safety incidents, annual totals for an average English hospital. Estimates of annual excess bed-days due to incidents for all hospitalized inpatients at risk in an average English hospital. DVT indicates deep-vein thrombosis; PE, pulmonary embolism.

preventable pressure ulcers (Table SDC1, Supplemental Digital Content 1, http://links.lww.com/MLR/B270 and SDC2, Supplemental Digital Content 1, http://links.lww.com/MLR/B270 for incidence in an average English hospital). Average patient characteristics vary quite markedly across incidents, in particular age (Tables SDC3a–f, Supplemental Digital Content 1, http://links.lww.com/MLR/B270), underlining the importance of adjusting for hypothetical future health and life expectancy in patients who die.

Statistical Analysis

We first calculated attributable deaths as the products of excess mortality and incidence, as previous studies have done. However, we then went further to estimate HLYs lost to these incidents, thus more truly demonstrating their impact on the patients and families concerned. To calculate the loss of HLYs by incident and year, we estimated hypothetical healthy life expectancy (HLE) of all patients with incidents from quality-of-life reductions due to preexisting comorbidities unrelated to the safety incident, and life expectancy estimates.[27] HLE is a combined estimate of the health and the length of life the patient would have had if the incident had not occurred. Life-years lived in less than perfect health were adjusted—or "devalued"—according to the extent of unrelated conditions suffered by the patients affected. Remaining HLE was calculated as the sum of the quality-adjusted life-years. To determine by how much hypothetical life-years needed to be devalued, we used estimates of the quality-of-life reductions associated with 141 common chronic conditions for the population in the United Kingdom[28] (see Tables SDC7, Supplemental Digital Content 1, http://links.lww.com/MLR/B270 and SDC8, Supplemental Digital Content 1, http://links.lww.com/MLR/B270). Some patients may have died from causes unrelated to the safety incident. We therefore adjusted calculation of lost HLYs by estimates of the average excess mortality associated with the incidents, to calculate excess mortality by comparing incident patients and a group of matched control patients without incidents. We further used this control group for estimating the hypothetical HLEs, to assure that they were unaffected by the adverse health consequences of the incidents. The control patients were matched to patients with incidents using propensity score matching, and they were therefore observationally near identical—except that they did not suffer an incident. Patients were matched on age, sex, the weighted Charlson comorbidity index, index of multiple social deprivation of patients' residence, number of diagnoses, and several characteristics of the treating hospital (teaching status, medical and nursing staffing, number of beds, and bed occupancy). Matching successfully eliminated bias in the covariates between incident and control patients to acceptable levels according to standard tests (see Tables SDC3a–f, Supplemental Digital Content 1, http://links.lww.com/MLR/B270) and overlay plots (see Figs. SDC1a–f, Supplemental Digital Content 1, http://links.lww.com/MLR/B270). Our estimates of HLE for patients with incidents were substantially smaller than ordinary life expectancy, except for very old patients (Fig. 1). This demonstrates that loss of health would be overestimated if unadjusted for existing comorbidities and age. Excess bed-days were estimated as the average difference in length of stay of incident and matched control patients (see section 2 Supplementary Methods in the SDC, Supplemental Digital Content 1, http://links.lww.com/MLR/B270 for a detailed explanation of the methods).

RESULTS

A total of 68 HLYs and 934 bed-days were lost to the 6 preventable patient safety incidents per 100,000 population

TABLE 1. Excess Mortality Risk and Average Bed-Days, Averages 2005/2006–2009/2010

	Excess Mortality Risk	SD	95% Confidence Interval	Excess Bed-Days	SD	95% Confidence Interval
Death in low-mortality HRGs	0.95	NA	NA	12.3	1.1	10.2, 14.4
Pressure ulcer	0.154	0.004	0.146, 0.162	15.5	0.3	14.9, 16.2
Central line infection	0.014	0.017	−0.021, 0.048	11.2	1.6	8.0, 14.4
Postoperative hip fracture	0.140	0.028	0.085, 0.196	21.2	2.6	16.0, 26.4
Deep-vein thrombosis/pulmonary embolism	0.083	0.005	0.074, 0.092	17.1	0.5	16.2, 18.0
Postoperative sepsis	0.155	0.009	0.137, 0.172	18.8	0.8	17.3, 20.4

The reported excess mortality risk and bed-days are "Average Treatment Effects on the Treated" (ATTs); mortality risk is a percentage, excess bed-days are measured in days; SDs for the ATTs were generated through bootstrapping using 1000 replications. For deaths in low-mortality HRG, ATTs do not need to be estimated because by definition all cases lead to death and mortality risk of controls is below 0.5%. We use 95% as a conservative and deterministic estimate of excess mortality risk for this incident.

HRGs indicates Healthcare Resource Group

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TABLE 2. Loss of Healthy Life-Years and Excess Bed-Days Due to 6 Patient Safety Incidents, Annual Estimates Per 100,000 Population, All English Hospitals

	Death in Low-Mortality HRGs		Pressure Ulcer		Central Line Infection		Postoperative Hip Fracture		Deep-vein Thrombosis/ Pulmonary Embolism		Postoperative Sepsis	
	HLYs Lost	Excess Bed-Days	HLYs Lost	Excess Bed-Days	HLYs Lost	Excess Bed-Days	HLYs Lost	Excess Bed-Days	HLYs Lost	Excess Bed-Days	HLYs Lost	Excess Bed-Days
2005/2006	25.4	52.4	20.6	472.5	0	10.4	0.3	8.2	9.4	183.6	5.3	70.2
95% CI	NA	52.4, 44.2	19.4, 21.8	449.4, 495.7	NA	7.1, 13.7	0.1, 0.4	5.8, 10.6	8.3, 10.6	173.1, 194.1	4.7, 5.9	64, 76.3
2006/2007	27.3	43.9	24.9	538.9	0	20.1	0.7	12.1	10.8	240.4	6.6	86
95% CI	NA	37.5, 50.3	23.6, 26.1	516.5, 561.2	NA	15.7, 24.5	0.5, 0.8	9.5, 14.7	9.6, 12	228, 252.9	6, 7.2	79.5, 92.4
2007/2008	25.4	42.7	24.7	535.2	0	13.4	0.3	10.3	13.1	243.4	6.1	84.4
95% CI	NA	35, 50.3	23.4, 26.1	513.6, 556.8	NA	9.7, 17.2	0.2, 0.5	7.6, 13	11.8, 14.4	231.2, 255.6	5.4, 6.7	77.4, 91.4
2008/2009	22.7	38.5	26.9	575.3	0	11.1	0.4	12.6	13	252.2	5.1	75.7
95% CI	NA	31.3, 45.8	25.5, 28.3	553.9, 596.6	NA	7.9, 14.3	0.2, 0.6	9.6, 15.7	11.7, 14.2	238.8, 265.7	4.5, 5.8	69.3, 82.2
2009/2010	22.3	31.3	33	652	0	7.3	0.4	11.7	11.3	259.8	5	73.4
95% CI	NA	25.1, 37.6	31.5, 34.4	628.9, 675.1	NA	4.8, 9.8	0.2, 0.6	9.1, 14.2	10, 12.6	246.9, 272.7	4.4, 5.6	67.4, 79.4
Mean (y)	24.6	41.8	26.0	554.8	0	13	0.4	11.0	11.5	235.9	5.6	77.9
95% CI	NA	34.6, 48.9	24.7, 27.3	532.5, 577.1	NA	9, 15.9	0.2, 0.6	8.3, 13.7	10.3, 12.7]	223.6, 248.2	5, 6.3	71.5, 84.3
% of total burden	36.1	4.5	38.2	59.4	0	1.3	0.6	1.2	16.9	25.3	8.2	8.3

Estimates for HLYs lost by deaths in low-mortality HRGs are deterministic by definition; HLYs lost to central line infections are zero because excess mortality risk is not statistically significant. 95% confidence intervals are based on SEs of estimates of excess mortality risk and bed-days, and obtained through bootstrapping (with 1000 repetitions). The % of total burden indicates how many HLYs are lost to an incident compared with overall HLYs lost to all 6 events, and how many extra bed-days are caused by the incident in comparison with all extra bed-days.

CI indicates confidence interval; HLYs, healthy life-years; HRGs, Healthcare Resource Group.

annually, averaged over 5 years (Table SDC12, Supplemental Digital Content 1, http://links.lww.com/MLR/B270). The typical English hospital lost approximately 165 HLYs and 2024 bed-days in capacity in total (Figs. 2, 3, and Tables SDC10, Supplemental Digital Content 1, http://links.lww.com/MLR/B270 and SDC11, Supplemental Digital Content 1, http://links.lww.com/MLR/B270). Assuming 1 HLY is valued at about £12,900,[29] the total loss of health due to 6 preventable safety incidents amounted to about £2.1 million in a typical English hospital annually (£877,000 or $1.3 million per 100,000 population). There is considerable uncertainty around both estimates. If an inpatient day in hospital costs £273,[30] annual excess bed-days amounted to about £553,000 (£255,000 or $390,000 per 100,000). Average excess mortality risks and bed-days per incident are shown in Table 1.

The greatest loss in health and excess bed-days was caused by preventable pressure ulcers at 26 lost HLYs and 555 days per 100,000 on average annually (Table 2). The high burden attributable to preventable ulcers in comparison with other incidents is confirmed by previous US studies based on legal claims data that found compensatory damages paid for this incident highest among all under investigation.[20,21] Deaths in low-mortality HRGs were the close second-highest cause of lost health and excess bed-days among the 6 incidents at 25 HLYs and 42 days. Although incidence was low, excess mortality was high at 95% because all cases by definition lead to death and loss of remaining life-years in relatively healthy patients. Previous studies have found inconsistencies with this general incident category, therefore our results should be subjected to further research.[31] DVT/PE caused comparably few lost HLYs at 12, but a considerable number of excess bed-days at 236, second only to ulcers. Preventable DVT/PE had low incidence and a comparably small excess mortality risk of 8%, compared with all cases of DVT/PE in hospitals, a result confirmed by other studies.[32] Postoperative sepsis caused only 6 lost HLYs and 78 bed-days. In the United States, the costs of sepsis have been estimated at $400 billion annually, which seems high in comparison.[33] Our results for the small health losses at <1 HLY due to postoperative hip fractures and central-line infections may be surprising, considering the attention that these 2 incidents receive. The results are explained by low incidence. Also, there was no increased mortality risk for central-line infections, a result found before.[34] Although excess average length of stay for hip fractures was highest among all incidents at 22 days, total excess bed-days were just 11 per 100,000, because incidence was low at 300 cases annually.

Our study has limitations. First, weaknesses in the coding and completeness of administrative hospital data are well-known and understood.[35] Although the AHRQ algorithms are considered the most sophisticated routines for identifying safety incidents in administrative data, the ICD-10 system was not specifically designed to identify medical injuries, resulting in potential errors.[36] AHRQ indicator rates may represent a lower limit of incidents currently recorded in administrative databases; the true rates could be substantially higher.[37] Further, we do not consider the impact of incidents on long-term health. Propensity score method can only adjust

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for observable confounders, and unobservable sources of patient complexity may have resulted in overestimates of the outcomes attributable to incidents.

CONCLUSIONS

There are now a variety of effective patient safety programs,[38] but no easy way of deciding which should have priority in an overarching patient safety strategy. Decision makers can use our research to prioritize among the 6 incidents, and allocate resources into further research and implementation of actual interventions according to the overall burden that is caused by each class of incident. Our results suggest placing high attention on the prevention of pressure ulcers. If burden to patients is main concern, then equal attention should be given to preventing deaths in low-mortality HRGs. This is not straightforward because these deaths may have varied causes related to general hospital performance. If financial burden to hospitals is a concern, then interventions to prevent and treat DVT/PE should receive high priority for policy action. Our results suggest that preventable postoperative sepsis, hip fractures, and central-line infections cause comparably small burden, which of course may reflect the considerable efforts that have already been invested in their prevention.

To place our findings in context, the burden caused by the 6 safety incidents is roughly comparable with the UK burden of Multiple Sclerosis (80 DALYs per 100,000), HIV/AIDS and Tuberculosis (63 DALYs), Cervical Cancer (58 DALYs), or Interpersonal Violence (57 DALYs).[39] Our estimate is higher than the Global Burden-of-Disease estimate of Disability-adjusted Life-years lost to "Adverse effects of medical treatment" for the United Kingdom in 2010 of 44.[39] However, these estimates were based on a different methodology, focused on a different set of incidents, and covered a larger population. The question which incidents should receive priority attention requires in addition information on the efficacy and costs of alternative interventions. Our findings can be used in cost-effectiveness studies to place a monetary value on the economic benefits of interventions that prevent incidents and mitigate their negative effects. Studies evaluating patient safety interventions can, when indicator data are available, use our methodology to assess the impact and cost-effectiveness of interventions. It can also be applied to the evaluation of other safety incidents. This will enable us to build a much more accurate picture of the overall burden of unsafe care and the potential clinical and economic benefits of improvements in hospital quality. Ultimately, we hope that our research will help reduce the regrettable and preventable loss of HLYs in hospitals.

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